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April 1961

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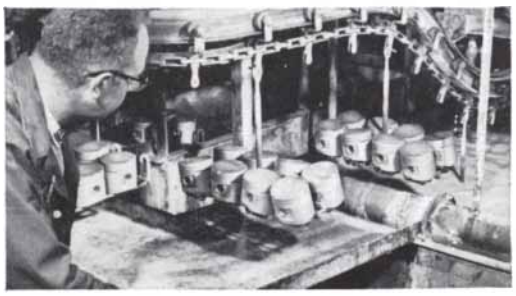

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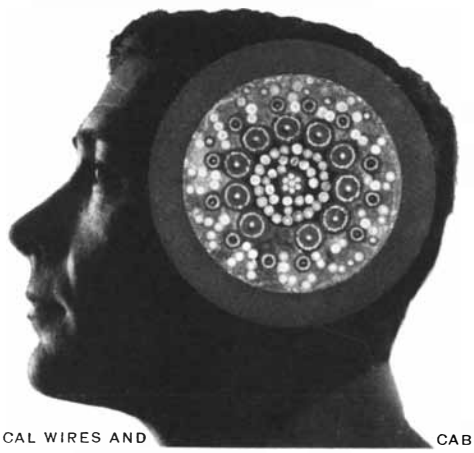

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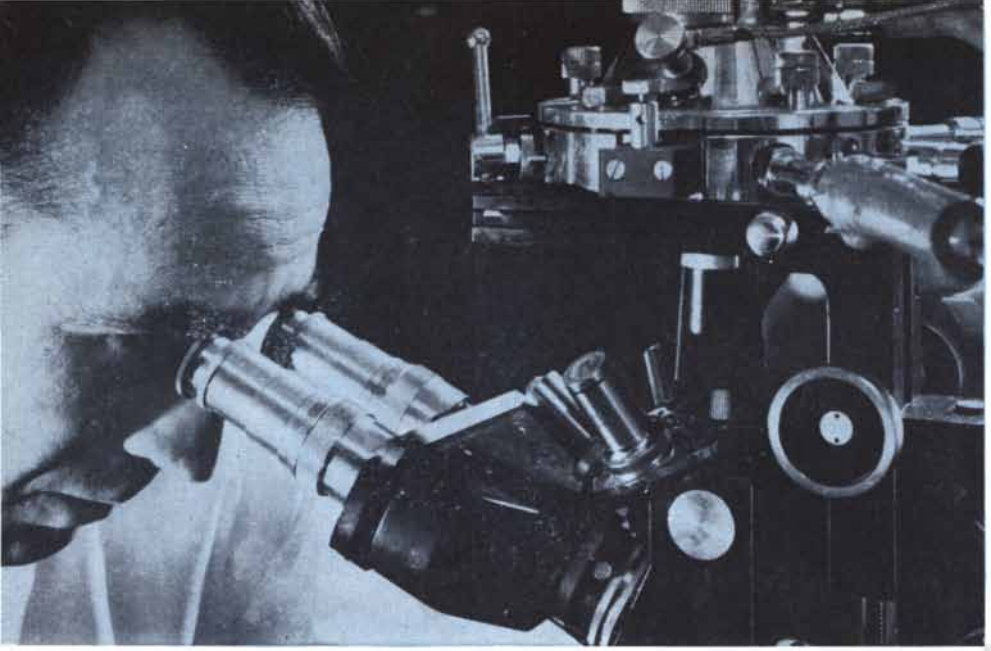

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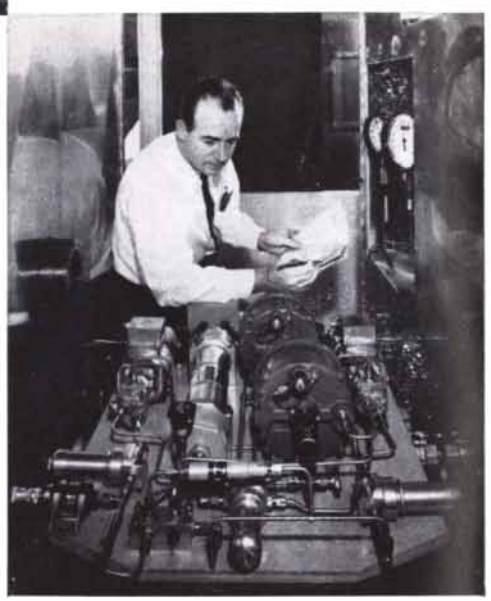

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9267

Established 1845 **SCIENTIFIC AMERICAN** April 1961 Volume 204 Number 4

ARTICLES

DEPARTMENTS

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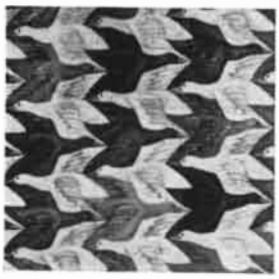

THE COVER

At first glance the painting on the cover may appear to show a flight of idealized birds of different colors but identical shapes flying from left to right. If the viewer looks closely, however, he will see that the spaces between the colored birds are entirely filled with white birds of the identical shape flying in the opposite direction. When such space-filling patterns are made up of simple polygons such as the hexagonal tiles on a bathroom floor, they are called "regular tessellations" (*see "Mathematical Games," page 164*). This freer kind of tessellation is based on a design by the Dutch artist Maurits C. Escher. Another of Escher's mosaics is on page 172.

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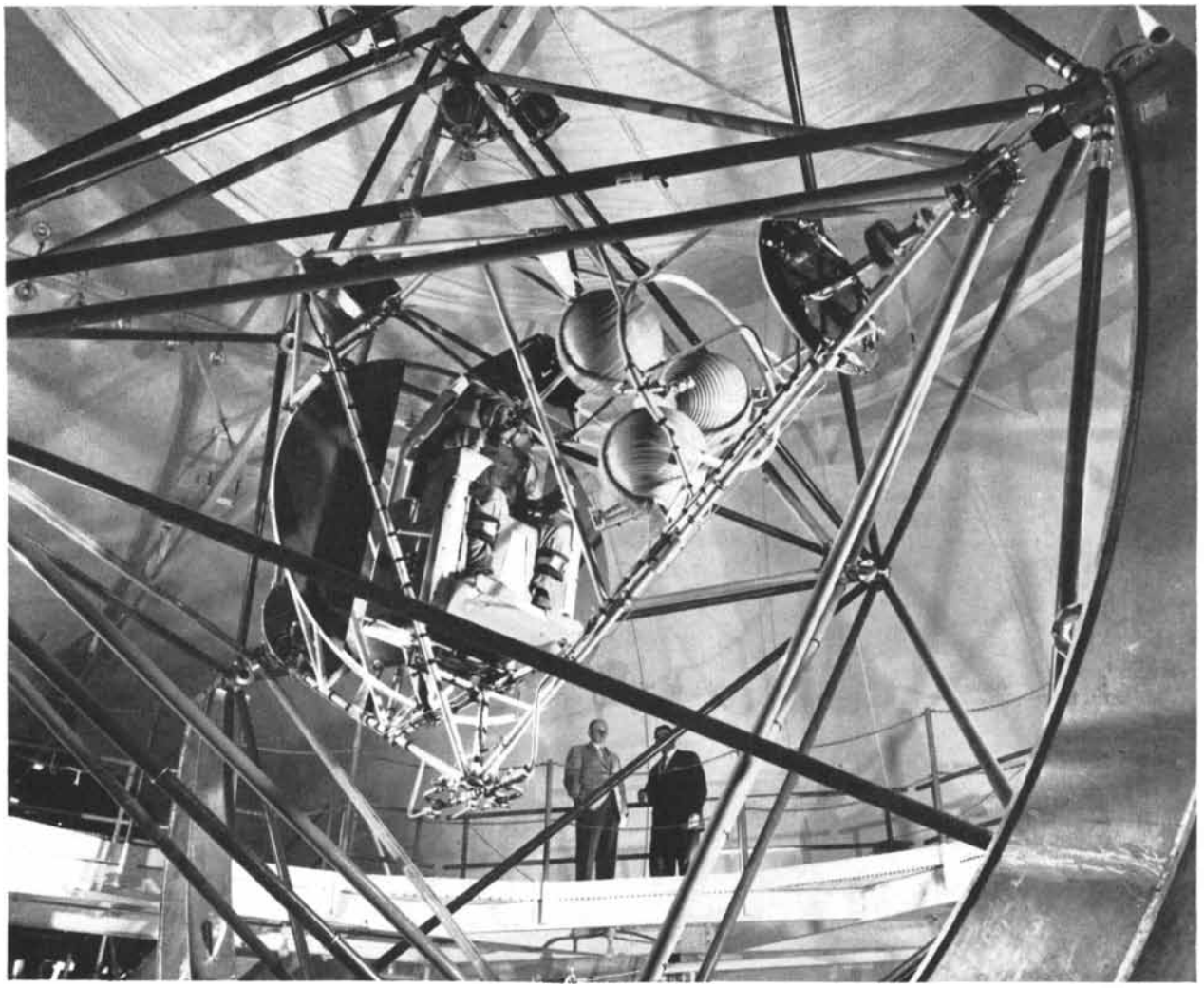

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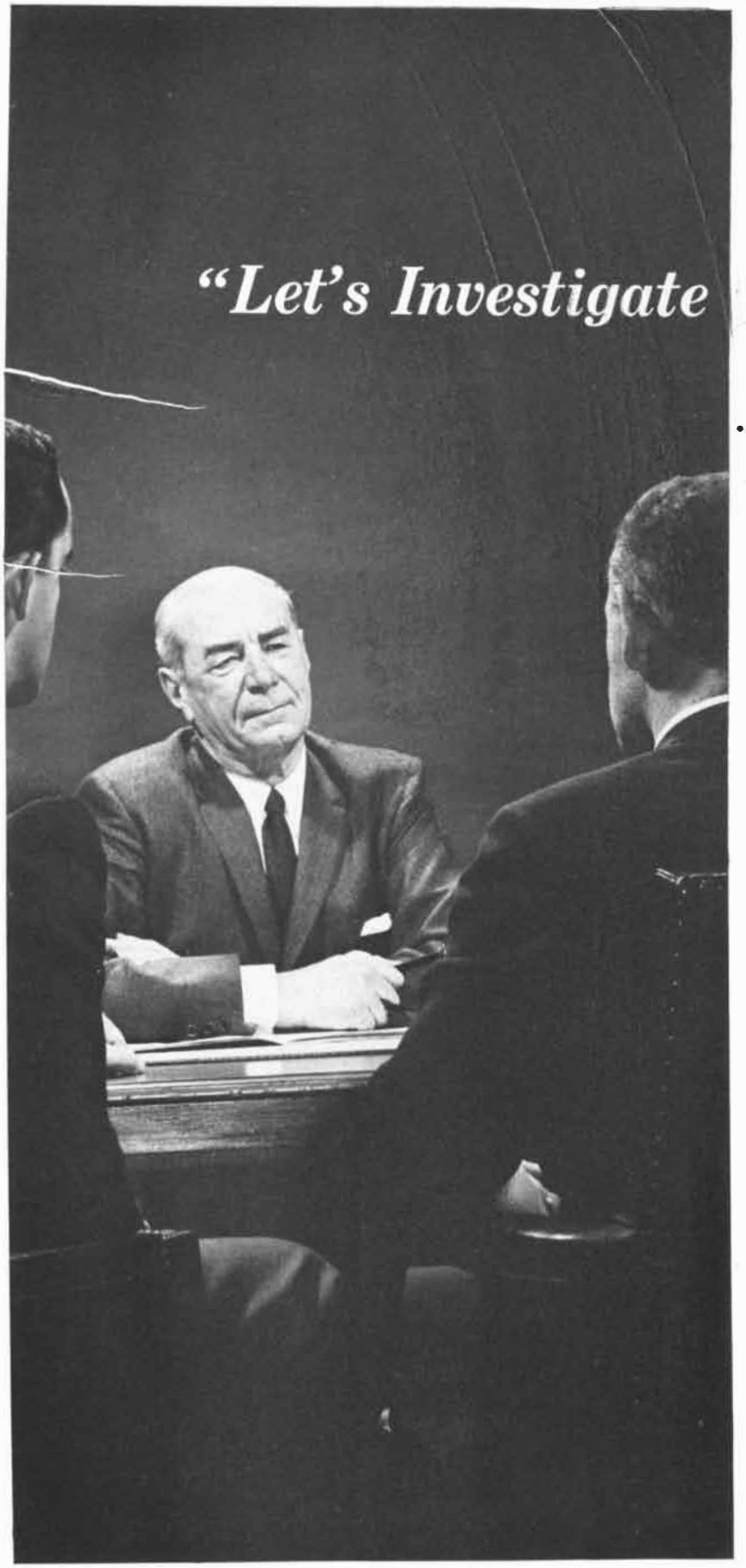

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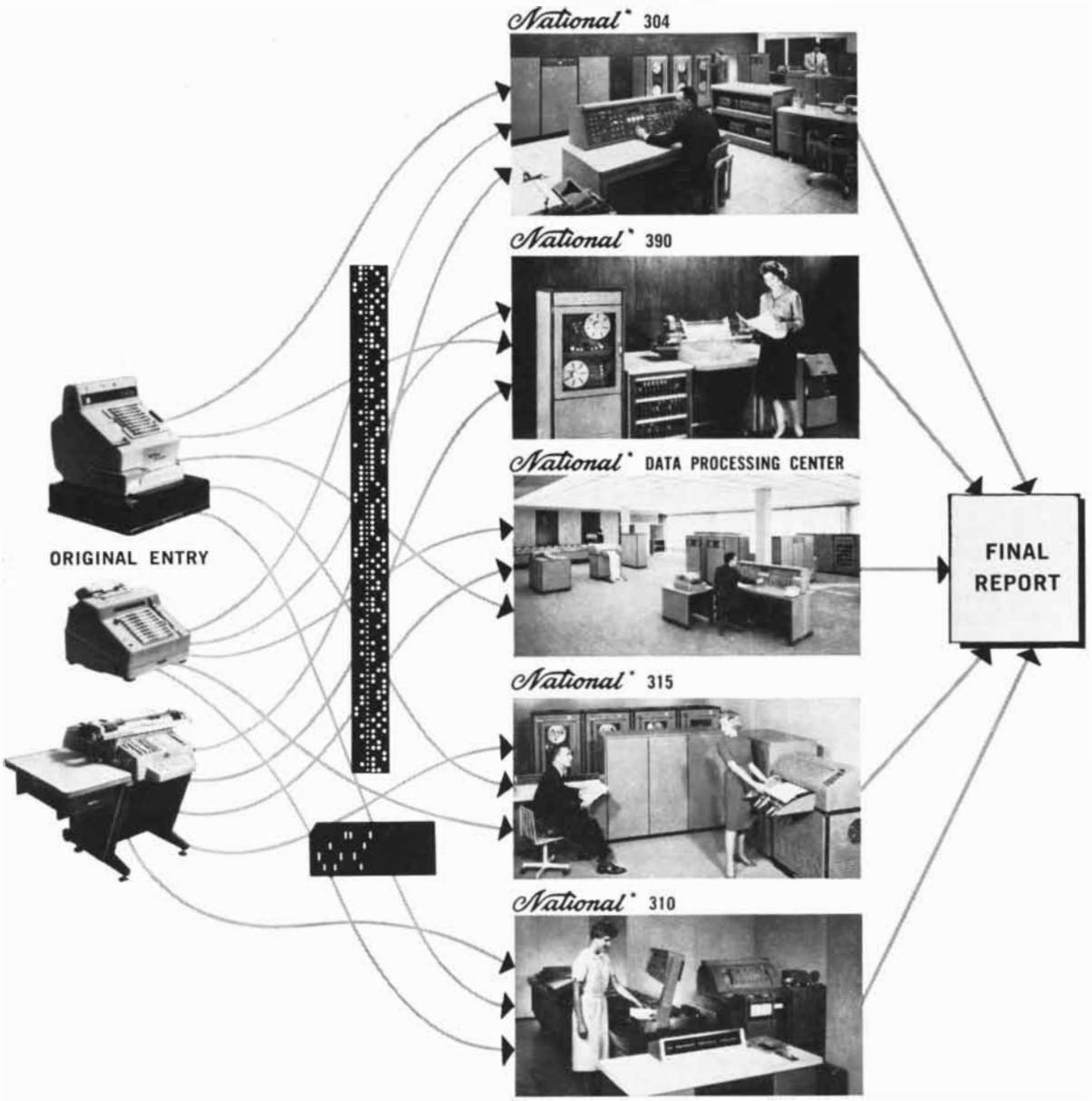

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LETTERS

Sirs:

It appears to me that in his recent interesting summary ["The Growth of Snow Crystals"; SCIENTIFIC AMERICAN, January] describing the formation of ice crystals in the atmosphere, B. J. Mason has overlooked an implication of the disappointing results of efforts to make rain by cloud-seeding for the past 12 years.

As Dr. Mason points out, supercooled clouds very commonly occur and persist for long periods of time in the atmosphere without forming ice crystals because there is usually only a very low concentration of ice-forming nuclei naturally present. With the discovery of techniques for seeding clouds by Vincent J. Schaefer and Bernard Vonnegut at the General Electric Research Laboratory, it became possible to increase the concentration of ice-forming nuclei by many orders of magnitude and rapidly to transform supercooled clouds over vast areas into ice crystals.

Since cloud-seeding with dry ice or silver iodide demonstrably causes ice crystals to form in large numbers in clouds, it provides a means for testing the widely held belief of meteorologists, including Dr. Mason, that most rain is produced by the Bergeron-Findeisen mechanism. Since according to this mechanism rain is made by the formation and subsequent melting of ice crys-

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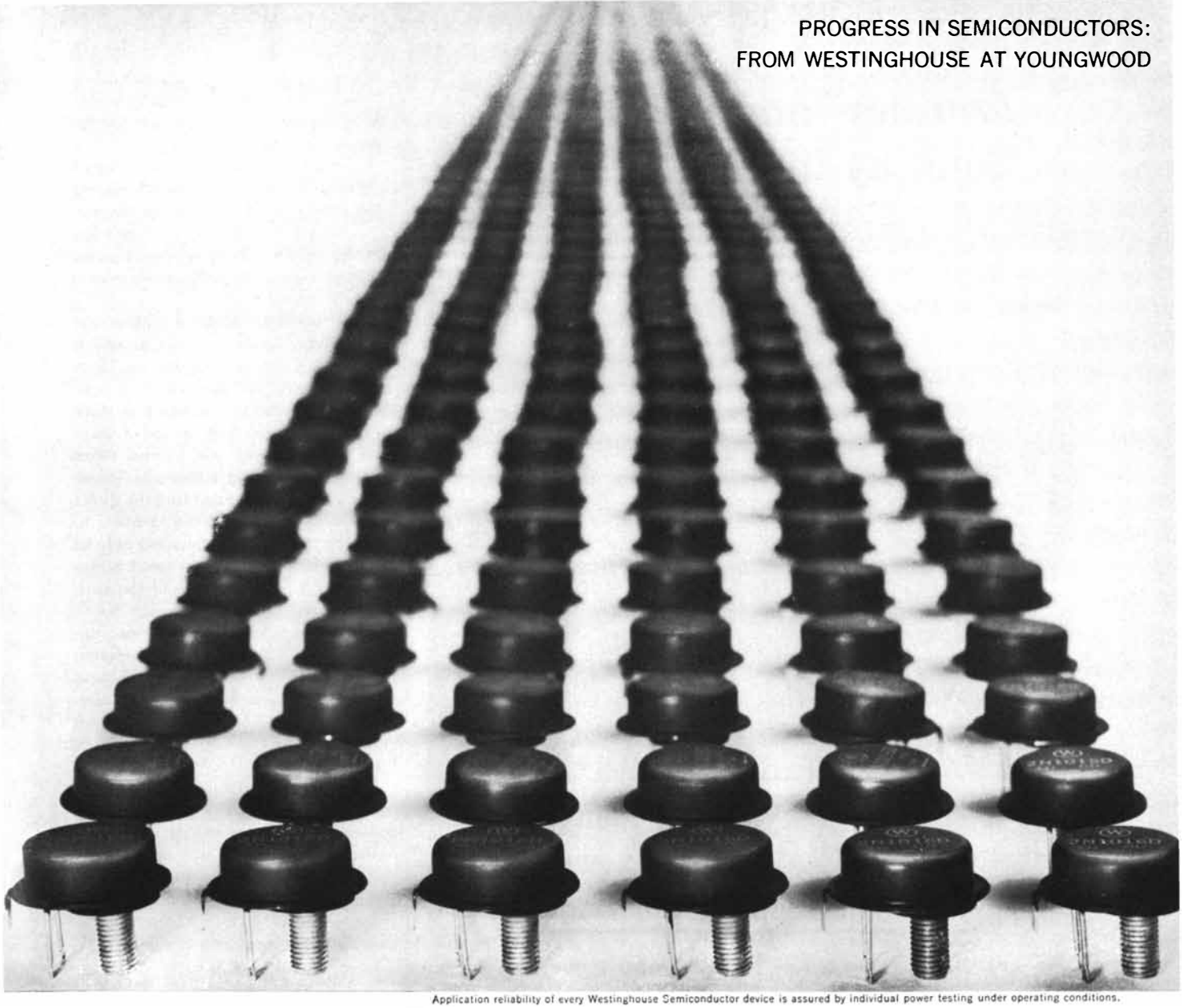

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tals, one might expect that the supplying of adequate ice-forming nuclei to supercooled clouds should cause spectacular increases in rainfall.

As Dr. Mason indicates, the increment in rainfall produced by cloud-seeding is so small that it is a matter for dispute. Accordingly, it must be concluded that the Bergeron-Findeisen mechanism is probably only of secondary importance in the formation of rain.

The many observations of copious rain falling from clouds, no part of which is below freezing temperature, suggest that other, far more effective rain-forming processes are probably at work in the atmosphere. With the aid of cloud physics radars, we and several other investigators (Louis J. Battan and Roscoe R. Braham) have learned that the direct coalescence of liquid cloud droplets to form rain commonly occurs not only in the tropics but over the United States and presumably over much of the temperate zones of the earth.

Observations of thunderstorms suggest that coalescence processes operate even within supercooled clouds; there is no reason to conclude that the rain-forming mechanism effective in warm clouds ceases to function at zero degrees centigrade.

In view of the failure of cloud-seeding to increase rainfall significantly, and the common occurrence of rain from coalescence processes, is it not possible that Dr. Mason and meteorologists in general are attaching too much importance to the Bergeron-Findeisen mechanism for the formation of rain?

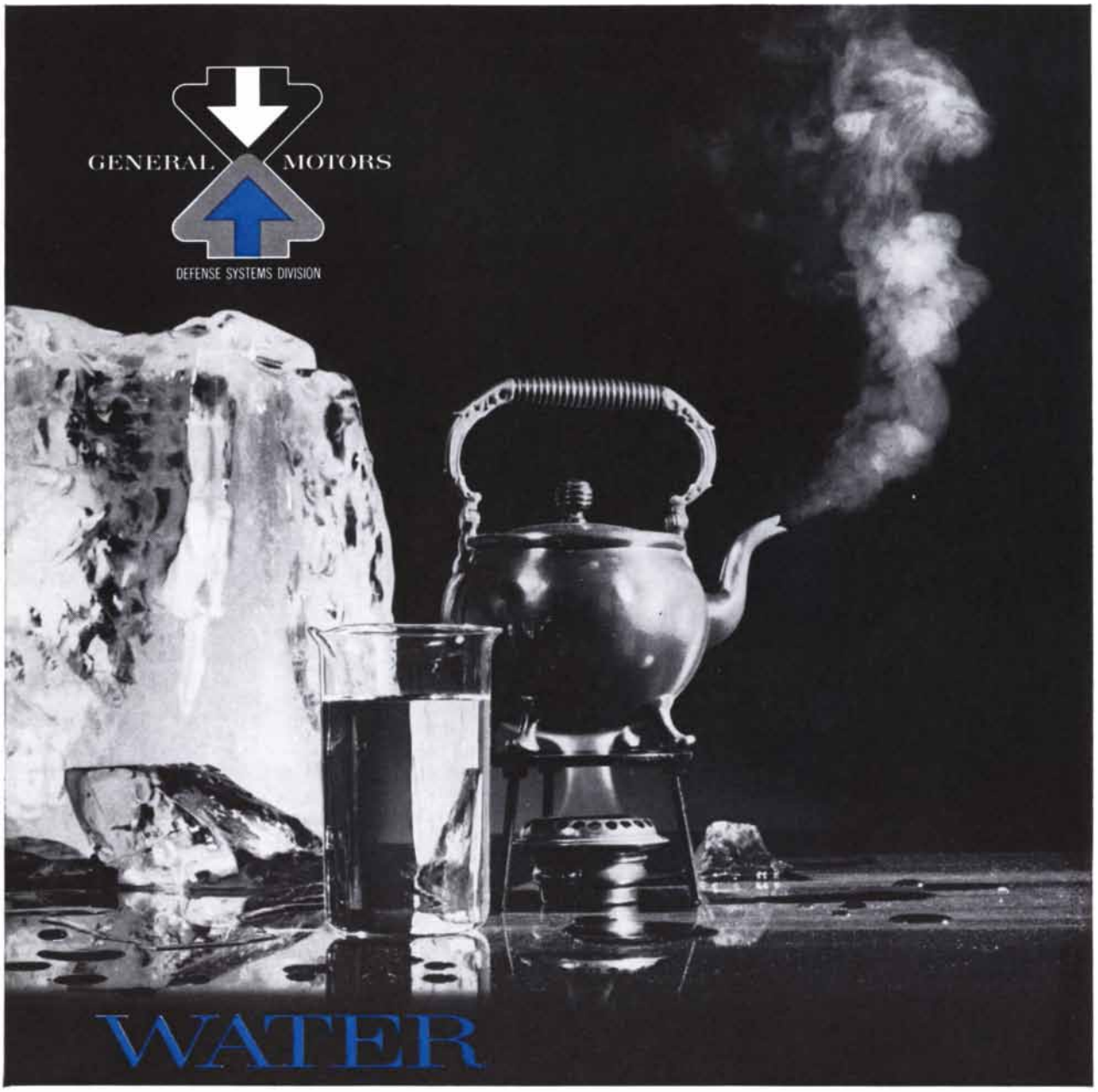
C. B. Moore

Arthur D. Little, Inc.
Cambridge, Mass.

Sirs:

Because the subject of my article was "The Growth of Snow Crystals" I naturally emphasized the particular precipitation mechanism in which snow crystals are involved but in doing so I did not wish to suggest that the coalescence process mentioned by Dr. Moore was unimportant.

There is strong evidence, both from aircraft and radar observations, that the ice-crystal mechanism is primarily responsible for the persistent widespread rain and snow that falls from the extensive layer-cloud systems commonly associated with fronts and depressions and is therefore responsible for much of the precipitation in temperate latitudes. I would not agree with Dr. Moore



...key to life

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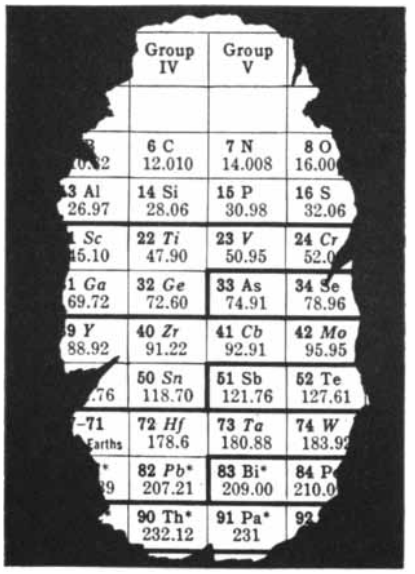
New reactive metals spark tubing development at Superior



In the past two decades much progress has been made in the metallurgy of reactive metal ores and the production of basic mill forms from them—first titanium, then zirconium, and more recently columbium, tantalum and vanadium. Today they are commercially available in limited supply as metalworking materials.

Superior began exploring the possibilities of these metals for small-diameter tubing as early as 1944. It was the first mill to successfully cold draw titanium and zirconium into this form. The experience gained in processing this metal, coupled with the development of the equipment to handle it, has enabled us to produce tubing from the other reactive metals with growing success.

Last year Superior was in the position to announce availability of columbium, tantalum and vanadium tubing. Today this is being supplied in quantities for test and evaluation to many different organizations. Applications for it are limited to a great extent by high cost, yet each material has distinct advantages that make it a valuable asset in many different installations.

Most promising of present and potential uses for columbium tubing are in the nuclear field. Here its low thermal neutron cross section (1.2 Barns) makes it ideal for fuel element cladding. Its excellent corrosion resistance to reactor coolants such as water, liquid metals, and molten salts is important, too. High strength retention at elevated temperatures is an important factor in its use in the field of jet aircraft, rockets and missiles. However, its effective use for high-temperature applications is limited to 2000°F for short exposure and 1000°F for long due to oxidation resistance.

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that because attempts to seed these clouds with artificial nuclei have failed to produce spectacular increases in rainfall one must conclude that the ice-crystal process is only of secondary importance. Rather, I think it is evidence of the fact that the natural precipitation-release mechanism in these deep, long-lived cloud systems is rather efficient and, in any case, is governed more by the large-scale features of the air and its motion than by the supply of ice nuclei.

The coalescence process, on the other hand, is mainly important in the formation of showers from clouds of limited extent. As I mentioned in my article, and as Dr. Moore points out, in warm weather rain may fall from such clouds, which are entirely warmer than zero degrees centigrade and cannot therefore contain ice crystals. In this case the rain is formed through the collision and aggregation of water droplets; the importance of this coalescence process has been stressed by my colleague Dr. Ludlam and me for several years. There have also been several attempts to stimulate it artificially by seeding the clouds with either water droplets or salt particles but here also the results have been rather inconclusive.

Ten years ago I would have agreed with Dr. Moore that the importance of the coalescence relative to the ice-crystal process was being underestimated but this is no longer the case. Indeed, the problem is rather to explain how it is that very small clouds forming in warm, unstable air precipitate so easily.

B. J. Mason

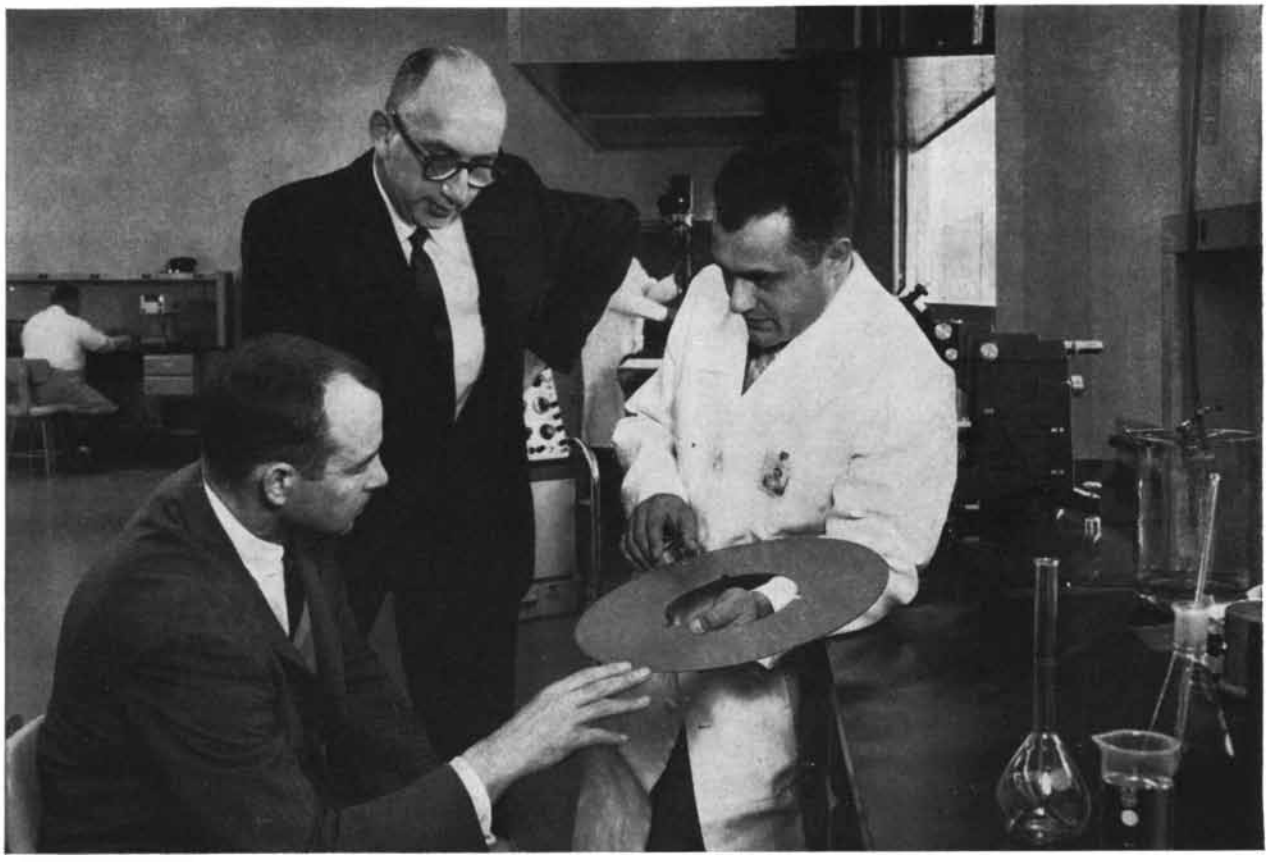
Imperial College of Science
and Technology
London, England

Sirs:

I wonder how many of your readers noticed a remarkable coincidence in your February issue. In the article "The Chemical Structure of Proteins," by William H. Stein and Stanford Moore, it is stated that the molecule of insulin contains 777 atoms. In the article "The Celestial Palace of Tycho Brahe," by John Christianson, it is said that Tycho's celestial catalogue listed the positions of 777 stars! Perhaps this is a poetic suggestion that biochemistry in the 20th century has attained the level of astronomy in the 16th.

Frederic H. Collins

New York, N.Y.



The Magnetic Surfacing Pilot Production Area; Mr. H. B. Dickinson, Vice President (left), and Mr. B. Diener (center) and Dr. M. B. Melillo (right) of the Component Development Division.

A Report from American Systems Incorporated...

A New Development in Magnetic Surfacing

In improving the performance and economy of many computing and data handling systems, the surfacing of magnetic memory drums, disks, rods, and tapes tends to be a limiting consideration. Now at American Systems Incorporated, an important new process for surfacing these components is in the pilot production stage. Based on a completely chemical (catalytic) principle, the American Systems process provides magnetic surfaces of greater metallurgical hardness and uniformity than conventional electroplating or spraying. Packing densities are also greater, and higher recording frequencies may be used. Further, the deposition may be controlled so that coercivity and remanence of the surface meet specific application requirements. In the pilot facility, a wide range of component sizes and shapes can be handled simply and rapidly.

Developed by Dr. Manlio Melillo of American Systems Component Development Division, the new process typifies the systems approach to component problems. In addition to magnetic surfacing, the activities of this division encompass component development for computer and communications systems technology.

Front-line technical efforts are also under way at American Systems in six other Divisions:

INFORMATION SCIENCES
Mathematical and statistical research; computer programming, and advanced programming systems; computation services; digital system studies; logical design; advanced systems analysis.

COMMAND AND CONTROL SYSTEMS
Logic of command and control complexes; systems design and development; data acquisition, processing and display; communications.

ELECTROMAGNETIC SYSTEMS
Electromagnetic physics; electronic and mechanical scanning antenna systems; development and manufacturing of special microwave components and complete sensor systems.

RESEARCH LABORATORIES
Solid state physics and systems; magnetic thin-film research and subsystems; advanced components for information processing.

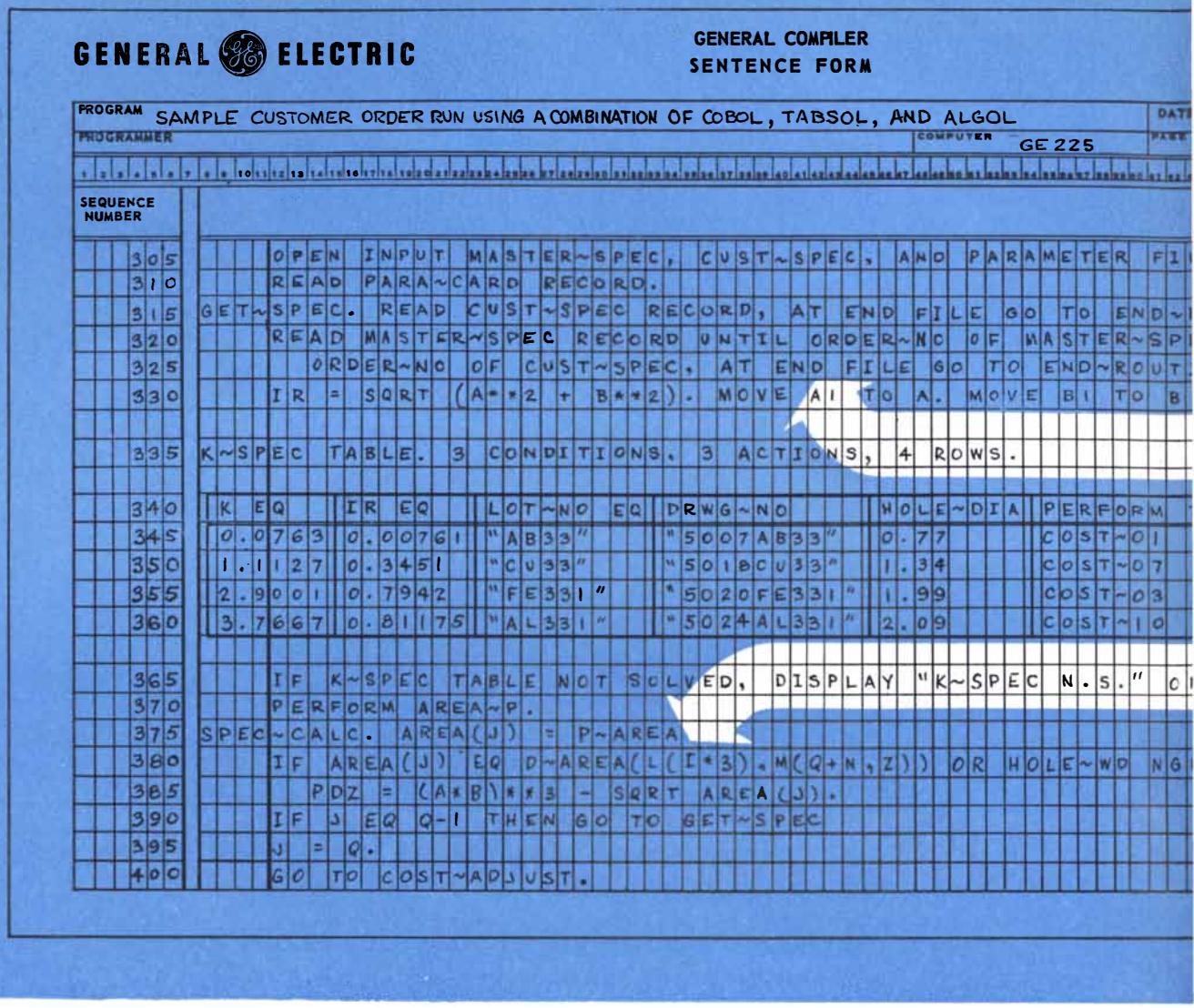
INSTRUMENTS
Research and development in analytical instruments; detection and monitoring of toxic high-energy missile fuel vapors; gas leak and water vapor detection; on-stream and process control instrumentation.

AUDIO-VISUAL
Audio-visual (Instructron) devices for instructional and assembly line applications; production of work stations designed on human factors principles.

These programs are being conducted by an outstanding staff of scientific and technical personnel, over half of whom have advanced degrees. Custom facilities for this work are located in a 27,000-square-foot plant. The first unit in a long range building program, this plant is situated on a 13-acre site.

Qualified scientists and engineers who are interested and experienced in our fields of activity are encouraged to investigate career opportunities with American Systems.

AMERICAN SYSTEMS *Incorporated*
1625 East 126th Street, Hawthorne, California


GENERAL ELECTRIC

GENERAL COMPILER
SENTENCE FORM

PROGRAM SAMPLE CUSTOMER ORDER RUN USING A COMBINATION OF COBOL, TABSOL, AND ALGOL

PROGRAMMER

COMPUTER GE 225

SEQUENCE NUMBER

```
305  OPEN INPUT MASTER~SPEC, CUST~SPEC, AND PARAMETER FI
310  READ PARA~CARD RECORD.
315  GET~SPEC. READ CUST~SPEC RECORD, AT END FILE GO TO END~
320  READ MASTER~SPEC RECORD UNTIL ORDER~NO OF MASTER~SP
325       ORDER~NO OF CUST~SPEC, AT END FILE GO TO END~ROUT
330  IR = SQRT (A**2 + B**2). MOVE A1 TO A. MOVE B1 TO B

335  K~SPEC TABLE. 3 CONDITIONS, 3 ACTIONS, 4 ROWS.

340  | K EQ    | IR EQ    | LOT~NO EQ | DRWG~NO      | HOLE~DIA | PERFORM |
345  | 0.0763  | 0.00761  | "AB33"    | "5007AB33"   | 0.77     | COST~01 |
350  | 1.1127  | 0.3451   | "CU33"    | "501BCU33"   | 1.34     | COST~07 |
355  | 2.9001  | 0.7942   | "FE331"   | "5020FE331"  | 1.99     | COST~03 |
360  | 3.7667  | 0.81175  | "AL331"   | "5024AL331"  | 2.09     | COST~10 |

365  IF K~SPEC TABLE NOT SOLVED, DISPLAY "K~SPEC N.S." C
370  PERFORM AREA~P.
375  SPEC~CALC. AREA(J) = P~AREA
380  IF AREA(J) EQ D~AREA(L(I*3), M(Q+N, Z)) OR HOLE~WD NG
385       PDZ = (A*B)**3 - SQRT AREA(J).
390  IF J EQ Q-1 THEN GO TO GET~SPEC
395  J = Q.
400  GO TO COST~ADJUST.
```

GECOM... A UNIQUE CONCEPT IN

now available in the GE 225 . . . and future General Electric general-purpose computers.

- processes COBOL, ALGOL and TABSOL*
- all problem statements easily read and understood
- extended usage . . . re-programming unnecessary
- programs produced faster . . . more efficiently

GECOM—the first truly GENERAL COMPILER SYSTEM—introduces a fresh, versatile approach to computer communication. Developed for the GE 225 computer, the GENERAL COMPILER *makes available all of the various proved programming techniques in one consistent, compact package.* No longer is it necessary to learn a dozen different programming systems to handle a full range of jobs effectively—each job is approached in *exactly the same way,* be it formula evaluation, a sort, or even a payroll. The language for describing any run is *consistent,* operating procedures and programming are *standard,* and documentation is readable and easily *understood.*

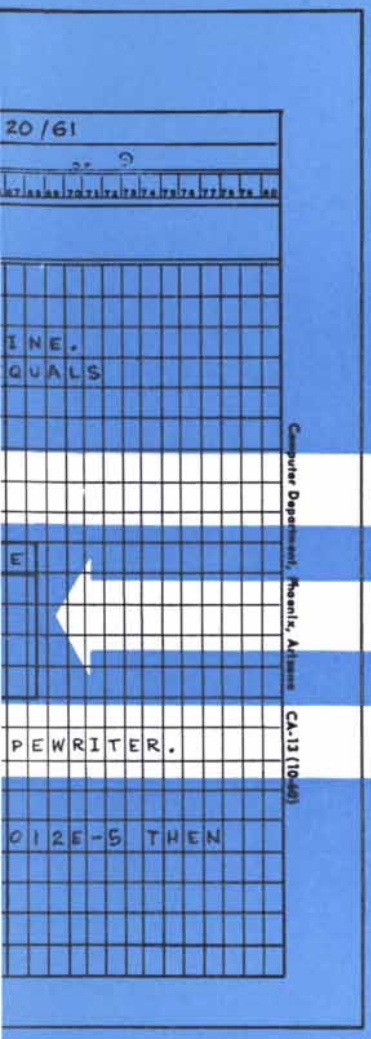
*A General Electric Trademark

THE GENERAL COMPILER PROVIDES—

A FAMILIAR LANGUAGE STRUCTURE—Problems need not be stated in machine code. The GENERAL COMPILER processes English language statements (COBOL), Algebraic expressions (ALGOL), and Structure Tables (TABSOL). It permits you to use all or any one of the computer languages . . . as your needs require. Still, you have available the capability to expand, use other languages and new techniques as your needs change.

A PROVED, ACCURATE CODER—Data Description and Problem Logic may be written in one, two, or a combination of the available languages producing a machine program of efficient, effective coding. Since the machine coding is derived directly from the logic of the problem statement, it is only at the logic level that debugging may have to be done.

A STANDARDIZED, UNDERSTANDABLE DOCUMENTATION—Because GENERAL COMPILER problems are written in familiar languages, they can be easily read and under-



GENERAL ELECTRIC'S NEW 225 GENERAL COMPILER

GECOM

COBOL

TABSOL*

ALGOL

Control Console and Central Processor of the GE 225 Information Processing System

COMPUTER COMMUNICATION

stood. In addition, problem format provides a high degree of standardization. Programs written for today's machines in GECOM format can be used for future General Electric computers—eliminating the need for re-programming.

AN EFFICIENT, ECONOMICAL USE OF COMPUTERS—Personnel training time and expense are sharply reduced since the novice programmer may use the familiar terminology of his profession. Manual coding is eliminated and debugging cut to a minimum. Thus, a machine program may be produced much faster and more efficiently than by present manual methods.

THE GENERAL COMPILER IS ANOTHER GENERAL ELECTRIC FIRST!

For more detailed information, write today for brochure CPB-144 on the new General Electric General Compiler. Also available: brochure CPB-101 on the GE 225 Information Processing System and CPB-81 on the GE 210 Data Processing System.

Write to: General Electric Company • Computer Department • Section 60H4 • Phoenix, Arizona.

Contact Your Nearest General Electric Computer Department District Office: Atlanta: 270 Peachtree St. N.W., JA 5-5739 • **Boston:** 140 Federal St., HU 2-1800, Ext. 311 • **Chicago:** 840 S. Canal St., WA 2-5611, Ext. 587 • **Cleveland:** 215 Euclid Ave., SU 1-6822 • **Dallas:** 3200 Maple Ave., RI 8-0589 • **Detroit:** 680 Antoinette St., TR 2-2600 • **Los Angeles:** 1010 S. Flower St., DU 1-3641 • **Louisville:** Bldg. 6, Appliance Pk., GL 4-7511 • **Minneapolis:** 6th & Hennepin, FE 2-7569 • **New York:** 122 E 42nd St., PL 1-1311, Ext. 2235 • **Philadelphia:** 2 Penn Center Plaza, LO 8-8085 • **Phoenix:** 3550 N. Central Ave., AM 4-3741 • **Pittsfield, Mass.:** 100 Woodlawn Ave., HI 3-3511 • **San Francisco:** 235 Montgomery St., DO 2-3740 • **Schenectady:** Bldg. 2, 1 River Rd., FR 4-2211, Ext. 5-4405 • **Seattle:** 710 Second Ave., MA 4-8300 • **St. Louis:** 818 Olive St., GE 6-4343 • **Syracuse:** 3001 James St., GR 6-4411, Ext. 7125 • **Washington, D.C. Area:** 7401 Wisc. Ave., Bethesda, Md., OL 2-8100 **In Canada:** Canadian General Electric Co., Ltd., Electronic Equipment and Tube Dept., 830 Lansdowne Ave., Toronto, Ont., Canada. **Outside U.S.A. and Canada:** Producer Goods Dept., Int'l. General Electric Co. Div., 150 E. 42nd St., N.Y.C., U.S.A.

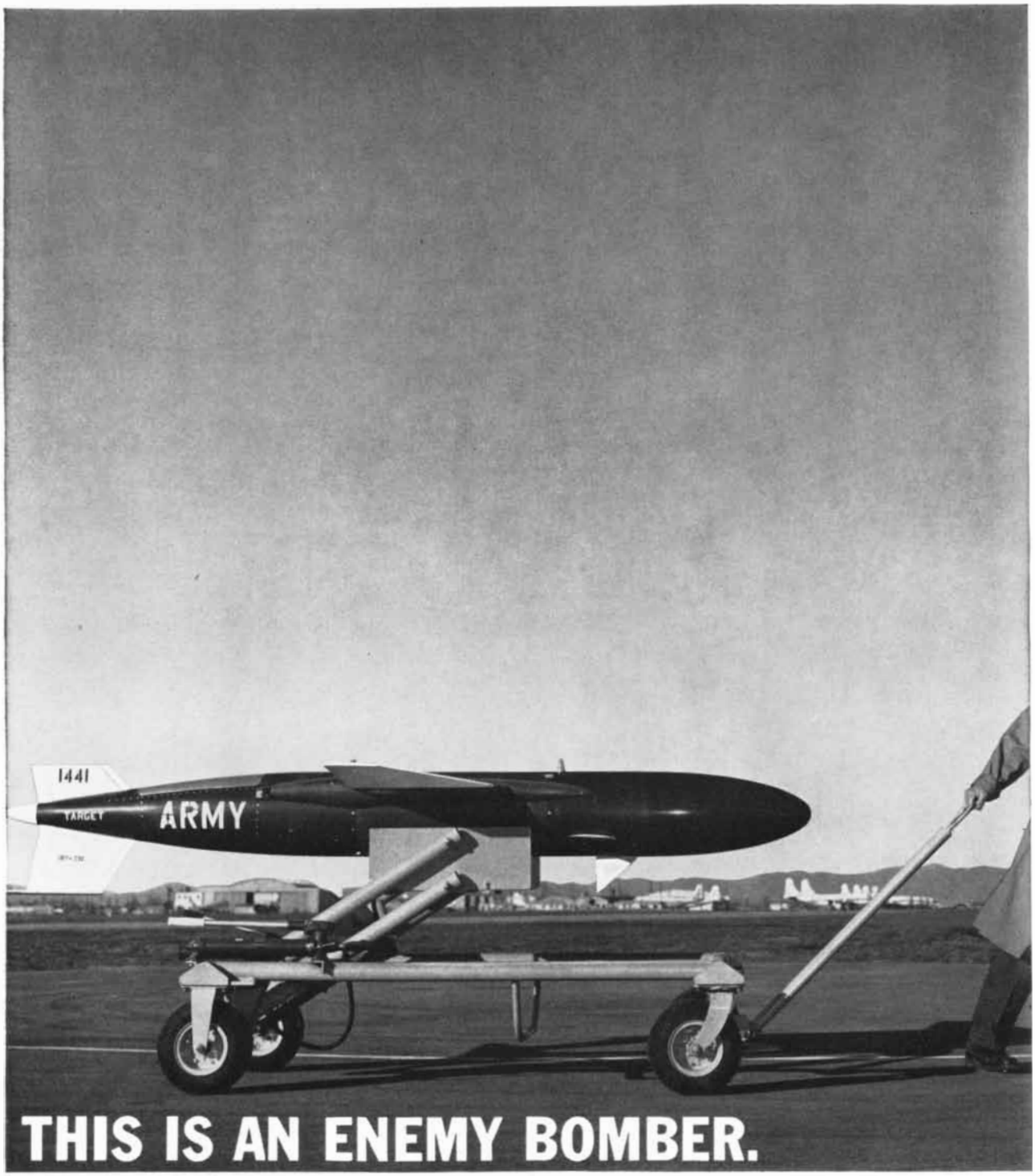
INFORMATION PROCESSING AUTOMATED BY GENERAL ELECTRIC

General Electric—Pioneer in computer systems for all phases of business, industrial, scientific, engineering and financial endeavor.

Progress Is Our Most Important Product

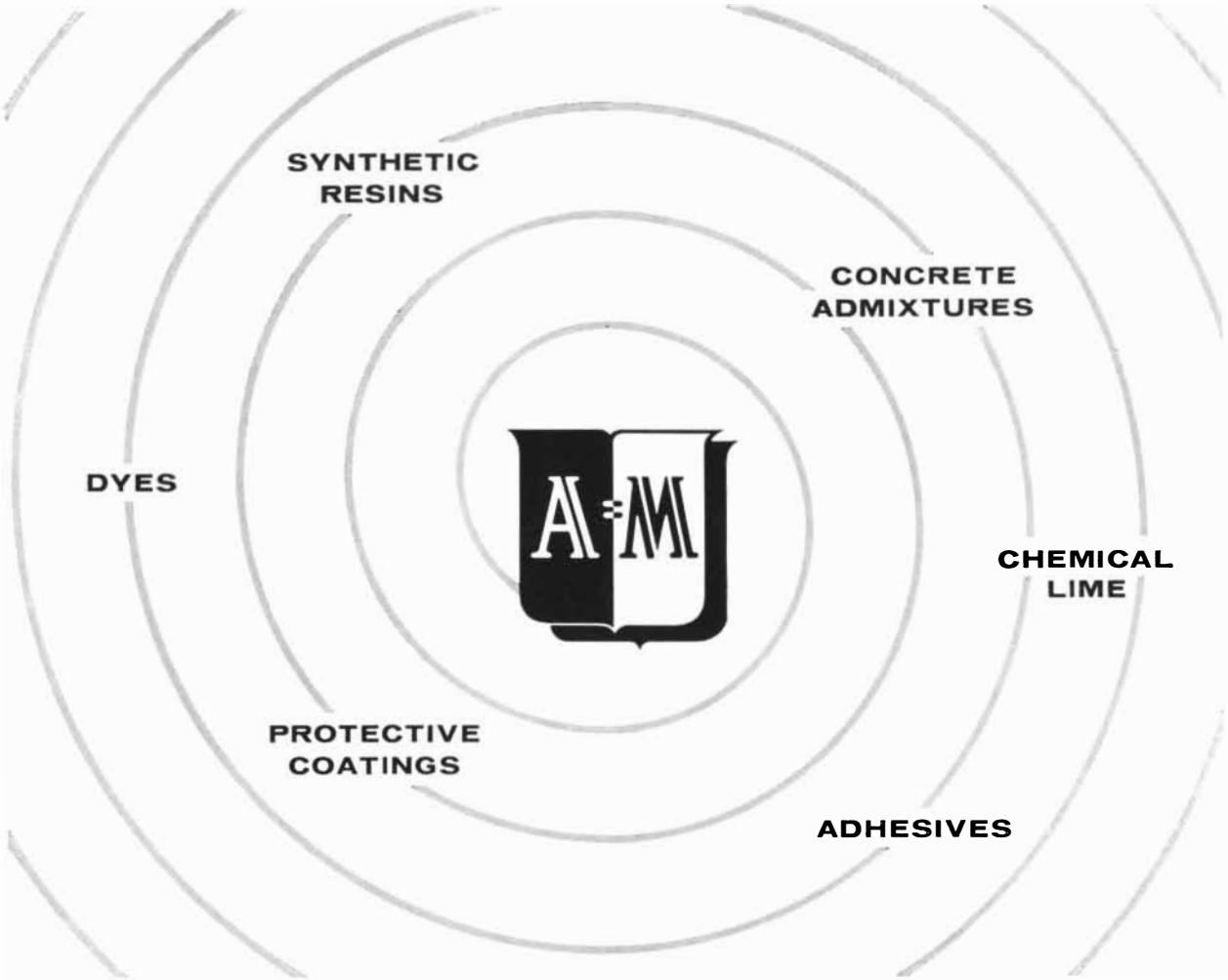
GENERAL ELECTRIC

CPA-60(4/61)



THIS IS AN ENEMY BOMBER.
NORTHROP BUILDS IT.

On a radar screen, the RP-76 target missile can look as big as the largest enemy bomber. Rocket powered, it flies faster than sound, operates above 70,000 feet. Yet this little giant is less than ten feet long, weighs just over 300 pounds, and parachutes down for re-use after completing its run. It is the heart of the Army's program for training the ground-to-air missile crews who guard our cities. The complete target and tracking system is made, managed and serviced for the Army by **RADIOPLANE** A DIVISION OF **NORTHROP**



AMERICAN-MARIETTA

Chemical Products

The growing number of industries using American-Marietta's chemical products results from the keying of both research and production to customers' specialized needs.

New type vinyl coatings for food and beverage containers—the first liquid ready-to-use sulfur dyes for clothing and fabrics—admixtures to improve concrete—processes basic to the production of synthetic resins . . . these are but a few of the achievements of American-Marietta's divisions in the chemical field.

Developed and improved through constant research, American-Marietta's diversified chemical products are used in hundreds of applications essential to construction and industry.

PAINTS • CHEMICAL COATINGS • SYNTHETIC RESINS
ADHESIVES • SEALANTS • METALLURGICAL PRODUCTS
PRINTING INKS • DYES • HOUSEHOLD PRODUCTS • LIME
REFRACTORIES • CONSTRUCTION MATERIALS • CEMENT

Progress through Research

A-M

American-Marietta
Company
Chicago 11, Illinois

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

APRIL, 1911: "Word has been received from Capt. Scott that Amundsen, like himself, is trying to reach the South Pole. Scott's ship, the *Terra Nova,* has returned to New Zealand after landing sledge parties on the ice, and has brought messages from Capt. Scott himself. It seems that Lieut. Pennell of the expedition found the *Fram,* Amundsen's ship, in Iceland Bay, and a Norwegian party fully equipped for a journey to the South Pole. On board the *Fram* were eight men and 16 Greenland dogs. In April, 1909, Amundsen stated that he intended to go to the North Pole. He left Norway ostensibly to travel via Cape Horn and Bering Strait to the North Pole Basin. On arriving at Madeira in October, he announced that he had changed his plans and was going to try for the South Pole. Nothing had been heard of Amundsen's expeditions until news was received from Scott."

"It was recently announced that the high-powered wireless telegraph station of the Navy Department is to be located on the southwest corner of the Fort Myer reservation. Here a number of towers, 450 feet high, will be erected for the purpose of supporting the antennæ. They will be arranged either in a triangle or a quadrangle. The effective radius of the station will probably be 1,500 miles. It was originally proposed to use the Washington Monument for supporting the antennæ, but owing to public sentiment the plans were changed."

"On February 10 the French Senate passed a bill that makes Greenwich time legal in France. When the law goes into effect French time will become nine minutes and 21 seconds slower than it is now. In order to avoid the expense of altering charts and sailing instructions, the law will not apply to French naval or other vessels, and it is not likely that any change will be made in the French almanacs. French railways are now run by a standard five minutes slower than Paris time, and the clocks inside stations are regulated by this standard, while the

NEW BELL LABORATORIES RESEARCH FORESHADOWS COMMUNICATIONS AT OPTICAL FREQUENCIES

A revolutionary new device, the continuously operating Optical Gas Maser, now under investigation at Bell Telephone Laboratories, foreshadows a whole new medium for communications: light.

Light waves vibrate at frequencies tens of millions of times higher than broadcast radio waves. Because of these high frequencies, a beam of light has exciting potentialities for handling enormous amounts of information.

Now for the first time, Bell Laboratories' new Optical Gas Maser continuously generates light waves that are "coherent." That is, the light waves move in phase as seen looking across the beam.

With further research, it is expected that such beams can be made to carry large amounts of information. The beams can be transmitted through long pipes. They can be projected very precisely through space, and might be used for communications between space vehicles.

Research with coherent light is another example of how Bell Laboratories prepares ahead for communications needs.

The Optical Gas Maser (above) was first demonstrated at Bell Telephone Laboratories. Heart of unit is a 40-inch tube containing helium and neon. Interaction between gas atoms produces a continuous, coherent beam of infrared light that may one day be used in communications.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

clocks on the outside of the stations give the correct Paris time. This confusing system will be abolished, and both the exterior and the interior clocks will be regulated by Greenwich time, by which the trains will be run."

"In its last issue, our esteemed contemporary, *The Navy,* published a map of the North Pole region, on which is plotted the exact route, as shown by his notebooks, along which Peary approached the Pole. The map was drawn and Peary's route plotted by two experts of the United States Coast and Geodetic Survey, working independently, and their calculations agree within a second of latitude. Mr. Mitchell, one of the experts, states that from his professional experience it would have been impossible for the observations set down in the notebooks to have been obtained except under the circumstances claimed. As the result of this report, our great explorer has received an altogether too tardy national recognition by being advanced to the grade of Rear Admiral. It is surely a strange anomaly that the attempt to rob Peary of his honors by one of the most stupendous lies of history should have so far succeeded that his own country has given him adequate official recognition only after the scientific societies of the world had presented him with 18 medals and honorary degrees, and had agreed, according to the language of the report, 'in pronouncing this the greatest geographical prize of the last three centuries.'"

"In the year 1810, 90 per cent of the commerce of the United States, and a considerable part of that of foreign nations, was carried by American ships. Furthermore, American shipping registered for oversea commerce had grown from 123,000 tons in 1789 to 981,000 tons in 1810. Today, not only is our share in the carrying of foreign commerce practically nothing, but our merchant marine is declining so fast that the day of its ultimate extinction is in sight; and although our foreign trade has grown to the enormous total of $3,000,000,000, we are dependent upon foreign ships for its transportation, and are paying the foreign shipowners annually in freight charges a sum of about $300,000,000."

"Among the figures that loom large in the splendid company of living German men of science, there is perhaps none whose life work and personality present a greater interest to the general public than Wilhelm Ostwald, whom we may justly call one of the founders of modern

the Eyes of Science are on

GEORGIA's RESOURCES *in* RESEARCH

Aeronautical Engineering / Chemical Engineering / Civil Engineering / Electrical Engineering / Industrial Engineering / Mechanical Engineering / Minerals Engineering / Textile Engineering / Ceramics / Chemistry / Mathematics / Physics / Electronics / Industrial Development / Systems Analysis / City Planning / Health Sciences / Nuclear Sciences Digital and Analog Computational Services / Technical Information Services

Georgia is opening the eyes of the world to new wonders in Science and Engineering. As a result of Georgia's record appropriations for education and research, young eyes will look deeper into the technological world of the future . . . and skilled scientists and engineers will discover and apply broad, new horizons for the betterment of man and industry.

For over 70 years, the Georgia Institute of Technology has been the recognized model in technological education in the South. Its engineering, science, architecture, and management graduates now make up the bulk of Georgia's technological manpower. This talent pool is sufficiently great to afford valuable manpower to areas outside the State.

During the past two decades, Georgia Tech through its Engineering Experiment Station and departmental research programs has established itself as the largest, most versatile engineering and industrial research agency in the area. From its research programs have come new products, new industries, a better understanding of the world in which we live, and a higher per capita income for the people of the State and the region.

Georgia Tech's educational and research progress is another indication of Georgia's future planning to provide scientifically equipped manpower and industrial research and product development for world benefit.

S. ERNEST VANDIVER, *Governor*

GEORGIA DEPARTMENT OF COMMERCE

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Georgia Dept. of Commerce
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Please send me details on ☐ Research and Business Opportunities in Georgia ☐ Resources for Research — Georgia Tech

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physical chemistry. He was born in 1853 at Riga. In 1881 Ostwald received a call to a professorship at Riga. Among the students trained by Ostwald there stands out Arrhenius, the originator of the ionic theory. Nernst also, one of the greatest physical chemists of the day, was planning to study under Ostwald at Riga, when the latter was called to Leipzig in 1887, whither Nernst followed him to become his assistant. Ostwald's creative work is imposing even if we consider only its volume. During the years 1887 to 1903 he published no less than 16,000 pages of original papers, textbooks, reviews and other matter. Of late years, especially since his retiring from university teaching, Ostwald has devoted his main efforts to writings of a philosophical and general character. The dominant note that sounds again and again in this work is his insistence on the significance of energy and the laws of energy transformations in our interpretation of the physical universe."

"The Singer tower, with its height of 612 feet, and the Metropolitan tower, just 700 feet in height, are to be eclipsed by the Woolworth Building, now under construction at Broadway and Barclay Street, New York City, whose finial will be 750 feet above the street level. There will be 30 stories in the main building, above which a tower 85 feet square will rise for another 25 stories."

APRIL, 1861: "Hunt's *Merchant's Magazine* compiles the following population figures from the returns furnished by the Census Bureau. In 1850 the population of the Northern States was 13,454,169; in 1860 the population of the same States was 18,950,759. In 1850 the free population of the Southern States was 6,412,501 and the slave population 3,200,412, a total of 9,612,913. In 1860 the free population of the same States was 8,434,126 and the slave population 3,998,563, a total of 12,432,689. The population of the seven seceded States is 5,053,754, 2,703,147 of which is free and 2,350,607 slave. The eight remaining slave States have 1,648,676 slaves. South Carolina and Mississippi are the only two States in which the slaves outnumber the free."

"A suspension bridge is now being constructed by Mr. J. Roebling over the Kentucky River, on the Lexington and

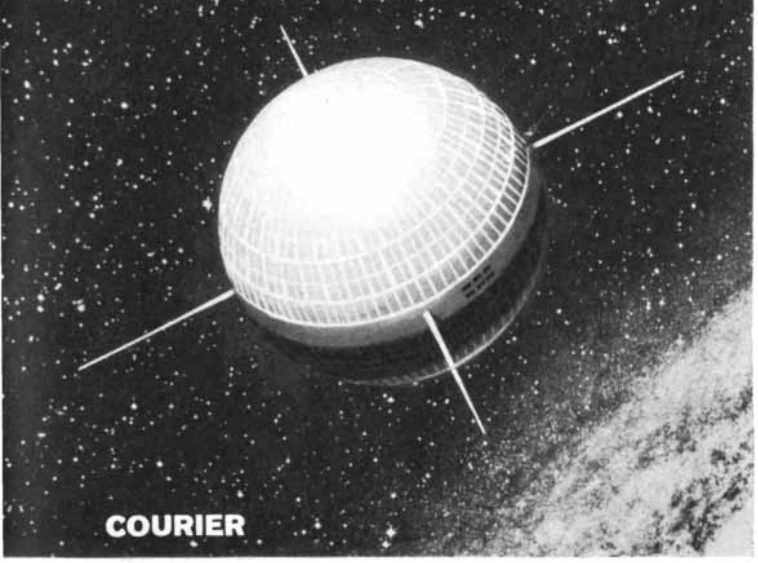
Danville Railroad, which will have a span of 1,224 feet from center to center of the towers, over a chasm 300 feet deep. When completed, it will be the longest single span in the world."

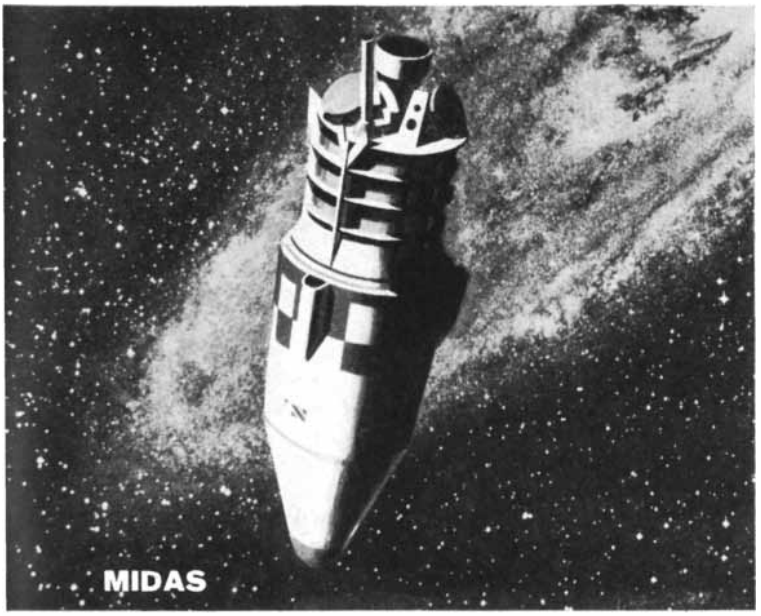
"Foreigners, under the new Patent Law, who have cases pending before the United States Patent Office, can have their applications withdrawn and receive back two-thirds of the fees paid, and then renew their application by paying only $15. The abolition of the excessive fees heretofore required of foreigners will do much to stimulate them to introduce many valuable inventions into this country, and enable them to protect themselves against unscrupulous pirates who lay violent hands upon everything within their reach."

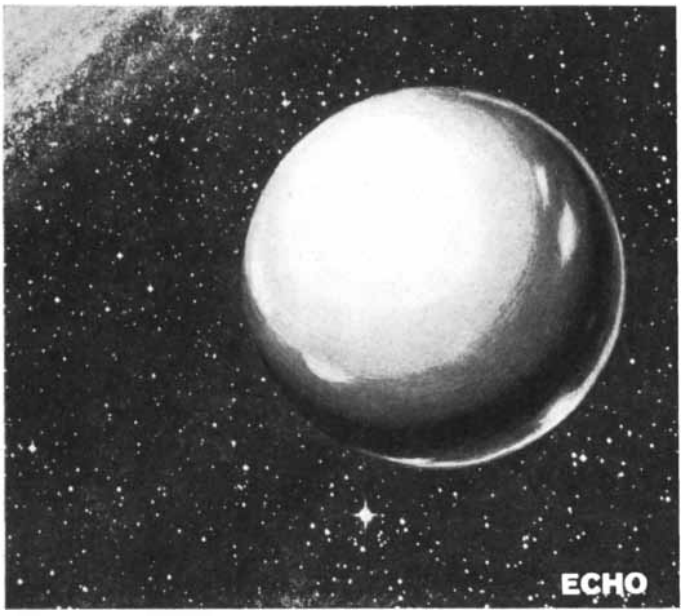
"At the late session of Congress an attempt to procure an extension of Morse's telegraph patents was opposed by Dr. Leverett Bradley. From Dr. Bradley's memorial in opposition to the extension, it seems that the line between Boston and New York yields sufficient profits every three months to pay for building the line! No definite statement can be made of the amount of the present wealth of Professor Morse, as that is a private matter which it might be deemed to his interest to keep from the public. From the large amount of very valuable telegraph stock Mr. Morse holds now, and from the highly valuable real estate in his splendid mansion near the Fifth-avenue, New York, his estate at Poughkeepsie, and other property, it is clear that he is a rich man, and his riches have been realized from his patents."

"The first result of the new method of analysis by the lines of the spectrum was to inform us what substances exist in the sun; the next result is the discovery of two new metals on the earth. One of these has been named cæsium, from the color of the peculiar lines in the spectrum of its light; the other is not yet named. Cæsium resembles potassium in its properties, and exists only in exceedingly minute quantities."

"Dr. Tyndall has shown, by a series of beautiful and conclusive experiments, that water has a decided color—that even in small thicknesses it is not the colorless substance it is usually imagined to be. When seen through a glass full of the liquid, of course it appears without color, but if looked at through a stratum of fifteen feet its color is very evident. In Dr. Tyndall's arrangement of the experi-







Philco Achievements in Space Technology

Philco has made many major contributions to the nation's vital space programs. COURIER, the world's first advanced communications satellite, was designed and built by Philco. Philco played a major role in the development and installation of the complex communications, command, tracking and data systems for the DISCOVERER program. Space-borne and ground communications systems for MIDAS and other satellites have been Philco designed. Philco developed and installed the tracking and receiving systems for the Air Force Passive Satellite Relay Link, which utilizes the ECHO satellite. In the field of human factors engineering, Philco has developed personnel subsystems for several major space projects. Philco also produces the world's largest 3-axis satellite tracking antennas.

These achievements are dramatic evidence of Philco's ability to integrate its extensive resources to the design and production of the most sophisticated electronic systems. For capacity, facilities and experience in space technology, look to the leader . . . look to Philco.

Government and Industrial Group, Philadelphia 44, Pennsylvania

PHILCO®

Famous for Quality the World Over

Communications and Weapons Division • Communications Systems Division
Computer Division • Sierra Electronic Division • Western Development Laboratories

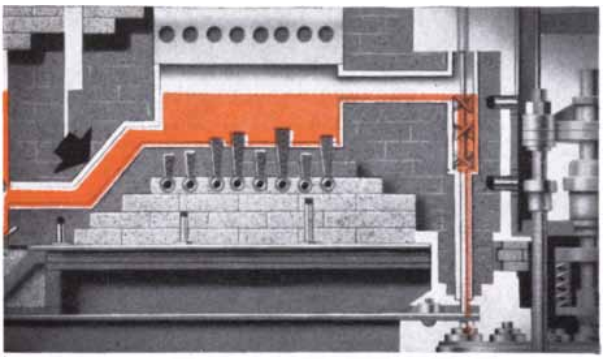
ment for showing this to a large audience, a tin tube, fifteen feet long and about three inches in diameter, is placed horizontally on a stand, and half filled with water. The tube is closed by plate glass at each end, and a beam of electric light is thrown through it from the further end. By this means an image of the contents of the tube is projected on a white screen. The image upon the screen being inverted by the lens, the upper air space in the tube is seen in the lower part of the image, which is quite colorless; whilst the upper portion, illuminated by the rays that pass through the stratum of water, is of a greenish blue color. The color varies from a pure green up to a blue, according to the purity or otherwise of the water."

"It is now the practice of every naval power to build steamers only, and to convert all sailing ships that are capable of it into steamers. Our sailing vessels, *without* steam, could not overtake steamships of *less* force, nor escape from those of *greater* force. This operates as a tremendous reduction, for it deprives us at once of 1,800 guns out of 2,300. But there is no help for it, and the fact is as stubborn as it is disagreeable. The Navy, then, upon which the Union must rely to represent it to foreign nations, if it were required to do so immediately, consists of seven screw frigates, five screw sloops, four side-wheel sloops and eight gun sloops, making a total of twenty-four vessels, carrying 386 guns. This is absolutely the entire national fleet of the United States, and no other statement of the case can make it greater."

"A lecture was recently delivered before the Royal Institution of Great Britain by Professor William Thomson of Glasgow on the subject of atmospheric electricity, in which he stated that by experiments with the air pump and 'vacuum tubes' for exhibiting the electric light, according as we obtain a vacuous space, it appears to be a conductor rather than an insulator. Professor Thomson said:—'We now look on space as full. We know that light is propagated like sound through pressure and motion. We know that there is no substance of caloric; inscrutable minute motions cause the expansion that is marked by the thermometer; these stimulate our sensations of heat. Fire is not laid up in coal any more than in a Leyden jar, but there is potential fire in each. We can conceive that electricity is an essence of matter, but whatever it is, one thing is quite certain, electricity in motion *is heat*.' "

NON-STOP PRODUCTION OF LENS GLASS...

Where any metal but Platinum



PLATINUM DOES BETTER FOR LESS. In this hot end of the Bausch & Lomb continuous-flow furnace only platinum has the stamina to stand up long enough to return a profit. It is used as a lining material and in agitators and thermocouples.

It seemed preposterous at first. Line even part of a 5-ton capacity furnace with platinum? . . .

But the engineers at Bausch & Lomb had a case and proved it. The only *sure* way to contain glass at volcanic heat for month after month is in platinum.

The proof? Platinum melts at 3224°F (1770°C). Retains adequate strength at ophthalmic glass refining temperatures (2600° - 2700°F). Doesn't dissolve in the melt to discolor, or degrade quality. Doesn't erodé or corrode in molten glass stream.

No other material provides the consistent purity essential to the economical mass-production of quality lenses.

The metal that masters molten glass may master a problem for you.

Where conditions involve high temperature and product purity, as in the production of lens glasses; or require peak catalytic efficiency, as in the refining of high octane gasoline; or a combination of severe corrosion and erosion must be met, as in the case of rayon production: or hard, highly con-

Platinum-lined five-ton furnace continuously fills molds with ophthalmic glass at Bausch & Lomb, makers of fine optical products. Furnace goes 18 months without shutdown. Glass must pass 23 quality tests.

would cost too much...

ductive surfaces, as in the production of printed electrical circuits; and many other products, the platinum metals have proved to be most economical.

Progress in research and development indicates a growing need for materials to cope with higher temperatures, higher pressures, more severe combinations of operating conditions . . . materials of proven ability to deliver long, trouble-free service life. To this end the unique potentials of the six platinum metals are being thoroughly explored on a continuing basis.

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

As a first step, write us for additional data on the unusual properties and successful applications of the six platinum metals and their alloys — indicating your field of interest or how we might be of assistance.

CAN THESE PROPERTIES OF THE PLATINUM METALS HELP YOU?

High Temperature Stability
Exceptional Chemical Inertness
Superior Wear Resistance
Peak Catalytic Activity
Low Vapor Pressure

The six platinum metals are:

PLATINUM • PALLADIUM • RHODIUM
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THE AUTHORS

WASSILY W. LEONTIEF and MARVIN HOFFENBERG ("The Economic Effects of Disarmament") are respectively Henry Lee Professor of Economics at Harvard University and a staff member of the Operations Research Office at Johns Hopkins University. Leontief studied economics at Leningrad State University and the University of Berlin, receiving his Ph.D. from the latter institution in 1928. He joined the faculty of Harvard in 1931. Leontief first applied his "input-output" analysis to the question of the economic impact of such large-scale shifts in Government fiscal policy as would attend disarmament when he served as consultant to the U. S. Department of Labor during World War II on a study of the postwar economic effects "that would result from the cessation of military production and the release of men from the armed forces." Hoffenberg was then a staff member of the Postwar Division in the Bureau of Labor Statistics and has collaborated with Leontief on many of the major undertakings in input-output analysis since then. A graduate of Ohio State University, Hoffenberg remained with the Bureau of Labor Statistics until 1952, at which time he joined the Rand Corporation. In 1956 he went to Washington as an economic consultant and two years later joined the staff of the Committee for Economic Development, at the same time acting as a consultant for the Operations Research Office. He took his present position last year.

HOWARD RASMUSSEN ("The Parathyroid Hormone") is assistant professor of physiology on the faculty of the Rockefeller Institute. He was graduated from Gettysburg College in 1948 with a B.A. in chemistry. After receiving an M.D. degree from the Harvard Medical School in 1952, Rasmussen spent three years at Massachusetts General Hospital and another year at University College Hospital Medical School in London. He joined the Rockefeller Institute in 1956 and acquired his Ph.D. there in 1959.

JAMES B. McGUIRE, EUGENE R. SPANGLER and LEM WONG ("The Size of the Solar System") have been working since 1957 at Space Technology Laboratories on problems related to artificial satellites and space probes. McGuire, a native of Newcastle, Ind., received a B.S. in electrical engineering from Purdue University in 1956 and an M.S. in physics from the University of California at Los Angeles in 1960. As a member of the technical staff in the Guidance and Navigation Department of Space Technology Laboratories, McGuire does research on the length of the astronomical unit and on problems of designing trajectories for lunar "soft landings" and interplanetary missions. Spangler was born in Des Moines, Iowa, studied engineering at the universities of Utah and California and received an M.A. from the University of Chicago in 1950. He is currently staff assistant in Space Systems Program Management. His work is principally concerned with the integration and presentation of technical information dealing with space systems and space experiments, notably those of *Explorer VI* and *Pioneer V.* Wong, who was born in Fargo, N.D., spent most of his youth in Hong Kong. After returning to the U. S. he studied physics at the University of California at Los Angeles, where he acquired a B.A. in 1955 and an M.S. in 1957. Also a member of the Guidance and Navigation Department, Wong does research on the application of celestial mechanics to spacecraft guidance and navigation. He was the principal designer of the computer program used in calculating the astronomical unit and the trajectory of *Pioneer V.*

MICHAEL E. DE BAKEY and LEONARD ENGEL ("Blood-Vessel Surgery") are respectively chairman of the department of surgery at Baylor University College of Medicine and a science writer. De Bakey was born in Lake Charles, La., in 1908. He acquired his B.S., M.D. and M.S. degrees at Tulane University, the last in 1935. After residencies at Charity Hospital in New Orleans and the universities of Strasbourg and Heidelberg, De Bakey joined the Tulane department of surgery in 1937. From 1942 to 1946 he was assigned to the Office of the Surgeon General, where his work won him the Legion of Merit in 1945. In 1948 he left Tulane to take his present position at Baylor. De Bakey is also clinical professor of surgery at the University of Texas Dental Branch. Engel was coauthor (with C. Walton Lillehei) of the article "Open-Heart Surgery" in the February, 1960, issue of this magazine.

JOHN A. KNAUSS ("The Cromwell Current") is assistant research oceanographer at the Scripps Institution of Oceanography. He had first planned

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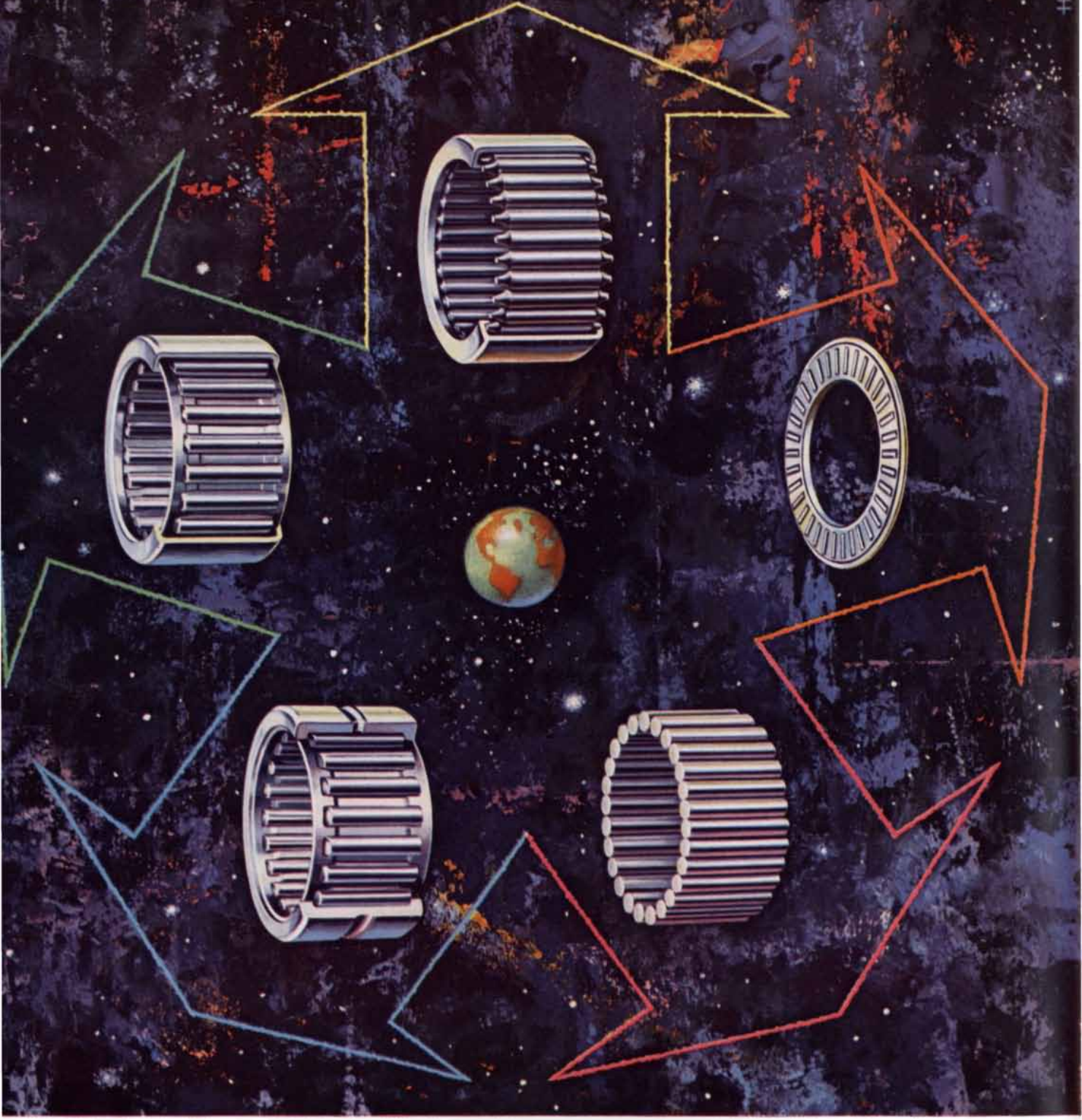

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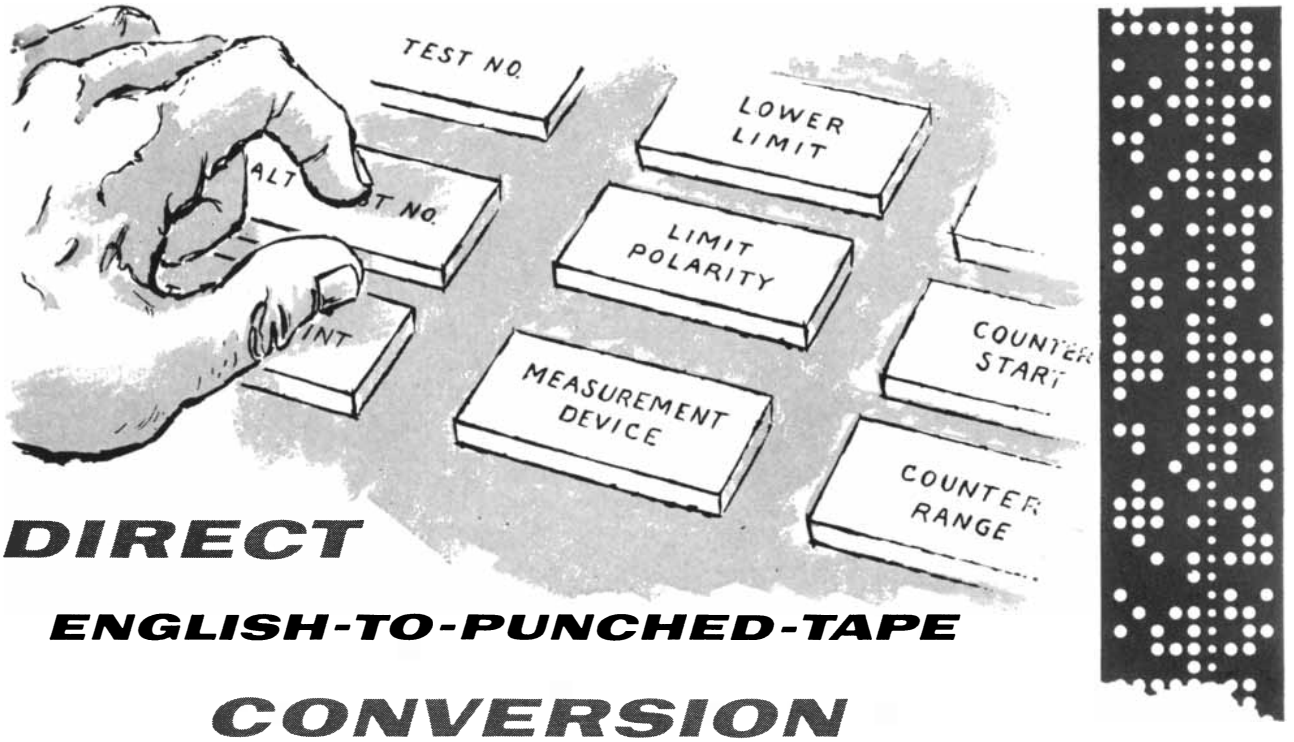
to study English at Oberlin College, "but," he writes, "this was 1943 and instead I found myself at the Massachusetts Institute of Technology in the Navy's V-12 program, studying meteorology. The jump from meteorology to oceanography is not too big, and I made it after the war." Knauss received a B.S. from M.I.T. in 1946, an M.A. in physics from the University of Michigan in 1949 and a Ph.D. in oceanography from the University of California in 1959. He joined the Scripps Institution in 1951.

RONALD C. RUSTAD ("Pinocytosis") is assistant professor of physiology at Florida State University. He was born in Minneapolis, Minn., in 1933 and received a B.A. in zoology from the University of California in 1954. He did graduate work under the direction of Daniel Mazia at the same institution, receiving a Ph.D. in biophysics in 1958. Most of Rustad's research has been devoted to the problem of why radiation delays cell division.

JESSE W. BEAMS ("Ultrahigh-Speed Rotation") is Francis H. Smith Professor of Physics and chairman of the department of physics at the University of Virginia. He was graduated from Fairmount College in 1921, did graduate work at the universities of Wisconsin and Virginia, received his Ph.D. from the latter institution in 1925 and became full professor there in 1930. From 1948 to 1954 he served on the board of directors of the Oak Ridge Institute of Nuclear Studies, and from 1954 to 1960 on the General Advisory Committee to the Atomic Energy Commission.

CHARLES F. COOPER ("The Ecology of Fire") works for the U. S. Agricultural Service in Boise, Idaho. He acquired a B.S. in forestry at the University of Minnesota in 1950, an M.S. at the University of Arizona and a Ph.D. in plant ecology at Duke University in 1958. "In the course of a rather short career," he writes, "I have been variously occupied as an aircraft mechanic, forester, pulpwood logger, manufacturer of creosoted fence posts, range conservationist and college teacher."

P. M. S. BLACKETT, who in this issue reviews Sir Charles Snow's *Science and Government*, is professor of physics at the Imperial College of Science and Technology in London. For his cosmic-ray research and his improvement of the Wilson cloud chamber Blackett received the 1948 Nobel prize in physics.



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Current at 6.3 volts	0.15	ampere
DIRECT INTERELECTRODE CAPACITANCES:		
Grid—No. 1 to plate	0.01	μμf
Grid—No. 1 to cathode, grid—No. 2, heater & shell	6.5	μμf
Plate to cathode, grid—No. 2, heater & shell	1.4	μμf
Heater to cathode	1.4	μμf
CHARACTERISTICS, CLASS A_1 AMPLIFIER:		
Plate Supply Voltage	125	volts
Grid—No. 2 Supply Voltage	50	volts
Cathode Resistor	68	ohms
Plate Resistance (Approx.)	0.2	megohm
Transconductance	10,600	μmhos
Plate Current	10	ma
Grid—No. 2 Current	2.7	ma
Grid—No. 1 Voltage (Approx.) for plate current of 10 μa	−4.5	volts

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GRID—No. 2 (SCREEN-GRID) SUPPLY VOLTAGE	330 max.	volts
GRID—No. 2 VOLTAGE	110 max.	volts
GRID—No. 1 (Control-Grid) VOLTAGE:		
Negative bias value	55 max.	volts
Peak positive value	2 max.	volts
CATHODE CURRENT	20 max.	ma
GRID—No. 1 CURRENT	2 max.	ma
PLATE DISSIPATION	2.2 max.	watts
GRID—No. 2 INPUT	0.2 max.	watt
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	100 max.	volts
Heater positive with respect to cathode	100 max.	volts
MAXIMUM CIRCUIT VALUES:		
Grid—No. 1 Circuit Resistance:*		
For fixed-bias operation	0.5 max.	megohm
For cathode-bias operation	1 max.	megohm

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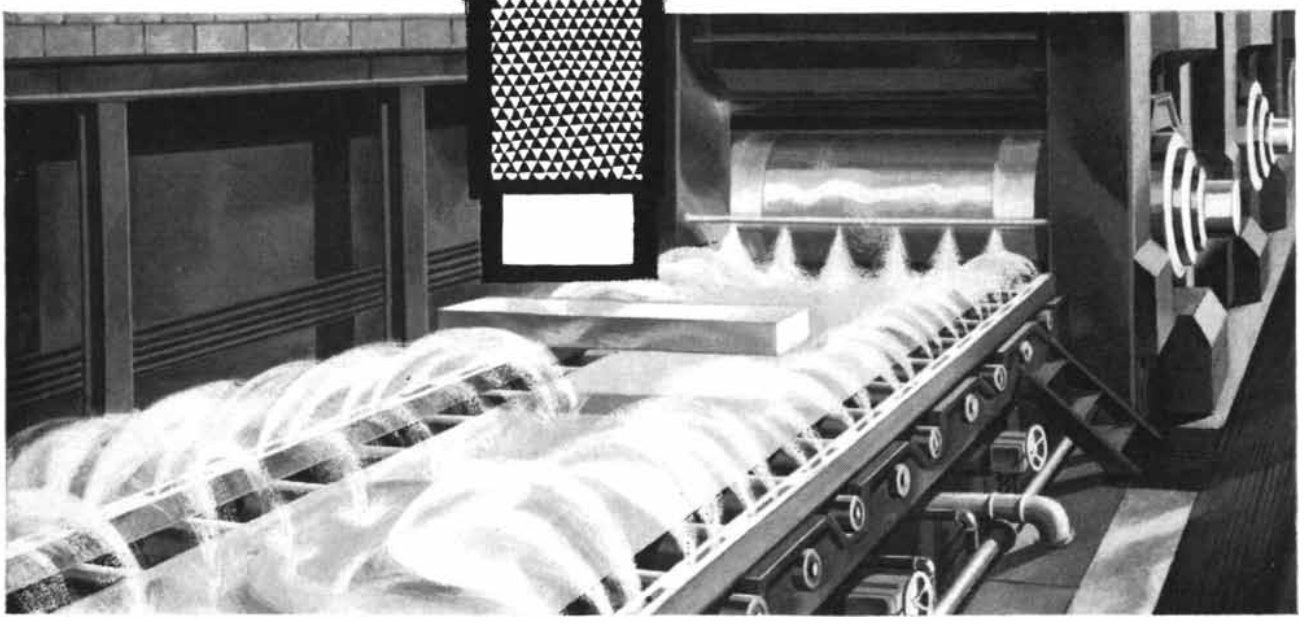

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The Monsanto Research Corporation conducts research and development programs to produce special new materials to fit specific requirements. This laboratory focuses the scientific resources of a major chemical company on creating special molecules. Here, basic science and applied technology in organic, inorganic, polymer and petroleum chemistry are integrated in the creative expedition.

Available to the government and prime contractors for contract research, the Monsanto Research Corporation provides the maximum probability of ultimate success in developing chemical materials for space-age technology because the "know-how" and research effort are concentrated in one well-rounded organization. It is currently at work in a number of vital areas of technology:

SOLID PROPELLANTS . . .

for the Bureau of Naval Ordnance, exploring a complete new type solid propellant with promise of advantages in specific impulse, safety and processing. Details on this project are classified. Information is available through the Solid Propellant Information Agency.

HULL-VIBRATION DAMPING . . .

for the Navy, Bureau of Ships, developing plastic coatings to damp vibration of metal parts. Study has developed a mathematical formula that relates actual engineering damping to fundamental constants of the polymers. Developed to date: a series of compounds that promise to be twice as effective as any previously known.

HIGH-HEAT-STABLE FLUORINE COMPOUNDS . . .

showing the most promise for use as high-temperature lubricants and fluids for the Air Force. By critical screening, Monsanto research has determined that perfluorobenzene appears to be a highly heat-stable building block. By screening various types of compounds, this order of heat stability was disclosed: certain compounds with fluorine and carbon only—stability greater than 1000°F.; special aromatics—up to 1000°F.; nitrogen heterocyclics—up to 950°F.; silicon compounds—to 900°F.; phosphorus compounds—to 850°F. Several major fields of fluorine chemistry have been "blocked out" and the research begun for heat-stable fluids, fuels, and lubricants.

CONTROLLED-PERMEABILITY FILMS . . .

research for the Office of Saline Water on plastic sheeting that can rapidly pass water but retain the ions of dissolved salts. These films would have a controlled permeability based upon their molecular structure—in effect, hold promise for separating a variety of salts from solution and specifically for purifying sea water.

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HEAT-RESISTANT ADHESIVES . . .

for the Air Force—polymers to develop high bond strengths between dissimilar materials at elevated temperatures. One series of polymers may yield metal-to-metal bonding that holds firm at 500-700°F., might be used to glue ovens together —and in many plants to eliminate welding.

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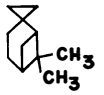
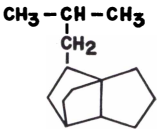
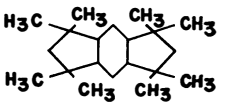


5,5-dimethyl-4,6-methanospiro[2.5]octane



8-isobutyltricyclo[4.2.2.0^{1,5}]decane

dispiro[5.0.5.1]tridecane



4,4,6,6,10,10,12,12-octamethyltricyclo-[7.3.0.0^{3,7}]dodecane

HIGH-TEMPERATURE LUBRICANT ADDITIVES . . .

for the Air Force—to provide extreme-pressure properties, pour-point modification, viscosity-index improvement, and oxidation resistance to synthetic lubricants that must operate in the temperature range of 600-800°F.

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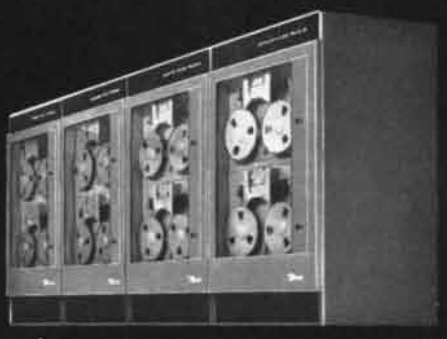

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Lord Acton... on men of science

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—*A Lecture on The Study of History, 1895*

Established 1845 SCIENTIFIC AMERICAN April 1961 Volume 204 Number 4

The Economic Effects of Disarmament

The technique of "input-output" analysis is here adapted to facilitate forecasting the effect on sales and jobs of the reallocation of the funds now expended for military purposes

by Wassily W. Leontief and Marvin Hoffenberg

The Federal Government of the U. S. has been spending somewhat more than $40 billion per year on the maintenance of the military establishment and the procurement of arms. These outlays have absorbed about 10 per cent of the gross national product, and they have exceeded by several billion dollars the combined net annual investment in manufacturing, service industries, transportation and agriculture. The negotiation of disarmament would eventually raise the possibility of a substantial cut in the military budget. Economists, market analysts and the makers of fiscal policy in Government and business have therefore begun to consider how the economy might otherwise employ the labor, the plant and the physical resources that now serve—directly and indirectly—the demands of the military establishment.

An increase in personal consumption, expansion of educational and medical services and facilities, acceleration of the rate of investment in domestic economic growth, enlargement of economic aid to underdeveloped countries—these are only a few of the many kinds of demand that would lay competing claims on the productive capacity made available by disarmament. There would be no problem if the goods that are listed in the typical procurement order from the U. S. Air Force missile base at Cape Canaveral also made up the shopping list of the average housewife. It would be merely a question of maintaining the total level of demand during the transition period. But swords do not serve readily as plowshares. In fact, the military shopping list is very different from the bills of goods presented by the various categories of civilian demand, and these in turn differ greatly from one another. So even if the total level of expenditures were maintained, the shift from military to nonmilitary budgets must be expected to increase the demand for the products of some industries and reduce the demand for the products of others. Furthermore, how the sales and employment figures of various industries will respond to the shifts depends upon the proportion in which each type of civilian demand, with its characteristic bill of goods, shares in the increase in total civilian demand.

The composition of the total civilian demand could possibly inhibit the overall increase in nonmilitary expenditures and so hold the country's economic activity at a lower level following a cut in the military budget. If most of the money saved were spent on highway construction, for example, a bottleneck would quickly develop in the supply of cement; meanwhile the electronics industry, which contributes much to military output but relatively little (directly or indirectly) to road building, would remain idle. On the other hand, if funds were allocated to a more balanced pattern of demand, they would secure more nearly full employment of the available human and physical resources. In the long run, of course, any mismatch between the productive capacities of individual industries and the changed pattern of demand would be rectified by reallocation of capital and labor. But such adjustment, as is well known, is quite painful and could take many months or even several years. The loss of time would represent an irredeemable loss of real income to individual citizens and to the nation as a whole.

What is needed in order to anticipate and forestall such losses is a picture of the dependence of various industries on military demand, plus the bill of goods of each one of the more important kinds of private and public nonmilitary demand that are likely to increase when military demand is reduced. The present study is a pilot effort to develop this information and show how it can be applied to forecasting the consequences of the transfer of expenditures from military to civilian purchases. Our research was supported in part by the Research Program on Economic Adjustments to Disarmament of the Center for Research in Conflict Resolution at the University of Michigan. The study does not attempt to predict how much the various kinds of civilian purchase might expend, any more than it tries to predict the actual magnitude of military cuts. The eight tables of figures presented here, however, make it possible to analyze the consequences of such shifts from military to civilian expenditures as can be pre-

DIRECT PURCHASES BY DEMAND CATEGORY

(MILLIONS OF 1947 DOLLARS)

PRODUCTION BY SECTOR	PERSONAL CONSUMPTION	BUSINESS INVESTMENT	RESIDENTIAL CONSTRUCTION	PUBLIC SERVICES CONSTRUCTION	MAINTENANCE CONSTRUCTION	EXPORTS (EXCEPT MILITARY)	EXPORTS TO INDIA (EXCEPT FOOD)	GOVERNMENT (NON-MILITARY)	MILITARY
1 FOOD AND KINDRED PRODUCTS	38,396					3,199	[5]	169	536
2 APPAREL AND TEXTILE-MILL PRODUCTS	14,532	20				1,167	[11]	109	143
3 LEATHER PRODUCTS	2,038	14				45		20	24
4 PAPER AND ALLIED PRODUCTS	597					184	[1]	104	
5 CHEMICALS AND ALLIED PRODUCTS	3,879	49				1,114	[16]	412	85
6 FUEL AND POWER	10,943					536	[4]	556	991
7 RUBBER AND RUBBER PRODUCTS	782					153	[2]	23	6
8 LUMBER AND WOOD PRODUCTS	2,555	526				108	[1]	66	19
9 NONMETALLIC MINERALS AND PRODUCTS	316	20				91	[2]	17	
10 PRIMARY METALS	21					473		4	
11 FABRICATED METAL PRODUCTS	1,109	186				330	[1]	57	106
12 MACHINERY (EXCEPT ELECTRICAL)	968	5,957				1,651	[23]	288	166
13 ELECTRICAL MACHINERY	3,160	2,150				464	[6]	74	915
14 TRANSPORTATION EQUIPMENT AND ORDNANCE	5,574	2,863				962	[22]	352	9,478
15 INSTRUMENTS AND ALLIED PRODUCTS	389	265				122	[2]	19	22
16 MISCELLANEOUS MANUFACTURING INDUSTRIES	2,088	96				91		97	
17 TRANSPORTATION	7,714	341				1,844	[35]	705	730
18 TRADE	37,242	2,161				812	[15]	40	78
19 SERVICE AND FINANCE	90,025					862	[2]	11,029	705
20 CONSTRUCTION		16,844	12,082	5,956	10,429				967
21 UNALLOCATED AND WASTE PRODUCTS						390	[7]		742
EXPENDITURES (MILLIONS OF 1958 DOLLARS)	**292,956**	**46,102**	**18,893**	**7,770**	**17,713**	**22,576**	**[189]**	**37,184**	**41,585**

TABLE 1. The figures in heavy type at bottom show the total quantities of goods and services (in 1958 dollars) delivered in 1958 to eight major categories of final demand, plus "Exports to India," a subtotal from the "Exports (except Military)" column. The demand categories approximate the breakdown of national expenditures in which the gross national product is usually stated. The figures in each column show the quantities purchased in each demand category from each production sector. Figures in each row show the deliveries made by each production sector to each demand category. The 1947-dollar figures do not yield 1958-dollar totals at bottom.

dicted. They should be of considerable help in spelling out the concrete quantitative implications of the alternative fiscal measures that the Government may have to take if and when disarmament becomes a fact. They should also enable business analysts to derive specific estimates of the demand for any particular goods or services or of the employment in a given industry from their own over-all projections of public and private expenditure.

These tables embody insights afforded "input-output" analysis [see "Input-Output Economics," by Wassily W. Leontief; SCIENTIFIC AMERICAN, October, 1951]. This technique is used today in many countries by governments and private businesses to chart the state of the national economy and to appraise the implications of specific economic actions that might affect its course. It anchors forecasting in the relatively stable fine structure of the economy and develops the important indirect relationships among the interdependent elements in the system.

In the highly integrated U. S. economy, for example, many industries deliver a large part or even all of their output not to final users but to other industries; in other words, a part or all of their output serves the needs of final users indirectly rather than directly. This does not make their dependence on the level and the structure of final demand any weaker, but it does make it more difficult to measure. In order to determine how much the demand for crude sulfur would diminish if the Army cut its purchases of trucks by $1 million, one must determine how much crude sulfur the chemical industry needs to make $1 million worth of sulfuric acid, how much sulfuric acid is used in the finishing of $1 million worth of steel sheet and how much steel sheet goes into $1 million worth of trucks. This is only one of several such linked chains connecting the output of crude sulfur to the final sales of automobiles. The input-output table of a national economy incorporates just this kind of information. The table (more properly a deck of punched cards or a magnetic tape) of interindustry relationships shows how much of the product of every other

DIRECT AND INDIRECT DEMAND BY DEMAND CATEGORY

(MILLIONS OF 1947 DOLLARS)

PRODUCTION BY SECTOR	PERSONAL CONSUMPTION	BUSINESS INVESTMENT	RESIDENTIAL CONSTRUCTION	PUBLIC SERVICES CONSTRUCTION	MAINTENANCE CONSTRUCTION	EXPORTS (EXCEPT MILITARY)	GOVERNMENT (NONMILITARY)	MILITARY	TOTAL OUTPUT
1 FOOD AND KINDRED PRODUCTS	86,166	754	462	70	351	5,766	1,362	1,513	96,444
2 APPAREL AND TEXTILE-MILL PRODUCTS	26,557	640	248	51	139	1,986	387	575	30,582
3 LEATHER PRODUCTS	3,314	117	23	8	19	113	77	116	3,786
4 PAPER AND ALLIED PRODUCTS	7,333	926	408	133	380	793	542	788	11,303
5 CHEMICALS AND ALLIED PRODUCTS	10,208	1,047	380	126	853	1,960	1,183	877	16,634
6 FUEL AND POWER	26,530	1,969	557	553	623	1,846	1,533	2,633	36,243
7 RUBBER AND RUBBER PRODUCTS	2,727	588	85	65	74	388	163	244	4,333
8 LUMBER AND WOOD PRODUCTS	4,918	2,309	2,446	120	883	340	198	451	11,665
9 NONMETALLIC MINERALS AND PRODUCTS	1,940	1,776	1,150	711	756	305	150	337	7,123
10 PRIMARY METALS	8,138	7,393	1,092	651	1,434	2,445	695	3,384	25,230
11 FABRICATED METAL PRODUCTS	5,988	4,462	1,147	428	1,438	945	382	1,281	16,071
12 MACHINERY (EXCEPT ELECTRICAL)	3,635	7,947	205	190	204	2,237	537	823	15,780
13 ELECTRICAL MACHINERY	5,757	4,128	343	121	407	852	245	3,110	14,962
14 TRANSPORTATION EQUIPMENT AND ORDNANCE	10,421	4,090	145	139	131	1,443	640	10,609	27,617
15 INSTRUMENTS AND ALLIED PRODUCTS	786	377	23	37	22	160	61	370	1,835
16 MISCELLANEOUS MANUFACTURING INDUSTRIES	3,403	235	35	14	36	166	218	119	4,225
17 TRANSPORTATION	15,147	2,261	951	512	675	2,658	1,418	1,486	25,108
18 TRADE	44,420	4,168	1,489	254	1,334	1,350	537	735	54,287
19 SERVICE AND FINANCE	118,402	3,196	1,350	913	893	2,410	12,204	1,886	141,254
20 CONSTRUCTION		16,844	12,082	5,956	10,429			967	46,278
21 UNALLOCATED AND WASTE PRODUCTS	9,583	2,172	490	190	433	1,270	1,143	2,144	17,426

TABLE 2. The total—direct and indirect—dependence of the production sectors on the military and nonmilitary demand categories is shown here. The column at right shows the total outputs of the sectors. Each column to the left shows how much the outputs would be reduced if that category of demand were eliminated. The figures in each case include direct deliveries to the demand category plus deliveries to other industries needed to permit them to make their deliveries to this demand category. The figures are thus larger than those in Table 1; compare, for example, the "Rubber and Rubber Products" entry in the "Military" column in these two tables.

industry each industry requires to make one unit of its output. It also shows the distribution of the output of each industry to every other industry and to the various categories of final demand.

As can be imagined, the preparation of such a table represents a major fact-finding and analytical task. The last complete, detailed input-output table of the U. S. was constructed for the year 1947. A trial check shows, however, that the structural relationships shown for that year still yield a reasonably good description of interindustry relationships in 1958. In the tables presented here the description of the interindustry relations, that is, the input-output matrix itself, has been omitted in order to bring into relief the less obvious but crucially important structural relationships between the industries and the various kinds of demand they serve. In other words, our tables show the end product of analytical computations, not the raw statistical material that went into them.

The industries have been aggregated in 20 or 58 production "sectors." The horizontal rows in each case show the outputs of each sector as they are distributed to various categories of civilian and military demand. The categories of demand approximate those in which the gross national product is commonly stated and the columns under each demand heading show the input of each production sector to that category in demand.

The first seven tables constitute the set of "tools" for working out the repercussions of an assumed step in disarmament and the accompanying transfer of expenditures to other categories of demand. The eighth table shows the answers yielded by such analysis in one particular, typical case.

The basic economic data for the year 1958 are presented in the first pair of tables. The figures in Table 1 [*opposite page*] are those in which the workings of the economy are commonly stated; they show only the direct purchases from each industry by each type of demand. For technical and statistical reasons the industry-by-industry outputs are stated in 1947 dollars; the figures in the columns therefore do not add up to the

DIRECT AND INDIRECT DEMAND PER $1,000,000 DIRECT PURCHASES BY DEMAND CATEGORY

(1947 DOLLARS)

PRODUCTION BY SECTOR	PERSONAL CONSUMPTION	BUSINESS INVESTMENT	RESIDENTIAL CONSTRUCTION	PUBLIC SERVICES CONSTRUCTION	MAINTENANCE CONSTRUCTION	EXPORTS (EXCEPT MILITARY)	EXPORTS TO INDIA (EXCEPT FOOD)	GOVERNMENT (NONMILITARY)	MILITARY
1 FOOD AND KINDRED PRODUCTS	294,127	16,362	24,459	9,022	19,839	255,386	[98,413]	36,623	36,374
2 APPAREL AND TEXTILE-MILL PRODUCTS	90,653	13,880	13,100	6,525	7,842	87,987	[99,471]	10,400	13,825
3 LEATHER PRODUCTS	11,312	2,534	1,196	991	1,084	5,014	[3,704]	2,063	2,777
4 PAPER AND ALLIED PRODUCTS	25,032	20,095	21,596	17,156	21,425	35,108	[40,741]	14,565	18,959
5 CHEMICALS AND ALLIED PRODUCTS	34,844	22,704	20,119	16,255	48,168	86,818	[134,392]	31,823	21,087
6 FUEL AND POWER	90,560	42,703	29,477	71,145	35,194	81,773	[94,709]	41,219	63,309
7 RUBBER AND RUBBER PRODUCTS	9,309	12,750	4,473	8,314	4,189	17,178	[25,926]	4,384	5,858
8 LUMBER AND WOOD PRODUCTS	16,788	50,093	129,461	15,405	49,822	15,038	[19,577]	5,333	10,850
9 NONMETALLIC MINERALS AND PRODUCTS	6,621	38,512	60,880	91,441	42,675	13,488	[23,810]	4,026	8,092
10 PRIMARY METALS	27,778	160,366	57,794	83,745	80,929	108,279	[119,577]	18,694	81,373
11 FABRICATED METAL PRODUCTS	20,439	96,788	60,705	55,045	81,189	41,867	[46,561]	10,284	30,812
12 MACHINERY (EXCEPT ELECTRICAL)	12,409	172,381	10,872	24,466	11,540	99,101	[164,021]	14,439	19,788
13 ELECTRICAL MACHINERY	19,652	89,534	18,139	15,611	22,972	37,726	[61,905]	6,581	74,779
14 TRANSPORTATION EQUIPMENT AND ORDNANCE	35,572	88,705	7,691	17,851	7,396	63,895	[158,730]	17,206	255,126
15 INSTRUMENTS AND ALLIED PRODUCTS	2,680	8,184	1,228	4,736	1,225	7,074	[13,228]	1,638	8,890
16 MISCELLANEOUS MANUFACTURING INDUSTRIES	11,615	5,095	1,826	1,828	2,044	7,340	[4,233]	5,860	2,869
17 TRANSPORTATION	51,703	49,041	50,336	65,933	38,108	117,736	[233,333]	38,129	35,729
18 TRADE	151,627	90,410	78,802	32,716	75,295	59,816	[106,878]	14,439	17,667
19 SERVICE AND FINANCE	404,164	69,329	71,466	117,542	50,421	106,728	[91,005]	328,208	45,348
20 CONSTRUCTION		365,364	639,496	766,538	588,777				23,254
21 UNALLOCATED AND WASTE PRODUCTS	32,711	47,113	25,925	24,402	24,462	56,272	[89,947]	30,739	51,567

TABLE 3. The columns show the output required of each production sector to fulfill the direct and indirect demand (*see Table 2*) generated by $1 million of direct purchases in each demand category. One can now estimate the outputs needed to fulfill any given final demand: simply multiply each figure in a column by the total assumed demand in that category. Multiplication of the figures in the "Military" column by the 1958-dollar total military expenditure in Table 1 reproduces the "Military" column in Table 2. The figures may be regarded as ratios reflecting constant structural relations between demand categories and production sectors.

totals in 1958 dollars printed in heavy type in the bottom row. Conceptually it is best to regard these 1947 figures as standing for physical quantities measured not in tons, yards or bushels but rather in units defined as "the amounts of the respective goods that could be purchased for $1 million at the prices prevailing in 1947."

Table 2 [*preceding page*] gives effect to the interindustry transactions and thus shows the true total dependence of each industry on each type of demand. At the end of each row is shown the total 1958 output of the industry in question. The entries to the left of it show by how much the total output would have been diminished if the direct purchases in that category of demand (*shown in Table 1*) had been reduced to zero. Thus the entries in the "Military" services column show that complete elimination of the military budget would have reduced the demand for "Food and Kindred Products" by $1,513 million, for "Apparel" by $575 million, and so on. These figures are considerably larger than the figures in the corresponding boxes in Table 1. The reason for this is that the direct-purchase figures show only the goods delivered to the military establishment, while the figures in Table 2 show the indirect as well as direct military demand and include the goods and services that must be delivered to other industries that need these inputs in order to produce, in their turn, the goods and services demanded by the final military users. Thus, as Table 1 shows, the rubber industry delivered in 1958 only $6 million worth of its goods to the military establishment; Table 2 shows, however, that a much larger part of its total output, $244 million, depended upon military demand. All told, the $41.6 billion ($16.7 billion in 1947 dollars) of direct purchases for military purposes in 1958 generated a total of some $86 billion ($34.5 billion in 1947 dollars) of direct and indirect military demand in the economy as a whole.

TOTAL EMPLOYMENT PER $100 MILLION DIRECT PURCHASES BY DEMAND CATEGORY

(1958 MAN YEARS)

EMPLOYMENT BY SECTOR

	PERSONAL CONSUMPTION	BUSINESS INVESTMENT	RESIDENTIAL CONSTRUCTION	PUBLIC SERVICES CONSTRUCTION	MAINTENANCE CONSTRUCTION	EXPORTS (EXCEPT MILITARY)	EXPORTS TO INDIA (EXCEPT FOOD)	GOVERNMENT (NONMILITARY)	MILITARY
1 FOOD AND KINDRED PRODUCTS	498	21	28		20	374	[128]	56	53
2 APPAREL AND TEXTILE-MILL PRODUCTS	658	80	72	35	41	502	[560]	66	86
3 LEATHER PRODUCTS	107	24	11	9	10	47	[34]	19	27
4 PAPER AND ALLIED PRODUCTS	121	97	104	85	105	170	[197]	71	91
5 CHEMICALS AND ALLIED PRODUCTS	180	128	94	85	211	481	[660]	168	128
6 FUEL AND POWER	359	163	114	236	127	283	[318]	172	220
7 RUBBER AND RUBBER PRODUCTS	54	74	27	49	24	100	[151]	26	34
8 LUMBER AND WOOD PRODUCTS	141	421	1,084	126	420	126	[164]	45	92
9 NONMETALLIC MINERALS AND PRODUCTS	60	348	548	828	385	123	[217]	36	73
10 PRIMARY METALS	133	782	262	435	380	496	[599]	88	364
11 FABRICATED METAL PRODUCTS	160	695	387	386	500	333	[392]	90	258
12 MACHINERY (EXCEPT ELECTRICAL)	97	1,379	85	175	88	755	[1,301]	108	169
13 ELECTRICAL MACHINERY	145	781	110	91	153	313	[513]	51	662
14 TRANSPORTATION EQUIPMENT AND ORDNANCE	156	466	38	73	36	370	[991]	78	2,467
15 INSTRUMENTS AND ALLIED PRODUCTS	36	110	17	63	16	94	[177]	22	119
16 MISCELLANEOUS MANUFACTURING INDUSTRIES	103	45	16	14	17	65	[37]	52	25
17 TRANSPORTATION	518	488	506	669	380	764	[1,523]	383	322
18 TRADE	2,674	1,600	1,369	616	1,297	1,060	[1,900]	258	322
19 SERVICE AND FINANCE	3,715	705	665	856	391	937	[883]	9,296	584
20 CONSTRUCTION		2,091	3,658	4,396	3,364				134
EMPLOYEES IN BUSINESS ESTABLISHMENTS	9,915	10,499	9,193	9,228	7,965	7,394	[10,746]	11,086	6,230
HOUSEHOLDS	870								
GOVERNMENT: CIVILIAN								9,649	1,977
ARMED FORCES									6,329
TOTAL EMPLOYEES	10,785	10,499	9,193	9,228	7,965	7,394	[10,746]	20,734	14,536

TABLE 4. The columns show the total employment (in 1958 man-years) required in each production sector to satisfy the direct and indirect demand generated by $100 million of direct purchases in each demand category. With these figures one may estimate the employment required in each production sector to fulfill any given final demand: multiply each figure in a column by the assumed demand in that category. Multiplication of figures in the "Military" column by the 1958-dollar total military expenditure in Table 1 shows this expenditure sustained 1,026,300 jobs in "Transportation Equipment and Ordnance" and 2,591,700 total "Business" jobs.

In the next pair of tables the relationships developed in Table 2 are restated in a form that begins to make them useful for purposes of analysis. It now becomes possible to deal with the question of how the sales and employment of various industries would be affected by a cut in military demand and a corresponding increase in one or another category of civilian demand. Table 3 [*opposite page*] shows the quantity of goods and services each industry has to produce in order to enable the economy as a whole to satisfy $1 million worth of direct purchases in any one category of demand. With these figures it is possible to estimate the total output of each industry that would be developed under any set of assumptions about the magnitude of expenditures in the various demand categories. In other words, the figures are useful for economic forecasting in general, quite apart from the question of disarmament. All of the figures in the main body of Table 2 can be synthesized, for example, by multiplying each one of the 1958 expenditure totals (printed in heavy type in Table 1) by the entries in the corresponding columns of Table 3.

In Table 4 [*above*] the output figures of Table 3 are translated into figures that show the volume of employment, industry by industry, engaged directly and indirectly in satisfying $100 million worth of direct purchases in each category of demand. This table may therefore be used along with Table 3 in estimating the detailed consequences of one or another change in the total pattern of demand. One simply multiplies the figures in each column by the assumed or given total expenditure in that demand category and thereby determines the level of employment in each industry that corresponds to that volume of expenditure. Again, as in the case of Table 3, the actual 1958 employment figures can be synthesized by performing these multiplications with the 1958 expenditure totals given in Table 1.

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PRODUCTION BY SECTOR AFTER REALLOCATION OF $1,000,000 DIRECT MILITARY PURCHASES

(THOUSANDS OF 1947 DOLLARS)

PRODUCTION BY SECTOR	EXPORTS TO INDIA (EXCEPT FOOD)	EXPORTS (EXCEPT MILITARY)	BUSINESS INVESTMENT	PERSONAL CONSUMPTION	PUBLIC SERVICES CONSTRUCTION	RESIDENTIAL CONSTRUCTION	MAINTENANCE CONSTRUCTION	GOVERNMENT (NONMILITARY)	MILITARY
14 TRANSPORTATION EQUIPMENT AND ORDNANCE	96	191	166	220	237	247	248	238	255
15 INSTRUMENTS AND ALLIED PRODUCTS	4	2	1	6	4	8	8	7	9
13 ELECTRICAL MACHINERY	13	37	15	55	59	57	52	68	75
1 FOOD AND KINDRED PRODUCTS	62	219	20	258	27	12	17		36
3 LEATHER PRODUCTS	1	2		9	2	2	2	1	3
2 APPAREL AND TEXTILE-MILL PRODUCTS	85	74		77	7	1	6	3	14
12 MACHINERY (EXCEPT ELECTRICAL)	144	79	153	7	5	9	8	5	20
6 FUEL AND POWER	31	18	21	27	8	34	28	22	63
10 PRIMARY METALS	38	27	79	54	2	24		63	81
16 MISCELLANEOUS MANUFACTURING INDUSTRIES	1	4	2	9	1	1	1	3	3
7 RUBBER AND RUBBER PRODUCTS	20	11	7	3	2	1	2	1	6
9 NONMETALLIC MINERALS AND PRODUCTS	16	5	30	1	83	53	35	4	8
11 FABRICATED METAL PRODUCTS	16	11	66	10	24	30	50	21	31
5 CHEMICALS AND ALLIED PRODUCTS	113	66	2	14	5	1	27	11	21
4 PAPER AND ALLIED PRODUCTS	22	16	1	6	2	3	3	4	19
8 LUMBER AND WOOD PRODUCTS	9	4	39	6	5	119	39	6	11
17 TRANSPORTATION	198	82	13	16	30	15	2	2	36
18 TRADE	89	42	73	134	15	61	58	3	18
19 SERVICE AND FINANCE	46	61	24	359	72	26	5	283	45
20 CONSTRUCTION	23	23	342	23	743	616	566	23	23

TABLE 5. This table, Table 6 and Table 7 are designed to short-cut the computations involved in analysis of the consequences of disarmament. The columns here show the net increase (*black figures*) or decrease (*red figures*) in the output of each production sector resulting from the transfer of $1 million of demand from the military to each of the eight nonmilitary categories of demand. The figures were obtained by subtracting from the entries in each of the first eight columns in Table 3 the corresponding entries in the "Military" column shown at far right. In this table the columns and rows have been rearranged to segregate red and black figures.

with the effects of a transfer of expenditures from the military to the various categories of civilian demand, Table 5 [*above*] and Table 6 [*opposite page*] provide a way to short-cut the task of computation. These tables show the net effect on the sales (or employment) of each industry that would result from the transfer of $1 million (or $100 million) from the "Military" column to each of the other demand columns. The order of columns and rows has been arranged in these tables so as to segregate the red figures—the negative changes in output and demand—above the diagonal falling from left to right. (The black figures —the positive changes in output and demand—fall correspondingly below the diagonal.) The tables bring out clearly the pronounced differences in the responses of the various industries and the equally pronounced differences in the capacity of the various types of civilian demand to absorb the goods and services now serving final military demand.

The "Transportation Equipment and Ordnance" industry emerges in the red figures at the top of these tables as the one that depends most heavily upon military demand. This group of industries includes the aircraft, motor vehicle, shipbuilding and railway-equipment industries along with ordnance proper. It is followed in the hierarchy of dependence upon military demand by "Instruments and Related Products" and "Electrical Machinery." On the other hand, in the lower rows of the table, the black figures opposite the "Transportation," "Trade" and "Service and Finance" industries show that their outputs are bound to increase whichever type of civilian demand lays claim to the resources that are released from military needs.

The reader will note that the industries appear in a slightly different order in the two tables, suggesting that an increase in output could be accompanied in some cases by a decrease in employment. This apparent inconsistency is a consequence of the necessarily gross "product mix" involved in summarizing the industrial economy in only 20 sectors; it reflects the fact that the principal increases in output are coming in these cases from industries having a lower

EMPLOYMENT BY SECTOR AFTER REALLOCATION OF $100 MILLION DIRECT MILITARY PURCHASES

(1958 MAN YEARS)

EMPLOYMENT BY SECTOR	EXPORTS TO INDIA (EXCEPT FOOD)	EXPORTS (EXCEPT MILITARY)	BUSINESS INVESTMENT	PERSONAL CONSUMPTION	PUBLIC SERVICES CONSTRUCTION	RESIDENTIAL CONSTRUCTION	MAINTENANCE CONSTRUCTION	GOVERNMENT (NONMILITARY)
14 TRANSPORTATION EQUIPMENT AND ORDNANCE	1,476	2,097	2,001	2,311	2,394	2,429	2,431	2,389
15 INSTRUMENTS AND ALLIED PRODUCTS	57	25	9	83	56	102	103	97
13 ELECTRICAL MACHINERY	149	349	119	517	571	552	509	611
2 APPAREL AND TEXTILE-MILL PRODUCTS	473	416	6	572	51	14	45	20
3 LEATHER PRODUCTS	8	20	3	80	18	16	17	8
6 FUEL AND POWER	98	63	57	139	16	106	93	48
12 MACHINERY (EXCEPT ELECTRICAL)	1,132	586	1,210	72	6	84	81	61
1 FOOD AND KINDRED PRODUCTS	75	321	32	445	53	25	33	3
16 MISCELLANEOUS MANUFACTURING INDUSTRIES	12	40	20	78	11	9	8	27
7 RUBBER AND RUBBER PRODUCTS	117	66	40	20	15	7	10	8
10 PRIMARY METALS	235	132	418	231	71	102	16	276
5 CHEMICALS AND ALLIED PRODUCTS	532	353	0	52	43	34	83	40
9 NONMETALLIC MINERALS AND PRODUCTS	144	50	275	13	755	475	312	37
11 FABRICATED METAL PRODUCTS	143	75	437	98	128	129	242	168
4 PAPER AND ALLIED PRODUCTS	106	79	6	30	6	13	14	20
8 LUMBER AND WOOD PRODUCTS	72	34	329	49	34	992	328	47
18 TRADE	1,578	738	1,278	2,352	294	1,047	975	64
19 SERVICE AND FINANCE	247	353	121	3,131	272	81	193	8,712
17 TRANSPORTATION	1,147	442	166	196	347	184	58	61
20 CONSTRUCTION	134	134	1,957	134	4,262	3,524	3,230	134
NET INCREASE IN BUSINESS EMPLOYMENT	4,516	1,163	4,268	3,685	2,997	2,963	1,735	4,855
TOTAL NEGATIVE CHANGE	1,625	2,471	2,108	3,325	3,203	3,480	3,523	3,854
TOTAL NEGATIVE CHANGE (FROM TABLE 7)	2,897	3,117	2,768	3,610	3,724	3,746	3,911	4,114

TABLE 6. The columns in this table show the net increase (*black figures*) or decrease (*red figures*) in employment (in 1958 man-years) in each production sector resulting from the transfer of $100 million of demand from the military to each of the seven nonmilitary categories of demand. The "Net Increase in Business Employment" figures are net after subtracting the negative changes shown in this table and totaled on the "Total Negative Change" row below. The "Total Negative Change (from Table 7)" row shows that a larger number of job holders would have to seek reemployment than is indicated by the coarser industrial breakdown in this table.

ratio of labor to output. Since employment is necessarily foremost among the concerns in any economic forecast, the industry-by-industry employment figures are shown in the fine detail of a 58-industry breakdown in Table 7 [*next page*].

What would be the effect on employment of a 20 per cent, or $8 billion, cut in a $40 billion military budget if this cut were accompanied by an equal increase in nonmilitary expenditures? Taking the simple case of the transfer of the entire expenditure to one or another category of civilian demand, one need only multiply the figures in the chosen category in Table 7 by 80. Thus on the unlikely assumption that the entire expenditure is moved into the "Government" column (which comprises all governmental demand except for military and construction activities of the Government), as many as 329,000 jobs held in private business establishments would be eliminated, and this would be offset by the creation of 717,000 new jobs in other private industries. The equally unlikely shift of demand to "Exports" to foreign countries would cause far less strain as measured in turnover of the labor force (only 249,000 jobs would be lost and 342,000 new jobs created). As this result suggests, exports draw upon much the same industries as the military, though for different products. The column "Exports to India," which appears in all the tables except 2 and 8, makes it possible to perform similar computations with the quite different bill of goods that would be involved in a substantial increase in economic aid to underdeveloped countries.

Table 8 [*page 55*] shows the effects upon employment in the 58 industries that follow from a more reasonable assumption: the projected $8 billion cut in the military budget is here transferred pro rata to the various categories of civilian demand, leaving their relative magnitudes unchanged. As can be seen, a total of 253,815 jobs would be eliminated in 19 industries and a total of 541,855 new jobs would be created in the other 38 industries—a net gain of 288,040 jobs. For purposes of comparison, it may be observed that during the recession of

EMPLOYMENT AFTER REALLOCATION OF $100 MILLION MILITARY PURCHASES TO EACH OF EIGHT OTHER DEMAND CATEGORIES

(1958 MAN YEARS)

		EXPORTS (EXCEPT MILITARY)	EXPORTS TO INDIA (EXCEPT FOOD)	BUSINESS INVESTMENT	PERSONAL CONSUMPTION	PUBLIC SERVICES CONSTRUCTION	HIGHWAY CONSTRUCTION	RESIDENTIAL CONSTRUCTION	CONSTRUCTION NONMILITARY
14	AIRCRAFT AND PARTS	1,653.5	1,554.7	1,652.9	1,703.8	1,707.1	1,707.1	1,707.1	1,705.0
14	ORDNANCE	341.7	341.7	341.7	341.7	341.7	341.7	341.7	341.7
14	SHIPS AND BOATS	275.1	267.6	271.0	338.5	349.1	343.6	343.0	343.9
13	RADIO	408.3	352.6	238.9	433.3	497.3	466.8	497.3	482.8
10	ALUMINUM	7.6	9.9	4.0	25.1	21.7	12.2	20.4	26.4
15	INSTRUMENTS	24.3	58.3	9.1	82.7	55.5	102.2	101.7	96.8
2	APPAREL	5.0	23.1	24.3	390.6	27.1	27.1	27.1	.2
10	COPPER	8.0	7.9	12.0	30.8	19.2	12.0	12.0	32.9
5	PLASTICS	51.8	14.4	4.7	17.1	27.7	19.3	26.4	34.6
17	OVERSEAS TRANSPORTATION (WATER)	103.3	228.0	9.7	6.6	9.7	10.0	10.2	7.5
17	OTHER TRANSPORTATION	33.8	9.7	64.3	73.7	44.0	66.9	64.4	50.5
6	ELECTRIC LIGHT AND POWER	14.8	2.1	11.2	72.2	21.8	29.9	23.9	23.1
19	PROFESSIONAL AND SERVICES	219.6	189.9	10.3	1,011.0	185.1	246.5	26.1	8,555.7
13	MOTORS, GENERATORS	.6	60.2	61.0	67.2	62.3	66.5	68.9	76.2
10	OTHER NONFERROUS METALS	4.4	18.8	16.9	31.6	25.3	13.3	22.7	38.0
11	METAL STAMPING	1.9	55.4	18.9	51.2	66.8	64.1	68.5	67.9
12	MACHINE TOOLS	66.3	337.3	150.0	37.3	37.6	43.0	42.9	39.6
6	PETROLEUM	1.4	63.2	75.9	4.5	3.7	74.2	91.5	86.8
12	POWER TRANSMISSION EQUIPMENT	24.5	77.5	31.3	8.3	3.6	13.7	14.2	12.5
12	ENGINES AND TURBINES	83.5	108.3	50.4	10.8	9.8	13.7	14.0	6.7
11	METAL CONTAINERS	16.3	11.0	2.0	7.2	5.6	3.0	6.2	7.2
13	ELECTRICAL EQUIPMENT (N.E.C.)	50.2	94.6	222.3	9.1	14.0	8.3	6.3	17.5
12	INDUSTRIAL MACHINERY	116.6	162.6	531.9	29.9	33.2	26.5	25.3	29.5
3	LEATHER AND LEATHER PRODUCTS	20.7	6.9	2.6	80.0	17.7	16.5	15.6	7.6
1	LIVESTOCK, POULTRY	42.1	27.6	14.1	113.8	19.5	12.1	15.3	1.2
14	RAILWAY EQUIPMENT	47.7	440.2	33.1	5.8	3.0	6.0	5.7	3.2
10	IRON AND STEEL FORGING	12.2	82.0	63.8	56.8	36.7	38.4	38.5	63.6
11	CUTLERY, TOOLS	25.9	28.8	56.5	41.0	7.8	5.8	17.2	54.1
5	MEDICAL SUPPLIES	62.6	142.0	9.0	23.5	10.1	8.8	9.5	22.0
1	FOOD PRODUCTS	218.7	5.5	21.8	271.0	30.2	24.6	24.9	3.7
13	INSULATED WIRE AND CABLE	1.8	45.6	71.1	29.0	9.5	28.7	13.5	33.7
10	IRON AND STEEL	115.3	152.2	329.7	86.3	100.7	92.1	8.7	114.7
5	ORGANIC CHEMICALS	90.2	117.2		9.3	8.7	3.8	8.2	4.4
7	RUBBER AND RUBBER PRODUCTS	66.0	116.6	40.4	20.4	14.8	9.8	7.1	8.3
11	PLUMBING FIXTURES	5.8	4.1	28.2	1.6	3.8	149.4	95.4	9.6
16	MISCELLANEOUS MANUFACTURING INDUSTRIES	39.5	11.9	20.1	77.8	11.0	8.3	9.3	27.2
2	TEXTILE MILL	421.0	497.1	17.8	181.1	24.5	18.0	13.3	19.9
1	GRAIN AND FEED CROPS	9.6	1.7	.3	5.0	1.0	.1	.1	.2
4	PAPER AND ALLIED PRODUCTS	79.0	106.0	6.8	30.6	5.7	14.4	13.7	19.9
5	INORGANIC CHEMICALS	63.8	60.2	.3	7.1	4.4	2.5	3.5	62.8
11	FABRICATED METALS	25.4	43.6	335.6	14.6	212.3	165.3	91.2	29.5
9	NONMETALLIC MINERALS	49.8	144.0	274.8	12.9	754.6	312.1	475.5	36.6
19	BUSINESS SERVICES	200.0	389.7	50.0	465.2	197.4	18.0	3.7	14.1
14	MOTOR VEHICLES	125.9	247.5	231.6	78.8	7.3	33.0	31.4	5.3
12	FARM, BUILDING, MINING MACHINERY	198.6	242.0	347.0	.8	76.2	5.6	2.8	27.7
5	MISCELLANEOUS CHEMICALS	84.0	198.5	13.0	28.9	7.6	104.2	13.6	5.9
8	LUMBER, WOOD PRODUCTS	33.9	71.9	328.9	49.2	34.2	328.1	991.6	47.0
12	PUMPS, COMPRESSORS	96.6	204.5	99.6	15.2	13.9	10.3	15.3	.7
13	ELECTRICAL APPLIANCES	5.9	3.2	3.1	20.8	12.0	3.4	6.1	1.5
18	TRADE	737.9	1,577.5	1,277.0	2,351.6	294.0	974.9	1,046.2	64.9
1	TOBACCO, ALCOHOLIC BEVERAGES	50.3	40.4	3.9	55.4	2.4	3.8	14.5	.3
17	RAILROADS, TRUCKING	373.5	983.4	240.8	129.0	401.4	135.4	258.6	18.7
6	COAL AND COKE	73.0	30.4	25.5	28.2	27.5	9.3	6.2	14.5
6	GAS UTILITIES	2.9	6.0	4.2	42.4	5.6	1.3	2.5	1.3
19	AUTO AND OTHER REPAIRS	15.0	19.7	39.0	83.4	177.2	44.4	37.2	14.1
19	BANKING, FINANCE	138.9	79.7	42.4	714.6	82.3	27.2	73.3	30.2
19	RESTAURANTS, HOTELS, AMUSEMENTS	218.4			856.3				97.6
20	CONSTRUCTION	133.7	133.7	1,957.1	133.7	4,262.7	3,229.9	3,524.2	133.7
	BUSINESS EMPLOYMENT: INCREASE	4,280.7	7,413.1	7,036.0	7,294.9	6,722.1	5,646.2	6,709.2	8,968.8
	DECREASE	3,117.4	2,897.0	2,767.8	3,610.4	3,724.5	3,910.9	3,746.0	4,113.9
	NET CHANGE	1,163.3	4,516.1	4,268.2	3,684.5	2,997.6	1,735.3	2,963.2	4,854.9
	TOTAL EMPLOYMENT: INCREASE	4,280.7	7,413.1	7,036.0	8,165.3	6,722.1	5,646.2	6,709.2	16,641.0
	DECREASE	11,423.2	11,202.8	11,073.6	11,916.2	12,030.3	12,216.7	12,051.8	10,443.0
	NET CHANGE	7,142.5	3,789.7	4,037.6	3,750.9	5,308.2	6,570.5	5,342.6	6,198.0

TABLE 7. The columns in this table provide the same information as Table 6; that is, they show the net change in employment resulting from the transfer of $100 million of demand from the military to each of the nonmilitary demand categories. But they relate this information to a finer breakdown of 58 production sectors. The key numbers at left show to which of the 20 larger sectors in the other tables each of these production sectors belongs. The figures at bottom show that the net increase in business employment would be offset in all but one demand category by release of uniformed and civilian personnel directly employed by Department of Defense.

1957 and 1958, employment fell in 54 and expanded in only four of the 58 industries; the combined loss of jobs amounted at that time to 1,411,000 man-years and the gain to only 7,000.

The net increases in "Business Employment" indicated in the transfer of expenditures from military to civilian demand are important, for it is likely that disarmament would be accompanied by the release of large numbers of civilian and uniformed personnel of the Department of Defense. If the cuts in personnel were directly proportional to the cut in the budget, then each $100 million cut would be accompanied by the release of 1,977 civilian workers and 6,329 uniformed men. Not one of the net increases in total business employment computed in Table 7 and Table 8 would be adequate to absorb entirely this addition to rolls of job seekers. The tables provide the means, however, for trying out sets of assumptions different from the simple ones demonstrated here.

The analytical methods employed in this study can obviously be used to answer many further questions. How would the industrial impact of disarmament be felt in various parts of the country? What would be the magnitude—and the effect on other industries—of the short-run production bottlenecks that could prevent some industries from supplying the additional output called for by changes in the composition of demand? How would the creation of the additional productive capacities required to meet such increased demand affect the level of output in industries supplying the requisite capital goods?

In making use of the material presented here, and in formulating additional questions, it is most important to keep in mind the fact that military expenditures constitute only one factor affecting the state of the U. S. economy. Since a substantial portion of the economic resources now serving military needs could be used to increase private or public investment, the question of the economic implications of disarmament necessarily leads to the more general problem of economic development and growth. In so far as foreign trade, and in particular foreign aid, enter into the picture, the effects of reduced military expenditures would have to be traced beyond the borders of our own national economy. This means that the present study does not pretend to answer all the questions, and suggests the nature of the fact-finding labor that is required if major economic changes are to be subjected to concrete, quantitative analysis.

EMPLOYMENT AFTER REALLOCATION OF $8 BILLION MILITARY PURCHASES TO OTHER DEMAND CATEGORIES

(THOUSANDS OF 1958 MAN YEARS)

		CHANGE IN EMPLOYMENT	PER CENT CHANGE IN EMPLOYMENT
14	ORDNANCE	27,336.0	19.24
14	AIRCRAFT AND PARTS	135,600.0	17.90
14	SHIPS AND BOATS	26,320.8	10.99
13	RADIO	33,036.8	6.07
10	ALUMINUM	1,707.2	2.82
15	INSTRUMENTS	5,944.0	2.42
10	COPPER	2,022.4	2.36
13	MOTORS, GENERATORS	4,086.4	2.04
10	IRON AND STEEL FORGING	3,050.4	1.31
10	OTHER NONFERROUS METALS	1,920.0	1.31
11	METAL STAMPING	3,526.4	1.06
5	PLASTICS	1,152.8	.70
11	CUTLERY, TOOLS	1,924.0	.70
13	INSULATED WIRE AND CABLE	1,035.2	.61
12	MACHINE TOOLS	1,055.2	.47
6	PETROLEUM	1,988.8	.38
12	POWER TRANSMISSION EQUIPMENT	258.4	.29
17	OVERSEAS TRANSPORTATION (WATER)	139.2	.27
10	IRON AND STEEL	1,711.2	.26
12	ENGINES AND TURBINES	38.4	.04
4	PAPER AND ALLIED PRODUCTS	1,945.6	.36
11	METAL CONTAINERS	344.0	44
5	ORGANIC CHEMICALS	800.8	.46
17	OTHER TRANSPORTATION	3,064.8	.60
7	RUBBER AND RUBBER PRODUCTS	1,592.0	63
17	RAILROADS, TRUCKING	12,338.4	.67
13	ELECTRICAL EQUIPMENT (N.E.C.)	1,388.0	.67
6	ELECTRIC LIGHT AND POWER	3,609.6	.73
5	INORGANIC CHEMICALS	1,048.0	.74
12	INDUSTRIAL MACHINERY	2,915.2	74
11	FABRICATED METALS	3,062.4	.78
9	NONMETALLIC MINERALS	5,231.2	.81
6	COAL AND COKE	2,186.4	.92
11	PLUMBING FIXTURES	1,073.6	.93
5	MISCELLANEOUS CHEMICALS	2,328.0	94
8	LUMBER, WOOD PRODUCTS	9,634.4	.98
19	BUSINESS SERVICES	26,111.2	1.00
14	MOTOR VEHICLES	6,437.6	1.01
3	LEATHER AND LEATHER PRODUCTS	4,108.0	1.15
5	MEDICAL SUPPLIES	1,694.4	1.17
16	MISCELLANEOUS MANUFACTURING INDUSTRIES	4,548.0	1.21
2	TEXTILE MILL	11,252.0	1.24
12	PUMPS, COMPRESSORS	2,124.8	1.26
20	CONSTRUCTION	36,086.4	1.36
1	LIVESTOCK, POULTRY	5,940.8	1.40
1	GRAIN AND FEED CROPS	297.6	1.40
13	ELECTRICAL APPLIANCES	1,187.2	1.44
12	FARM, BUILDING, MINING MACHINERY	3,953.6	1.44
19	PROFESSIONAL AND SERVICES	108,730.4	1.46
6	GAS UTILITIES	2,317.6	1.47
18	TRADE	144,533.6	1.51
19	AUTO AND OTHER REPAIRS	5,402.4	1.51
1	FOOD PRODUCTS	14,848.0	1.53
2	APPAREL	20,199.2	1.61
19	BANKING, FINANCE	39,332.0	1.66
1	TOBACCO, ALCOHOLIC BEVERAGES	3,225.6	1.69
19	RESTAURANTS, HOTELS, AMUSEMENTS	46,824.8	1.81
14	RAILWAY EQUIPMENT	99.2	1.95
	BUSINESS EMPLOYMENT: INCREASE	541,855.2	1.42
	DECREASE	253,815.2	6.85
	NET CHANGE	288,040.0	.69
	TOTAL EMPLOYMENT: INCREASE	639,376.5	1.41
	DECREASE	760,135.2	11.99
	NET CHANGE	120,758.7	.22

TABLE 8. The figures here reflect the changes in employment by the 58 production sectors that would follow from a 20 per cent, or $8 billion, cut in military expenditure and reallocation of this demand proportionally to other demand categories. The totals show a net increase of 288,040 job openings under "Business Employment" but a net deficit of 120,759 job openings under "Total Employment," resulting from release of personnel by the military.

THE PARATHYROID HORMONE

A protein hormone that proved difficult to isolate, it acts upon bones, kidneys and gastrointestinal tract to regulate the level of calcium in the internal environment of the body

by Howard Rasmussen

There are eight well-defined endocrine glands in the human body, and together they secrete into the bloodstream at least 20 different kinds of hormone. These hormones fall into two main groups: the steroid hormones from the adrenal glands and sex organs, and the protein and peptide hormones of the pituitary gland, pancreas, thyroid and parathyroid glands. With the development of new techniques for separating complex protein mixtures, many of the second group have now been obtained in pure form. The most recently isolated is the parathyroid hormone. Only when the pure hormone is available for study can its properties and function be rigorously established. The availability of the pure parathyroid hormone has enabled physiologists to clear up basic controversies as to its function, and physiological studies have underscored the subtlety of its action.

Hormones are appropriately called chemical messengers; the word "hormone" means "I arouse to activity." The arousal ability of such hormones as those produced by the adrenal glands is well known. There is, however, another class of hormones, of which the parathyroid hormone is a member, that operates silently, so to speak, but no less profoundly. These hormones are concerned primarily with maintaining the constancy of the *milieu intérieur*. This is the felicitous term proposed nearly a century ago by the French physiologist Claude Bernard, who used it to emphasize that the cells of the body are insulated from the erratic, and frequently harsh, external environment by a carefully regulated internal environment composed of the circulating fluids—blood plasma and extracellular fluid—that bathe them. In the 1920's Walter B. Cannon of the Harvard Medical School introduced the term "homeostasis" to describe the varied physiological processes that endow the *milieu intérieur* with its remarkable stability.

One of the most important constituents of the internal environment is the calcium ion, which is released when calcium compounds go into solution and dissociate. An optimum calcium-ion concentration is necessary for the normal transmission of nerve impulses, the contraction of muscles, the coagulation of blood, the fertilization of eggs and the formation of bone. A precise endocrine control system has evolved to ensure a stable concentration of this essential ion in the *milieu intérieur*. The two hormones of major importance in this system are vitamin D and the parathyroid hormone.

Vitamin D can be classified as a hormone because it is manufactured in the skin (which is an organ) when the skin is exposed to sunlight. The vitamin is important in the prevention of rickets, a wasting disease of bone. Because man no longer goes around seminude, a substance that was once adequately supplied by internal synthesis (a hormone) has become an essential factor in the diet (a vitamin).

The parathyroid hormone is a protein secreted by the parathyroid glands: four tiny organs located in the neck adjacent to, or embedded in, the thyroid gland [*see illustration on opposite page*]. Amphibia and all higher animals have parathyroid glands. In man the glands are reddish-brown and resemble slightly flattened garden peas. They are composed of cords of secretory epithelial cells, separated by a small number of fat cells. Notwithstanding their name, they are distinct from the thyroid gland both in structure and in function. The parathyroids were first described over 100 years ago by the British anatomist Richard Owen, who found them while dissecting an Indian rhinoceros. Owen's discovery went unnoticed, but the glands were rediscovered by a number of investigators. Among them was the Swedish anatomist Ivor Sandström, who gave them their name in 1880.

Some 16 years later, G. Vassale and F. Generali of Italy removed the parathyroids from experimental animals and observed that before the animals died their muscles twitched, went into spasms and finally became rigid. In 1909 W. G. MacCallum and Carl Voegtlin of Johns Hopkins University attributed these muscle symptoms to a calcium deficiency; they had found that removal of the parathyroids was followed by a decrease in the amount of calcium in the blood. A few years later Isidor Greenwald of Roosevelt Hospital in New York observed that the decrease in calcium was accompanied by an increase in blood phosphate. In 1925 J. B. Collip and his co-workers at the University of Alberta prepared the first stable acid extract of beef parathyroid glands; when injected into experimental animals or humans, it increased the calcium content and decreased the phosphate content of the blood plasma. Shortly thereafter the conditions of hyperparathyroidism (overactivity of the parathyroids) and hypoparathyroidism (underactivity) were recognized as causes of human disease.

At about the same time vitamin D was identified chemically and was shown to be an essential dietary factor, important in the regulation of calcium and phosphate metabolism. Because vitamin D and the parathyroid hormone overlap in function and to some extent act synergistically (reinforce each other's activity),

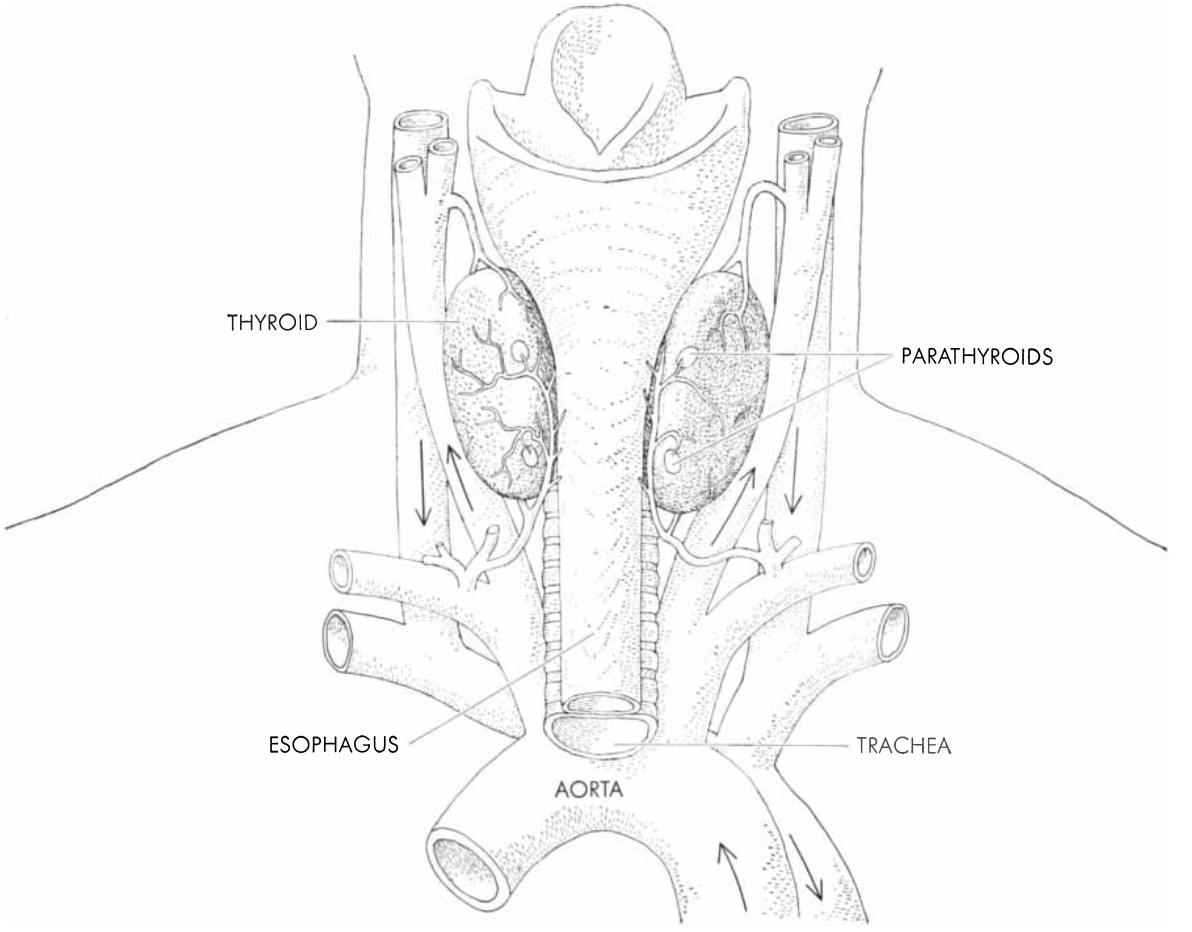
it is only very recently that their physiological roles have been satisfactorily disentangled. The work proceeded along two general lines: biochemists sought to isolate in pure form and to identify chemically the parathyroid hormone; physiologists sought to clarify the mechanisms by which vitamin D and the parathyroid hormone control the metabolism of calcium and phosphate.

Last year Lyman C. Craig and I, working at the Rockefeller Institute in New York, finished purifying the parathyroid hormone and established that it was a protein. The task took five years. To obtain one milligram of pure parathyroid hormone we had to process 200,000 milligrams of fresh beef parathyroid tissue, representing the glands from 300 animals. In starting such a job, the first step is to find a reliable method for detecting hormonal activity in crude extracts. We adopted a method that had been developed by A. H. Gordon and his associates in England and Paul Munson and his colleagues at Harvard University. They injected crude extracts of parathyroid hormone into rats whose parathyroid glands had been removed and then measured the concentration of calcium in the rats' blood plasma. Changes in the concentration are directly related to the amount of hormonal activity in the crude extract. Using this assay we began separating the hormone from the many nonhormonal constituents of the glands.

We tried several methods of extracting the hormone before settling on a method devised by Gerald Aurbach of Tufts University. He had found that a concentrated phenol solution would extract most of the hormone. Unfortunately phenol also extracts many other proteins. When Aurbach tried to purify his crude extracts by making the hormone precipitate out of solution preferentially, he had only limited success. We as well as Aurbach began looking for a better separation method. After experimenting with various techniques, including electrophoresis, chromatography and ultracentrifugation, we concluded (as did Aurbach independently) that the separation method known as countercurrent distribution was the most promising.

This technique exploits the fact that when proteins are shaken together with two nonmiscible liquids, both of which will dissolve proteins, each protein will be distributed between the two liquids in a unique manner. After repeated extractions of this sort, proteins that prefer one solvent can be separated with high purity from proteins that prefer a second solvent. The actual separation is carried out in long rows of interconnected tubes, which permit the process to be fully automatic [*see illustrations on next two pages*]. The mixture of proteins, dissolved in the proper solvents, is placed in the first few tubes of the train; after the machine has carried out 100 or more separate transfers by rocking back and forth, the various tubes are analyzed for their protein content.

The distribution pattern illustrated

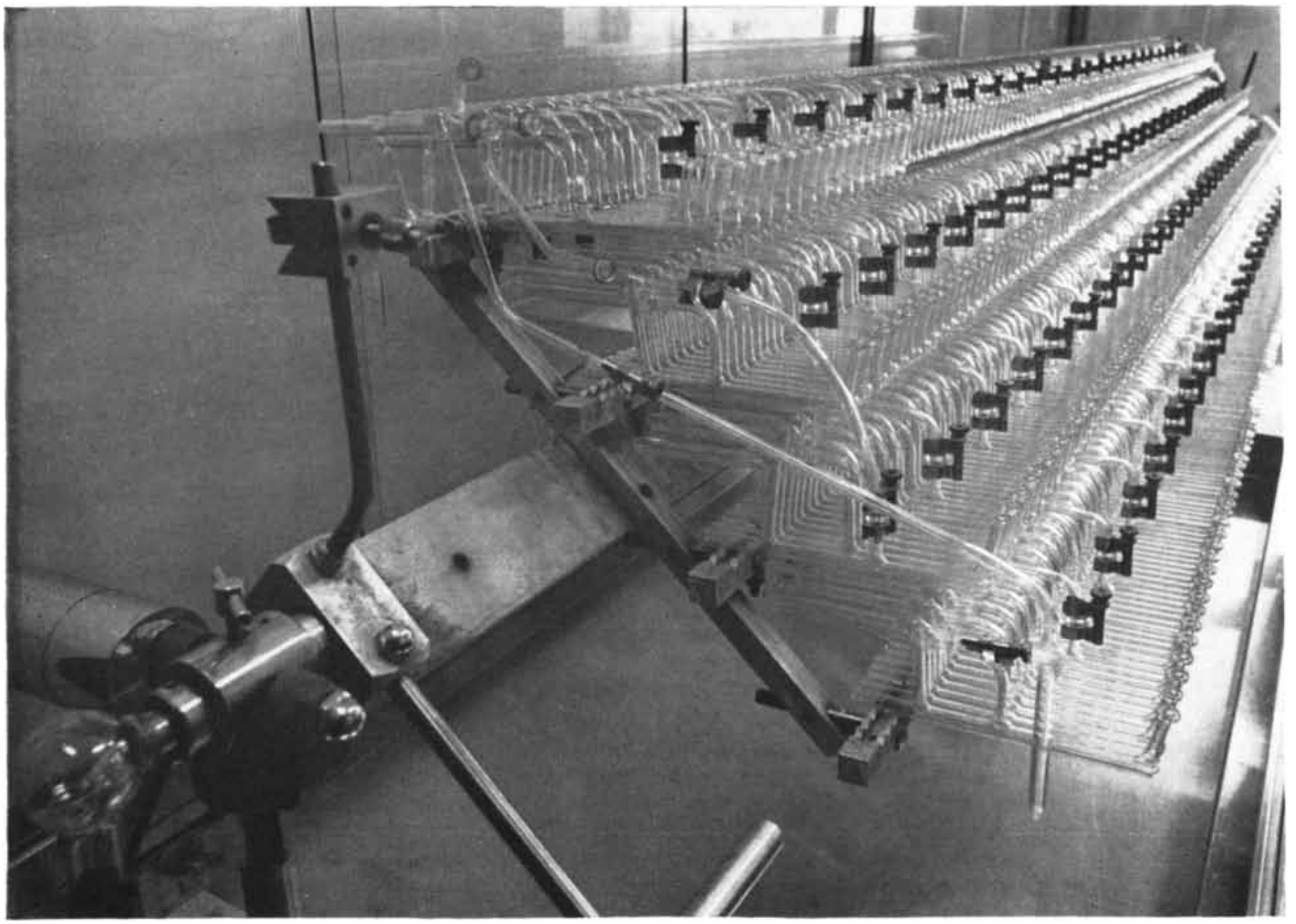


PARATHYROID GLANDS are four small reddish-brown bodies embedded in the rear of the thyroid gland. They are structurally and functionally distinct from the larger gland. Here the thyroid, the parathyroids and nearby structures are viewed from the back.

on page 60 was obtained when a crude parathyroid extract was run for 250 transfers in a two-phase system composed of pyridine, butanol, acetic acid and water. At this point we knew only that proteins had concentrated in certain tubes; we still knew nothing about their hormonal activity. By evaporation and freeze-drying we removed the solvents from samples representing the different protein peaks. For assay purposes the dry protein powder recovered from each peak was suspended in sterile oil and injected under the skin of each of six rats. Six hours later a sample of blood was taken from each rat. After the removal of red blood cells, each sample of clear plasma was analyzed chemically for its calcium content. Another group of rats served as a control and received no hormone; still others received graded doses of a standard crude hormone preparation. By comparing the responses of the various groups it was found that only the second peak [*labeled "A" in the illustration on page 60*] showed hormonal activity. Its specific activity was about 10 times that of the crude starting material. The one small peak, containing less than 10 per cent of the protein estimated to be in the crude extract, contained over 85 per cent of the hormonal activity.

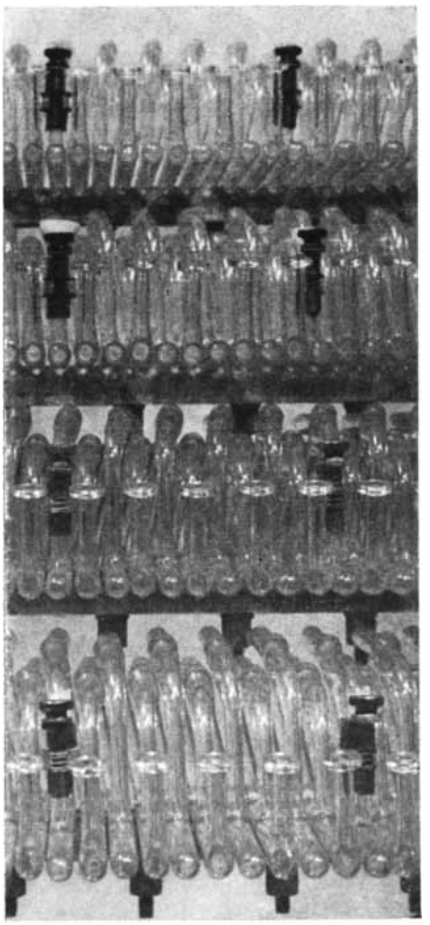
The partially purified material was returned to the countercurrent distribution machine and subjected to another 2,600 transfers. This time the parathyroid hormone was separated completely from the other proteins. The molecule of the hormone was found to be rather small as protein molecules go: it has a molecular weight of 9,500 (9,500 times the weight of the hydrogen atom). It is larger, however, than the molecule of the hormone insulin, which has a molecular weight of 5,733. The molecule of the parathyroid hormone is made up of a chain of 83 separate amino acid residues of 17 different amino acids. The exact sequence in which these are assembled has not been established, but we know that only 33 of them are required for the protein to exert its characteristic effects. The other 50 amino acid residues apparently help to stabilize the essential 33. The determination of the sequence of the 83 amino acids is now being undertaken with the methods used to establish the amino acid sequence of insulin and other proteins [see "The Chemical Structure of Proteins," by William H. Stein and Stanford Moore; SCIENTIFIC AMERICAN, February].

With the isolation of the pure parathyroid hormone it became possible to reinvestigate its mode of action. It had been known, of course, that when a crude parathyroid extract is administered to an experimental animal or to a human subject, it increases the amount of calcium and decreases the amount of phosphate in the internal environment, it increases the excretion of phosphate in the urine and at first it decreases the excretion of calcium. If, however, the amount of calcium in the internal environment becomes excessive, there is a rise in the calcium excreted. All these



COUNTERCURRENT DISTRIBUTION MACHINE provided the means for separating the parathyroid hormone from the mixture of proteins present in a crude extract obtained from hundreds of beef parathyroid glands. The machine operates on the principle of differential extraction. If a mixture of proteins is shaken together with two immiscible liquids, both of them protein solvents, each type of protein will distribute itself between the two liquid phases in a unique way. The machine, by rocking back and forth, subjects a mixture of proteins to repeated extractions. As a result different proteins concentrate in different regions of the machine.

changes are the result of changes in the function of the various organs concerned with maintaining a constant calcium content in the internal environment. There has been considerable controversy as to how the hormone alters their function. Some physiologists contended that the primary hormonal action was to increase the excretion of phosphate in the urine and that all the other effects followed as a consequence. Others proposed that the hormone's only significant effect was to bring about the release of calcium stored in so-called nonexchangeable bone: the relatively old bone, which normally does not enter into chemical transactions with body fluids. (As we shall see, the newly formed bone is called exchangeable bone because it remains in equilibrium with surrounding fluids.) Still other physiologists suggested that there might be two hormones; one acting on the kidney, the other on the bone. It has now been shown that our purified parathyroid protein acts on both the kidneys and bone.



The detail view at right indicates how the glass tubes are interconnected, permitting the two liquid phases to move in opposite directions. The machine was designed by Lyman C. Craig of the Rockefeller Institute.

A direct action on bone has been demonstrated by Pieter Gaillard of the University of Leiden in the Netherlands in an ingenious series of experiments using the recently developed techniques of tissue- and organ-culture. In one set of culture tubes he grew thin sections of bone from the skulls of newborn mice; in another set of tubes he grew small bits of fetal parathyroid tissue. When both the bone and the parathyroid tissue were growing well separately, he put them together. Before long he could see changes in the bone indicating increased activity of the bone-destroying cells called osteoclasts. It is these cells that release calcium from storage and make it available elsewhere. Gaillard then took just the fluid from the parathyroid cultures and placed it in the cultures of bone. Again he observed the same changes in the bone, suggesting that the cells of the parathyroid tissue growing outside the body were secreting a hormone into the tissue-culture fluid. Finally he took our purified parathyroid hormone and placed it in the bone cultures. Once again he observed the destruction of the bone and all the other histological changes associated with hyperparathyroidism [*see middle illustration on page 62*].

While this work was going on, Ray Lavender and Theodore Pullman of the University of Chicago, working in collaboration with the author, unequivocally demonstrated that the hormone had a direct effect on the kidneys. They infused solutions of pure parathyroid hormone into the artery of one kidney of a dog, and measured the amount of phosphate in the urine collected separately from each kidney. They found a marked increase in the amount of phosphate in the urine from the infused side and little or no change in the phosphate content of the urine from the other kidney.

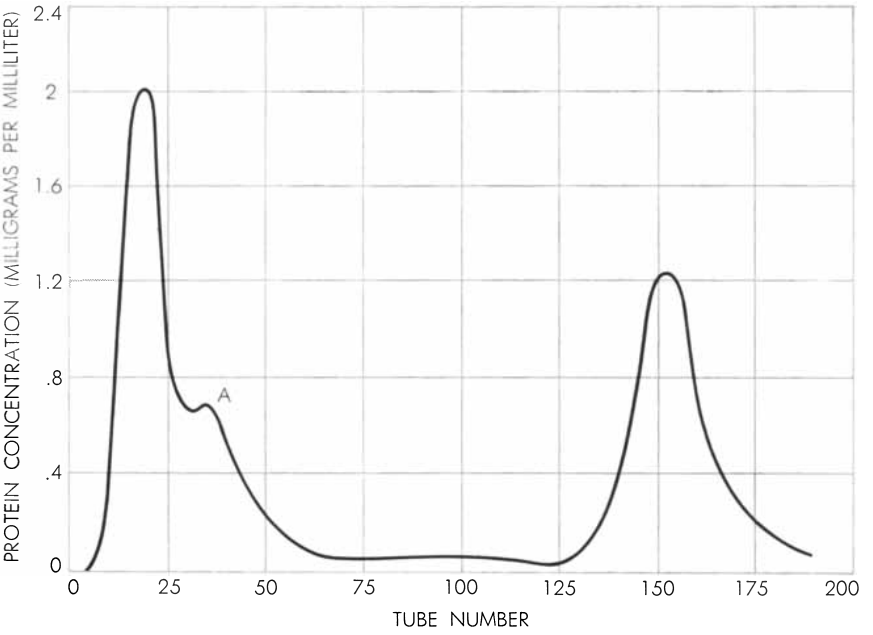
Earlier investigators concentrated almost exclusively upon the bone and kidney as possible sites of action of the parathyroid hormone. More recent studies indicate that the hormone also influences the rate of exchange of calcium in the lactating mammary gland and in the gastrointestinal tract. In the past two years we have established that the parathyroid hormone acts in the gastrointestinal tract to promote the absorption of calcium into the bloodstream.

It is now possible to present with some confidence a unified picture of how the parathyroid glands control the concentration of the calcium in the internal environment [*see illustration on page 61*]. Many other endocrine systems are under the control of secretions from the anterior part of the pituitary gland, but this is not true of the parathyroid glands. The secretory activity of the parathyroids is controlled by the concentration of a simple substance in the circulating blood: the calcium ion itself. When the concentration of this ion falls, the glands are stimulated to secrete more hormone, much as a thermostatically controlled furnace increases its heat output as the temperature falls. Instead of a thermostat there is a "calciostat" in the cells of the parathyroid glands. Once the hormone is released into the bloodstream it is carried to the parts of the body in which its action takes place. It acts on the intestinal cells to increase the absorption of calcium; it acts on the cells of the kidney tubules to increase the reabsorption of calcium from the filtered urine; and it acts upon the bone cells to convert them to osteoclastic cells, which break down the nonexchangeable bone and release the stored calcium. All these effects lead to an increase in the concentration of calcium in the internal environment. The hormone has the additional effect on the cells of the kidney tubules of making them excrete more phosphate into the urine, thereby diminishing the amount of phosphate in the internal environment. This more than offsets the increased phosphate released by the breakdown of bone. The final result is an increase in the amount of calcium and a decrease in the amount of phosphate in the blood plasma and extracellular fluid. Once the calcium-ion concentration has been restored to normal, the fact is perceived by the calciostat, which thereupon decreases the output of the hormone. In many respects this system is analogous to a servomechanism employing the principle of negative feedback.

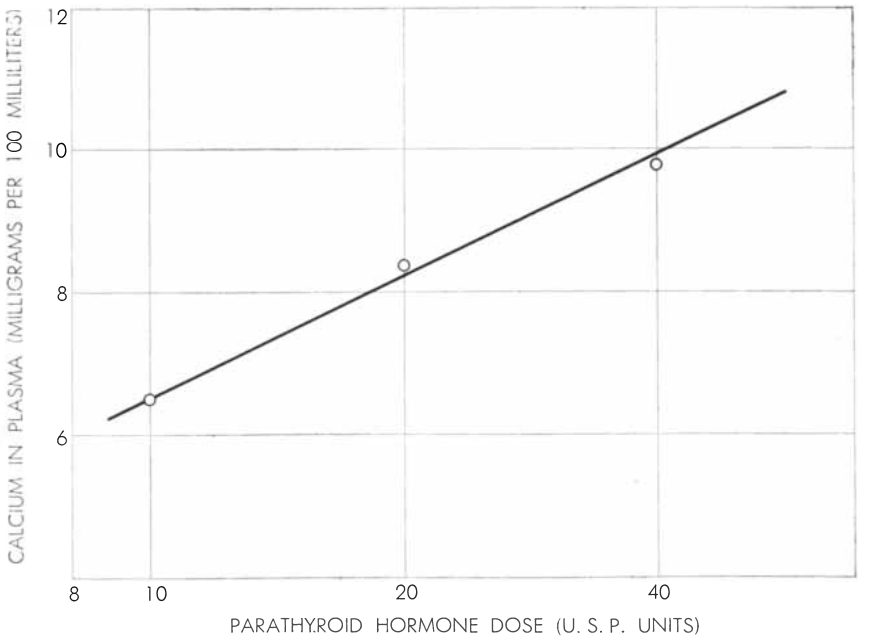
It may seem puzzling that such an elaborate system is required. Why couldn't either the bone or the kidneys, under parathyroid control, maintain the calcium content of the *milieu intérieur*? Actually, there are striking differences in the capacity and rapidity with which the various organs respond to the hormone. The responses of the kidneys and gastrointestinal tract are rapid, sensitive to small changes in hormone concentration and of limited capacity. The response of bone is slow, insensitive and of nearly unlimited capacity. By integrating these two types of response, the organism is able to achieve a wider range and finer degree of control than would be possible by utilizing either response alone.

Before describing the role played by vitamin D in calcium-phosphate me-

tabolism it is necessary to digress for a moment to discuss bone, its nature and its relationship to the calcium and phosphate ions in the internal environment. Until recently bone was considered an inert tissue, but studies made with the radioactive isotopes of calcium and phosphorous have shown the bone is being remodeled constantly. Bone contains more than 98 per cent of the body's calcium and about 66 per cent of its phosphate. These are deposited as a complex salt, hydroxyapatite, in a framework of protein fibers called collagen. Specific cells, the osteoblasts, manufacture these fibers and align them to form the bone template. When sufficient concentrations of calcium and phosphate ions are circulating in the internal environment, they interact with specific sites on the collagen fibers to form small hydroxyapatite crystals, which then slowly grow. While small and growing they constitute exchangeable bone, able quickly to return calcium and phosphate ions to the internal environment. As the crystals keep growing they exclude more and more water until they become nonexchangeable bone—a solid, inert, diffusion-locked mass that does not release its ions readily. In the adult organism more than 99 per cent of the bone is in this condition. Eventually all the bone would assume this state if it were not being remodeled constantly, even deep in the interior of bones. By means of a radioactive isotope of calcium it is possible to estimate that in a normal adult human enough old bone is broken down each day to release approximately half a gram of calcium into the internal environment. This breakdown, or reabsorption, of bone is brought about by the action of the osteoclasts, which not only dissolve the bone mineral but also destroy the bone collagen. The dissolved old bone is normally replaced by an equivalent amount of new bone.



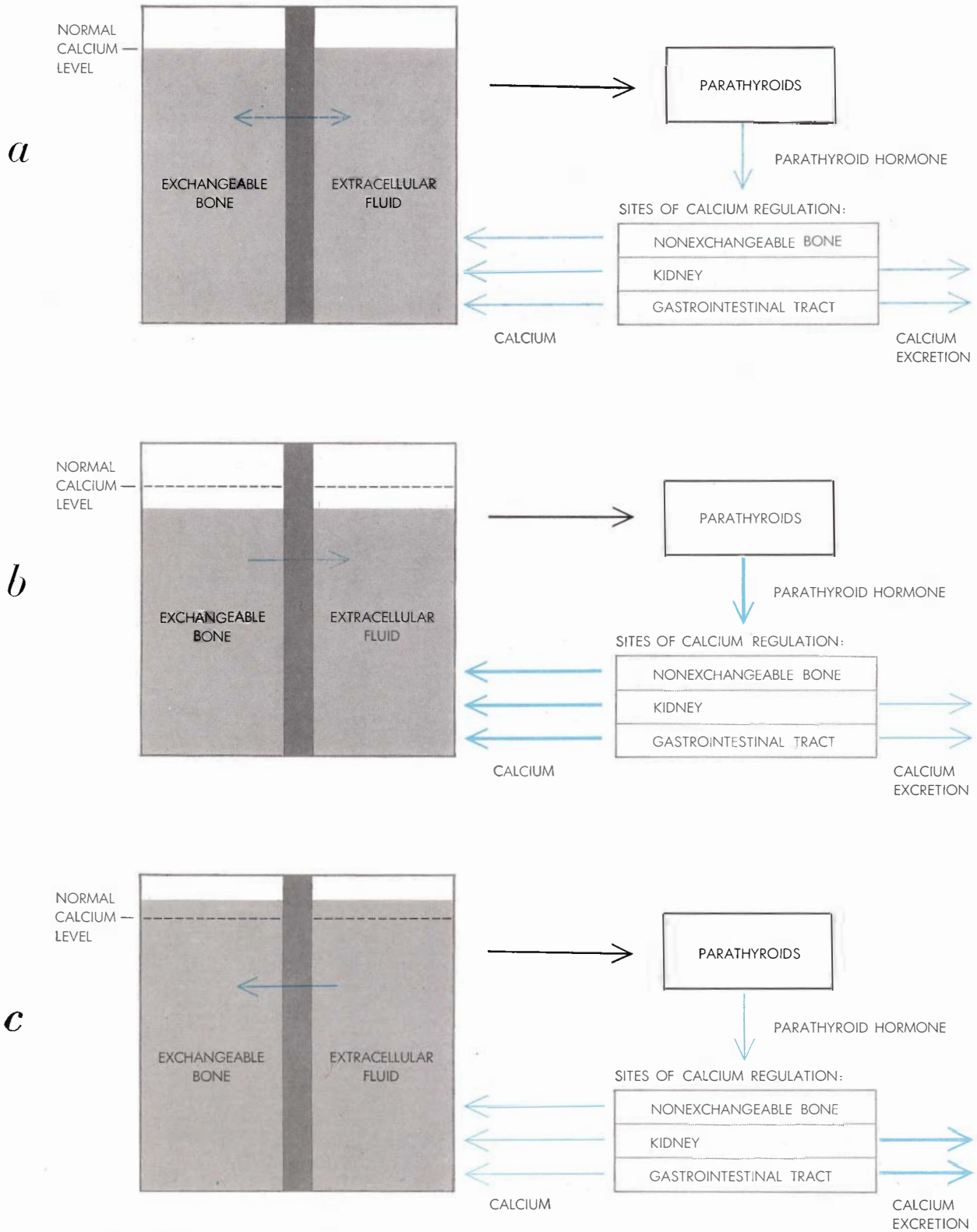
PROTEIN DISTRIBUTION CURVE shows by tube number where parathyroid proteins were concentrated by countercurrent separation. Animal assay found hormone in peak *A*.



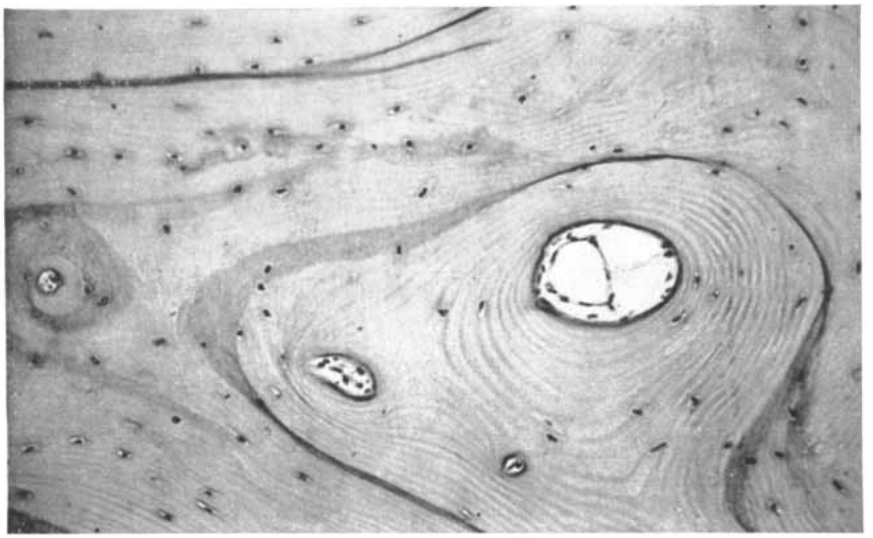
ANIMAL ASSAY CURVE shows how calcium-ion level in blood plasma is raised by injection of graded doses of parathyroid extract. Test animals lacked parathyroid glands.

To simplify slightly, one may regard the ions in the circulating fluids as being in simple equilibrium with those in the exchangeable bone. This implies that ions will leave the exchangeable bone when the amount of either phosphate or calcium falls in the plasma and extracellular fluid. Calcium and phosphate will enter the exchangeable bone if their concentrations increase in the body fluids. Consequently the exchangeable bone, acting as a buffer, is the first line of defense in controlling the concentration of these ions in the internal environment of the body.

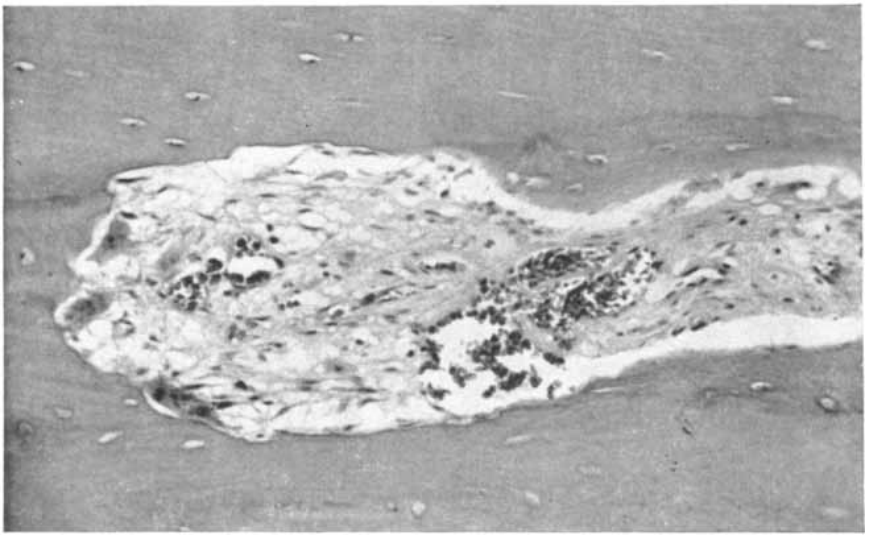
This leads us back to the role of vitamin D. Unless the total amount of calcium and phosphate ions in the internal environment is kept at a certain critical level, bone formation stops. The maintenance of this level appears to be the primary function of vitamin D. Under normal conditions calcium is excreted primarily in the feces; phosphate, primarily in the urine. Vitamin D reduces the excretion of each by promoting their retention in the body. When vitamin D is lacking, there is a decline in the total amount of calcium and phosphate in the internal environment; bone collagen no longer becomes calcified and eventually the bones stop growing, bend and break. This is the condition known as rickets. It is obvious that vitamin D cannot correct a lack of calcium in the diet. It can, however, promote maximum retention of whatever calcium is avail-



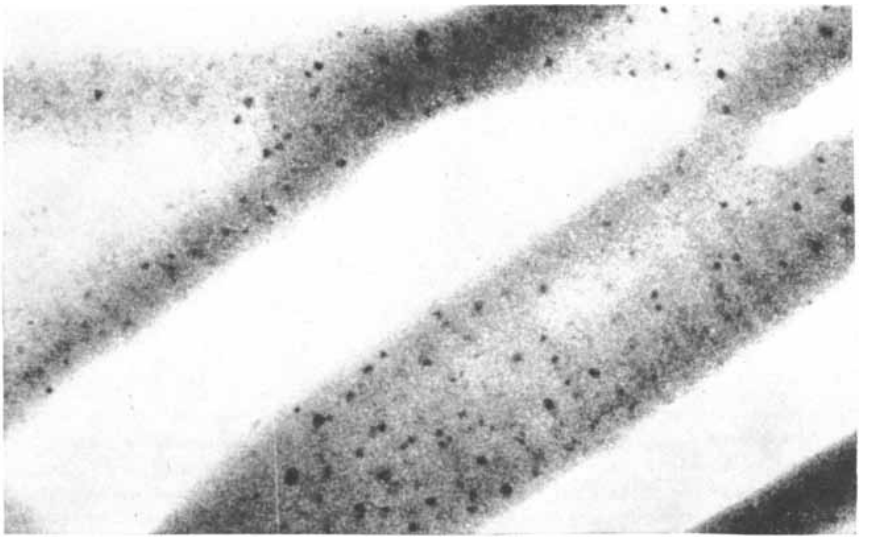
ACTION OF PARATHYROID GLANDS is symbolized in this sequence of three diagrams. In *a* the calcium-ion concentration of the extracellular fluid is at a normal level and is in equilibrium with the calcium ions deposited in exchangeable bone (*gray tone in two boxes at left*). Calcium-ion level is also normal in blood reaching the parathyroid glands (*horizontal black arrow*), resulting in a normal output of hormone. At the three sites of calcium regulation the hormone sees to it that the proper amount of calcium is retained and the proper amount is excreted to maintain optimum calcium level in the extracellular fluid. In *b* a drop in this level causes an immediate drop in the calcium stored in exchangeable bone. The drop is also signaled to the parathyroids by the decreased calcium in the blood plasma. A rise in hormone output follows, which promotes retention of calcium by gastrointestinal tract and kidneys and causes withdrawal of calcium from nonexchangeable bone. The result is a reduction in calcium excretion and an increased supply to the extracellular fluid. In *c* an oversupply of calcium in the extracellular fluid causes a reversal of the whole process.



NORMAL BONE has the appearance of a contour map. This magnified section through a canal shows how layers of new bone grow into the canal and narrow it. This micrograph and the one below were made by H. R. Dudley of the Massachusetts General Hospital.



HYPERPARATHYROID BONE shows fibrous tissue filling a canal (*entire central area*). The parathyroid hormone has stimulated formation of special cells called osteoclasts, which destroy the bone and return its calcium and phosphate to the blood and extracellular fluid.



EXCHANGEABLE BONE is formed when crystals of hydroxyapatite (*small black spots*) are deposited along collagen fibers. As crystals grow they fuse into nonexchangeable bone. Micrograph was made by Melvin J. Glimcher of the Massachusetts General Hospital.

able. And it can do more. By promoting retention of phosphate it can often maintain the product of the two ion concentrations (calcium times phosphate) above the critical level. So long as this level is maintained, bone calcification will take place regardless of the absolute level of calcium ion.

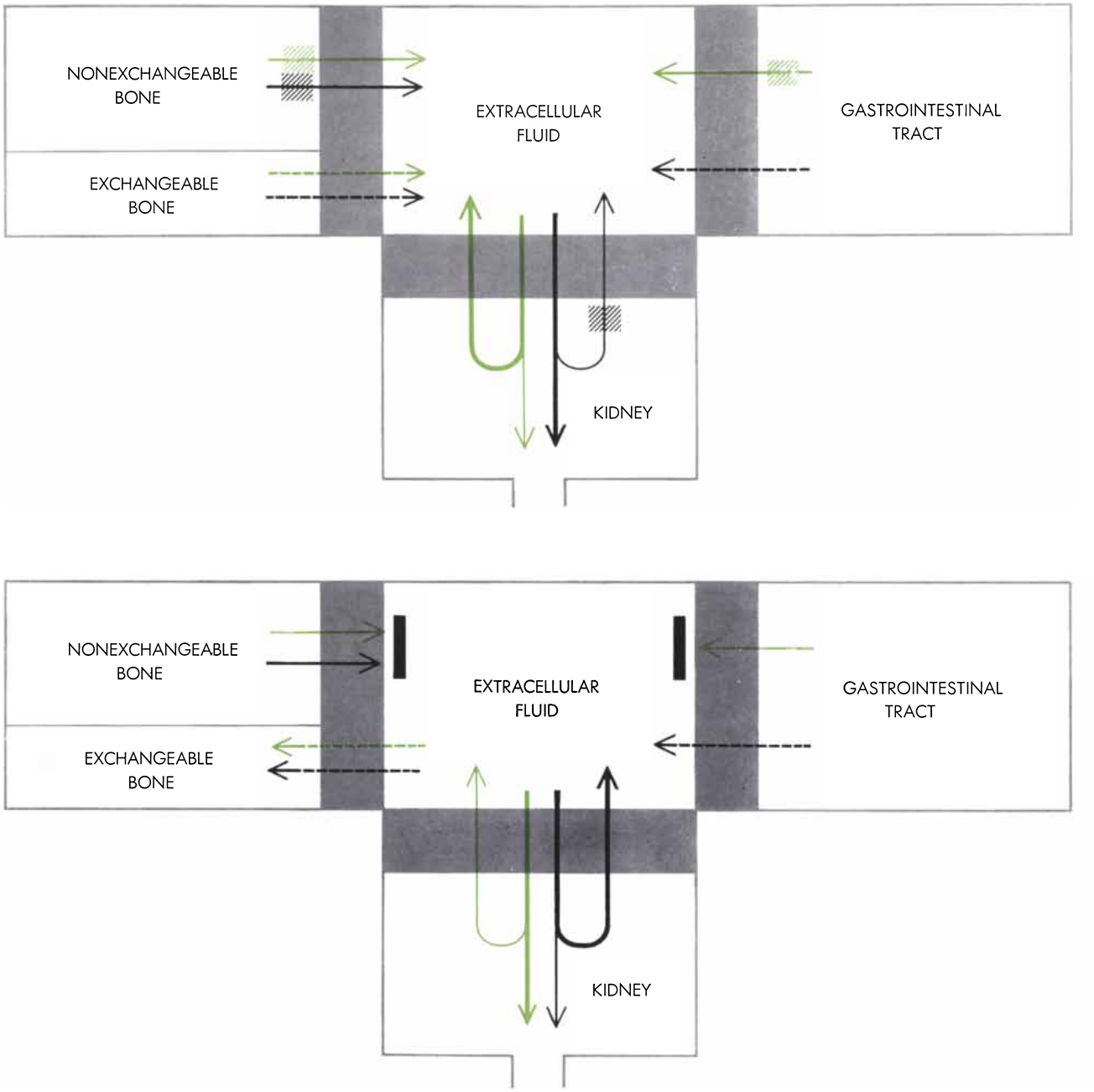
Nerve and muscle cells, however, are critically dependent on the proper concentration of calcium ions for optimum functioning. Maintenance of this concentration is the task of the parathyroid glands. Vitamin D and parathyroid hormone, acting in concert, control both the total amount and the ratio of the calcium and phosphate in the internal environment. Their relationship is such that adequate amounts of vitamin D must be available for the hormone to exert its characteristic effects. The converse, however, does not hold true; vitamin D can act in the complete absence of the parathyroid hormone and can, in large doses, overcome the effects of parathyroid deficiency. When both are present in proper amounts, the regulation of the calcium and phosphate content of the internal environment is brought about as shown in the illustration on the next page.

Although vitamin D and parathyroid hormone are the two most important endocrine agents in this regulatory system, other hormones play a role. The steroid hormones of the cortex of the adrenal glands, the growth hormone of the pituitary gland, insulin from the pancreas, the thyroid hormone and the sex hormones all influence one or more of the processes of bone growth and reabsorption, or the metabolism of calcium and phosphate. Ultimately they can also influence the activity of the parathyroid glands.

It is evident, therefore, that a variety of diseases, particularly those affecting the bones, kidneys and gastrointestinal tract, can lead to alterations in calcium and phosphate metabolism and consequently to changes in parathyroid gland activity. Conversely, diseases of the parathyroid glands can upset the functioning of many organs. Hyperparathyroidism usually results from benign tumors of these glands and is characterized by changes in the function of the kidneys, nervous system, bones and gastrointestinal tract. Removal of the tumors usually effects a complete cure. Hypoparathyroidism, or underactivity of the glands, may have no apparent cause in some cases; in other cases it results from inadvertent removal of the parathyroid glands during surgical operations on the neck, particularly those

on the thyroid gland. Its most striking manifestation is increased neuromuscular activity. The logical therapeutic agent for this condition is parathyroid hormone. Since the hormone is not yet available commercially, the present treatment is to increase the calcium content and decrease the phosphate content of the diet, and to administer large doses of vitamin D.

Although we have a general understanding of what the parathyroid hormone is, where it acts and what diseases result from too little or too much of it, we still have no knowledge of the specific biochemical reactions it controls within the various cells to bring about changes in their function. Now that the pure hormone is available for biochemical studies, our knowledge in this area should increase rapidly.



CALCIUM AND PHOSPHATE REGULATION is accomplished jointly by parathyroid hormone and vitamin D. When the extracellular fluid is low in calcium (*top*), the hormone acts upon nonexchangeable bone, kidney and gastrointestinal tract to increase the supply. It also increases excretion of phosphate from the kidney to eliminate phosphate produced by reabsorption of bone. Vitamin D acts synergistically with the hormone except in the kidneys, where the vitamin causes phosphate retention. When extracellular fluid contains an excess of calcium (*bottom*), the supply of parathyroid hormone drops. Flow of calcium from nonexchangeable bone and gastrointestinal tract is much reduced; excretion of calcium by the kidneys is increased and excretion of phosphate decreased. Integrated action of the hormone and vitamin D is the predominant means of controlling both total amount and ratio of calcium and phosphate ions in the internal environment.

The Size of the Solar System

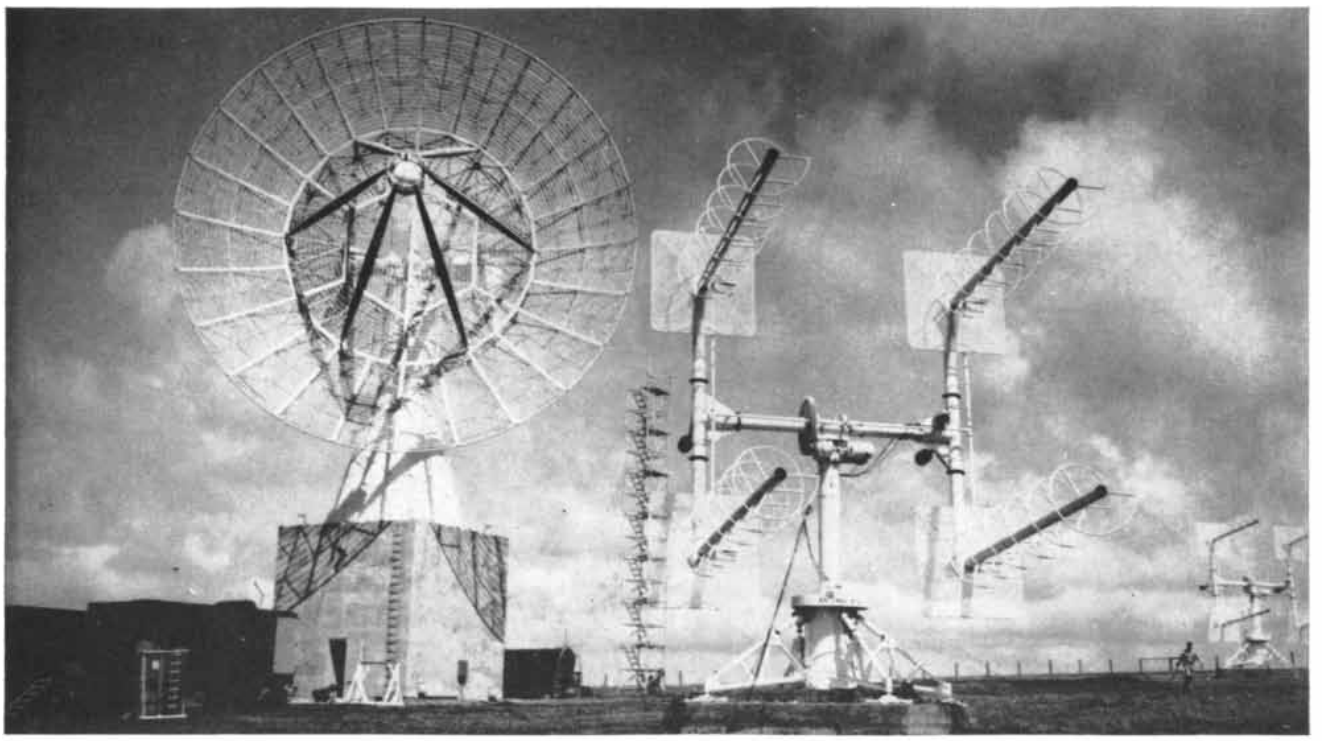
Telescopic methods leave an uncertainty of as much as 170,000 miles in the earth-sun distance. Space vehicles such as Pioneer V and the Soviet probe now headed toward Venus can help to cut the uncertainty

by James B. McGuire, Eugene R. Spangler and Lem Wong

For centuries astronomers have been mapping the solar system with ever increasing precision. The orbits of the planets are now so accurately defined that it is possible to predict within hundredths of a second of arc the angular position, with respect to the earth, of any planet for many years ahead. For the purposes of observation and prediction the job of mapping the solar system may be said to be complete. But the map has one important flaw. Although all of its angular relationships are correct, it lacks an accurate scale of distance. Now that there are space vehicles capable of exploring the solar system, the flaw has become serious. To reach the planets the interplanetary navigator must know precisely how far away they are—and he doesn't.

It may be learned next month how close the Venus probe launched by the U.S.S.R. on February 12 will come to its target. After the vehicle had been on its way for two weeks, Soviet sources predicted, on the basis of tracking data, that it would pass within 100,000 kilometers (about 60,000 miles) of Venus late in May. This prediction presumably reflects the departure from the planned trajectory caused by a small error—a very small one indeed—in the initial guidance of the vehicle during the powered portion of its flight. (The spacecraft was launched toward Venus from an earth-orbiting satellite, a remarkable technical achievement.) What the Soviet workers cannot know with more certainty than anyone else is how close the *planned* trajectory, if perfectly achieved, would have carried their probe to Venus.

The problem facing trajectory planners is that even the most refined recent measurements of the size of the solar system differ from one another by as much



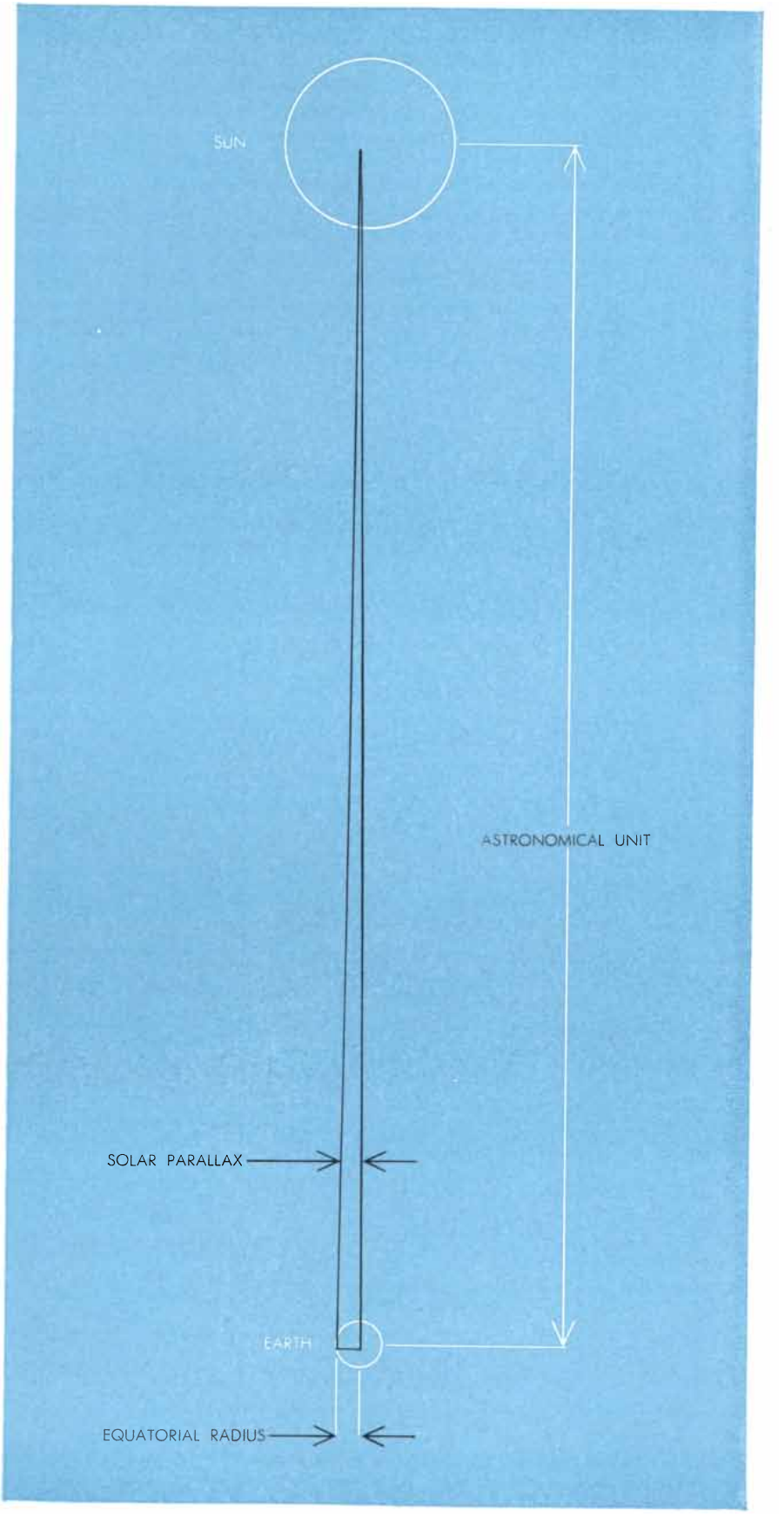
TRACKING STATION at South Point in Hawaii is one of two that followed the flight of *Pioneer V*. The other station at Jodrell Bank, England, picked up the probe's last signals at 22.46 million miles. The probe provided a new value of earth-sun distance.

as four parts in 10,000. This implies that even with flawless guidance a probe aimed at Venus could miss the center of its target by as much as 10,000 miles, or the surface of the planet by 6,000 miles.

Since the Russians have announced that measurement of interplanetary distances is high among their objectives, it is not likely that they will attempt midcourse corrections of their probe's trajectory. Although such corrections could assist the probe in reaching Venus, they would increase the number of uncertainties in the trajectory calculation and thereby degrade the quality of distance measurements. It is possible to deduce from the probe's date of launching and its predicted time of arrival in the vicinity of Venus that the Russians have an opportunity to make the most accurate measurement yet of interplanetary distances.

These distances are not the only uncertainties that face the planners of space flights. Since it is not known precisely how far the earth travels in making one circuit around the sun, the earth's true velocity is also not known. Consequently when space vehicles are launched, both the velocity and the position of the terrestrial launching platform are uncertain. Once a vehicle has been launched one does not know accurately where it should be, how fast it should be going, where it should be aimed and where it will find its target.

The telescope will not be of much help in obtaining better information. Astronomers have wrung about all the accuracy possible from optical data. One is obliged, therefore, to look to new technological methods for improving knowledge of distances. One method is to transmit powerful radar signals and measure closely the time it takes for them to reach a nearby planet and be reflected back to earth. Interesting but inconclusive values have already been secured by this means. However, the method that particularly appeals to those of us concerned with space exploration is the use of space probes themselves as measuring tools. For this purpose, moreover, it is not important whether the probes come close to other planets or not. As we shall see, very useful distance information was obtained from *Pioneer V*, the 95-pound U. S. space vehicle launched just over a year ago and tracked for more than 22 million miles. If the Russians can maintain radio contact with their 1,400-pound Venus probe for a greater distance, they should be



ASTRONOMICAL UNIT is the mean distance from the center of the earth to the center of the sun. Solar parallax is angle subtended by earth's equatorial radius at this distance.

able to improve on the distance values obtained from *Pioneer V*.

The unit of distance that astronomers use to calibrate the map of the solar system is the astronomical unit (A.U.). This is the mean distance from the center of the earth to the center of the sun, or, to put it another way, half the major axis of the earth's elliptical orbit. It has been known for some three centuries that the astronomical unit is about 93 million miles. The first rough values were obtained by simultaneously sighting to the center of the sun at sunrise and again at sunset. The distance separating the two sightings—the diameter of the earth—provided the base line, and the sighting angles provide the two angles needed for a straightforward trigonometric calculation. The third angle of the triangle (conventionally half of the angle) is called the angle of parallax. Astronomers came to define the solar parallax as the angle subtended by the mean equatorial radius of the earth at a distance of 1 A.U. [*see illustration on preceding page*].

From geodetic-survey measurements the earth's radius is known with an accuracy of plus or minus 200 feet, or with far higher percentage of accuracy than any other element in the astronomical-unit calculation. Following tradition, astronomers always regard the solar parallax—however obtained—as the fundamental value and the astronomical unit as the derived value.

The official value of the solar parallax is 8.80 seconds of arc, adopted in 1896 by the Congress of Directors of National Ephemerides and never revised. This value is still used in most astronomical tables. The same congress also adopted an official value for the mass of the earth, which, as it happens, is inconsistent with the solar parallax value. The value of mass adopted in 1896 corre-

SOURCE	METHOD	SOLAR PARALLAX (SECONDS OF ARC)	A.U. (MILLIONS OF MILES)	A.U. SPREAD (MILLIONS OF MILES)
NEWCOMB [1895] REVISED	MASS RATIO OF EARTH TO SUN FROM SECULAR VARIATIONS OF INNER PLANETS	8.764 ± 0.007	93.28	93.20 — 93.35
HINKS [1901]	TRIGONOMETRY FROM ORBIT OF EROS	8.806 ± 0.004	92.83	92.79 — 92.87
NOTEBOOM [1921]	MASS RATIO OF EARTH TO SUN FROM PERTURBATION OF EROS	8.799 ± 0.001	92.91	92.90 — 92.92
SPENCER JONES [1928]	DOPPLER DISPLACEMENT OF STELLAR SPECTRA	8.803 ± 0.004	92.87	92.82 — 92.91
SPENCER JONES [1931]	TRIGONOMETRY FROM ORBIT OF EROS	8.790 ± 0.001	93.00	92.99 — 93.01
WITT [1933]	TRIGONOMETRY FROM ORBIT OF EROS	8.799 ± 0.001	92.91	92.90 — 92.92
ADAMS [1941]	DOPPLER DISPLACEMENT OF STELLAR SPECTRA	8.805 ± 0.007	92.84	92.77 — 92.92
BROUWER [1950]	MASS RATIO OF EARTH TO SUN FROM PERTURBATION OF MOON	8.7925 ± 0.003	92.977	92.945 — 93.008
RABE [1950]	MASS RATIO OF EARTH TO SUN FROM PERTURBATION OF EROS	8.79835 ± 0.00039	92.9148	92.9107 — 92.9190
MILLSTONE HILL [1958]	DISTANCE OF VENUS FROM RADAR ECHOES	8.8022 ± 0.0001	92.874	92.873 — 92.875
JODRELL BANK [1959]	DISTANCE OF VENUS FROM RADAR ECHOES	8.8020 ± 0.0005	92.876	92.871 — 92.882
S.T.L. [1960]	MASS RATIO OF EARTH TO SUN FROM ORBIT OF PIONEER V	8.79738 ± 0.0008	92.9251	92.9166 — 92.9335

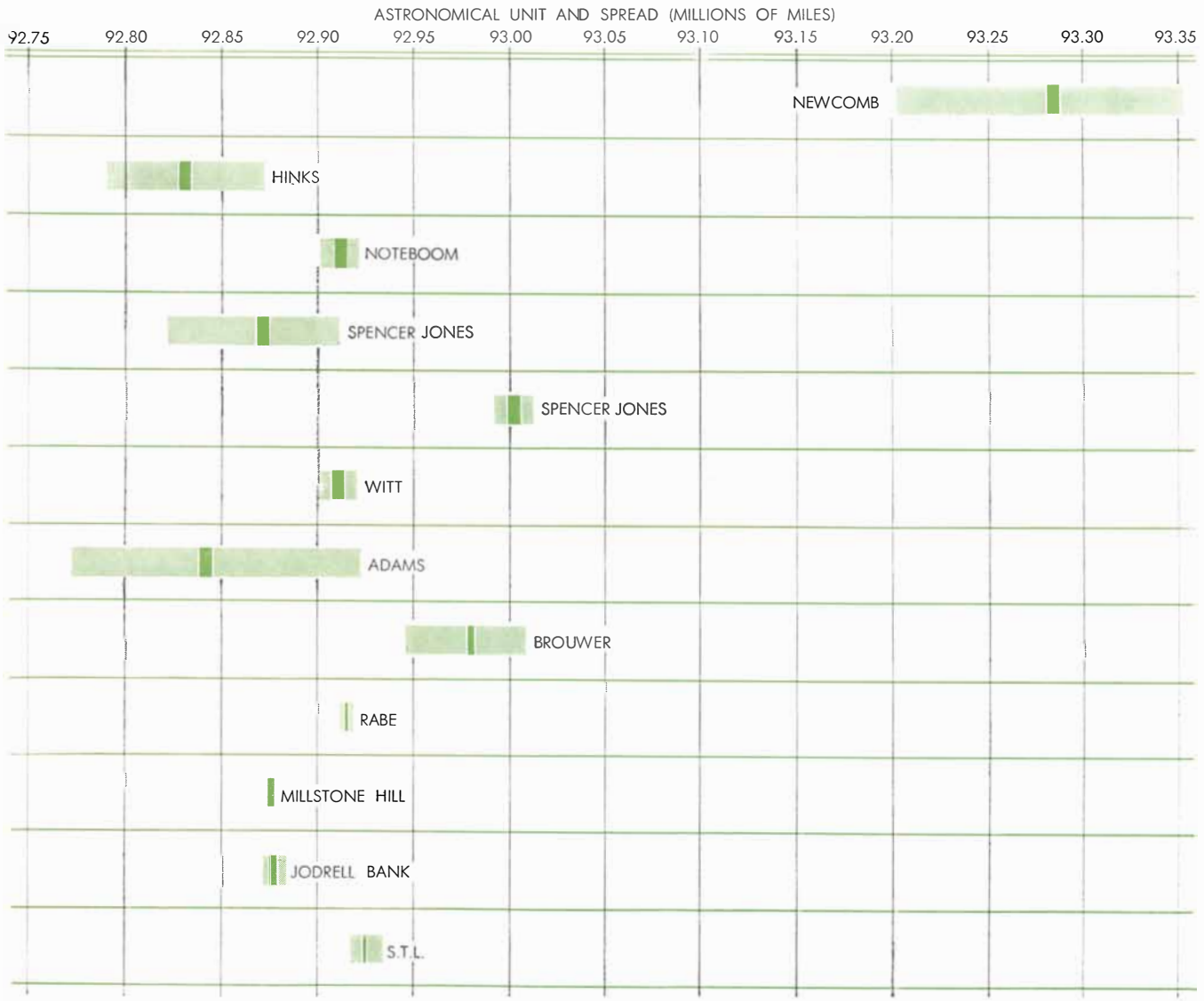
TWELVE VALUES FOR ASTRONOMICAL UNIT, computed by various methods over the past 60-odd years, present the interplanetary navigator with a perplexing choice. The distance to the planet he wishes to reach depends on the value he selects for the astronomical unit. Although Simon Newcomb's value of 1895 is almost surely wrong, none of the other values can be dismissed out of hand; all are based on defensible methods. The solar parallax (*third column*) is the tiny apex angle in the slim narrow triangle formed by lines connecting the center of the sun and the two ends of the earth's equatorial radius. The astronomical unit can be computed from the solar parallax and the earth's radius. The "plus or minus" figures after the solar parallax values show the range of uncertainty

sponds to a solar parallax of 8.79 seconds of arc. This difference of .01 second represents a difference of 100,000 miles in the astronomical unit.

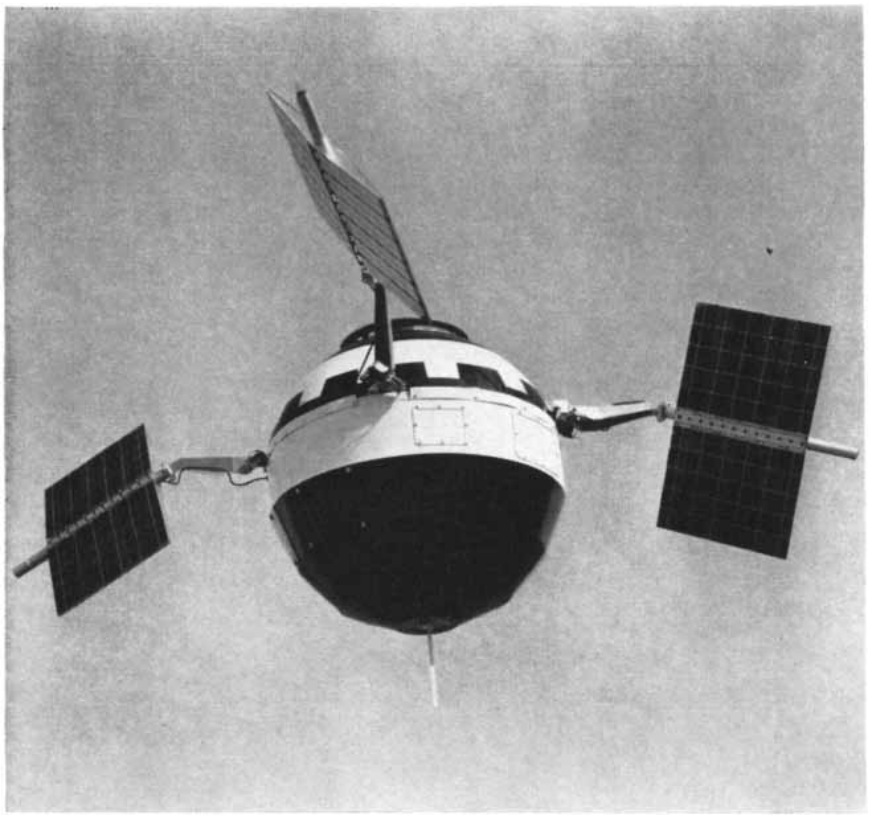
Measuring the solar parallax directly is unprofitable because the angle is less than 10 seconds of arc, and the sun is not a point source of light. Consequently astronomers have turned to indirect methods to refine the values assigned to the solar parallax. In recent times there have been no fewer than 11 independent, painstaking attempts.

In 1895 Simon Newcomb, a noted U. S. astronomer who was instrumental in the international adoption of basic constants in astronomy, combined 140 years of observations of the sun and of four inner planets to obtain a ratio for the mass of the earth to the mass of the sun. From this he calculated that the solar parallax was 8.759 seconds of arc and that the astronomical unit was 93.34 million miles. As Newcomb himself recognized, the parallax was surprisingly low and the astronomical unit correspondingly high; hence his values were set aside by the Congress of Directors of National Ephemerides when it met the following year.

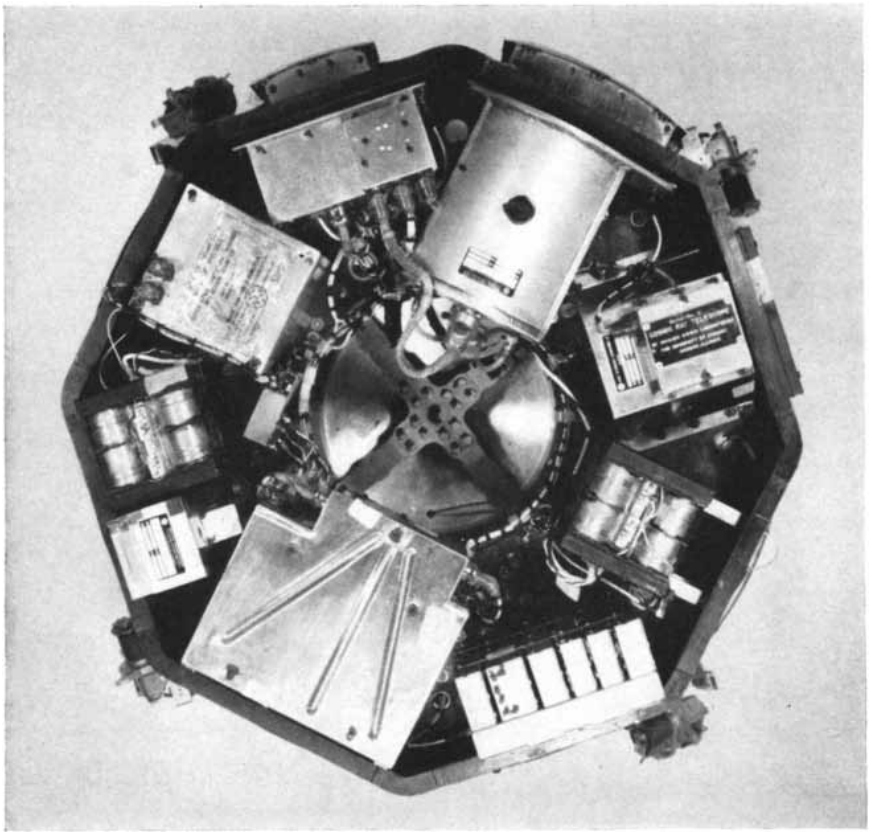
Some years later Harold Spencer Jones (who was Astronomer Royal of Great Britain from 1933 to 1955) revised Newcomb's figures by making relativity corrections and other adjustments. The net effect was to raise Newcomb's parallax value only slightly, to 8.764 seconds of arc. Since then no one has obtained so small a value for the parallax or so high a figure for the astronomical unit [*see illustration at bottom of these two pages*]. Newcomb's computations were very possibly marred by observational errors. When Mars and Venus are nearest the earth, their relatively large angular diameters (respectively 20 seconds and 65 seconds) combine with other factors to make pre-



in each method of calculation. This uncertainty is reflected in the spread of the astronomical unit (*fifth column and above*). Of the methods based on conventional telescopic data, that used by Eugene K. Rabe has the highest order of precision, with a spread of only 8,300 miles. Rabe's value, nevertheless, could depart more than that from the true value if his method contained a hidden error. Tracking data from *Pioneer V* suggest that Rabe may be low by 10,000 miles or more. Values based on Venus radar echoes show Rabe to be too high.



PIONEER V, the 94.8-pound space probe launched last year, is 26 inches in diameter and has four "paddle wheels" carrying solar cells. On January 16, 1961, the vehicle completed its first trip around sun after traveling some 530 million miles in 10 months and five days.



INTERIOR OF PIONEER V houses diversity of electronic gear. Reading clockwise from top, units facing each of sides are: transmitter, cosmic ray telescope, batteries, command receiver, computer, decoder and batteries, Geiger counter, and frequency converter.

cise determination of position difficult.

The discovery in 1898 of the asteroid Eros by Gustav Witt of the Urania Observatory in Berlin opened a new route to the determination of the astronomical unit. Eros, an irregularly shaped body that is probably no more than 15 miles in its largest diameter, provides essentially a point source of light; moreover, it swings at times to within 14 million miles of the earth (much closer than does Venus) to produce a large angle of parallax. Two international programs have been organized for the observation of Eros, the first in 1900 and 1901 (when the maximum parallax of the asteroid was 28 seconds) and the second in 1930 and 1931 (when the asteroid was in favorable opposition and its maximum parallax was 50 seconds). The results of the first program gave A. R. Hinks of the Royal Geographical Society a value of 8.806 $\pm$ .004 for the solar parallax, and results of the second gave Spencer Jones a value of 8.790 $\pm$ .001. Spencer Jones based his value on 2,847 photographs made by 24 observatories in 14 countries. The Hinks and Spencer Jones values, though both are based on Eros, are the highest and lowest obtained in this century. They represent a discrepancy of some 170,000 miles in the astronomical unit.

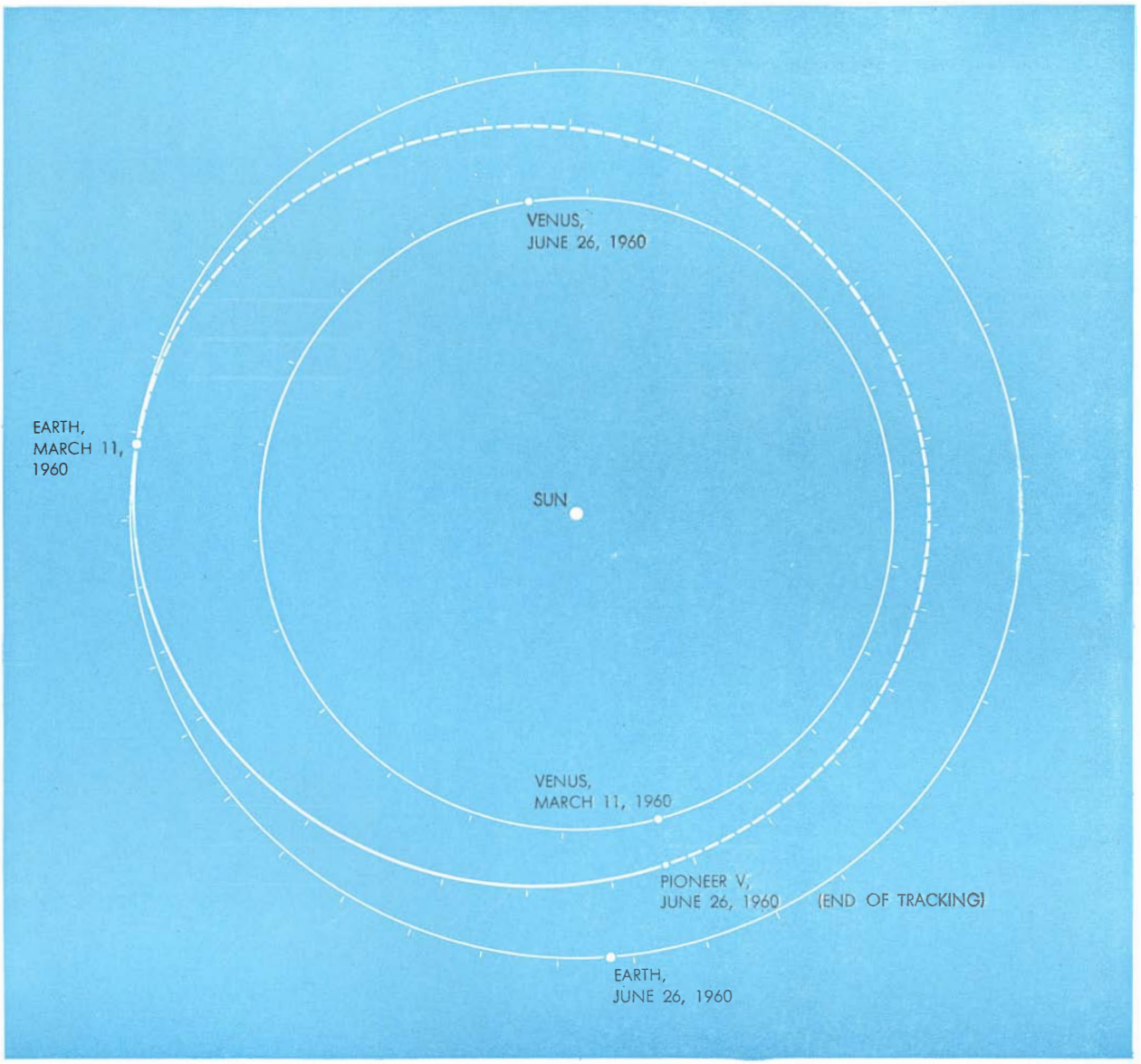
In 1921 E. Noteboom of Germany and in 1933 Witt also used Eros to derive the solar parallax. Whereas Spencer Jones had employed trigonometric calculations, Noteboom and Witt determined the perturbations in the orbit of Eros caused by the mass of the earth-moon system. By this means they obtained a value for the mass of the earth with respect to the sun, and from this they derived the solar parallax. Within their limits of accuracy the Noteboom and Witt calculations were in perfect agreement: 8.799 $\pm$ .001 seconds of arc.

In 1950 Eugene K. Rabe of the Cincinnati Observatory made a still more sophisticated analysis of the perturbations in the orbit of Eros. He included observations of Eros from 1926 to 1945 and took into account not only the earth-moon mass but also the masses of Mercury, Venus, Mars, Jupiter, Saturn and Neptune. The calculations required an electronic computer. Rabe's value of the solar parallax confirms that of Noteboom and Witt and extends the accuracy still further to 8.79835 $\pm$ .00039. This is the value that we have been using at Space Technology Laboratories for trajectory planning and analysis, and it would not be surprising if Soviet workers are also using it.

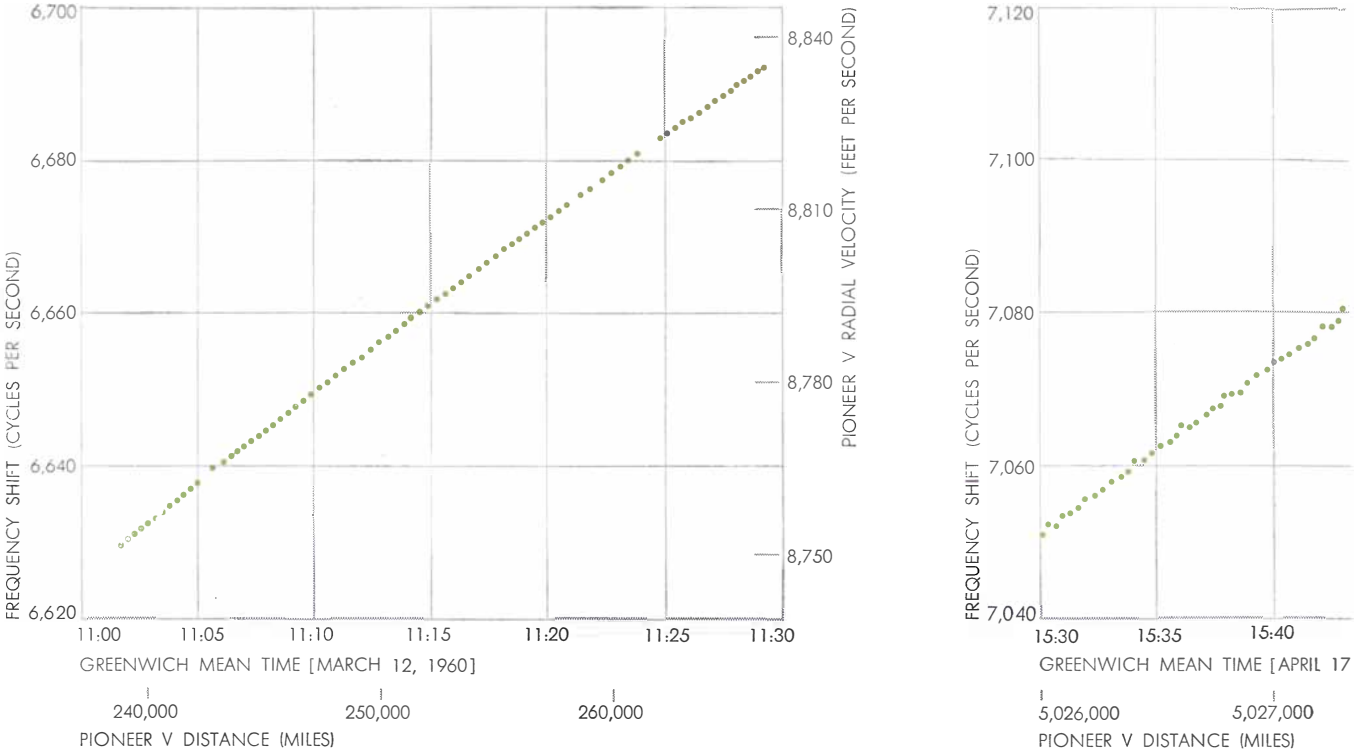
In spite of the remarkable agreement among these three independent calculations based on Eros, other methods, equally defensible, have given other answers. One method tries to establish the velocity of the earth directly, from which it is an easy step to the astronomical unit and to solar parallax. One effect of the earth's velocity is to impart a Doppler shift to the light from a star, a shift that is proportional to the velocity of the earth. In 1928 Spencer Jones calculated the velocity of the earth's motion around the sun from spectrographic observations of 21 stars and used this velocity to infer a solar parallax of 8.803 ± .004 seconds. In 1941 Walter S. Adams of the Mount Wilson Observatory analyzed 37 spectrograms of the star Alpha Boötis also to determine how much the spectra were shifted in frequency by the velocity of the earth at different points in its orbit. From these shifts Adams computed a parallax value of 8.805 ± .007.

One final parallax value, published in 1950 by Dirk Brouwer of the Yale University Observatory, completes the list of those based on standard astronomical data. Brouwer's work, together with Rabe's, may represent the last of the classical determinations. Brouwer made a refined study of lunar perturbations. The sun has a greater perturbing effect on the moon's orbit when the moon is nearest the sun than when it is farthest away. The magnitude of the additional perturbation depends on the distance separating sun, moon and earth. Brouwer deduced the perturbation by careful analysis of a series of lunar occultations of certain stars, and reached a value of 8.7925 ± .003 for the solar parallax. The value, the next to lowest of those made in this century, seems somewhat questionable. A major source of error in the method is that surface irregularities on the moon lead to irregularities in occultation times.

The first of the nonclassical methods was utilized successfully in 1958 by workers at the Lincoln Laboratory of the

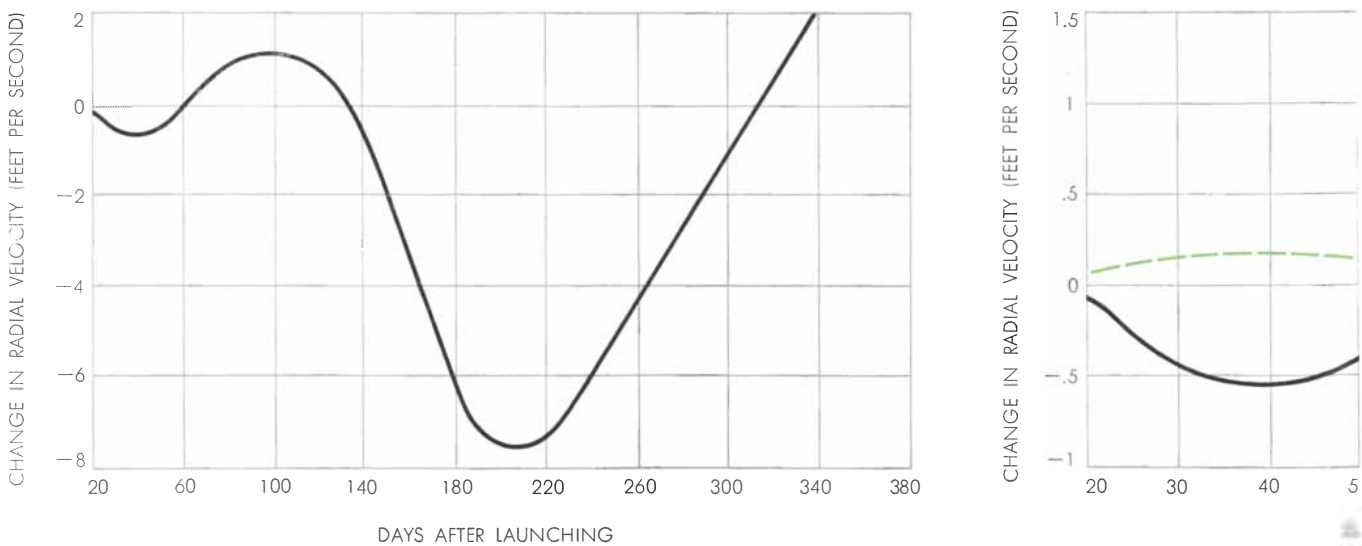


ORBIT OF PIONEER V was planned to come as close to the orbit of Venus as was possible with the power available in the launching rocket. Very much greater power would have been needed to take the probe close to Venus itself because of its extremely unfavorable position at date of launching. Dashes beside the orbits show the positions of earth, Venus and *Pioneer V* at 10-day intervals.

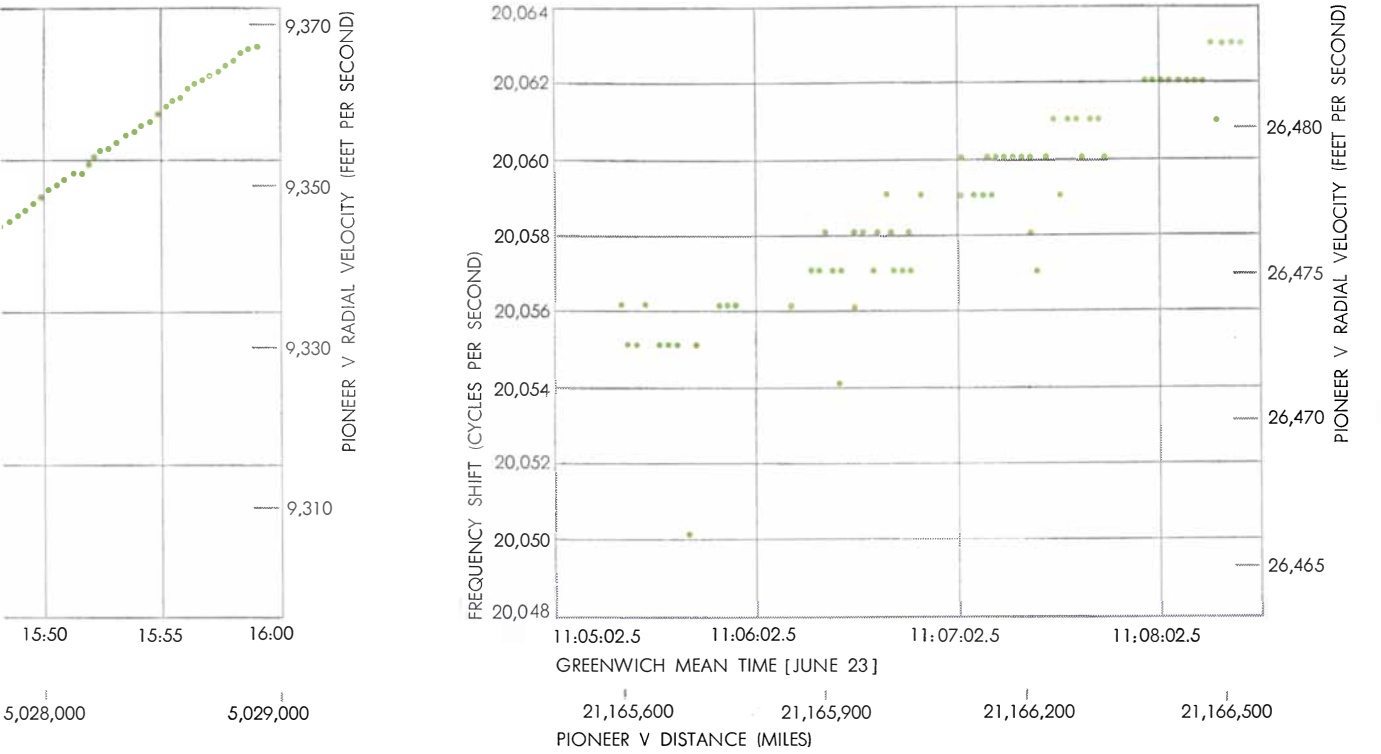


DOPPLER-SHIFT MEASUREMENTS in radio signals were the sole source of information for calculating the speed, position and trajectory of *Pioneer V*. After receiving a signal from earth, instruments in *Pioneer V* lowered its frequency by 1/17th of the received value and transmitted it back to earth. Any change in the vehicle's radial velocity (the velocity as measured along a line

Massachusetts Institute of Technology. They aimed a powerful radar signal at Venus from M.I.T.'s Millstone Hill Observatory and measured the time necessary to receive an echo. After a round trip of some 56 million miles, requiring about five minutes, the return signal was so faint that the individual pulses did not emerge above the prevailing level of radio noise. But by transmitting a signal consisting of a coded pattern of pulses it was possible, after lengthy computer analysis of the received signal, to extract what appeared to be the coded echo from the surrounding noise [*see illustration on page 72*]. The time taken for the round trip was translated into a value of 8.8022 ± .0001 for the solar parallax. The following year the Jodrell Bank Observatory of the University of Manchester used its 250-foot radio telescope to repeat the M.I.T. experiment and derived a solar parallax of 8.8020 ± .0005. The two results are so close that they



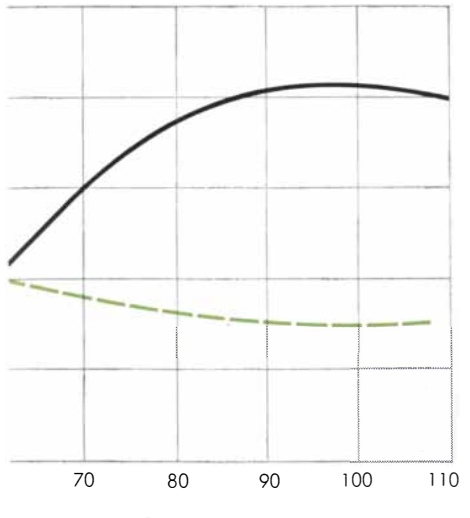
NEW VALUE FOR THE ASTRONOMICAL UNIT was obtained by comparing the observed radial velocity of *Pioneer V* with that predicted by some assumed value of the A.U. The value assumed by Space Technology Laboratories was that of Rabe: 92,914,800 miles. Chart at left shows the extent to which radial velocity of *Pioneer V* would depart from that predicted if the true A.U. were five parts in 10,000 smaller than Rabe's value. Colored curve at right, based on probe's actual radial velocity, shows departure as-



from the center of the earth to the vehicle) would change the frequency of the signals, as received, both going out and returning. These three charts, for three widely separated days, show how the change in frequency (a decrease in each case) can be translated into a change in radial velocity. The scatter in values in the chart at far right is due to noise and to characteristics of the receiver.

give values for the astronomical unit differing by only about 2,000 miles. On the other hand, they lead to an astronomical unit that is a full 40,000 miles shorter than Rabe's value.

These, then, were the astronomical-unit choices confronting us at the Space Technology Laboratories a little over a year ago when we were planning a trajectory to carry *Pioneer V* to the general vicinity of the orbit of Venus. We concluded that Rabe's value of the astronomical unit was the best possible choice. It is supported by Noteboom and Witt and is not excluded by Adams.



suming its initial position and velocity were known perfectly. Departure implies that the true value for the astronomical unit is 1.1 parts in 10,000 larger than Rabe's value.

If we could track *Pioneer V* long enough —at least 60 days—we knew we could obtain a good check on Rabe. Any difference between Rabe's value for the astronomical unit and the true value would lead to slightly different trajectories. The basic trajectory measurement we hoped to make with *Pioneer V* was its radial velocity, which is that component of its velocity on a line directly away from the earth. The means for measuring this component were sensitive enough to detect readily a discrepancy of five parts in 10,000 between the assumed and true values of the astronomical unit. It can be seen from the accompanying curve [*illustration at bottom of these two pages*] that the effect of any discrepancy is greatly magnified as time goes on; thus there was much to be gained by tracking *Pioneer V* as long as possible.

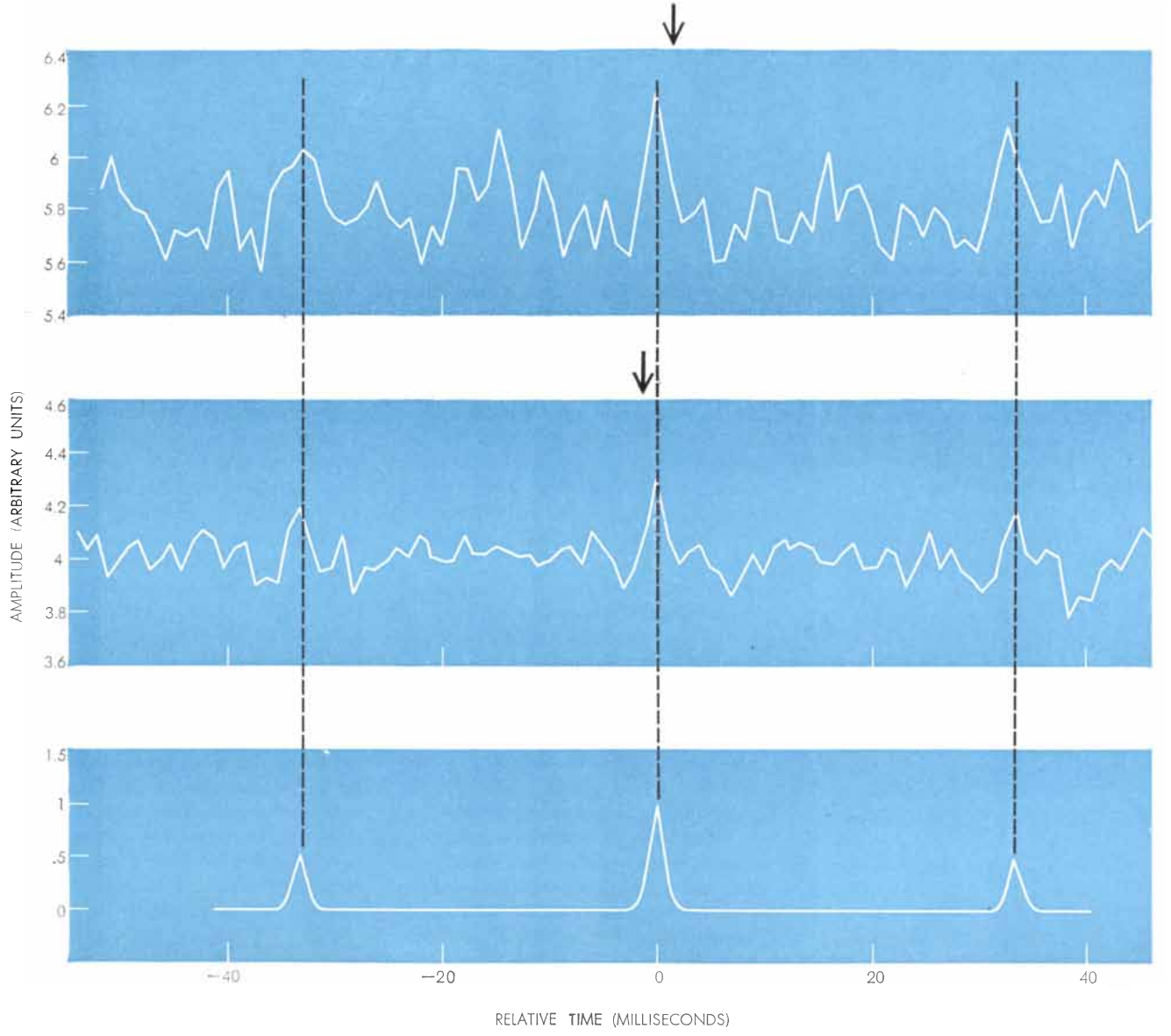
Pioneer V's radial velocity was determined by measuring the Doppler shift of radio signals by tracking stations located in Hawaii and at Jodrell Bank in England. During every tracking exercise the ground station beamed an ultrahigh-frequency signal to *Pioneer V;* the vehicle's receiver locked onto this signal, reduced its frequency by precisely 1/17 of the received value and passed it on to the vehicle's transmitter for return to earth. Continual measurement of the round-trip Doppler shift in this radio signal provided all the information needed to calculate the trajectory of the probe. When the round-trip time of the signal to and from *Pioneer V* became appreciable (it reached about four minutes during the final days of contact), it was important to measure any small frequency drift in the ground transmitter that occurred between transmission and reception. For this purpose a rubidium-gas frequency standard was used in the tracking station at Jodrell Bank.

Pioneer V was tracked daily for 108 days from its launching on March 11 until June 26, when it was 22.46 million miles from earth. The final signals from the vehicle came from its five-watt transmitter, the range of which far exceeded expectations. A transmitter of 150 watts was turned on when *Pioneer V* reached eight million miles, but because of decreased battery capacity in the craft it could not be turned on after May 21. The

expected range of the larger transmitter was 100 million miles. Toward the end of June the return signal from the five-watt transmitter was so weak that it was often obscured by noise [*see last in series of three illustrations at top of preceding two pages*]. Nevertheless, by the use of statistical techniques to separate signal from noise we could obtain useful Doppler measurements as long as ground receivers could detect the *Pioneer V* signal.

Our laboratory had devised a computer program to calculate the trajectory of *Pioneer V* from the Doppler values, taking into account perturbations caused by Mercury, Venus, Earth, Mars, Jupiter and Saturn. This trajectory was then compared with that predicted by Rabe's value of the solar parallax. The discrepancy showed that Rabe's value needs to be reduced by 1.1 parts in 10,000, or by .00011. Multiplying Rabe's 8.79835 by .00011 yields .00097, the amount to be subtracted. Hence the solar parallax value obtained from *Pioneer V* is 8.79738 seconds of arc, with an accuracy of ± .0008 second. This converts to an astronomical unit of 92,925,100 miles, ± 8,500 miles. Had we been able to maintain radio contact with *Pioneer V* out to 100 million miles, as we had hoped, we would have been able to ascertain the solar parallax with accuracy and reliability to within ± .0001 second, and to determine the astronomical unit to within 2,000 miles.

From the flight of *Pioneer V* we have obtained what amounts to increased confidence in Rabe's value, though not necessarily an improvement on it. We can now be reasonably certain that the astronomical unit is no less than 92,911,000 miles (Rabe's minimum value) and no more than 92,934,000 miles (the maximum from *Pioneer V*). This still leaves a substantial uncertainty of some 23,000 miles. We shall have to wait and see if the Soviet Venus probe can reduce it.



RADAR SIGNALS BOUNCED OFF VENUS by Lincoln Laboratory of Massachusetts Institute of Technology indicate an A.U. of 92,874,000 miles, or about 50,000 miles less than the value obtained from *Pioneer V*. The discrepancy is unexplained. The signal beamed at Venus consisted of a coded sequence of pulses whose patterned echo could be extracted from background noise by a statistical technique called cross-correlation. The two upper curves show the cross-correlation evidence for echoes recorded on February 10 and 12, 1958. The bottom curve shows the cross-correlation peaks expected in the absence of noise. After all corrections had been made, the signal travel-time on the two days showed an unexplained discrepancy of 2.2 milliseconds, amounting to about 200 miles in the earth-Venus distance. The vertical black arrows indicate how much each day's echo was displaced from the mean value.

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There is a temptation to devise an ad slogan around the conjunction of 25's but to resist this temptation is not difficult. Indeed, the far greater difficulties of the logistic problem compel us to direct the advertising of *Kodachrome II Film* largely to the likes of you, who read such magazines as this one.

You can quickly grasp the implications of the fact that despite the increase of speed, there has been improvement in sharpness and graininess characteristics, not sacrifice as one would expect. Furthermore, bright colors are brighter, pastels cleaner, contrast lessened to cover a wider subject-brightness range. With the "bright sunlight" setting for 8mm movies reduced from *f*/8 to midway between *f*/11 and *f*/16, you have more depth of field. On a "cloudy bright" day you can use *f*/8 and be in focus as close as 3½ feet without a close-up attachment over your regular 13mm lens. Indoors, with only two reflector flood lamps at the camera and an *f*/1.9 setting, you will be able to move farther back than before—as far as 20 feet.

Alas, the logistics. You grasp the implications but you wear no mark on your brow that entitles you to *Kodachrome II Film* if the dealer has just sold his last roll to your less scientifically inclined neighbor. Pity the dealer trying to deal fairly with the probably insufficient quantity of *Kodachrome II* that is currently reaching him. Pity us trying to fill those long, long pipelines with *Kodachrome II Film* while also keeping *Kodachrome I* flowing through the same pipelines without turbulence. Pity us trying to do this with a product which has to go through a production line twice—and be retained in the purchaser's possession for an uncontrolled period of time in between. Pity us.

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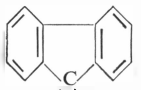
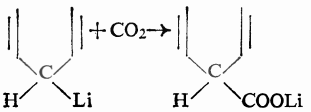
Methyl Fluorene - 9 - Carboxylate (Eastman 8164) represents a week's work last summer by one of these young men. The man he was hired to assist specializes in organometallic reactions. The mentor found a lithium reaction to give him in the April 1960 *Analytical Chemistry* on page 554. The summer man reacted lithium wire with bromobenzene to produce phenyllithium. He used this to replace one of the central hydrogens in



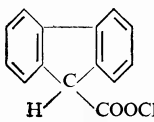
fluorene

by lithium.

Next,



On acidification, an H replaced the Li. He then esterified with methanol, with HCl as catalyst. His product,



was good enough to overcome the skepticism of our genial but skeptical chief control chemist.

Nobody patted him on the head for his accomplishment. All he accomplished was to make it unnecessary for other chemists who look up the *Anal. Chem.* reference to spend a week of their own time preparing the reagent that has been found to react with a wide variety of alkyl halides to yield sharp-melting derivatives. Since such reagents are few and far between, you may even wish to send for a procedural abstract. Or for an employment application form.

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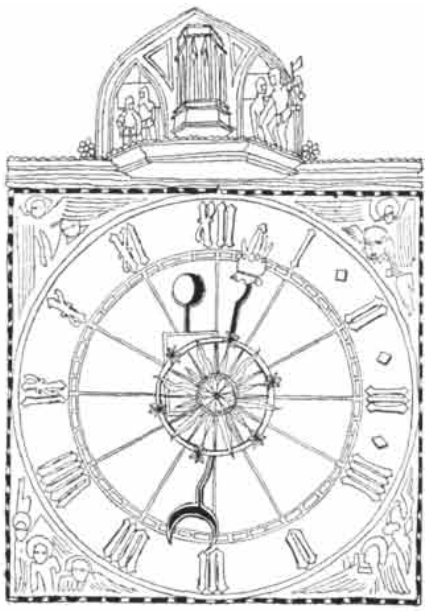
This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science



Activity in Space

The U.S.S.R. space probe now on its way toward Venus has already set one notable record: it is the first space vehicle to have been launched from a "coasting" orbit around the earth instead of directly from the earth's surface. In order to fall from the earth into the smaller orbit of Venus the probe had to be slowed to an orbital speed around the sun less than that of the earth. This was accomplished on February 12 by firing it back along the earth's orbit from its satellite platform, which had been sent up earlier the same day.

According to Soviet announcements the rocket will pass within some 60,000 miles of Venus on about May 20. If it comes no closer than this, it will still be well outside the opaque cloud layer that hides the surface of the planet. Assuming that its radio continues to function and that the signal can carry 43 million miles back to earth, the probe should in any case provide valuable information on distances in the solar system [*see "The Size of the Solar System," page 64*]. So far the long-distance record for radio contact is 22.5 million miles, established by *Pioneer V*.

On its journey the 1,400-pound "automatic interplanetary station" is recording data on "cosmic radiation, magnetic fields, interplanetary matter and registration of micrometeoritic impacts." A shutter system regulates the internal temperature. The chemical batteries that power its radio (which transmits on 922.8 megacycles, but only on command) are replenished by solar cells. An orientation mechanism is to stabilize the probe when it reaches the vicinity of Venus so its instruments are turned toward Venus and its "precision aerial faces earth."

The Venus shot was the most spectacular in a busy month. The U.S.S.R. began by sending up the seven-ton earth satellite *Sputnik VII*, and then the Venus probe launcher, *Sputnik VIII*, a week later. In the course of the month the U. S. put four satellites into orbit—an Explorer balloon, two Discoverers and a Transit navigation satellite.

At the end of February the total count of earth satellites stood at 45, of which 36 were launched by the U. S. and nine by the U.S.S.R. Twenty-one of these were still in orbit. Each country also had two artificial planets in solar orbit, and the Russians had landed a rocket on the moon.

Earliest Man

Fossil remains of a new human species, the earliest yet uncovered, have been found in Olduvai Gorge in Tanganyika. Portions of the skeletons of two individuals, a child and an adult, were dug up by L. S. B. Leakey, who also discovered Zinjanthropus, the "nut-cracker" man-ape, in the same region. The fragments have yet to be precisely dated but Leakey is confident they are considerably older than half a million years. With the remains was found a bone tool, probably used for working leather. Leakey believes that the tool was used by the newly discovered man and not by Zinjanthropus.

The new species—as yet unnamed—is older than Zinjanthropus but more manlike. The more complete remains are those of the child, who was about 11 years old, and include the skull, part of the jaw and a collarbone, and parts of the hands and a foot. The skull lacks the apelike sagittal crest of Zinjanthropus. This suggests, says Leakey, that "we are dealing with a hominid with a larger brain capacity and somewhat less specialized than Zinjanthropus." But the child had canine teeth resembling those of Proconsul, an East African ape of 30 million years ago. The proportions of the collarbone indicate that the newly found hominid had a bigger chest than modern man. Neither the height nor the sex of the child, who appears to have been

THE CITIZEN

killed by a blow on the head, has been determined. The remains of the adult are much scantier, consisting only of hand bones, a collarbone and a few teeth.

Missing Minuses

Electrons have recently been detected in primary cosmic radiation, but not nearly enough of them to clear up a long-standing mystery. Previously all the primary particles raining down on the earth's atmosphere from space have appeared to have a positive electric charge. Yet they were presumably formed with an equal number of negative charges, which should also be able to reach the earth.

In *Physical Review Letters* last month physicists reported finally observing some negatively charged electrons. Peter Meyer and Rochus Vogt of the University of Chicago suspended a scintillation counter from a balloon that made three flights to altitudes of just over 100,000 feet at Fort Churchill, Manitoba. The counter was arranged to exclude secondary electrons (resulting from cosmic ray collisions) and to detect primary electrons in the low-energy range. The number of incoming primary electrons found was about 35 per cent of the number of incoming protons. James A. Earl of the University of Minnesota sent a cloud chamber designed to record high-energy electrons to a comparable altitude. It registered three primary electrons for every 100 incoming protons.

Although primary cosmic ray electrons do not reach the surface of the earth, they do penetrate the atmosphere below 100,000 feet. They are not easily detected below that level because many are captured and because of the large number of secondary electrons at lower altitudes. Earl believes, however, that not many are lost at 100,000 feet, so that detectors sent to higher altitudes would presumably not register substantially higher numbers of primary electrons.

Egg-shaped Equator

The earth is somewhat out of round through the Equator as well as from north to south. Calculations based on the orbits of the first two Vanguard satellites indicate that the earth's circumference at the Equator is a slightly

irregular ellipsoid. An equatorial diameter drawn from a point just east of the tip of Brazil to the Admiralty Islands would be 1,400 feet longer than the diameter at right angles to it, from a point south of California to one south of Iran.

Geophysicists had been aware from gravitation measurements that the earth's equatorial circumference is not truly round but they did not know its actual shape. The calculations that determined it were made by Imre E. Izsak of the Smithsonian Astrophysical Observatory. Earlier work on the satellite orbits had disclosed an asymmetry north and south, the Northern Hemisphere being slightly larger than the Southern.

Lost Illusions

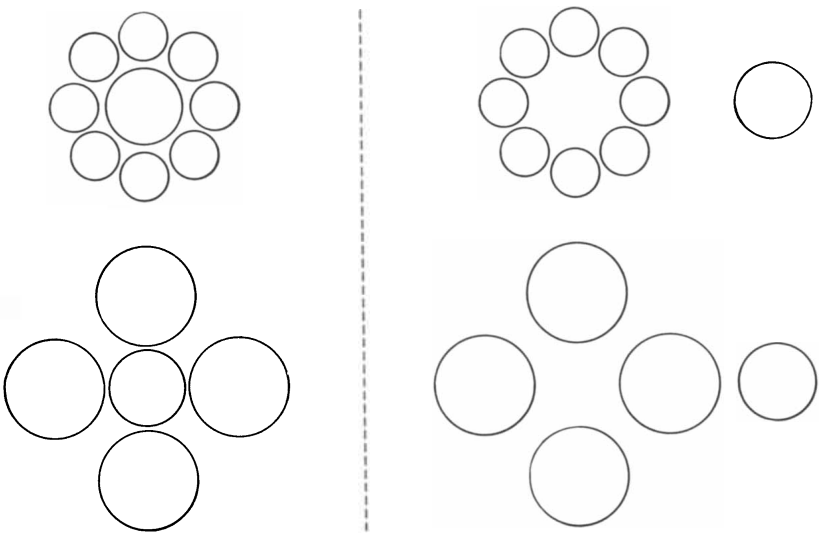
An experiment conducted recently by a Japanese psychologist suggests that optical illusions occur in the eye of the beholder and not in his mind.

A typical optical illusion [*see illustration below*] consists of two identical circles, one of which is surrounded by smaller circles and the other by larger circles; the first central circle appears to be larger than the second. Sonoko Ohwaki of Tohoku University, who describes his experiment in the journal *Tohoku Psychologica Folia*, conceived the idea of separating part of the illusion figure from the rest of it and then allowing an experimental subject to recombine the two parts by viewing them in a stereoscope. In the circle illusion, for example, the central circles were presented to one eye and the surrounding circles to the other eye. When 24 subjects viewed the figure in this way, 15 of them could not see the illusion at all; that is, to them the two central circles appeared to have the same size.

Ohwaki obtained much the same result with three other standard illusion figures used in the experiment. When his subjects viewed the figures both normally and stereoscopically, their responses indicated that in 69 per cent of the cases the stereoscopic illusion was weaker. In view of the fact that the stereoscopically presented figures were assembled in the brain and not in the retina, the illusion would appear to occur in the retina. Ohwaki does not rule out the possibility that the brain plays a role in optical illusions, but his experiments contradict the traditional psychological view that processes in the brain are solely responsible for such illusions.

NASA Administrator

James Edwin Webb, President Kennedy's appointee as Administrator of the National Aeronautics and Space Administration (NASA), is a 54-year-old businessman who has also been active in public service. Prior to his appointment he was a director of Kerr-McGee Oil Industries, Incorporated, and assistant to its president. During President Tru-



TITCHENER ILLUSION (*left*) causes the central circle at top to appear larger than the corresponding circle at bottom. The circles are identical. In the experiment conducted by Sonoko Ohwaki this figure was divided into two parts (*right*) and observed by subjects through a stereoscope. The two rings of circles just to right of broken line were seen through one lens of the stereoscope; the two circles at far right, through the other.

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man's administration he served as Director of the Bureau of the Budget and as an Undersecretary of State.

In his new position Webb will head an organization that has the third largest budget of any independent Government agency (after the Veterans Administration and the Atomic Energy Commission) and spends the third largest amount on research and development (after the Department of Defense and the AEC). Created in 1958 to succeed the National Advisory Committee for Aeronautics, NASA started with a budget of $339,000,000. For the fiscal year ending June 30, 1961, its expenditures will total $915,000,000. Approximately two-thirds of this, or $617,915,000, is allocated to research and development. In the same period the Department of Defense is spending $3.9 billion on research and development and the AEC $662 million. The proposed NASA budget for the next fiscal year is $1,119,630,000, with $819,819,000 marked for research and development.

Electrons and the Living Cell

One of the most dramatic advances in biology during the past decade has been the unfolding of the detailed structure of the cell under the electron microscope. But there was always the question of how closely the killed, adulterated and sliced-up specimens on which the instrument usually operated resemble living organisms. Now a group of workers in France has succeeded in making the first electron micrographs of intact living cells.

Gaston Dupouy and his colleagues at the Electron Optics Laboratory in Toulouse devised a method of protecting bacteria from the high vacuum required in an electron microscope. The specimens were encased in tiny capsules filled with air and exposed to the electron beam through collodion windows. To drive the beam through the array the voltage was stepped up from the usual 50,000 volts to a million, and the electrons were fired in short bursts to minimize injury to the bacteria. The entire instrument, including the million-volt accelerator, is housed in an aluminum sphere 78 feet in diameter.

After emerging from the microscope the bacteria were lively enough to grow and reproduce. The pictures showed the organisms magnified 25,000 diameters. However, the results so far lack the fine detail of ordinary electron micrographs. The latter are made with specimens coated or impregnated with heavy metals to increase the scattering effect on elec-

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

Microplasticity: The Behavior of Materials Under Microstresses

Minute deformations, caused by only small stresses and involving the movement of only a few dislocations, are not accounted for in existing stress—strain tables. Recently such deformations have assumed vital importance and new data are sorely needed.

The bridge-building engineer refers to his well-thumbed tables of yield points based on 45 years of compilation by the Bureau of Standards and other agencies, allows a safety factor, and rests assured his bridge will stand and perform well for many years. These yield stresses correspond to a deformation of about .002 inch per inch.

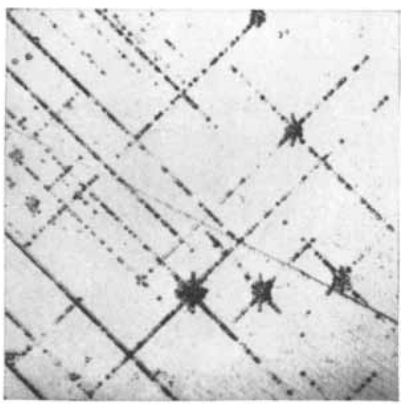
But the space age engineer, concerned with micro-inches of tolerance, finds these tables almost useless. A deformation of one micro-inch (.000001 in.) per inch can be significant. Data are needed for deformations of this small order of magnitude. For example, the yield point of beryllium is listed as 35,000 psi, a yield involving millions of dislocations. Actually microstress yields occur at 2200 psi.

Reversible elastic deformation involves only a stretching of inter-atomic bonds. Permanent plastic deformation results when these bonds are broken, due to the movement of dislocations, and new bonds form. A one micro-inch "step" results from the emergence of only 100 atomic dislocations. Today's design engineers are concerned with just such a minute deformation.

The regular arrangement of atoms in a crystal is disturbed by defects. Dislocations are one type of defect. These exist naturally in crystals and normally migrate when stress is applied. They glide along crystallographic planes causing the crystal to shear.

Stress levels which may be tolerated determine the material chosen for a particular application. Normally, in working with metals the movement of minute dislocations is restricted by conventional alloying and heat treating techniques This, however, raises a serious problem for the design engineer working to close tolerances in that metals so treated are no longer thermodynamically stable. This introduces potential dimensional instability.

With this as a background, Honeywell scientists are exploring the use of unconventional materials in which dislocation movement is fundamentally difficult due to the character of their atomic bonding. For example, pure alumina has proven excellent in its ability to resist dislocation and to retain dimensional stability. Honeywell engineers working with this material successfully in advanced gyros have found that dislocation movement cannot be measured prior to fracture. At the same time it remained dimensionally stable up to 500°C.



150X Photomicrograph of surface of etched magnesium oxide showing the movements of dislocations on crystal planes.

Honeywell research scientists are engaged in a broad program in this field and are using a number of investigative techniques. Photomicrography of etched materials is proving to be an ideal approach. Etched pits of dislocation can be clearly seen and have been measured. Samples have been subjected to further stress and the motion of dislocations noted or measured by this technique.

For some polycrystalline materials such as aluminum and beryllium, no satisfactory, delicate etch is known. Therefore strain gages are used to measure deformation in these materials.

Obviously a better understanding of the micromechanical behavior of materials is needed. Where choice of materials is critical, it is essential to be able to predict performance and to have some criteria which ultimately result in improving materials.

It is hoped that present work in this area of microplasticity will open new possibilities for the functional use of materials presently considered unconventional and, at the same time enable us to meet new, more precise design requirements.

If you are engaged in scientific work involving microplasticity or are interested in techniques involved in improving the physical properties of materials and would like to know more about Honeywell's research in this area, you are invited to correspond with: Dr. C. H. Li, Honeywell Research Center, Hopkins, Minnesota.

trons and are most often cut into thin sections to improve definition.

Stubborn Staph

Strains of *Staphylococcus* resistant to the new synthetic penicillin designed specially to combat these organisms have already turned up on both sides of the Atlantic. Patricia Jevons of the Staphylococcus Reference Laboratory in London has reported encountering three such strains in more than 5,000 cultures tested over a two-month period. A comparable percentage has been found by Heinz F. Eichenwald of the Cornell–New York Medical Center.

Resistance to the synthetic penicillin must involve a different mechanism than does resistance to natural penicillin. Staphylococci counter the action of the natural antibiotic by secreting a penicillin-inactivating enzyme, penicillinase. Synthetic penicillin, however, is not affected by penicillinase. Eichenwald believes that the microorganisms resist it simply by ignoring it; *i.e.*, that their metabolism can proceed by pathways that penicillin does not block.

The new resistant strains were recovered from patients and so are virulent. Resistance to both natural and synthetic penicillins, moreover, could presumably occur in the same organism. But the small proportion of staphylococci so far found resistant to synthetic penicillin gives promise that a serious threat, if any, still lies in the future and that synthetic penicillin can be effectively used for some time to come.

Superconductor Magnet

A novel electromagnet, which takes advantage of superconductivity to produce very strong magnetic fields from very small quantities of electric power, has been developed by Bell Telephone Laboratories.

In most materials that exhibit superconductivity (loss of electrical resistance at temperatures near absolute zero) the state is destroyed by strong magnetic fields. Hence such materials cannot be used as cores for powerful electromagnets. In 1954 B. T. Matthias, a physicist at Bell Laboratories, prepared an alloy of three parts niobium and one part tin that retains its superconductivity even in extremely strong fields. It proved too brittle, however, to draw into wire. J. E. Kunzler and his fellow metallurgists at Bell Laboratories have now solved the wire-drawing problem by forming a tube of niobium a quarter-inch in diameter and filling the tube with the

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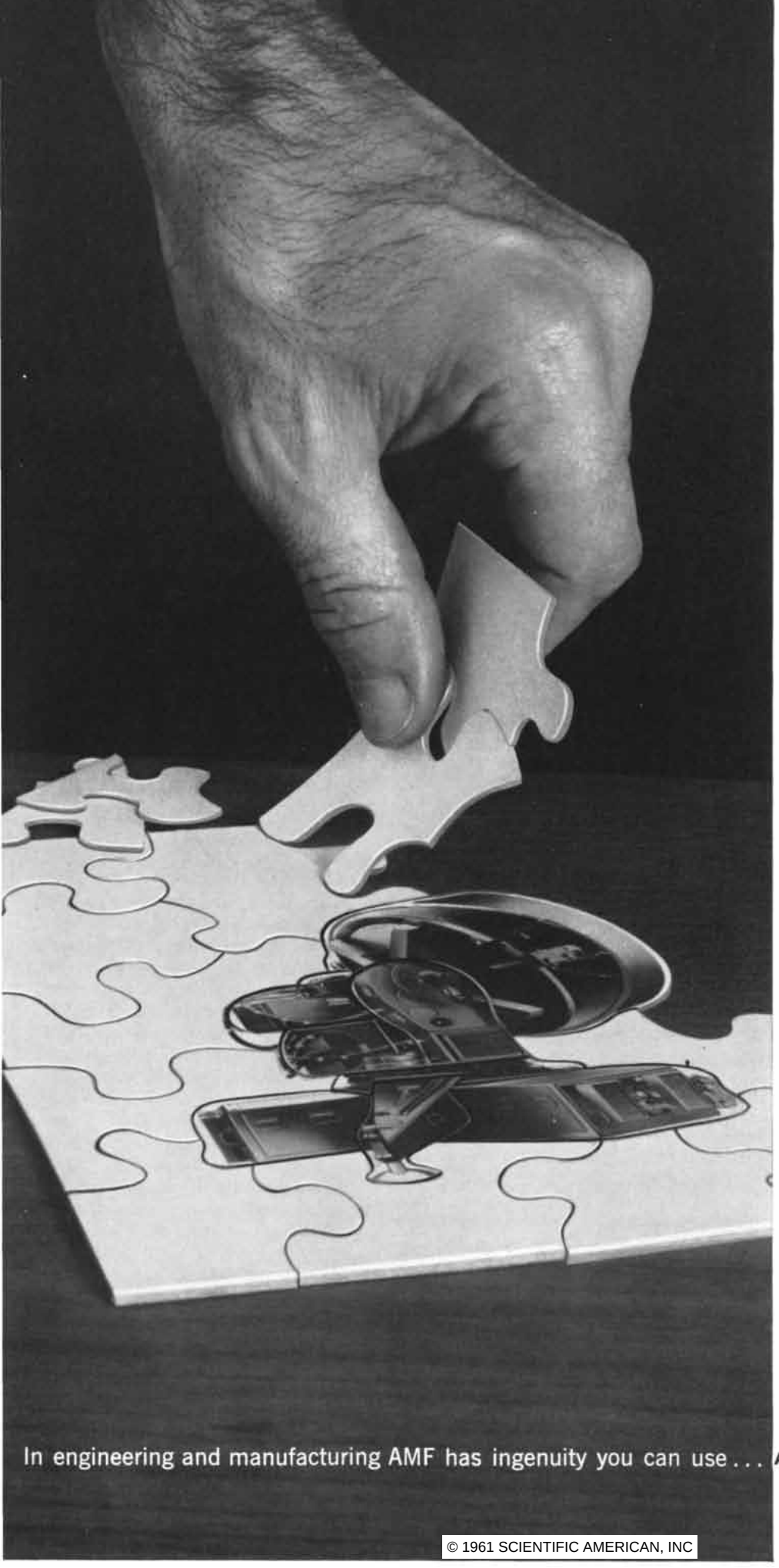
alloy in powder form. The tube is then drawn into wire of the desired fineness and baked at 1,000 degrees centigrade to fuse the alloy powder inside. Since pure niobium is not a superconductor, the niobium coating serves as an insulator when a superconductive current flows within the wire.

The wire is capable of generating magnetic fields up to 88,000 gausses—nearly 150,000 times the strength of the magnetic field at the surface of the earth—without losing its superconductivity. Because the wire is superconductive, a continuous source of electric power is not needed to keep the current flowing and sustain the field. Power is required only to start the flow and to operate the refrigeration equipment needed to maintain superconducting temperatures. The new magnet is expected to have application in various areas where large fields are required, especially in experiments on controlled thermonuclear fusion, in which magnetic fields are utilized to contain the heated gases. The enormous quantities of power needed to generate large magnetic fields by conventional means have been a serious obstacle to thermonuclear research.

Mutation Mechanisms

Biochemists have begun to pin-point the effects of mutation-inducing chemicals on the molecule of the hereditary material, deoxyribonucleic acid (DNA). At a meeting of the Biophysical Society in St. Louis, Ernst Freese of the University of Wisconsin reported on the mutagenic action of hydroxylamine. This substance combines with cytosine, one of the four bases attached to the backbone of the double-stranded DNA molecule. (Genetic information is thought to be contained in the sequence of the bases.) When the DNA strand containing a cytosine-hydroxylamine complex subsequently assembles a complementary strand during the duplication of the DNA molecule, the complex tends to pair with adenine on the second strand, rather than with guanine, the normal partner of cytosine. Consequently the order of bases in the new material differs from that in the original partner of the treated strand. In another report Alfred Gierer of the Max Planck Institute at Tubingen in Germany described a similar action for nitrous acid. This mutagen, however, acts on both adenine and cytosine.

Freese has also distinguished two other chemical effects: one in which a cytosine-guanine pair is replaced by an adenine-thymine or vice versa, and another



He solved this puzzle by taking it apart!

Like oil and water, extreme precision and "complete" mobility resist combination in tracking radar antennas. Designing for one of these characteristics "automatically" precludes the other. *That* was this AMF Engineer's puzzle—to put *both* precision *and* mobility in an antenna for duty with the Marine Corps.

He solved the puzzle, literally, by taking apart the solution—AMF's TPQ-10 antenna—into 10 rugged, portable, submersible, precision-fabricated packages. TPQ-10 is designed for helicopter transport. Each component can be dropped in water; it will come up for more. The packaged antenna on its pallet can be dropped on land from 3 feet without impairing precision.

Each component can be *picked* up—the largest weighs 425 lbs.—and can be handled by 3 men. A crew of 6 can put TPQ-10 together in 20 minutes with one standard wrench.

Among the design innovations that solved the puzzle is a "piggyback" gear arrangement that puts both azimuth and elevation drives in one package. Result: almost half the parts and weight of separate components. Precision fabrication is typified by the reflector arms, held to a .005" deviation over 45 inches!

(For unclassified information on early warning and radar antenna systems, write Dept. CS 1, address below.)

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in which the two members of a pair change places on the two strands.

By studying chemical mutations, Freese said, investigators are starting to identify particular groups of bases with specific genetic characteristics. Moreover, they can sometimes predict that a certain compound will have mutagenic properties, although not what mutation it will produce. Most of the research so far has been on microorganisms. Freese points out that an agent that affects DNA in one setting may well affect it in another. He suggests that substances found to be mutagenic in microorganisms—caffeine is one example—should be checked for its action on the cells of higher animals and man.

How to Beat the Game

An instructor in mathematics at the Massachusetts Institute of Technology has devised a strategy for winning at the card game twenty-one, or blackjack. The system will benefit only the idle rich, however. The edge it gives the player is so small that he needs a large initial capital and a lot of time to run up substantial winnings.

The system had its origin a few years ago when four college students, serving as Army draftees at Aberdeen Proving Ground, used a desk calculator to work out a method that would limit the expectations of loss in playing against a gambling house to two cents in $10. Edward Thorp, the M.I.T. instructor, heard of their work and tried it successfully at Las Vegas. Then he extended the calculations with the aid of an electronic computer. He found that the chances of winning in any one hand depend greatly on what has been played in previous hands, if twenty-one is played in the usual way—that is, if hands are dealt continuously until the deck is exhausted. For instance, the house will win more often than the player if the aces have been exhausted, and the player will win more often if fives have been exhausted.

In order to win the player must obviously minimize his bets when the aces are exhausted or when other situations favorable to the house obtain and maximize them when conditions favor him. During favorable hands the player must also play by a further set of rules that Thorp has elaborated for different possible combinations of cards. Hands favorable to the player, however, come up only about one time in 10. So he expects only a modest net profit unless he has enough capital to make really large bets on favorable hands.

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IN THE PHYSICAL SCIENCES

is dependent on precise measurement of infinitesimally small voltages and currents, electrical energy such as that involved in the measurement of ions in air.

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BLOOD-VESSEL SURGERY

Techniques developed largely during the past decade make it possible to repair the damage caused by several forms of cardiovascular disease and restore normal circulation

by Michael E. De Bakey and Leonard Engel

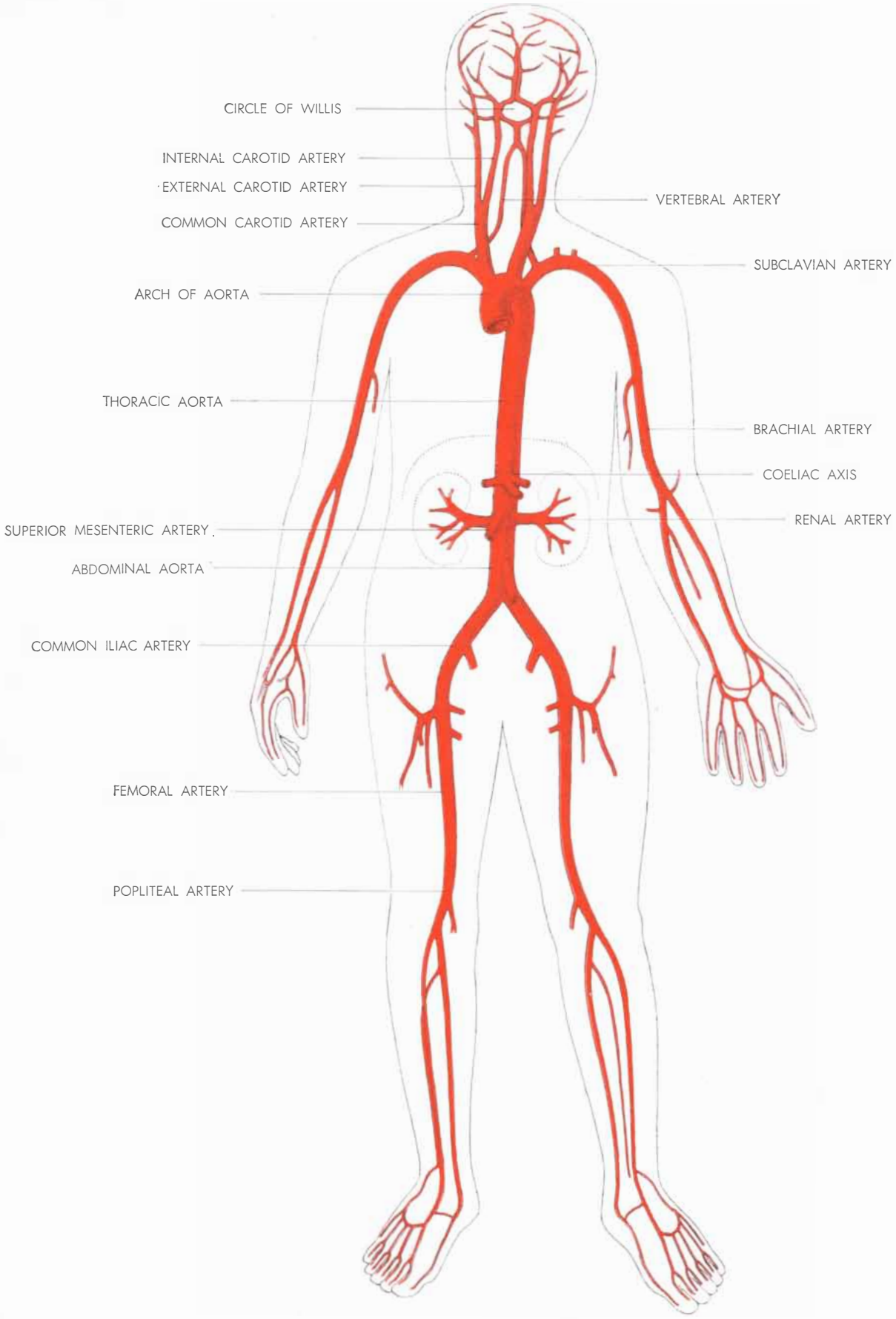
Almost half of the deaths that occur each year in the U. S. result from defects in some part of the piping that carries blood through the body. These days no one can be unaware of the unsolved problems in cardiovascular disease. What is perhaps less widely realized is the extent to which certain of these problems have been solved in the past decade, notably by surgery. Many blood-vessel diseases that were fatal or crippling can now be treated and cured by operation.

What the vascular surgeon does is essentially simple. He eliminates obstructions and stops leaks, providing clear, secure channels to keep blood flowing to vital organs. In practice, of course, the job is not easy. Operating on blood vessels is one of the most exacting surgical procedures, with extremely small margins for error in cutting, stitching and handling tissue and in the choice of the particular method of repair. The task is often complicated by difficulties in reaching and working on vital vessels. Like so many of the developments that have lately transformed medicine, vascular surgery was made possible by a number of collateral advances, including antibiotics, modern techniques of anesthesia and blood banks. The new synthetic fibers have played an important part; tubes made of them are used more often for blood-vessel grafts today than are segments of vessels obtained from human donors.

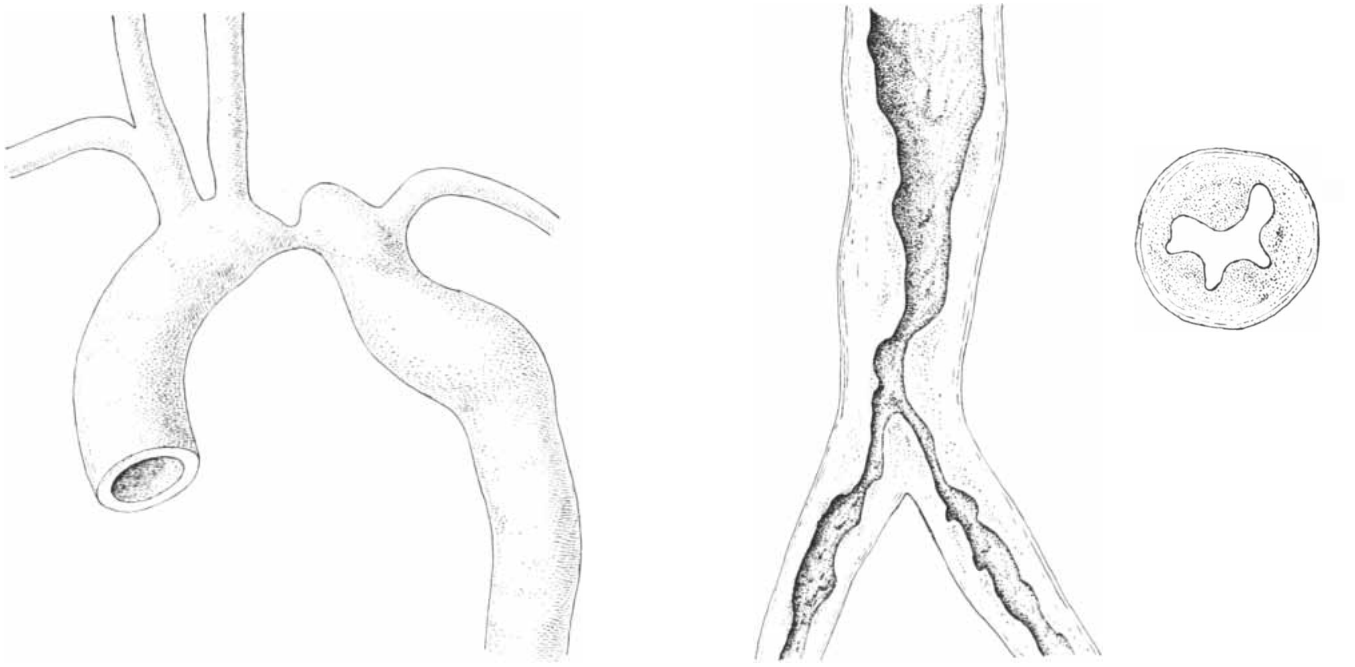
ABDOMINAL ANEURYSM is repaired at Methodist Hospital in Houston, Texas. A weakened portion of patient's aorta that has ballooned out is replaced with knitted plastic tube.

Methods of making blood vessels visible with X rays are essential to practical vascular surgery. The basic procedure—injecting a substance that strongly absorbs X rays into the vessel to be studied and immediately making an X-ray photograph—goes back to the pioneering efforts of Jean Sicard and Jacques Forestier of France and Reynaldo dos Santos of Portugal in the 1920's. Now improved absorbing substances and various other stratagems have made it possible to view major blood vessels in almost every part of the body.

The circulatory system of the average adult contains more than 60,000 miles of vessels, ranging in size from the aorta, as thick as a garden hose, to capillaries so fine that red blood cells must pass through them in single file. Of course, the surgeon does not attempt to work on the smallest tubes; in general he deals only with vessels a quarter of an inch or more in diameter. Furthermore, half of the system—the veins, which return blood from the tissues to the heart—is relatively free of trouble. The surgeon is seldom called upon to construct new venous channels. When he does operate on a vein, it is often to tie it off in order to prevent a clot that has formed in it



SYSTEMIC ARTERIES supply the body with oxygenated blood provided by the pulmonary circulation (not shown). Also omitted from this drawing are the coronary arteries that supply the heart muscle itself. Except for the vertebral arteries and the circle of Willis, the common damage sites indicated are accessible to surgery. Vessels less than a quarter-inch in diameter are rarely operated on.



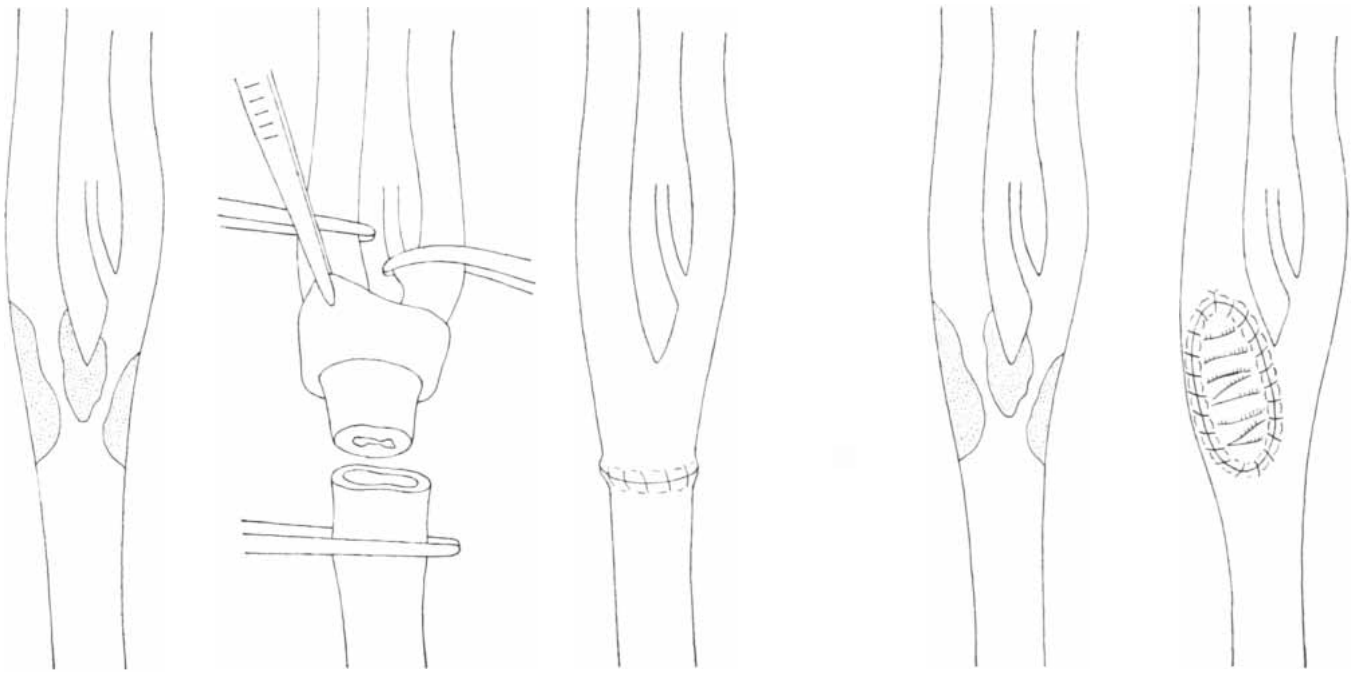
COMMON DEFECTS in blood vessels that the surgeon is called on to repair are almost always located in arteries. At left is shown a coarctation, or congenital narrowing, in the aorta. The next two drawings depict, in longitudinal and cross section, a portion of

from breaking loose and migrating to a vital spot such as the lung.

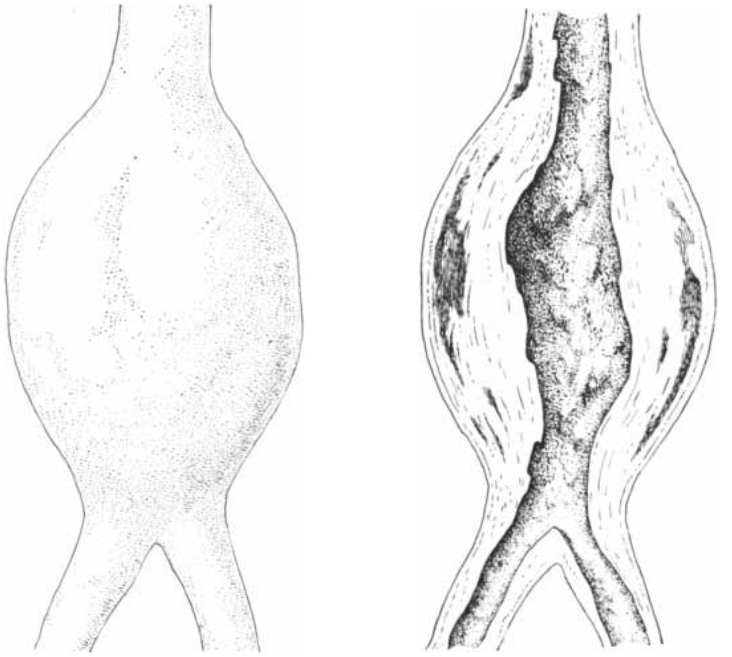
Diseases of Blood Vessels

The principal circulatory difficulties occur in the arteries. Some individuals are born with a local constriction in a vessel; congenital stenosis, as the condition is called, can affect any of the major arteries. More often arteries are blocked as a result of what seems to be almost the characteristic disease of modern Western civilization: atherosclerosis. Fatty material accumulates in the lining of the arteries, and obstructing clots can then grow on the deposits.

A different type of problem is presented by the aneurysm, a balloon-like pouch that develops at a weak point in the wall of an artery. Under the pounding of the bloodstream, the aneurysm becomes progressively larger and its walls thinner and weaker. If untreated, it is likely to burst, causing a fatal hemorrhage. Even if it does not rupture, it can damage neighboring organs and tissues. Aneurysm is caused chiefly by atherosclerosis, which sometimes erodes the tough, elastic inner lining of the artery. The thin outer layer that is left is too weak to withstand the rhythmic thrust of the blood, and it stretches.



FOUR METHODS are used by surgeons to repair damaged blood vessels. The group of drawings at left illustrate endarterectomy. The artery is severed, its outer coating is peeled back, an atherosclerotic deposit is scraped away and the vessel is sewed together.



artery narrowed by atherosclerotic deposits. The pair at right show an aneurysm, the result of a weakened arterial wall, as it appears from the outside and in longitudinal section.

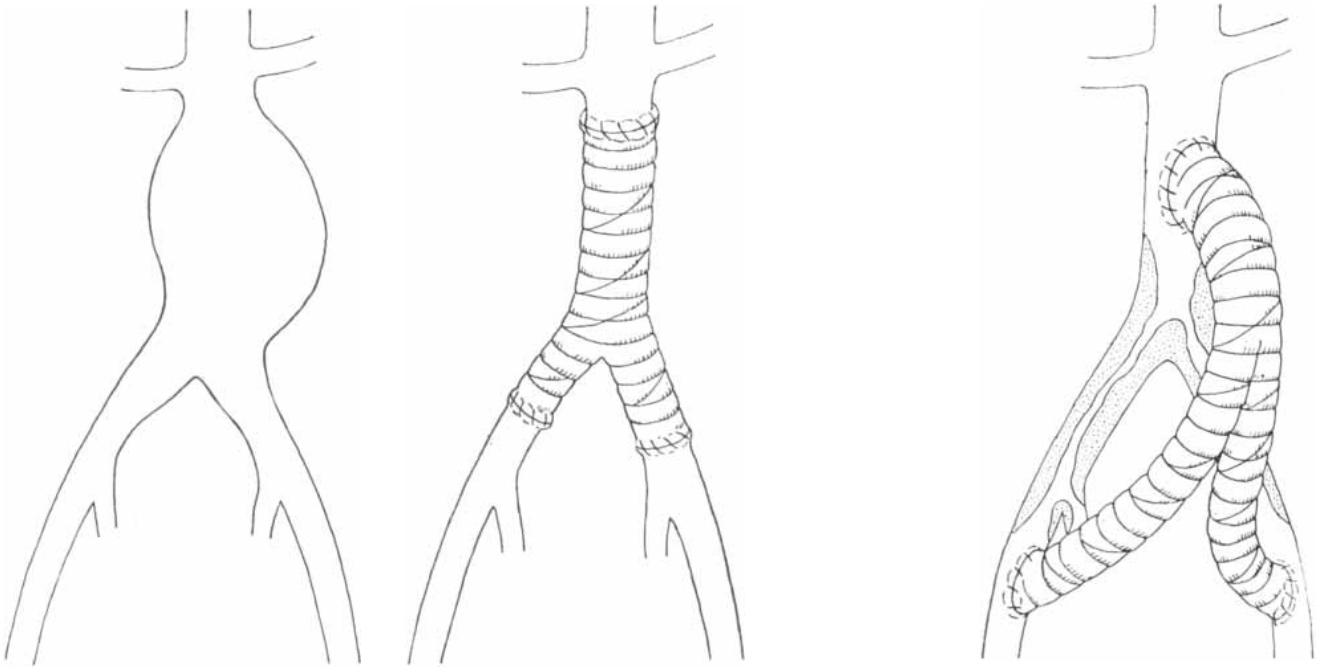
The pulsating sac of blood of an aneurysm is often so conspicuous as to demand attention. It is therefore not surprising that vascular surgery began with attempts to operate for aneurysm. In 1785 the famous British surgeon John Hunter devised the first treatment for aneurysms of the popliteal artery, a large vessel in the leg. He simply tied off the artery above the aneurysm. Hunter's operation was frequently performed, but it was seldom effective because blood tended to leak back into the aneurysm from collateral vessels.

Better methods had to wait until aseptic surgery made it possible for animals to survive experimental operations. In 1902 Rudolph Matas of the Tulane University School of Medicine succeeded in closing the entrance to an aneurysm by sewing it up. Within the next few years other experiments demonstrated that damaged sections of artery could be cut out altogether and the channel restored by grafting in a segment from a donor animal or, if not too much of the artery was removed, by suturing together the cut ends. Such operations were even performed on human patients, but only occasionally and usually only for popliteal aneurysms.

Surgical Techniques

Systematic surgery of arterial obstructions and aneurysms really began in 1944. In that year Robert E. Gross of the Harvard Medical School and Clarence Crafoord and K. G. V. Nylin of the Karolinska Institute in Stockholm operated for coarctation of the aorta. This is a congenital constriction in the large artery that carries oxygenated blood out of the left side of the heart and distributes it to various circulatory loops. Once Gross and Crafoord and Nylin had shown that sections of the aorta could be excised and the ends joined, other surgeons were emboldened to try similar procedures in other sections of the vascular tree.

Over the years technique has advanced, and today's vascular surgeon has at his disposal four ways of repairing arterial defects. The simplest is endarterectomy, the removal of an obstructing clot by opening the vessel and scraping out the clot. Introduced in 1947 by the Portuguese surgeon J. C. dos Santos (the son of the Reynaldo dos Santos mentioned earlier), endarterectomy is



In the next group an opening made in the artery wall for the purpose of an endarterectomy is closed with a patch graft. Graft replacement of a diseased section is shown in group third from left. At right such a section has been shunted with a bypass graft.

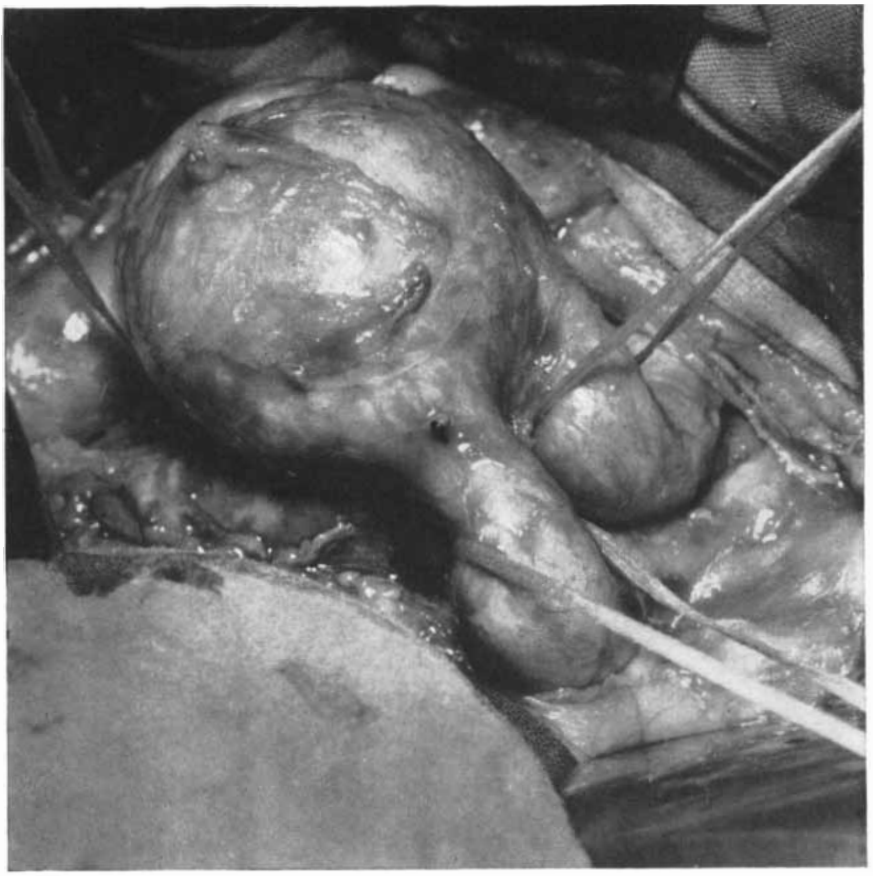
GRAFT REPLACEMENT OPERATION for an abdominal aneurysm is photographed in close-up. After reaching the operating site the surgeon cuts out the diseased section (*top left*). Then he prepares a section of knitted plastic tubing of the proper size to replace the excised vessel (*top right*). After the graft is sewed into place (*bottom left*) peritoneum is closed over it (*bottom right*).

useful when a vessel is blocked by a well-localized plug. The second method is the bypass graft, devised 10 years ago by Jean Kunlin of France: the obstructed section of artery is left in place and bypassed with a natural or synthetic graft. The third procedure, which is the preferred method of treating aneurysms and is widely used in treating obstructions, is graft replacement; here the diseased segment is removed and replaced with a graft. The newest technique is patch, or gore, grafting: widening the bore of an artery by inserting a strip of material in its wall, much as a seamstress lets out a skirt by inserting an extra gore of cloth.

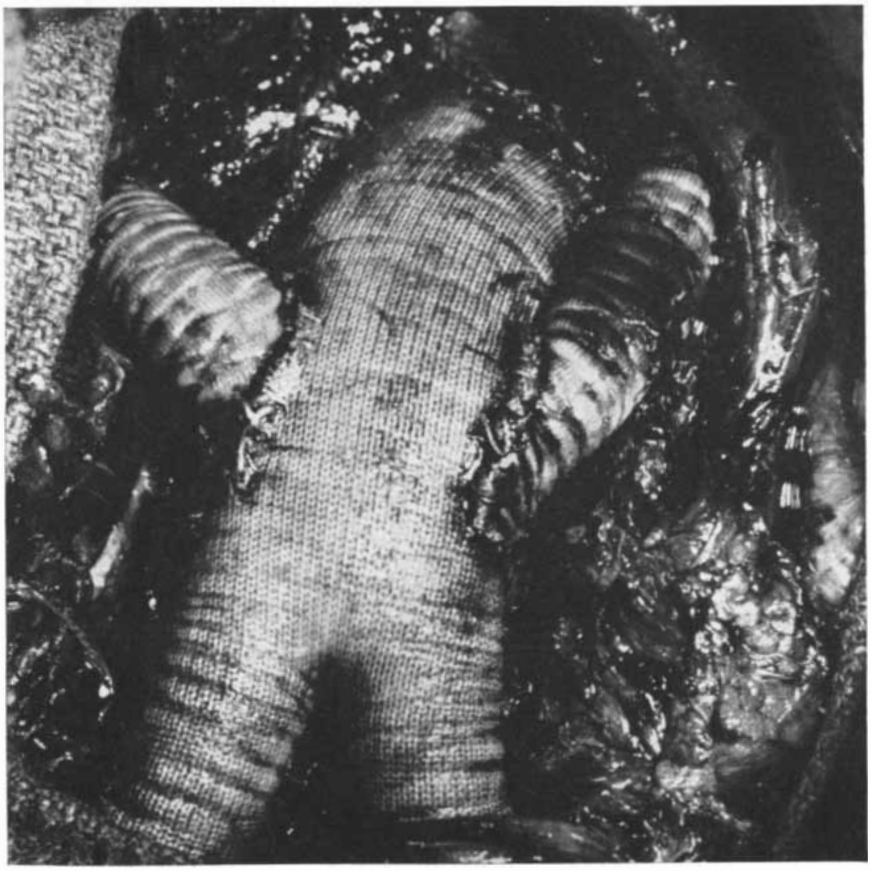
The first blood-vessel grafts were made with segments of artery removed from cadavers. Usually, of course, tissues cannot be transplanted from one individual to another; the host's immunological defenses soon kill the grafted tissue. This is no bar to the utilization of blood-vessel grafts. Unlike other transplanted tissues, they need not be alive to perform their function. They serve merely as a framework on which new tissue is laid down by the host. Human blood vessels, however, are hard to obtain and are not easy to preserve. Moreover, their small branches must be carefully tied off, and even the soundest looking vessel may contain hidden defects that make it no better than the artery it is to replace.

For these reasons investigators early began to look for substitutes. Aluminum and glass tubes lined with paraffin were tried by Alexis Carrel, who in 1912 won a Nobel prize for his contribution to physiology and surgery, including the development of methods of stitching blood vessels. Subsequently surgical experimenters used tubes of gold, silver and other metals, rigid plastic tubes and flexible plastic sponge.

None worked very well. The first vascular prostheses to be at all satisfactory were made of synthetic fibers. Nylon, Vinyon N, Orlon, Teflon and Dacron have been used, in woven, braided and knitted form. Seamless flexible tubes knitted of crimped Dacron have performed best, in the experience of the vascular surgery group at the Baylor University College of Medicine. (The group is headed by the senior author of this article.) They retain their strength in the body for many years, cause little tissue reaction, can be sterilized by autoclaving, can be cut with scissors or scalpel in any direction without fraying, are not damaged by arterial clamps and can be manufactured in a variety of shapes and sizes, with secondary branches to adapt them for use in almost



ANEURYSM of the abdominal aorta is photographed before surgical removal. Such ballooning pouches usually result from atherosclerosis, which erodes the inner wall of the artery.



GRAFT REPLACEMENT of sections of the abdominal aorta (*large tube*), iliac arteries (*lower branches*) and renal arteries (*upper branches*) is shown in place and functioning.

any situation. Compared with tubes of other synthetic materials and with human blood-vessel segments, the Dacron grafts consistently gave the lowest rate of mortality and of failure. Three years ago the blood-vessel bank that had been maintained at Baylor was shut down.

Surgery for Stroke

The consequences of vascular disease, and of corrective surgery, depend not only on the type of blood-vessel damage but also on the region of the body served by the defective vessels. Let us see what the vascular surgeon has been able to accomplish in some of the more important kinds of disease. Consider first the arteries leading to the head. Obstructions in these vessels are a major factor in stroke, and surgical relief of such obstructions is dramatically changing the outlook for many patients with one of the unhappiest of human ailments.

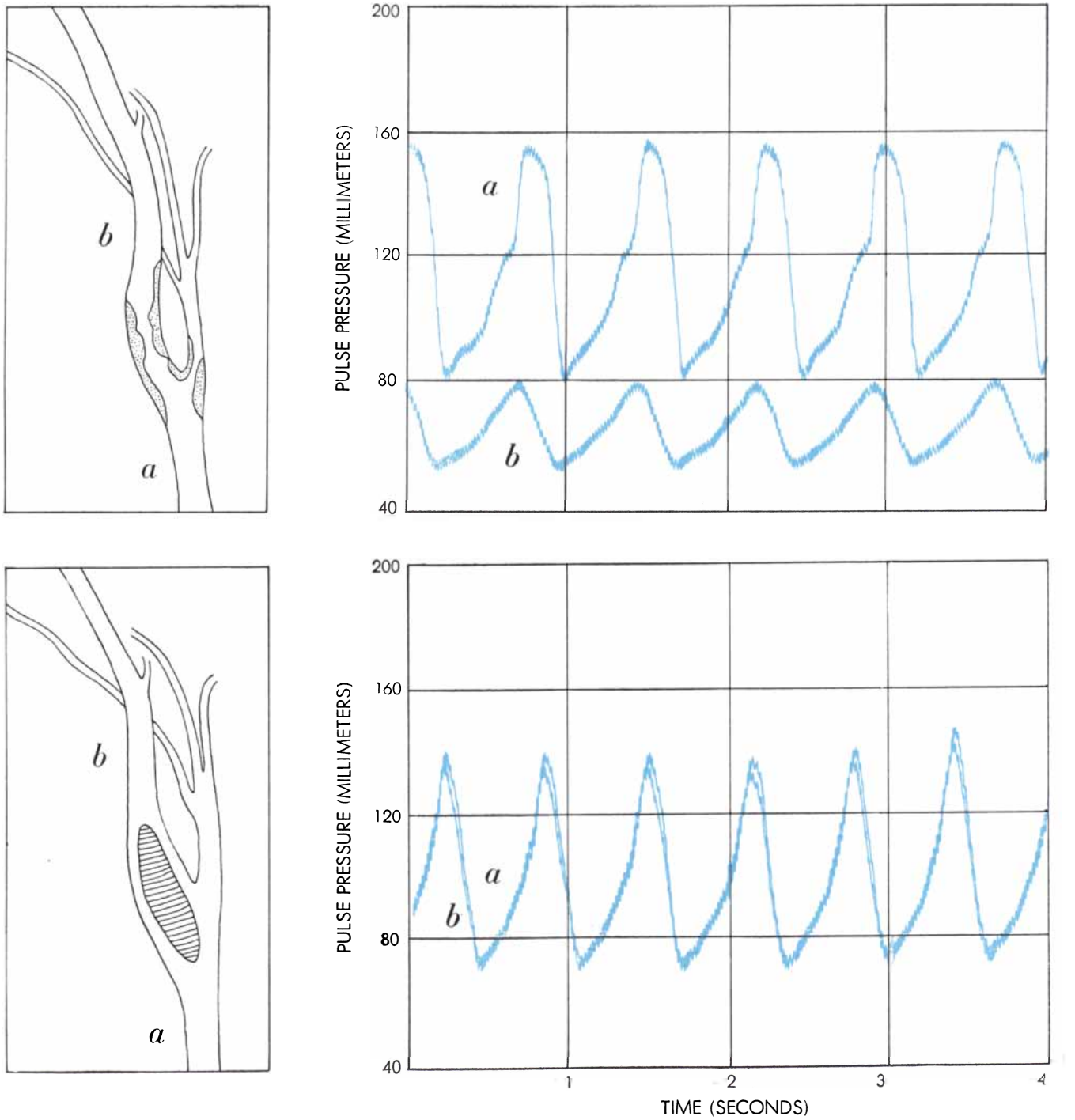
Strokes result either from the hemorrhage of a blood vessel in the brain (usually as a consequence of high blood pressure) or from the formation of a clot that deprives part of the brain of its blood supply. Strokes cause one in every nine deaths in the U. S., and much suffering and disability. Until recently the entire subject was steeped in hopelessness. Surgery could help in a modest number of cases of cerebral hemorrhage resulting from a congenital aneurysm. The common form of stroke seemed beyond effective treatment of any kind.

A key difficulty lay in the speed with

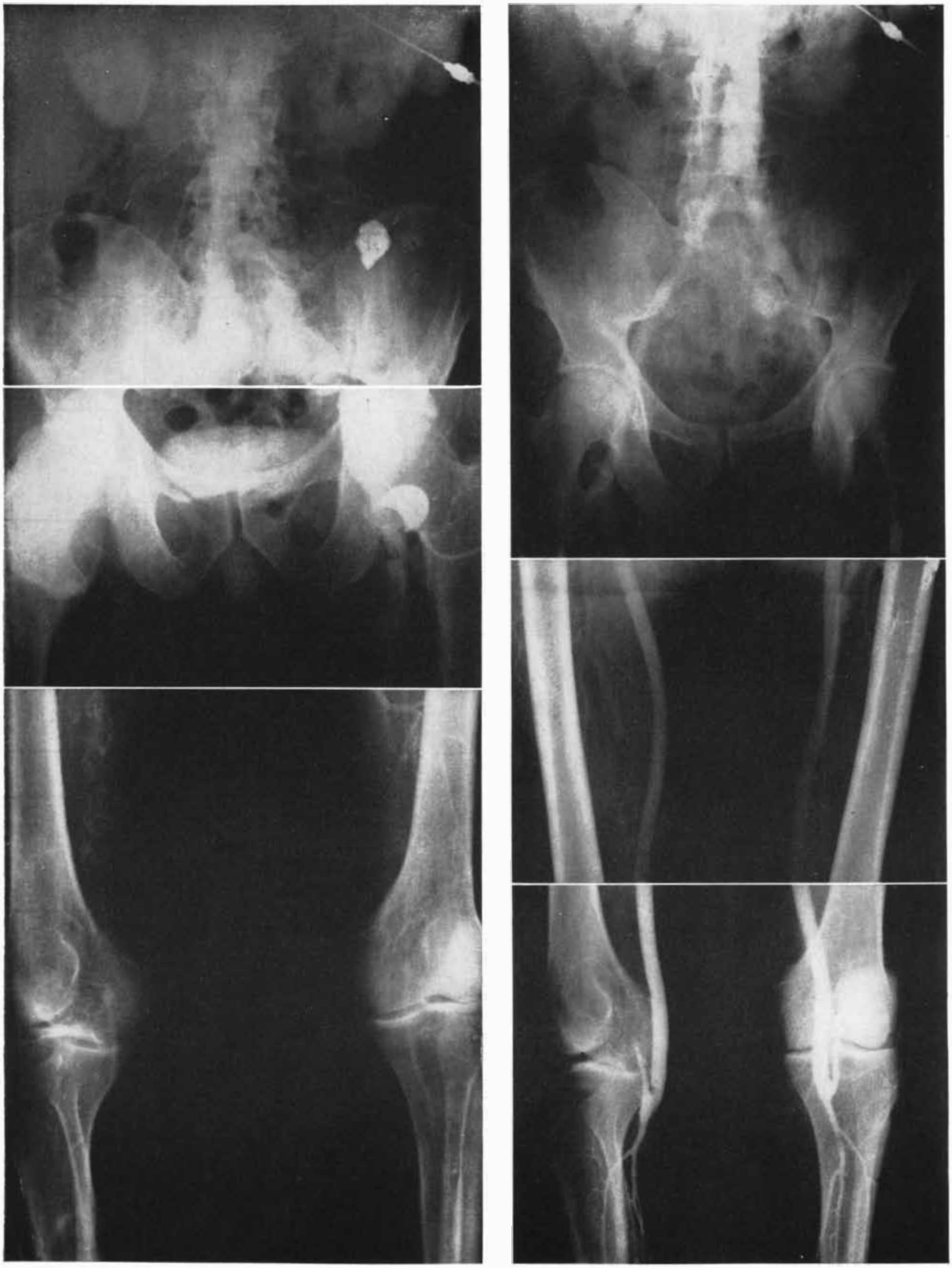
BLOOD-VESSEL X RAYS are one of the recent developments that have made vascular surgery practical. At left is a view of a section of carotid artery partially plugged by atherosclerotic deposits, as in top drawing on opposite page. At right is the same region after

which brain tissue is destroyed by deprivation of blood: a few minutes is enough to produce irreversible damage. A substantial measure of protection is provided, however, by multiple sources of supply. Blood reaches the brain through four vessels (the left and right internal carotid arteries and the left and right vertebral arteries) that originate from three distinct points in the aorta. The four arteries, moreover, join to form a ring at the base of the brain—the circle of Willis—from which the several regions of the brain are supplied by other vessels. Consequently the closure of one of the arteries leading to the brain need not spell instant disaster.

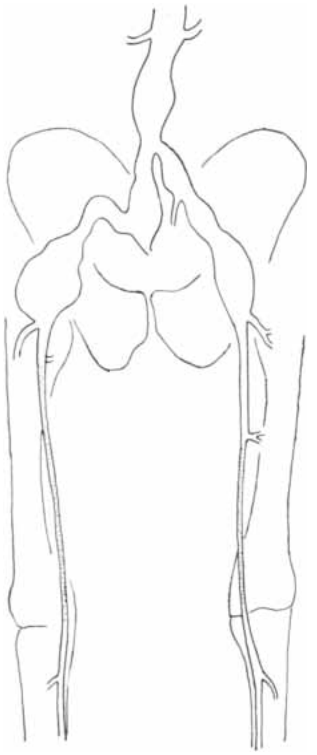
Not long ago several groups of physicians, notably Irving S. Wright and his colleagues at the Cornell University Medical College and C. H. Millikan and his associates at the Mayo Clinic, began prescribing anticlotting drugs to patients who appeared to be in imminent danger of suffering a stroke. The telltale indications were transient loss of sensation or muscular control in the face, temporary disturbances of vision and the like. Wright and Millikan took them not as signs of neurosis (a frequent interpretation) but of an impaired cerebral blood supply. Over a period of several years treated subjects had many fewer strokes than did people with the same symptoms who were not given anticlotting drugs. But the treatment, which acts to prevent the formation of new clots and the extension of existing ones, can only keep the patient's situation from getting

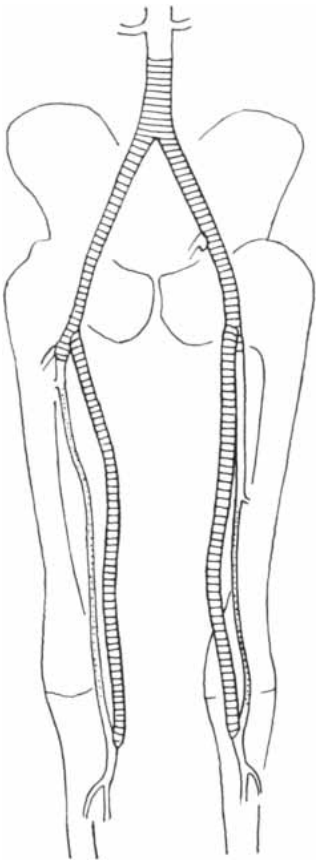


repair by endarterectomy and patch graft (*bottom drawing*). The traces at right on this page record pressure of arterial pulse. At top are pulses in front of the plug (*a*) and beyond it (*b*) before operation. At bottom both of the pulses are traced after the operation.



MULTIPLE LESIONS in the lower aorta and iliac and femoral arteries are seen in preoperative X ray (*left*) and top drawing. Aneurysms in aorta and iliac were repaired with a replacement graft and plugged section of femoral arteries with a bypass graft.





Postoperative X ray (*right*) provides dramatic evidence of restoration of circulation.

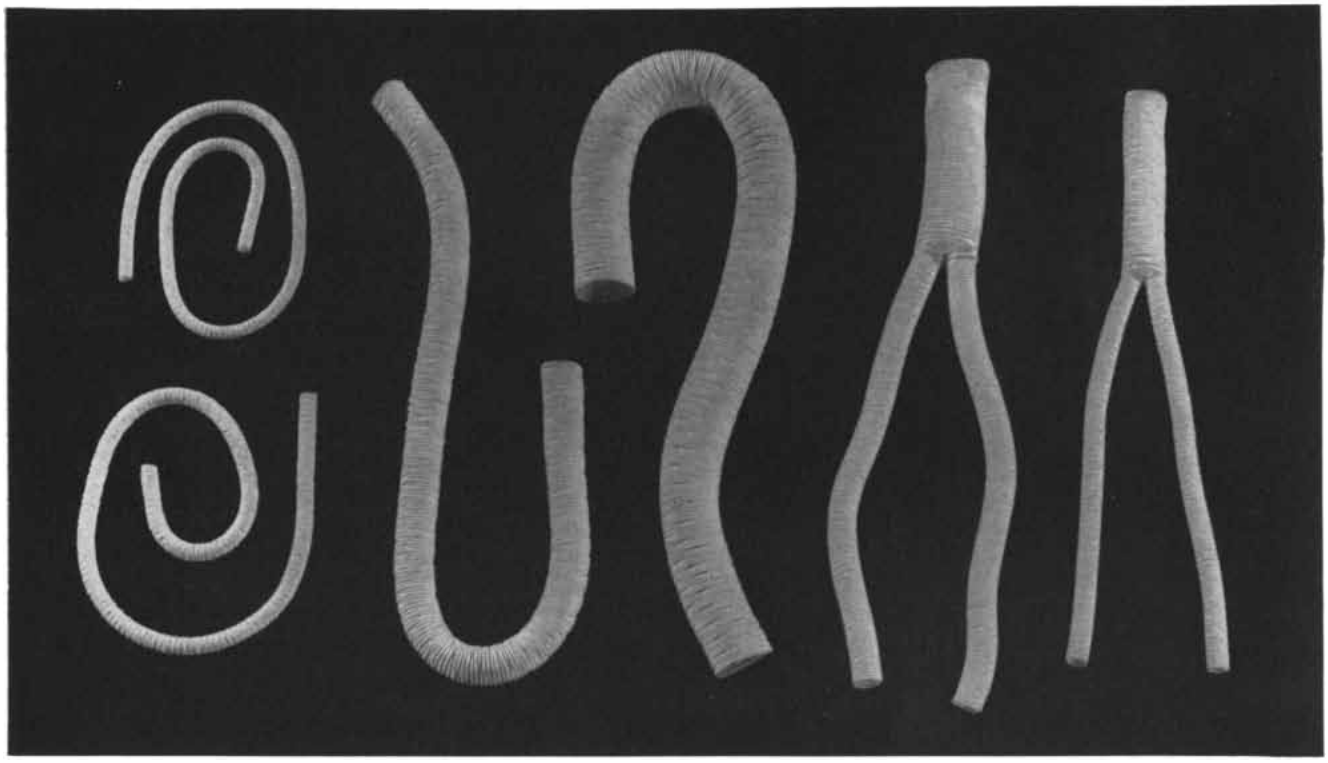
worse. It does not dissolve atherosclerotic plaques or plugs nor does it restore normal circulation.

For the past seven years the Baylor group has been using surgery to correct impairment of cerebral blood flow. Operations have been performed on more than 350 individuals who had recently suffered strokes (or who showed other signs of cerebral arterial insufficiency) resulting from obstructions in one or more of the arteries entering the brain. In more than 90 per cent of the cases flow was successfully restored by means of a bypass graft or a combination of endarterectomy and patch grafting. Neurological function was greatly improved or returned to normal in almost all patients with restored circulation. The exceptions were patients with signs of severe brain damage of at least several days' duration at the time of operation.

For the present such operations are limited to arteries outside the brain. Blood-vessel surgery within the brain is still severely limited by the risk of damage to essential brain tissue from the tying off of bleeding vessels and other standard procedures. But X-ray studies (at Baylor and elsewhere) of some thousands of patients show that more than 40 per cent of strokes involve occlusions in the neck, the head (outside the cranium) or the arch of the aorta, and these are all accessible to vascular surgery. The problem is to recognize the signs of impaired blood flow and get the patient to a vascular surgeon before the major arteries are obliterated and the brain damage is permanent.

No less striking than the reversal of cerebral degeneration has been the cure of a severe form of high blood pressure. The cause (or causes) of most hypertension is still unknown. A considerable number of cases, however, are now found to arise from atherosclerotic plugs in one or both of the arteries that deliver blood to the kidneys. At one time it was thought that a simple reduction of blood supply led to the high blood pressure. Recent experiments suggest a more complex mechanism. The obstruction damps out the normal pulsations in the flow of blood and this in some way triggers the release of angiotensin, a powerful pressure-raising substance. At any rate, where hypertension of this kind was formerly treated by removing the affected kidney, the surgeon now reestablishes normal pulsatile blood flow to the kidney by repairing the renal artery or providing a new one.

One of the most common sites of vas-



BLOOD-VESSEL GRAFTS, formerly taken from cadavers, are now more commonly made of synthetic materials. The vascular surgery group at Baylor University College of Medicine has had the most success with the type shown here: seamless, flexible tubes knitted of Dacron, with diameters ranging from a quarter-inch to an inch. They cause little tissue reaction and retain their strength for years.

cular disease is the leg, which receives its blood supply through the femoral and popliteal arteries [*see illustration on page 89*]. Vascular surgeons are now frequently called on to deal with popliteal aneurysms and with femoral and popliteal occlusions. As experience has accumulated in the past few years, it has been found that surgery can often cure so-called "Buerger's disease." This is an impairment of circulation long attributed to chronic destructive inflammation of the small vessels of the leg and foot. The condition can occur in people still in their 20's and 30's and, when severe enough, requires amputation of the affected part. A number of young patients who have come to the Baylor group as supposed victims of Buerger's disease have proved on X-ray examination to be suffering instead from well-localized, easily treated atherosclerotic plugs in either the femoral or the popliteal artery. In fact, current studies suggest that Buerger's disease as originally conceived may not exist at all, and that this ailment, which has claimed so many legs over the years, is usually an operable form of arteriosclerosis.

Surgery in the Aorta

The greatest challenge to vascular surgery is disease of the aorta. Aneurysms and clots are found with equal frequency in this trunk-line vessel from the heart, sometimes affecting a restricted section, sometimes the entire length. Both are serious hazards to life and both confront the surgeon with formidable problems.

One problem arises from the necessity of maintaining circulation to vital organs while the aorta is under repair. In an operation on a leg artery circulation is simply shut off with clamps until the surgery is completed. The flow of blood to the leg can be stopped for as long as an hour and a half without harm. The flow normally carried by the thoracic aorta can be interrupted for only a minute or two. Vascular surgeons have investigated many arrangements for maintaining circulation, ranging from the heart-lung machine to temporary shunts around the operative site. In certain cases the surgeon lowers the patient's body temperature to extend the time during which vital vessels can be clamped. While all these measures have their place, the one used most often by the Baylor group is a temporary shunt directly from the left side of the heart to a part of the aorta past the area of surgery, or to other suitable vessels. As soon as the chest has been opened, a flexible plastic tube is inserted into the left auricle—an intrusion the heart withstands well. The tube not only maintains the flow of oxygenated blood that enters this chamber from the lungs but also prevents an undesirable rise in pressure in the heart when the aorta is clamped off. A simple roller pump connected to the shunt pipe helps propel the diverted blood back into the circulation.

Most patients in need of an operation on the aorta are in their 40's or older, and many have additional ailments that make them poor surgical risks. Thus it is hardly surprising that success in this field has come only recently. Operations for aneurysm of the aortic arch—the region nearest the heart—still have a mortality rate of nearly 50 per cent and are justified only by the 100 per cent mortality of aneurysms in this region. However, when the aneurysm is in the descending thoracic aorta, the next section of the great vessel, the surgical mortality rate drops to 15 per cent (in the experience of the Baylor group). And for aneurysms of lower parts the risk is further decreased. In the last several hundred operations for aneurysm of the abdominal aorta at Baylor, including emergency operations for ruptured aneurysms, the mortality has been 3 per cent. Operations for occlusion of the abdominal aorta have had a death rate of only 2 per cent.

The techniques of vascular surgery

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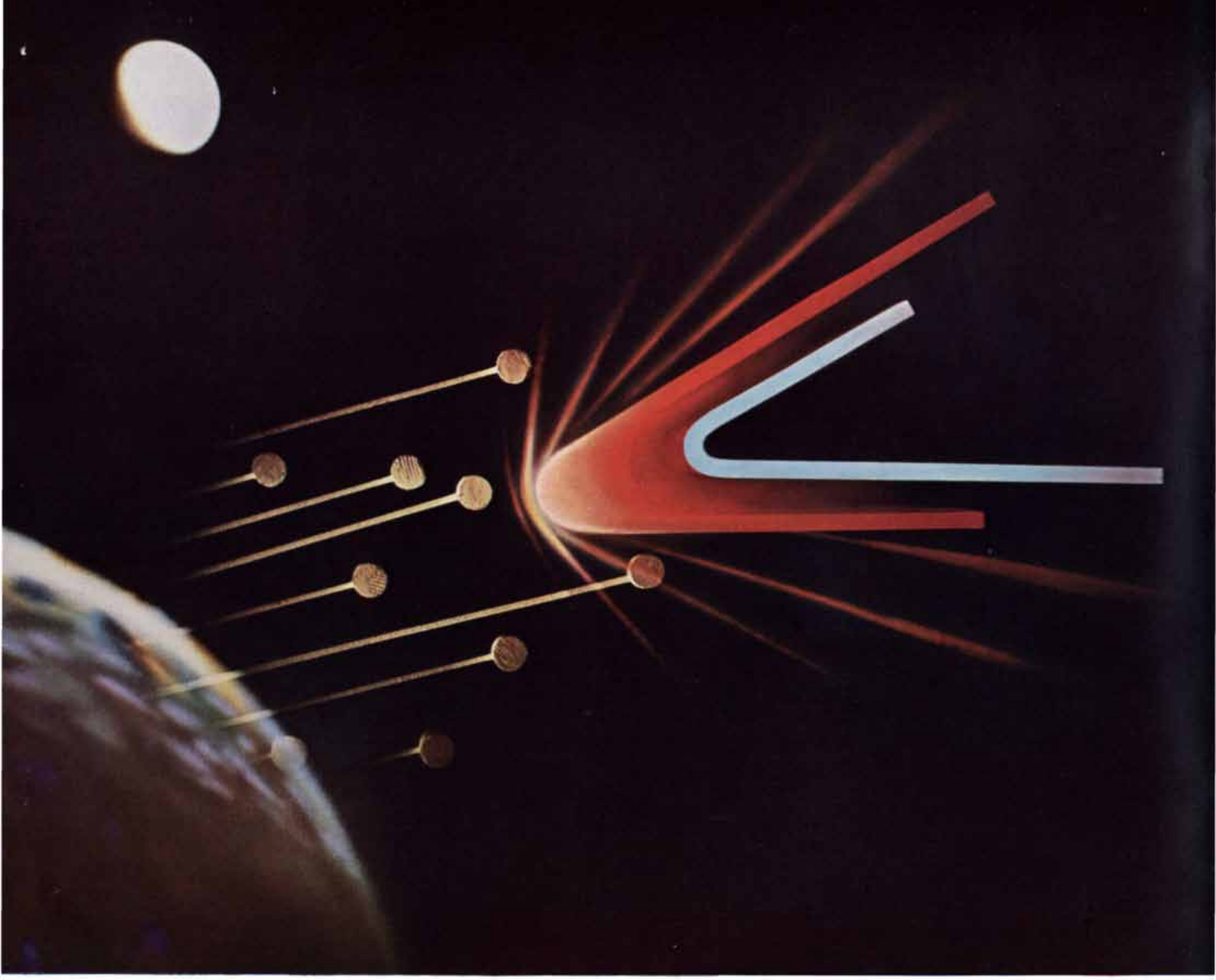

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are now being applied to treat not only diseased vessels but also injured ones. Blood-vessel injuries can be accidental or can occur in the surgical removal of an extensive cancer. Without the means for repairing vascular damage this lifesaving procedure could not be carried out. An exciting prospect is the transplantation of organs; here too the skills of the vascular surgeon are required to establish good connection between the organ and the circulation of the patient in whom it is grafted. Of course, if such operations are to be done routinely, the problem of the host's immunological response to the graft must first be solved.

Finally, we should mention the ingenious experiments of Oscar Creech, Jr., and his associates at the Tulane University School of Medicine. They have hit upon the idea of isolating the circulation of a part of the body in which there is localized disease. By connecting the major vessels serving the region to a heart-lung machine, they provide the region with an independent supply of oxygenated blood, to which can be added drugs in concentration far higher than would be tolerated by the patient's whole body. When the treatment is completed, the drug is flushed out and normal circulation is restored.

So far the scheme has been tried only in highly malignant cancer (with remarkable palliation in some cases, but with no cures, because of the limited effectiveness of present anticancer drugs) and in deep-seated chronic infections (with promising results). Any number of additional possibilities come immediately to mind: for example, clot-dissolving agents could be circulated through obstructed vessels, and powerful drugs could be used to treat diseases that affect a single organ. Perfusion treatment seems almost certain to be a powerful addition to medical technique.

When blood-vessel surgery first emerged as a practical operating-room procedure, some physicians questioned its usefulness. Vascular disease, they argued, is progressive and widespread throughout the body; difficulties are bound to recur soon after operation, if indeed the operation helps at all. There are forms of blood-vessel disease in which this is true. In many others, however, a large body of experience has now demonstrated that damage is mostly confined to limited segments of the vascular tree, and that surgery can restore essentially normal circulation to the great majority of patients.

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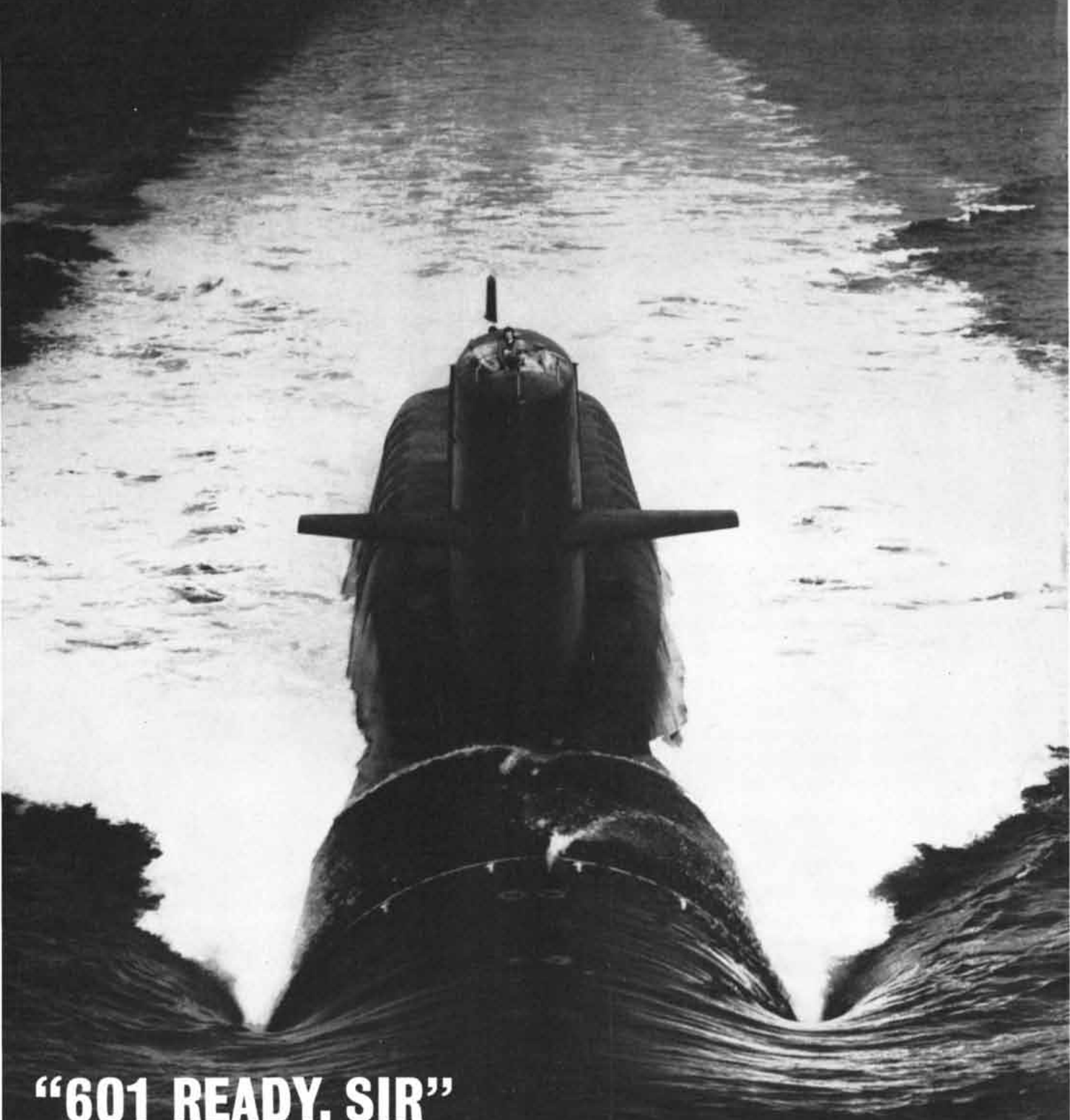

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The Cromwell Current

This thin ribbon of water flows east along the Equator just beneath the surface of the Pacific. Discovered only recently, it ranks as one of the greatest ocean currents

by John A. Knauss

In September, 1951, a research vessel of the U. S. Fish and Wildlife Service on a fishing expedition in the central Pacific encountered a surprising phenomenon: as the ship drifted westward with the South Equatorial Current, gear at the end of long fishing lines, some 50 meters down, was pulled rapidly to the east. The vessel had happened upon an uncharted subsurface current—one that has turned out to be the second largest in the Pacific Ocean.

Investigations during the past 10 years have established the Pacific Equatorial Undercurrent, or Cromwell Current (after the late Townsend Cromwell, the first oceanographer to study it), as a most unusual phenomenon. It is long and fast and remarkably thin—about 1,500 times as wide as it is deep. Running eastward just below the surface,

HORIZON, one of two ships on the Dolphin Expedition to study the Cromwell Current, is a 143-foot converted Navy tug operated by the Scripps Institution of Oceanography of the University of California. The tall frames handle the oceanographic equipment.

it is sharply bounded by the generally westward-moving currents around it. Present theory does not explain these characteristics, or indeed why such a current should exist at all.

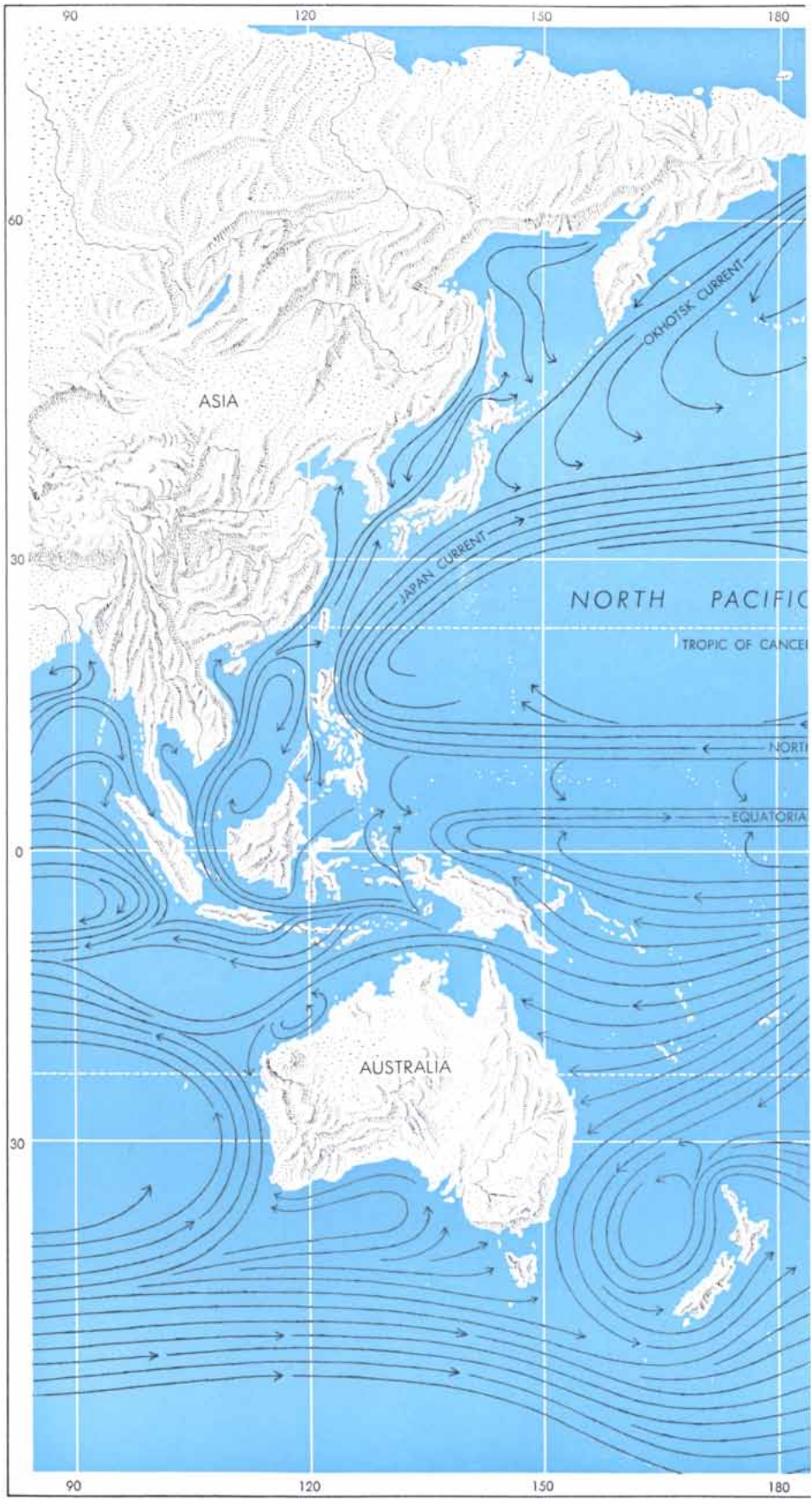
Since it does exist, how did it remain so long undiscovered? Every other major current in the central Pacific had already been charted 100 years ago. All of them, however, are surface currents, which were detected and measured by ship-drift observations. A submerged flow cannot, of course, be found by this method.

Most of what we know about velocities of currents beneath the surface has been learned by calculation. In the open ocean, away from shoals or land masses, the water at any level moves in response to two forces: horizontal pressure and the so-called Coriolis force. Horizontal pressure differences arise from variation in the height of the sea surface, and of the layers underneath, because of changes in the density of the water from place to place. The density in turn depends on temperature and salinity (as well as depth). As temperature and salinity measurements have accumulated over the past few decades they have disclosed a number of instances of large horizontal pressure differences in subsurface layers from which oceanographers could predict the existence of currents.

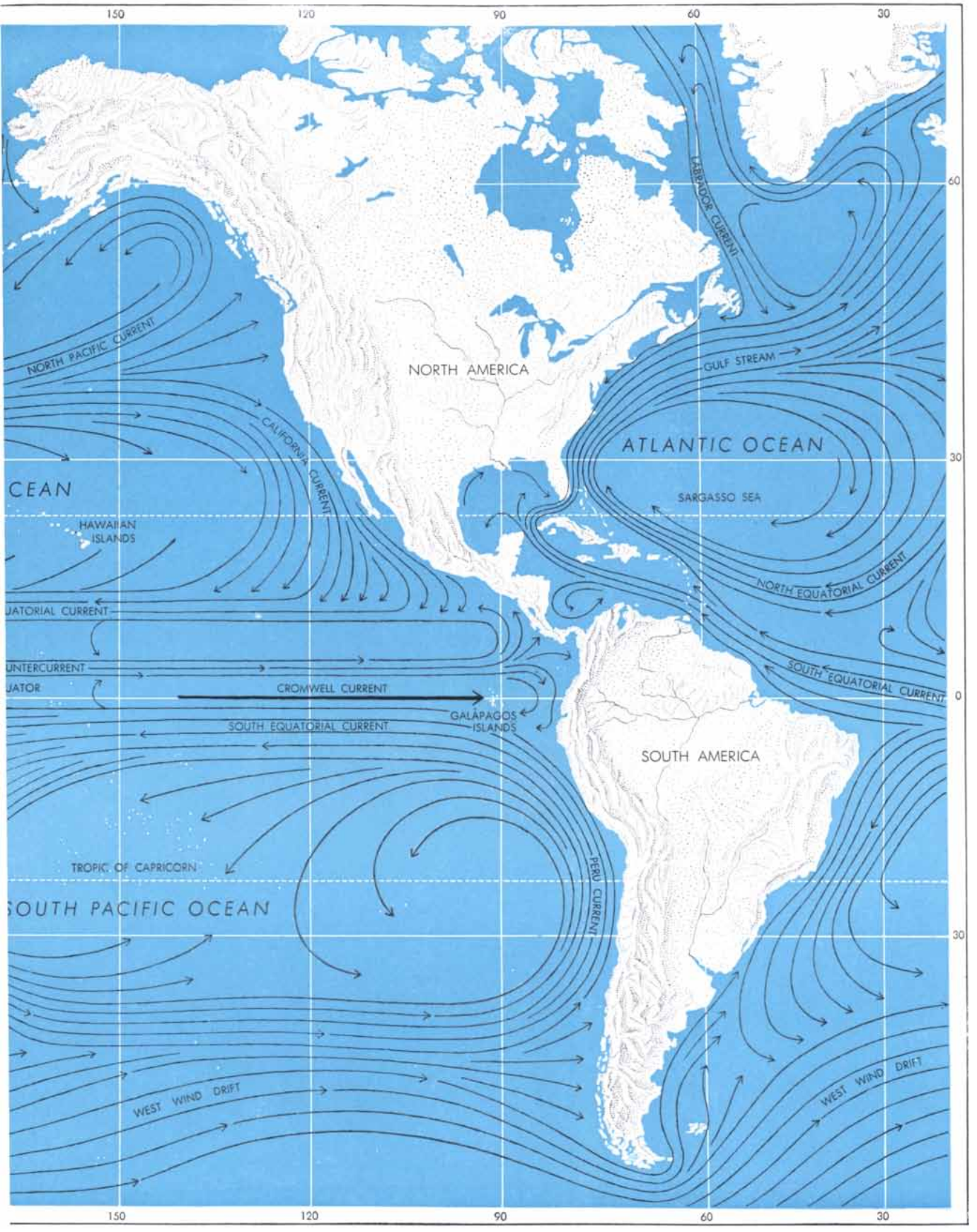
Because of the rotation of the earth, water currents do not flow directly between points of higher and lower pressure. They are deflected with respect to the spinning ocean floor beneath—to the right in the Northern Hemisphere, to the left in the Southern—by the Coriolis force [see "The Coriolis Effect," by James E. McDonald; SCIENTIFIC AMERICAN, May, 1952]. The spin and the force are maximum at the poles and decrease with latitude.

In calculating the actual motion of a mass of water, the two forces are combined in the "geostrophic equation" (from the Greek *geo*, earth, and *strophe*, turning). The horizontal pressure gradient is determined from observations of temperature and salinity; the Coriolis force, from the latitude.

At the Equator, however, the earth's surface does not twist, and the Coriolis force is zero. (An observer suspended above the Equator would see the ground below him moving in a straight line, not turning like a merry-go-round.) Hence the geostrophic equation no longer applies. With the dropping out of the Coriolis force, weaker effects come into



MAJOR CURRENTS in the Pacific and western Atlantic are shown on this map. The currents are influenced by prevailing winds, rotation of the earth, differences in water



density and the shape of the ocean basin. The Cromwell Current has been located by observations along the line shown on the map, but there is evidence that it extends as far as 160 degrees East. It may in fact extend all the way across the Pacific, or 8,000 miles.

play. These are not yet understood, and water movement at the Equator cannot be calculated accurately.

So the first hint of something unexpected did not come until 1951, and then it came by accident. During the months after the initial discovery, other fishing vessels in the area reported the same peculiar eastward drift. In the summer of 1952 the Fish and Wildlife Service dispatched an expedition under Cromwell, Raymond Montgomery and Richard Stroup to investigate the currents in the vicinity of the Equator.

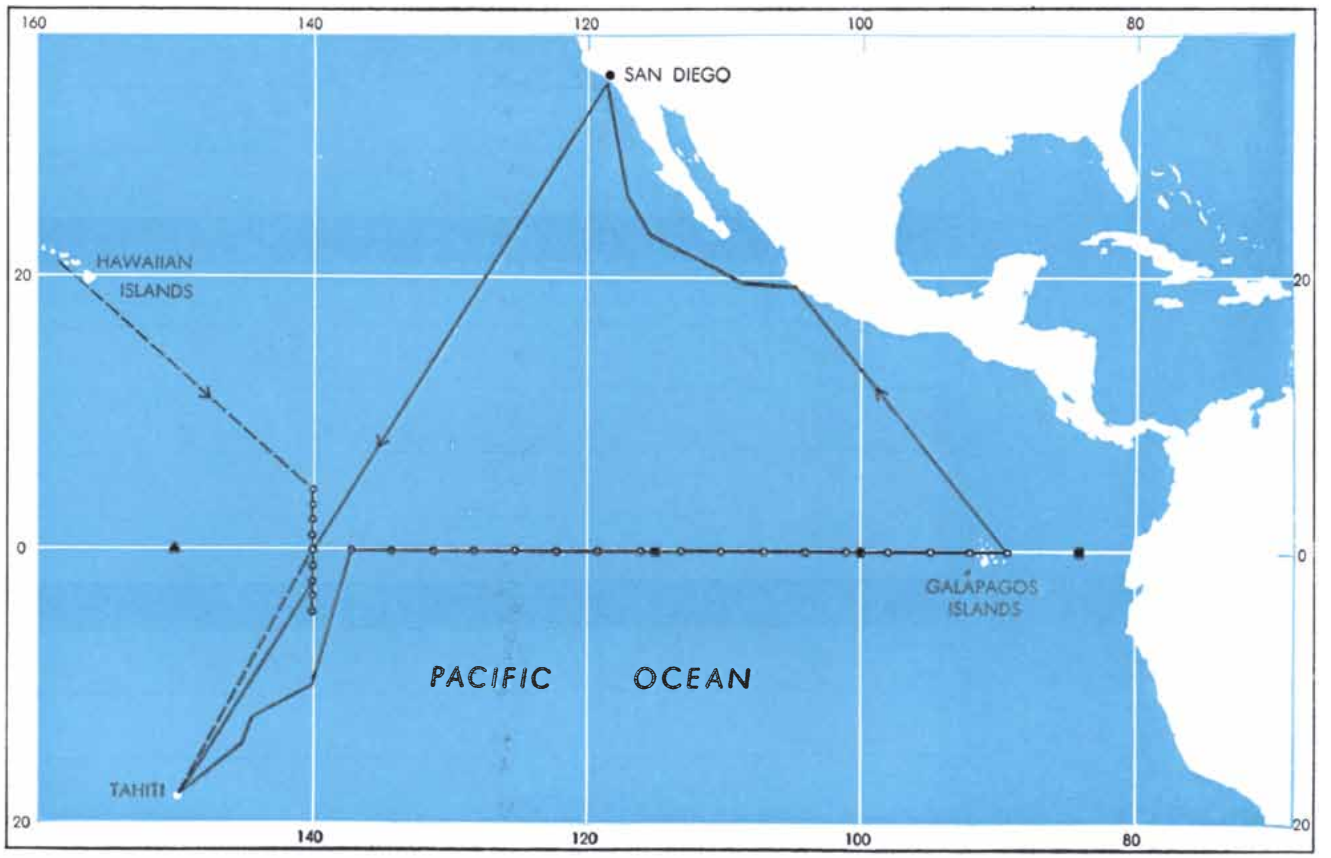
Observations were made by following two markers: one attached to a net buoyed to float at the surface, the other fastened to a sea anchor weighted to remain submerged. Ten days of measurements in the vicinity of 150 degrees West longitude (approximately south of Hawaii) demonstrated beyond doubt a marked reversal of current at a depth of 50 to 100 meters. Below this level the water flowed to the east at a speed of more than a knot. The undersea current showed up at the Equator, but not at two degrees North, some 125 miles away. In 1955 Cromwell and the author carried out the same type of measurement at 115 and 105 degrees West (south of Lower California and Mexico) with similar results, proving that the reversal was not an isolated phenomenon.

As part of the International Geophysical Year it was decided to devote an entire cruise to the study of the strange equatorial current. The Dolphin Expedition set out in the spring of 1958 with two ships: the *Hugh M. Smith* of the Fish and Wildlife Service, with Joseph King and Murice Rinkel in charge; and the *Horizon* of the Scripps Institution of Oceanography, under the author. The two ships worked across the current for a month along 140 degrees West; the *Horizon* spent another month tracing the current eastward along the Equator to the Galápagos Islands.

Accurate measurement of currents in the open ocean depends on establishing a satisfactory system of reference. Current meters show the speed and direction of flow with respect to a ship to which they are attached. But the ship itself is moving in an unknown way, under the influence of wind, wave and surface current. Even when the ship is swinging at anchor, it often moves at a speed comparable to that of the current to be measured.

On the Dolphin cruise we used a taut-wire buoy as a reference point [*see illustration on page 112*]. The key to the stability of this device is a buoyant sphere anchored well below the surface. It holds the long, heavy anchoring wire nearly vertical; a light surface marker fastened to the float by a thin line exerts little horizontal drag on it. We found that the circle of movement of the surface marker could be kept to a few hundred meters.

The flow of water with respect to our ships was measured with a propeller-type meter incorporating a magnetic compass to determine direction and a pressure gauge to indicate depth. The readings of all the instruments were transmitted to shipboard electrically



ROUTE OF DOLPHIN EXPEDITION and the location of earlier observations of the Cromwell Current are mapped. The ships taking part in Dolphin first worked together at 140 degrees West to determine the cross section of the current. *Horizon* went on alone to track the current eastward.

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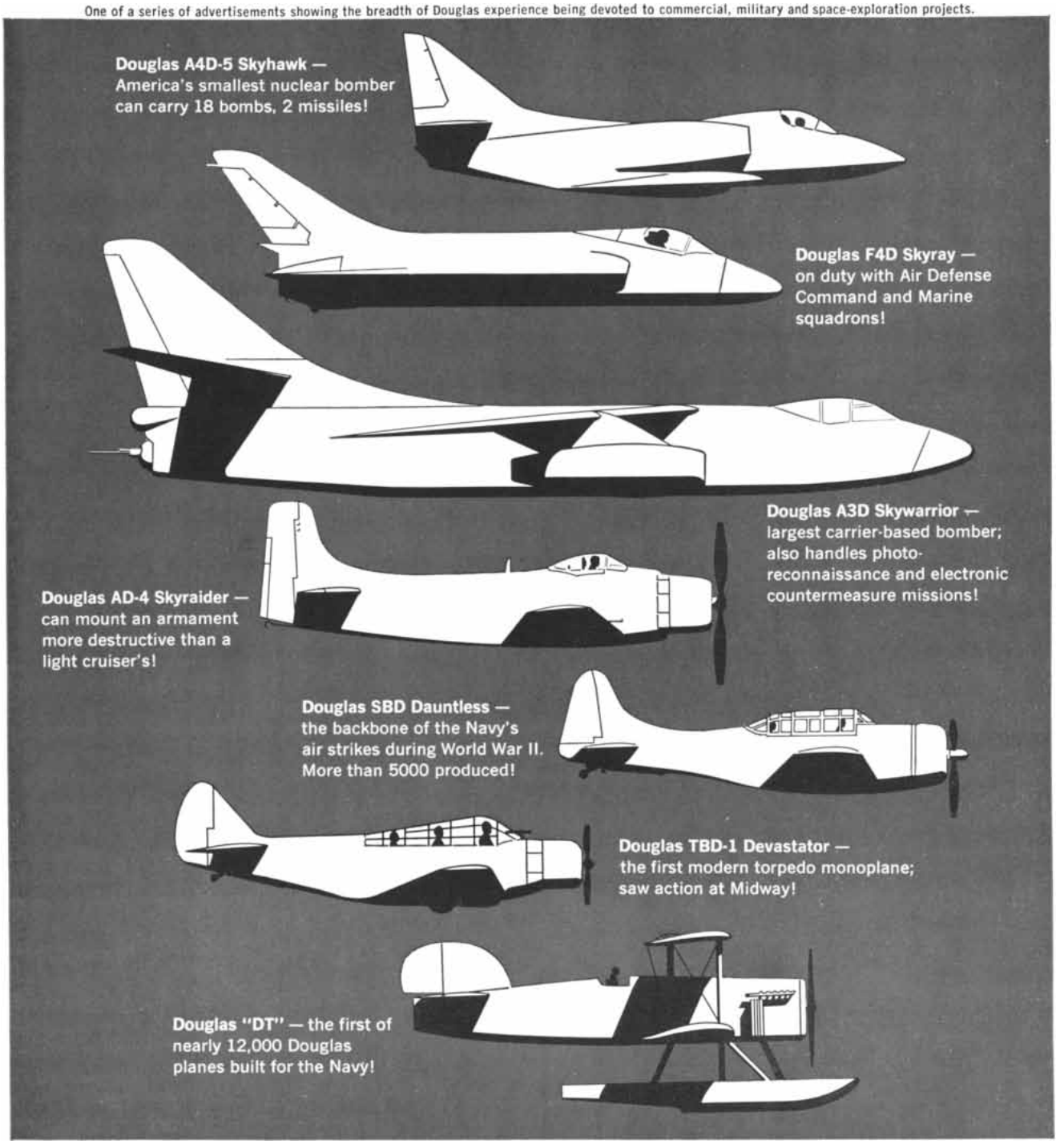

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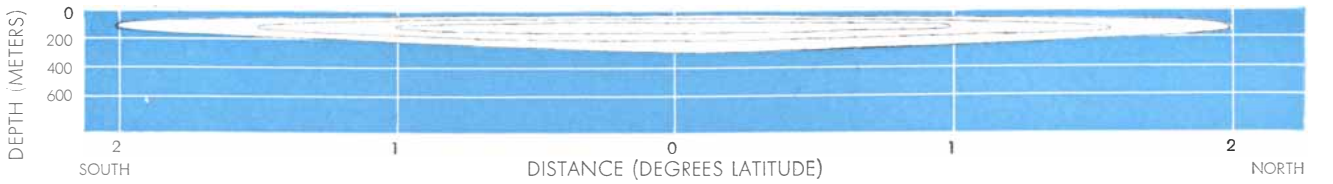


EXTREME THINNESS of the current is apparent even in this cross section, in which the vertical scale is exaggerated 50 times. Center contour line bounds area in which current moves at least 120 centimeters per second. Next contour is at 60 centimeters per second.

over the wire that held them. As the data were recorded, the drift of the ship with respect to the taut-wire buoy was simultaneously measured by radar. By combining the two velocities—of the current with respect to the ship and of the ship with respect to the buoy—we obtained an absolute value for the speed and direction of the current.

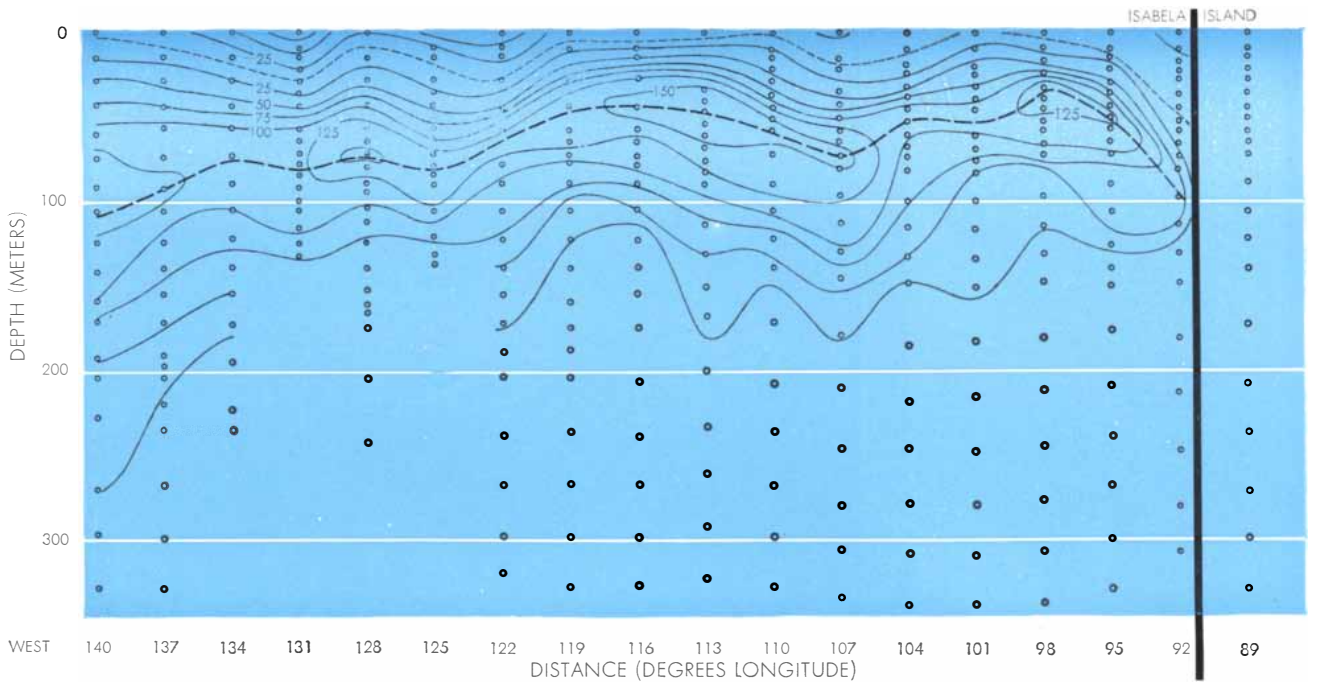
The method is far from perfect. Our measurements appeared to have an accuracy of no more than three-tenths of a knot. Although not very satisfactory for studying slow, vaguely defined currents, the method was adequate for dealing with a high-velocity, sharply bounded flow. At the weak lower fringe of the current the current meter was supplemented by a Swallow float. This is an aluminum tube, weighted to float at a specified depth, carrying a sonar transmitter that can be tracked from the ship by hydrophones.

As has already been mentioned, our observations showed that the Cromwell Current is very shallow. At 140 degrees West its upper limit lies about 20 meters below the surface and its core is 100 meters deep. There the water flows at speeds of two and a half to three knots (125 to 150 centimeters per second)—faster than any other major current in the equatorial Pacific. At a depth of 350 meters the speed has dropped to about a fifth of a knot, and by 500 meters the flow is reversed, running to the west again at a tenth of a knot or so. The variation of velocity with depth, particularly in the upper part of the current, is very sharp: changes of three knots in 150 meters are found regularly.

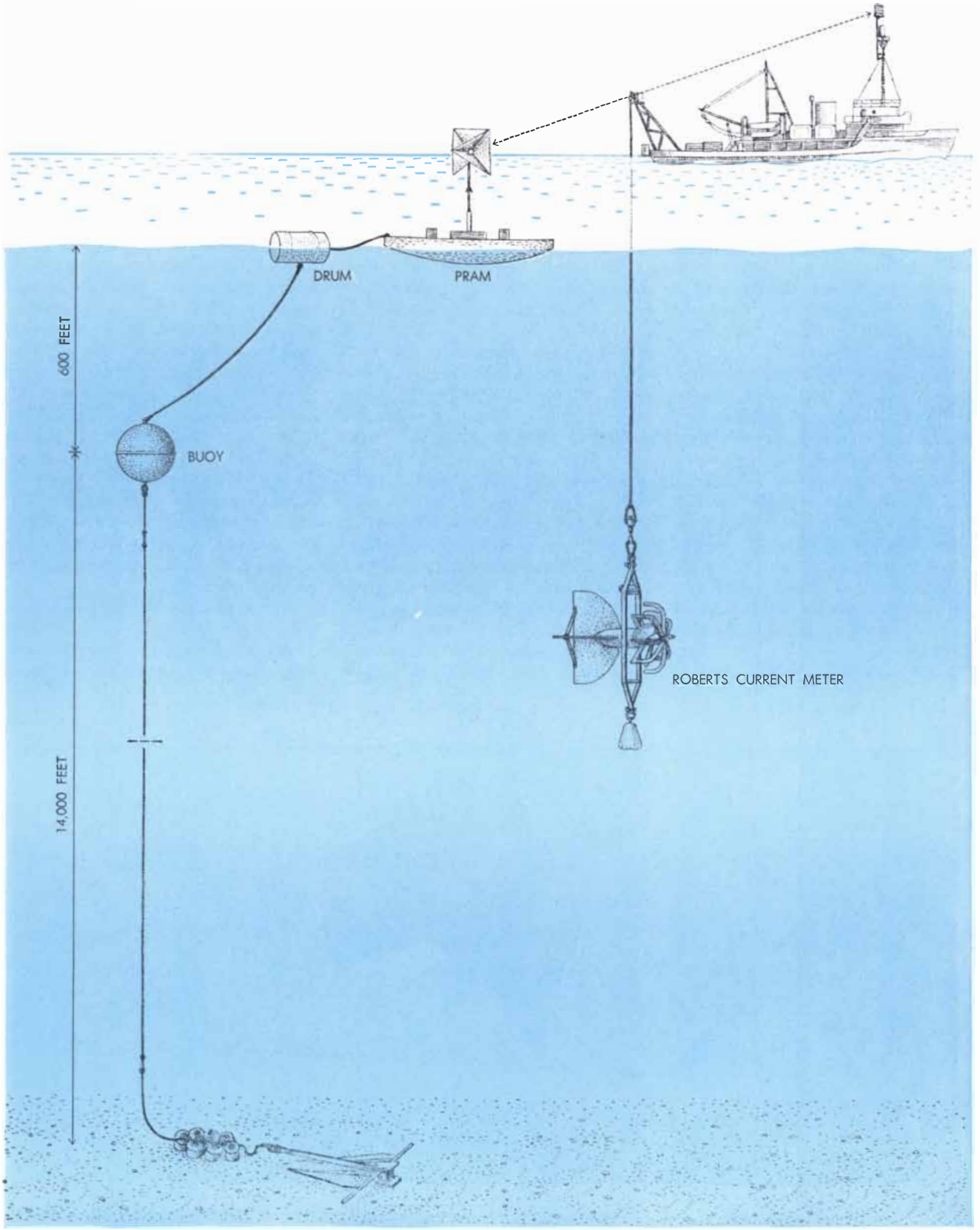
A scale model of the Cromwell Current five inches wide would be no thicker than the paper cover of this magazine. Yet this shallow ribbon carries an enormous amount of water—more than 40 million cubic meters, or 40 million tons, per second. This makes it the largest current in the region and, in the Pacific as a whole, second only to the Japan Current, or Kuroshio (analogous to the Gulf Stream in the Atlantic). The Japan Current carries about 65 million cubic meters per second; the Gulf Stream about 75 million.

Perhaps the most striking feature of the Cromwell Current is its symmetry about the Equator. The current is very weak or missing at two degrees North and at two degrees South. Whereas most of the major wind and current systems of the earth shift their positions somewhat with the seasons, the Cromwell never seems to leave the Equator. The only comparable phenomenon is the Berson westerlies, a wind system at a height of some 20,000 feet that also appears to be tied to the Equator.

The current is remarkably steady in other ways. It appears to vary little in speed or depth, and only gradually with change in longitude. In two weeks



SIDE VIEW OF CURRENT along the Equator shows how the velocity profile varies with longitude. Each dot is a point where the current was measured, and contours outline areas of equal velocity surrounding the high-speed core (*indicated by heavy broken line*). The negative 25-centimeter-per-second contour at the top shows westbound current. Vertical exaggeration is 7,500.



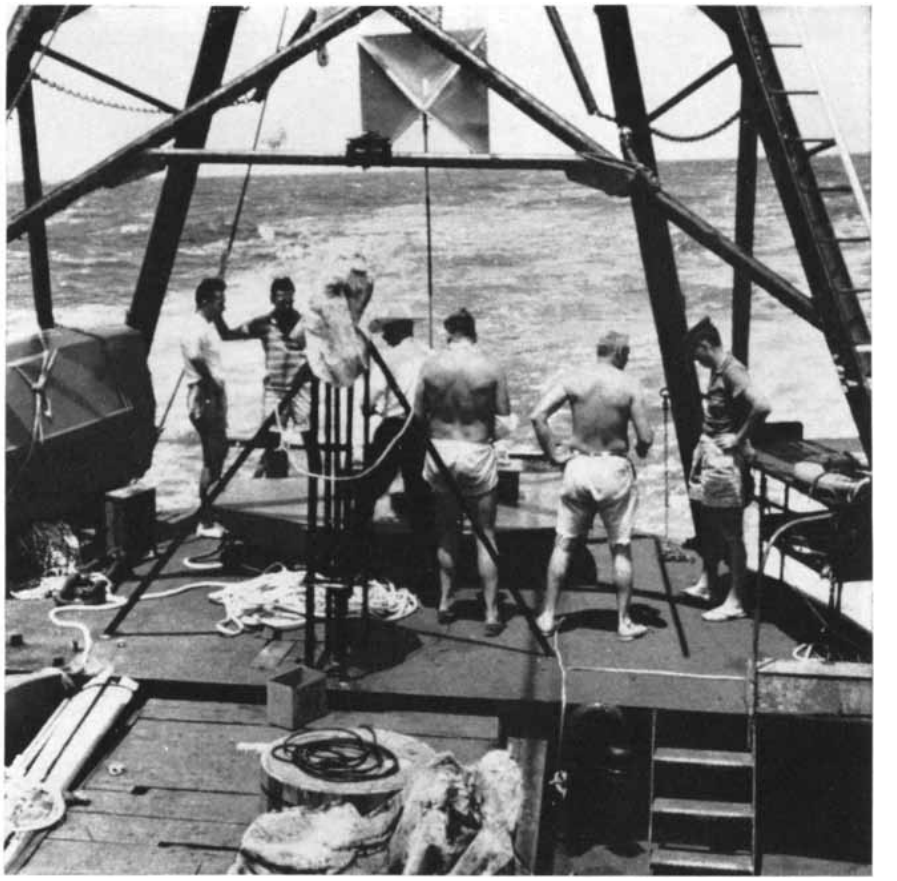
MAJOR TOOLS of the Dolphin Expedition were the taut-wire buoy (*left*) and Roberts current meter (*right*). The subsurface steel sphere buoyed the anchoring wire, and the "pram" provided a radar target, making it possible to measure the ship's drift. This drift was subtracted from readings obtained by the current meter (*shown here out of scale*) to get current velocity at various depths.

of successive daily measurements on the Equator at 140 degrees West, the speed of the peak-velocity core stayed between 120 and 150 centimeters per second, and its depth remained close to the 100-meter level. As we sailed eastward along the Equator, we found the core rising gradually to about 40 meters and then falling sharply as it approached the Galápagos Islands at 90 degrees West. For most of the interval the speed varied between 100 and 150 centimeters per second, but it dropped much lower near the Galápagos.

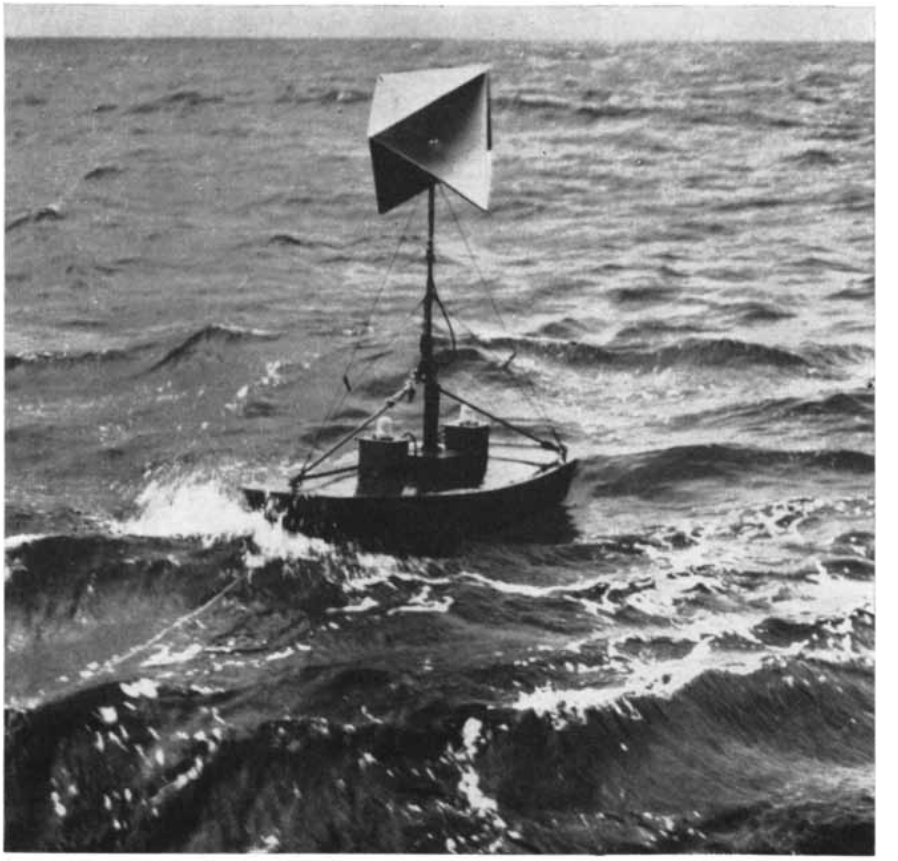
These islands, as of now, mark the eastern terminus of the Cromwell Current. The origin of the current in the western Pacific is uncertain, so we do not know how long the current is. It has been traced by direct observation from 150 to 90 degrees West, a distance of 3,500 nautical miles. There is strong indirect evidence that the current extends as far as 170 degrees West and some evidence for its existence even at 160 degrees East, in the vicinity of the Solomon Islands. In fact, recent measurements made by the Japanese Hydrographic Office suggest that the Cromwell will be found across the entire Pacific Ocean, which would give it a total length of 8,000 miles.

Whatever its starting point, the Cromwell Current continues at full speed to within 200 miles of Isabela Island, the largest in the Galápagos group, which straddles the Equator. It is still traveling at more than a knot (50 centimeters per second) within 20 miles of Isabela. But it is missing on the far side of the Galápagos—at least observations at 89 degrees West during the Dolphin cruise and at 84 degrees West in 1955 failed to show it.

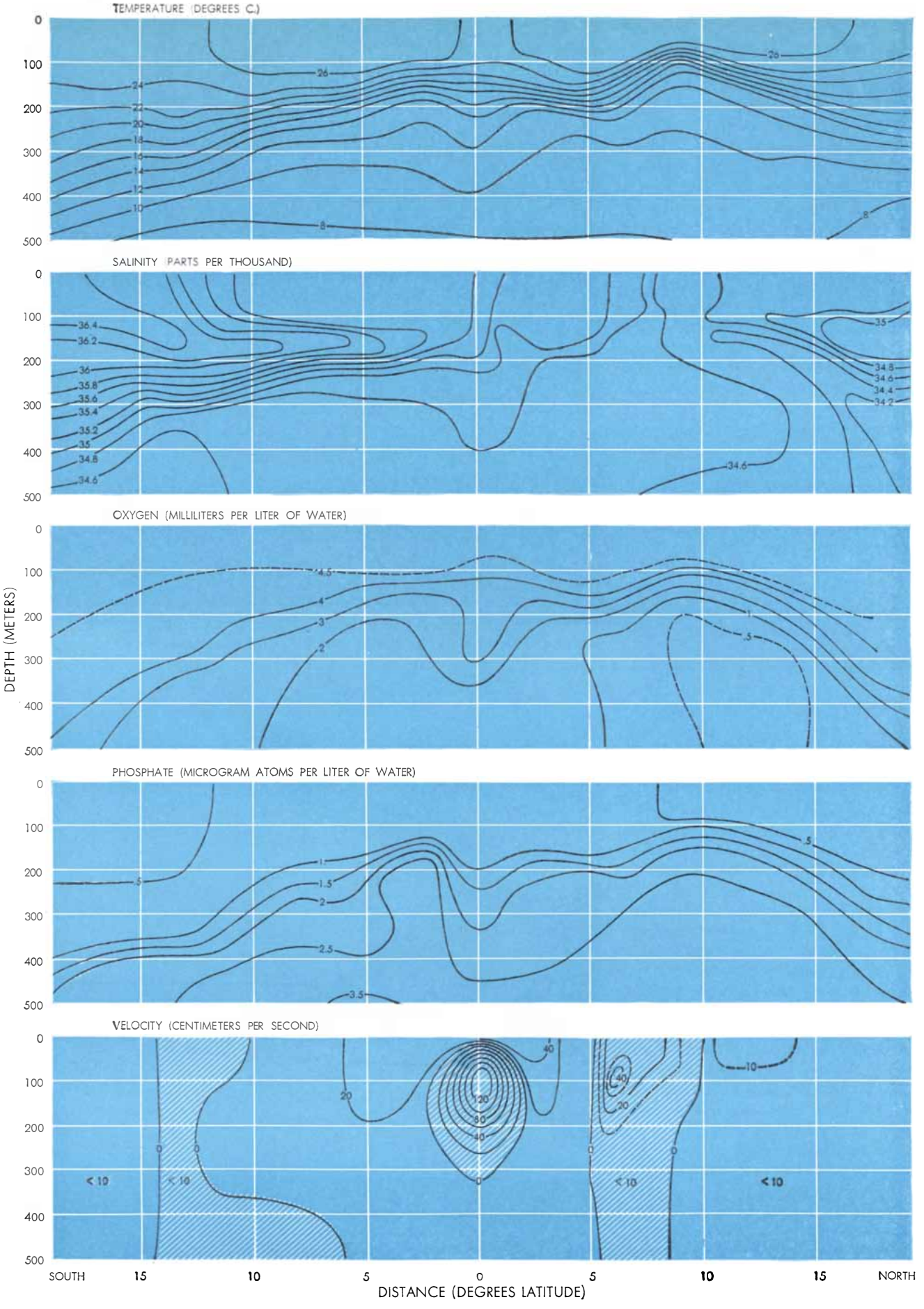
A current that transports 40 million tons of water a second cannot suddenly stop dead. At the moment there seem to be three possible explanations for the apparent disappearance of the current. The first, and least likely, is that the current actually maintains its integrity but leaves the Equator near the Galápagos. Second, the current may lose water to its sides continuously during the last 1,000 miles or so of its eastward run, even though the flow at its center is undiminished. If so, there would be much less water to account for at the Galápagos. So far, all measurements except those at 140 degrees West have been made within five miles of the Equator. They show only how the core behaves, not how well the edges hold up. Finally, it is possible that violent



BUOY MARKER is launched over the stern of *Horizon* for the first time as the expedition begins its observations. The marker provided a reference point for measuring the drift.



MARKER RIDES AT ANCHOR in mid-Pacific. The marker, an eight-foot pram, is moored by the line at left to the taut-wire buoy. The pram carries a metallic target for radar tracking.



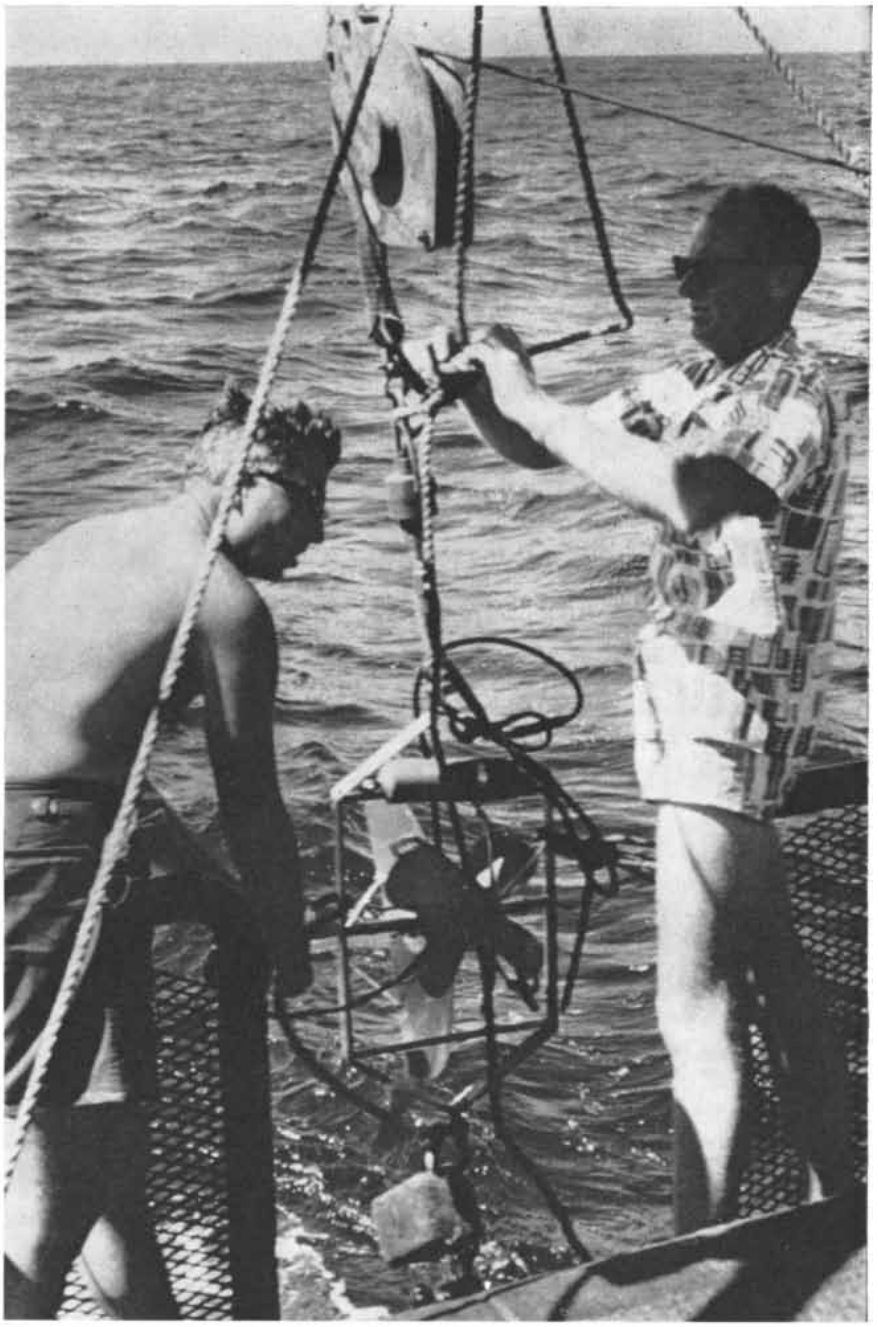
and large-scale mixing occurs as the Cromwell runs into the Galápagos, with large quantities of surrounding water being dragged into the current and slowing it down.

There is some evidence that both processes are operating; that the current loses some water to the sides over a long distance and also entrains some surrounding water near the end. We are planning a three-month cruise of the newest Scripps Institution research vessel, *Argo*, for the fall of this year to find out.

Another question that should be answered soon is whether there are currents in the Atlantic or Indian oceans that are similar to the Cromwell. Observations in the Atlantic give every reason to expect that such a current will indeed be found there. The equatorial waters in all oceans are characterized by an upper layer of warm, well-mixed water of nearly uniform temperature, separated from the colder intermediate and deep water by a narrow zone in which the temperature changes rapidly. This zone is called a thermocline. The water in the thermocline and immediately below it has very little oxygen dissolved in it and is relatively rich in phosphate. The thermocline also shows a rather sharp gradient in the salinity of the water.

In the region of the Cromwell Current all these qualities—temperature, oxygen and phosphate content and salinity—show anomalous values. The distribution of values, which is obviously related to the velocity cross section of the current [*see illustration on opposite page*], suggests a strong vertical mixing action that carries water from the surface down into the submerged flow. Comparable measurements in Atlantic waters show a closely similar distribution along the Equator, and so the existence of a similar current seems highly probable. Indeed, an observation by J. Y. Buchanan back in

CROSS SECTION athwart the Equator shows how anomalies in temperature, salinity, oxygen and phosphate content are associated with the Cromwell Current. The Cromwell appears in the center of the bottom chart, in which the hatched areas are eastward currents and the solid-color areas westward. Upper charts show how the region of the Cromwell is marked by weakening of the layer of sharp temperature change, lack of maximum salinity and mixing downward of water high in oxygen and low in phosphate. The vertical exaggeration is 2,000.



CURRENT METER is prepared for lowering by the author (*left*) and a colleague. Readings, recorded electrically on ship, give speed and direction of current and depth of water.

1886 indicated just such a reversal of current on the Equator at 10 degrees West.

There are not yet enough observations from the Indian Ocean to indicate whether or not the same sort of mixing takes place at the Equator. It is known, however, that conditions there differ in several ways from those in the Pacific and Atlantic. The equatorial region of the Indian Ocean is under the influence of the monsoon, and the winds and currents change with the season. One of the major efforts of the International Indian Ocean Expedition of 1962 and 1963 will be to investigate the equatorial circulation during the various seasons.

The Cromwell Current challenges the theorist as well as the explorer. According to our observations, the current is in geostrophic equilibrium to within 30 miles of the Equator. That is, even though the Coriolis force is very small, it still appears to be in balance with the pressure gradient. But the fact that the current appears to be in geostrophic balance near its outer edges does not constitute an explanation. A number of theories have been proposed, but more detailed observation will be required to determine which, if any, is correct.

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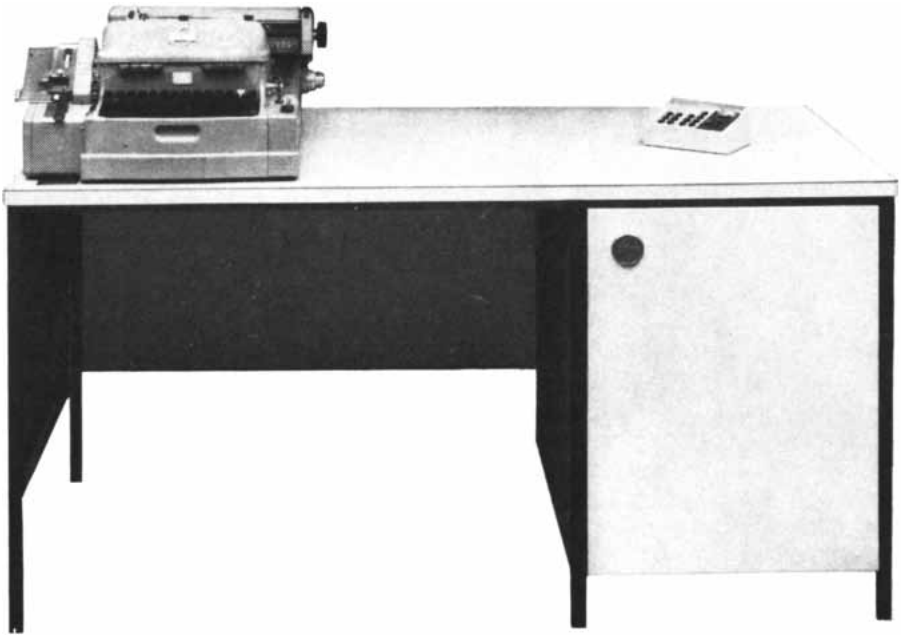

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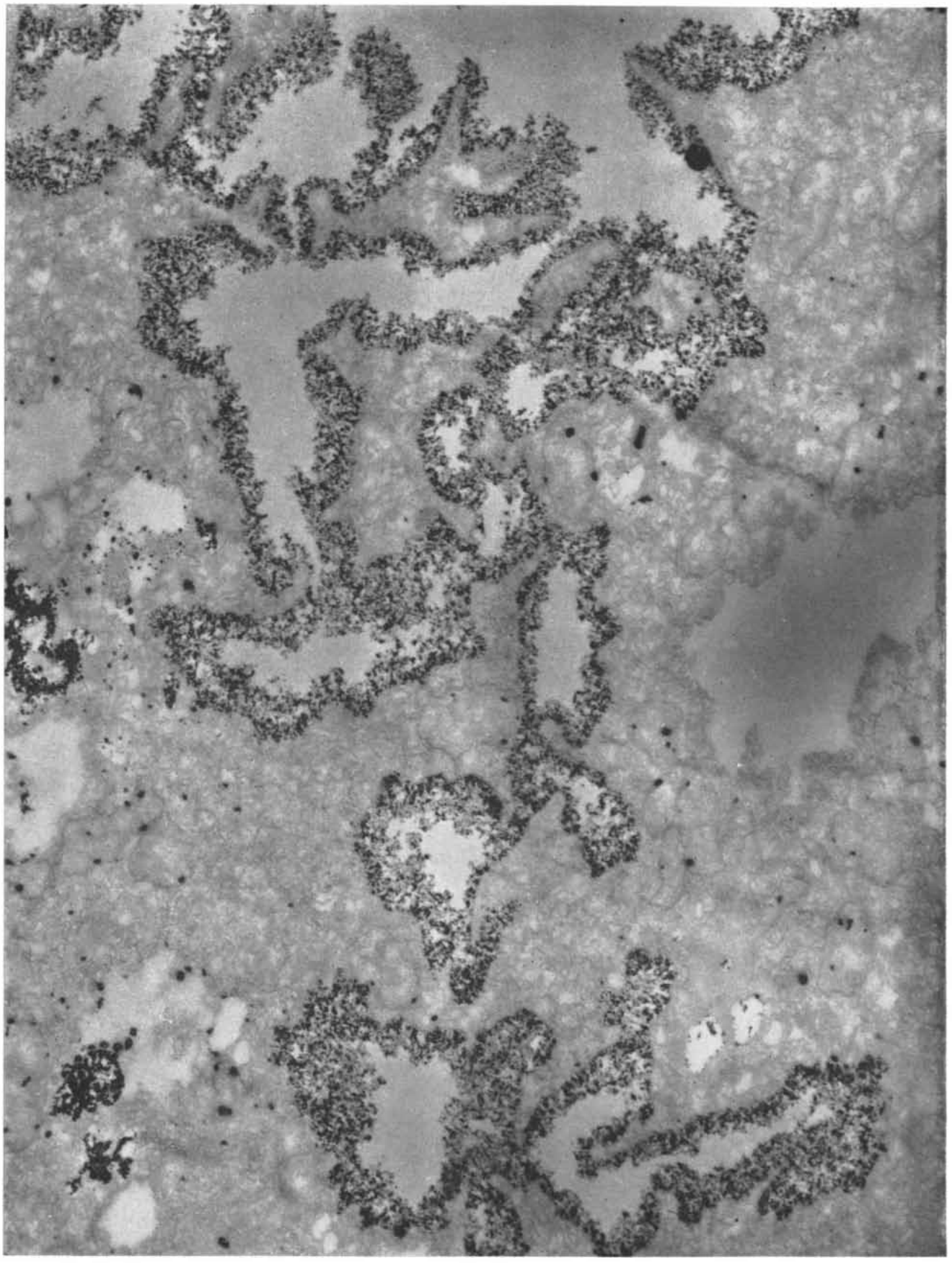


PINOCYTOSIS CHANNEL, seen in section, coils deeply into the cytoplasm of an amoeba. Thorium dioxide, a compound that induces pinocytosis, lines the walls of the tunnel. Darker concentrations of thorium dioxide in pinocytosis vacuoles at left (*center and bottom*) resulted from an earlier exposure of the amoeba to the compound. Magnification is 13,700 diameters. This electron micrograph was made by Philip W. Brandt and George D. Pappas of the Columbia University College of Physicians and Surgeons.

PINOCYTOSIS

The word means "drinking by cells." Actually it is the term for a complex process whereby a cell can take in nutrients and other substances to which the cell membrane seems impermeable

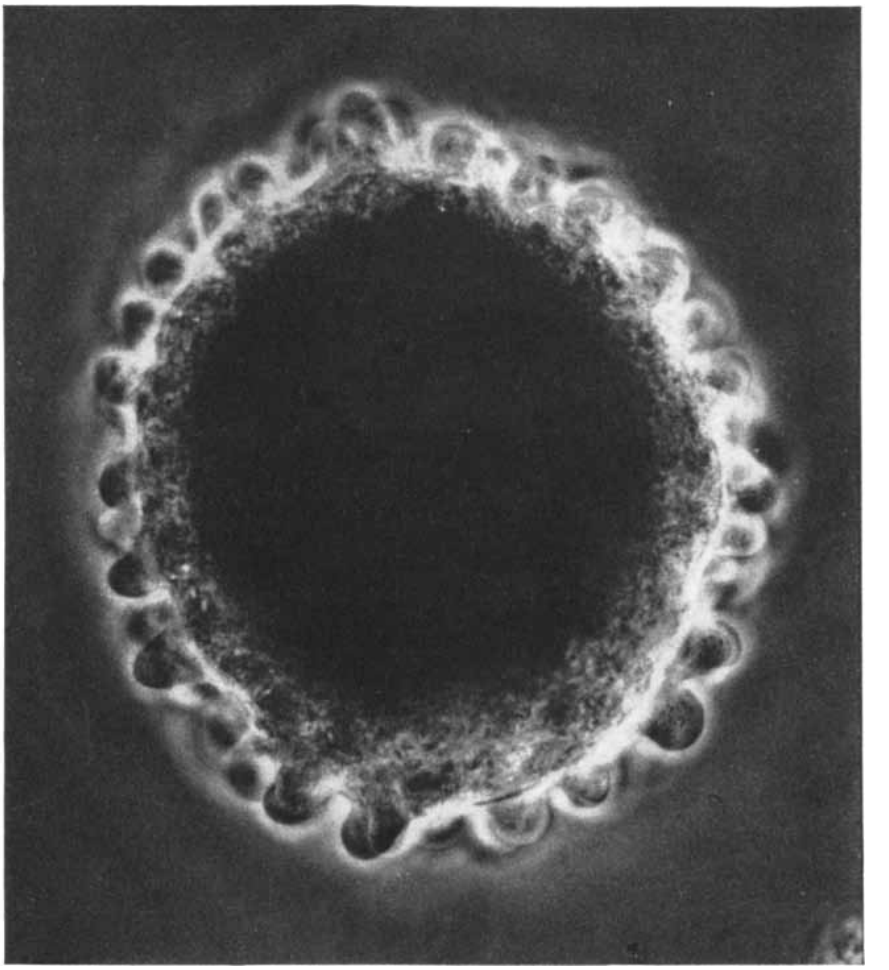
by Ronald C. Rustad

One of the leading problems of biology is to explain how a cell moves nutrients and other substances across its outer membrane. There are probably submicroscopic holes in the cell wall through which small molecules can diffuse [see "Pores in the Cell Membrane," by Arthur K. Solomon; SCIENTIFIC AMERICAN, December, 1960]. But some molecules cross the barrier even though they are too big to get through the holes. Somehow the cell helps them across. Several mechanisms have been proposed to account for this "active transport" of substances. With a single exception all of them are still hypothetical. The only mechanism that has actually been observed is the one called pinocytosis.

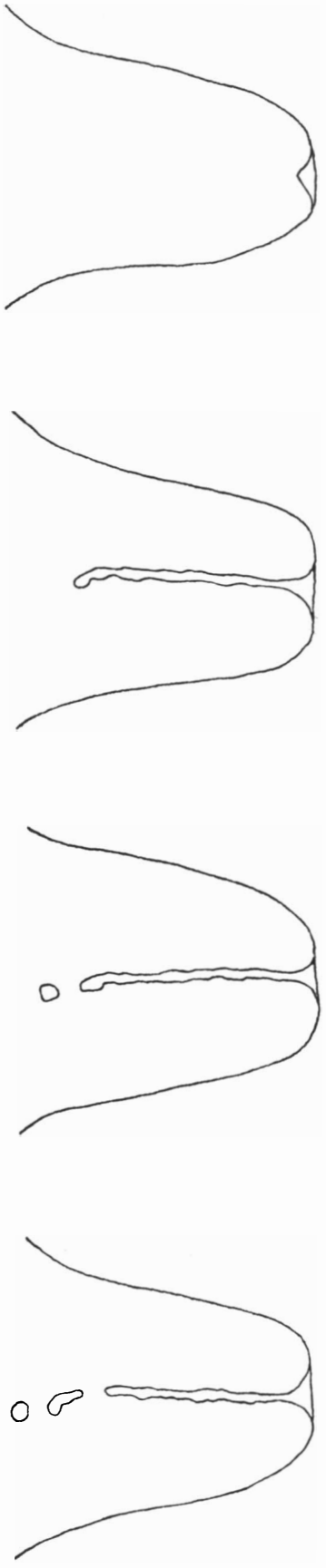
The name comes from the Greek words for "drink" and "cell." Under the microscope the process appears to be aptly described. As an amoeba, for example, starts to "drink," a number of depressions form in its outer coat. In some cases the indentations take the shape of cups as much as 50 microns (50 thousandths of a millimeter) across; more commonly they are narrow channels one or two microns in diameter, extending down through small, raised cones that look like tiny volcanoes [*see illustration on next page*]. Whatever its shape, the channel, filled with the liquid by which the cell is surrounded, next closes off at a point near the bottom. Then the tiny pocket breaks away and migrates toward the interior of the cell. Eventually the substance trapped in this "pinosome" finds its way into the surrounding cytoplasm.

Many different types of cell have been found to conduct a process similar to the one just described, the details varying with the cell and the nature of the surrounding medium. Animal cells in tissue culture put out tiny projections that fuse together to trap droplets of fluid. In recent electron microscope studies of a number of mammalian cells, and at least some plant cells, channels and pockets smaller than a micron in diameter have been discovered. These too are presumably instances of pinocytosis. They are especially common in cells of kidney and other tissues that are characterized by a high rate of active transport.

Pinocytosis was apparently observed for the first time in 1925 by J. Graham Edwards of Johns Hopkins University.



AMOEBA IN STRONG PROTEIN SOLUTION that induces pinocytosis acquires rounded shape and hundreds of short pseudopods that look like volcanoes. Here pinocytosis has ceased but amoeba retains odd shape. Photomicrograph was made by author of article.



PINOCYTOSIS IN AMOEBAE begins with extension of short pseudopod (*top*). A channel forms in it, then droplets pinched from end of channel migrate into the cytoplasm.

He noticed the relatively large, cuplike depressions that amoebae form when certain simple salts are added to their culture solution. In 1931 Warren H. Lewis of Johns Hopkins University discovered an analogous phenomenon in cells grown in tissue culture. He named it pinocytosis, in contrast to phagocytosis, the term used to describe the ingestion of solid particles by certain cells. Lewis was probably the first worker to appreciate the importance of pinocytosis in the economy of cells. He pointed out that the process would enable them to "take in substances that cannot diffuse into them or be taken in by ordinary phagocytosis." Soon thereafter Samuel O. Mast and W. L. Doyle of Johns Hopkins University carried out some systematic experiments on pinocytosis in the amoeba. They found that salts and proteins in the culture medium induce the process, but that carbohydrates do not.

Following the observations of Lewis and of Mast and Doyle, little (if any) physiological work was done for two decades. Then in 1954 Heinz Holter, Cicily Chapman-Andresen and their colleagues at the Carlsberg Laboratory in Copenhagen began a quantitative investigation of the uptake of materials by pinocytosis. In one simple and elegant experiment they demonstrated that glucose, which amoebae normally absorb only in trace amounts, enters freely by means of pinocytosis. The experimenters put some amoebae in a solution containing glucose labeled with radioactive atoms and found that a negligible quantity of labeled material passed into the cells. When a protein was added to the medium to induce pinocytosis, however, the amoebae took in large amounts of the sugar and consumed it in their metabolic processes. Here one molecule had helped another to enter the cell. Some workers believe that certain hormones may act in the same way.

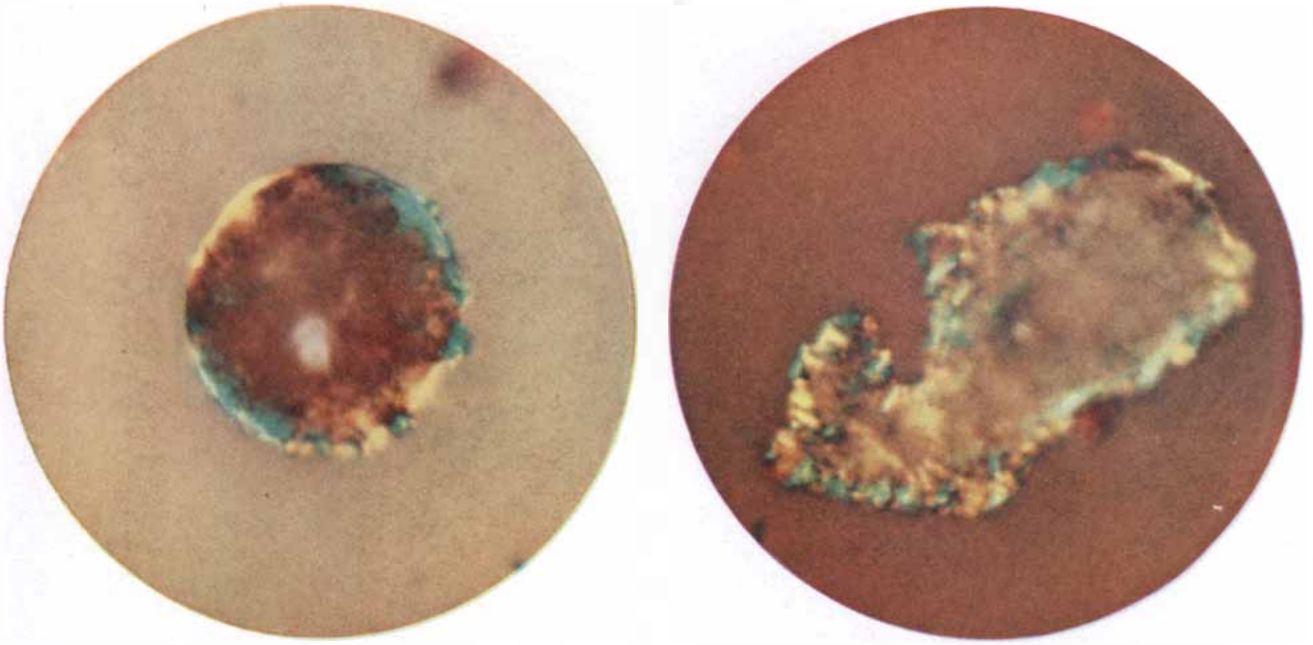
Amoebae are now known to conduct some pinocytosis even in standard culture solution, but only infrequently and only over a small portion of their total surface. A higher level of activity depends on the addition of other substances to the medium and it can be controlled by the experimenter. The amoeba is therefore a favorite subject for this kind of investigation. Among the substances, in addition to proteins and salts, that have been found to induce pinocytosis in amoebae are viruses and amino acids. Curiously, large doses of ultraviolet light also set off the process. Simple sugars, polysaccharides and ribonucleic acid apparently do not do so.

Are pinocytosis channels the result of a complex biochemical process or a simple physical response of the lipoprotein membrane around the cell? The question is prompted by the fact that purely physical changes can cause folding and the formation of tubes in the monomolecular layers of protein. A clue to the nature of a reaction can often be obtained by observing what inhibits it. This is what Noël de Terra and I began to study while we were at the University of California. (I have continued the work at Florida State University.) In one series of experiments we placed amoebae in a protein solution that normally induces pinocytosis and then introduced cyanide or carbon monoxide. The channels failed to appear. Cyanide and carbon monoxide inhibit the formation of adenosine triphosphate (ATP), the substance that furnishes energy for almost all biochemical processes. Apparently pinocytosis requires ATP and therefore involves at least one energy-consuming chemical reaction.

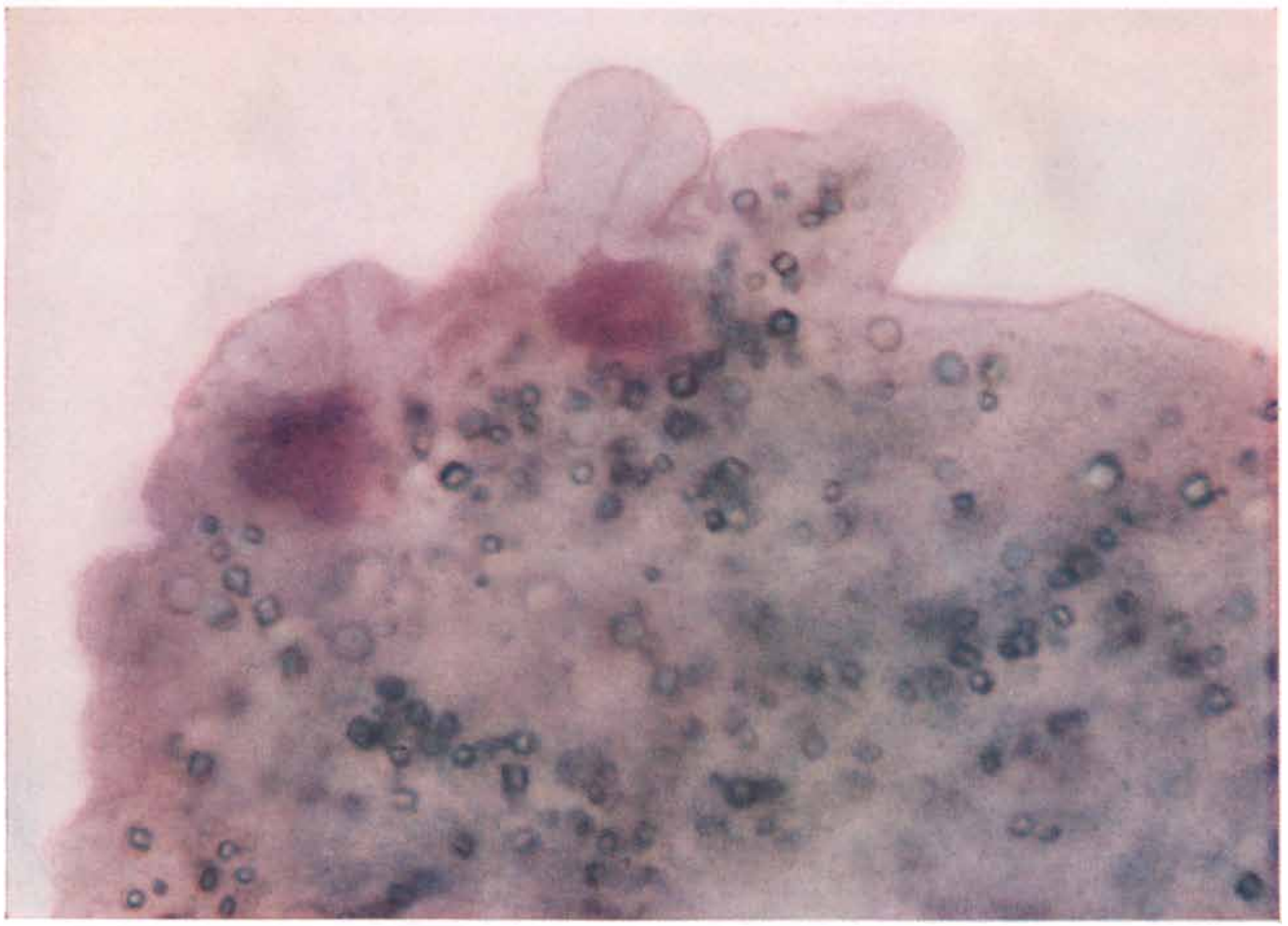
The idea drew further support from the effects of changes in temperature. Physical reactions are relatively insensitive to temperature, whereas chemical reactions are markedly affected, slowing down as the temperature drops. At 22 degrees centigrade channels appear in amoebae three or four minutes after they are placed in protein solution. When we cooled the medium to six degrees, the first channels took 30 or 40 minutes to show up.

Temperature dependence suggested a technique for a further experiment that would test whether pinocytosis results from a single reaction or a sequence. We bathed amoebae in protein solutions at six degrees C. for about 15 minutes—approximately half the time necessary for channels to appear at that temperature. Then we removed the cells and washed them in an ordinary nonprotein medium, also at six degrees. When the washed amoebae were placed in standard amoeba medium at 22 degrees, many channels rapidly formed. Pinocytosis can therefore take place after the inducing agent has been removed, showing that the process consists of a minimum of two steps.

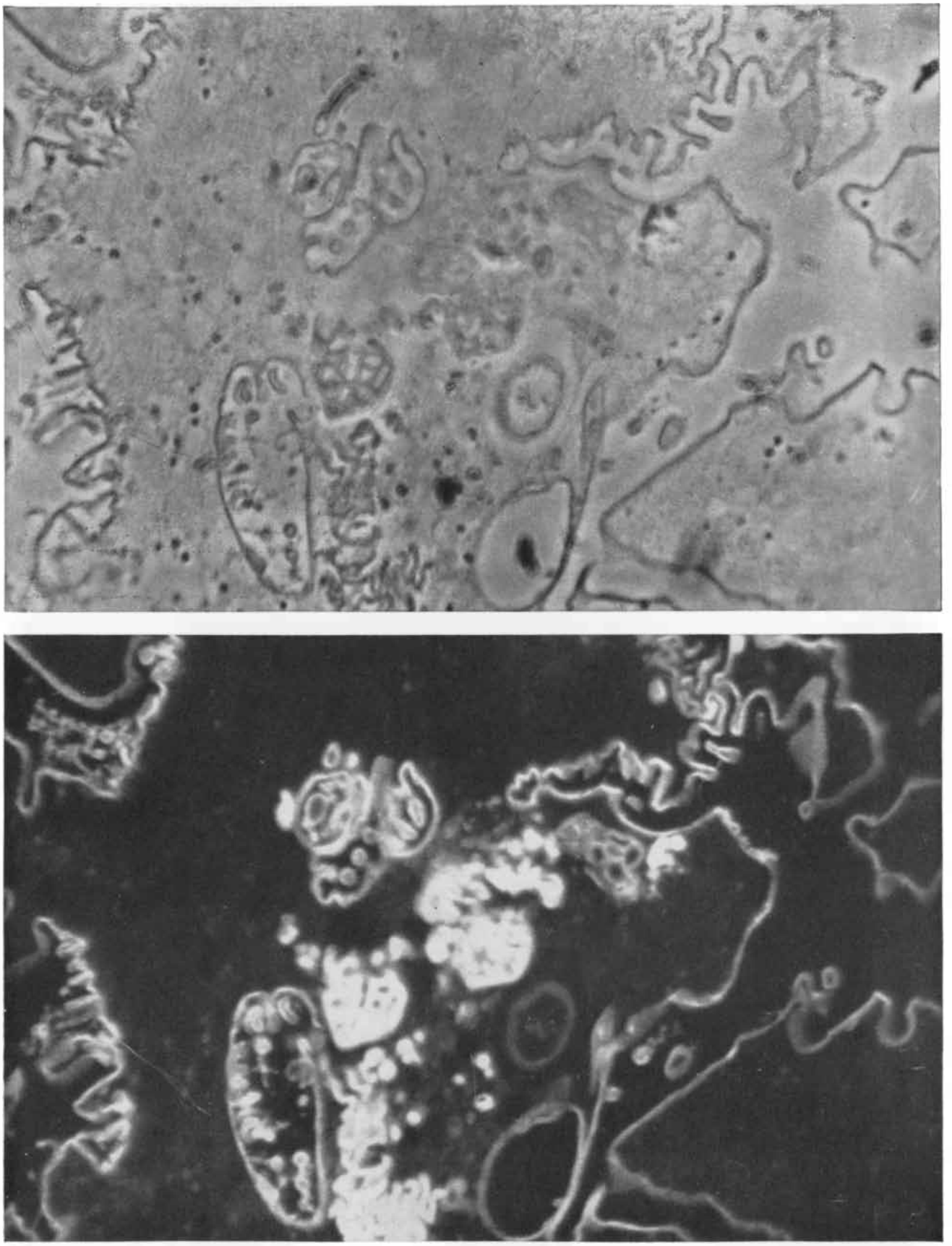
In 1957 Philip W. Brandt, then at the University of Pennsylvania, identified the first step. It had been known for some time that proteins and salts could be bound to various biological membranes. Brandt undertook to find out whether this happens during pino-



DYE ON SURFACE OF LIVING AMOEBAE shows orientation when viewed under polarizing microscope. The dye, toluidine blue, looks bluish on surface lying along one axis but yellow on a surface perpendicular to that axis. This indicates that dye molecules attach to surface of amoeba in an orderly array. The effect is most apparent in rounded amoeba at left. Amoeba at right is in more familiar "blob" shape. These two photomicrographs were made by J. M. Mitchison of the University of Edinburgh.



PINOCYTOSIS IS INDUCED by toluidine blue. Stained pinocytosis channels coming in from edge of cell are visible at left and at top center. As surface is drawn into the cell in channels, concentrations of stained material appear at base of channels. These dense areas often seem coiled. This photomicrograph of a living amoeba was made by Lynne Rustad, the wife of the author.



SURFACE BINDING OF PROTEIN as first step in pinocytosis is made visible in photomicrographs taken by Philip W. Brandt while he was working at the University of Pennsylvania. At top is phase-contrast photomicrograph of a section of an amoeba that had been fed protein, then freeze-dried. Highly irregular cell membrane, coiled pinocytosis channels and several membrane-enclosed sacs are visible. The section was washed with an antibody tagged with fluorescein, a dye that fluoresces under ultraviolet light. The antibody then combined with the protein. Fluorescence photomicrograph at bottom shows that the cell membrane, channels and inner surface of vacuoles are coated with the bound protein. The section has been magnified approximately 3,200 diameters.

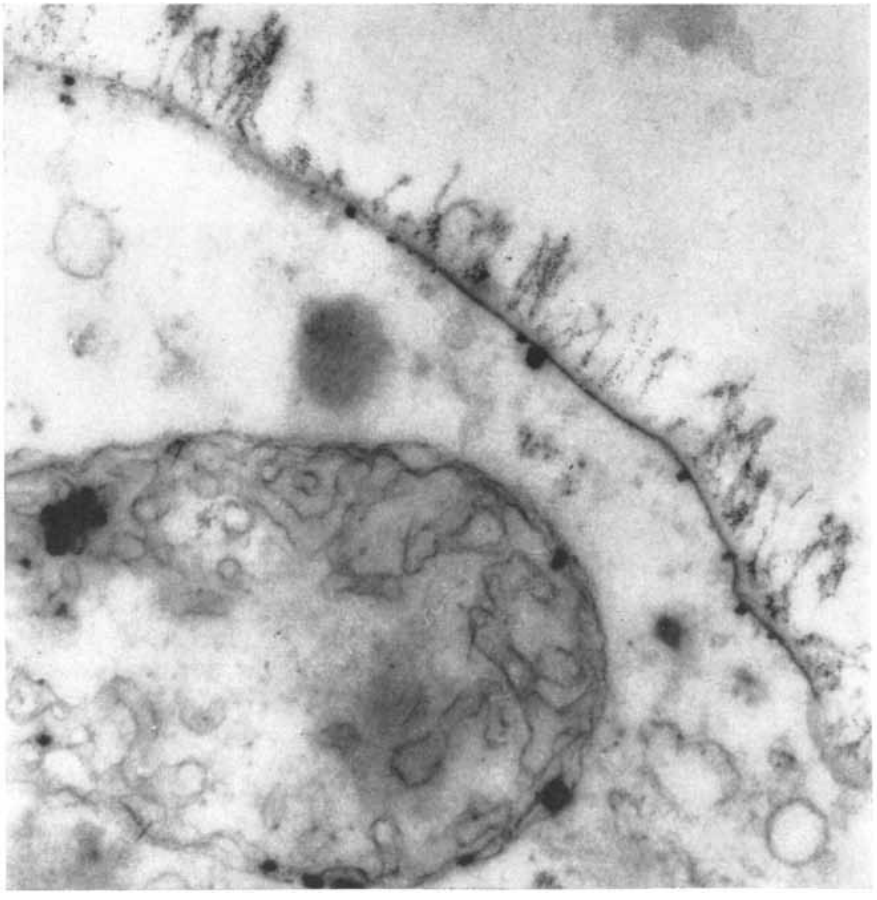
cytosis. He exposed amoebae to a protein for varying lengths of time, then freeze-dried the cells and cut them into thin sections. These he treated with an antibody to the protein. The antibody had been labeled with fluorescein, a dye that fluoresces in ultraviolet light. The dye-carrying antibody combined with the protein. Under ultraviolet radiation, the sections showed a high concentration of protein on the outer surface of the cells and also on the inner surfaces of pinosomes within the cytoplasm [*see illustrations on opposite page*]. This indicated that the protein is first bound to the outside of the cell membrane and then "swallowed" as pinocytosis channels form and are pinched off.

At about the same time Verne N. Schumaker, working in the laboratory of Jean Brachet at the Free University of Brussels, used radioactive protein to measure the rate of uptake. He found that in five minutes an amoeba can bind 50 times the amount of protein contained in its own volume of solution. He showed that it does this even at low temperatures or in the presence of chemicals, such as cyanide, that inhibit the formation of channels.

The work of Brandt and Schumaker brought about a revision in the concept of pinocytosis. The idea of drinking is obviously misleading, in view of the major role played by the binding of a large amount of protein at the surface. A great deal more material is taken into the cell through pinocytosis than would have been predicted from the volume of fluid ingested. The winding channels, which have a large surface area, serve primarily as a means of entry for bound material rather than for liquid. The phenomenon of binding suggests that cells more specialized than amoebae may have specific chemical groups in their membrane surfaces that selectively take up certain molecules.

In the early 1950's J. M. Mitchison of the University of Edinburgh had used dyes to study the nature of the surface of amoebae. He found that basic (alkaline) dyes such as toluidine blue can attach themselves to the surface of a living amoeba, presumably by combining with acidic groups of atoms. Not only that; the dye molecules assume a fixed orientation with respect to the surface of the cell membrane. The effect is easy to detect in the polarizing microscope: dye molecules lying in one plane look bluish, while those oriented perpendicularly to that plane look yellow [*see top illustrations on page 123*]. While at Edinburgh I confirmed Mitchison's ob-

HAIRLIKE EXTENSIONS of coating on exterior of amoeba furnish vast area for binding of molecules. Oval structures are mitochondria. Magnification here is 30,500 diameters.



MOLECULES OF FERRITIN (*tiny black dots*), a dense protein, are attached to "hairs" of exterior coat of an amoeba. Cell membrane, which is impermeable to large molecules, is line next to cytoplasm. Black spots are thought to be artifacts created by fixation of cell for micrography. Mucopolysaccharide coating and hairs lie outside membrane. Enlargement is 45,300 diameters. Electron micrographs on this page were made by Brandt and Pappas.

servations and also discovered that dyes induce pinocytosis.

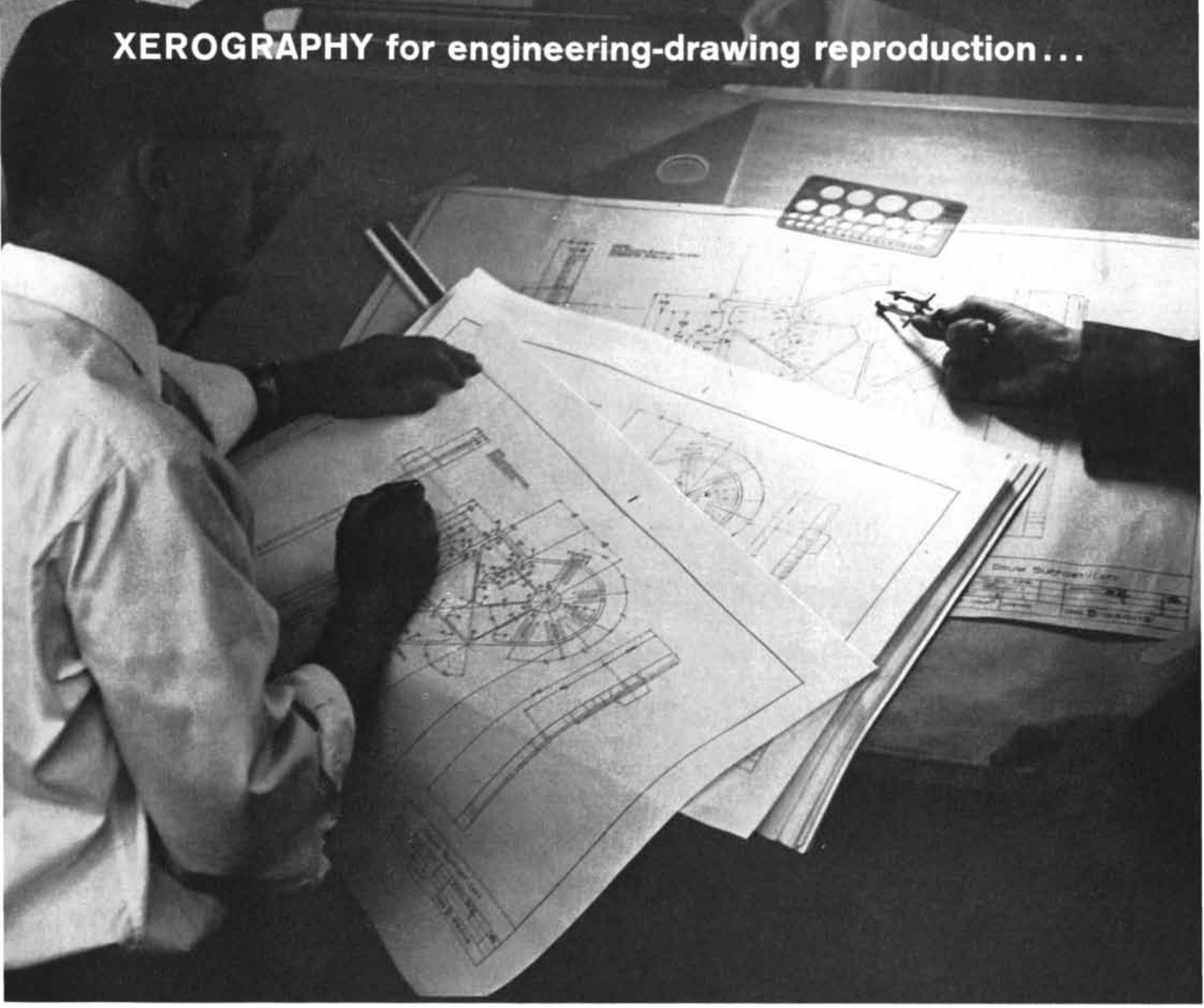
When basic dyes and proteins are placed in solution together, they compete for the same surface sites. Hence it appears that proteins too are attached to the surface of the amoeba in an orderly molecular array. It may be that electrostatic forces are responsible for the binding; the negative charge on acidic sites would attract positively charged basic groups on a protein or dye, the two joining in a saltlike combination.

Exactly where are the binding sites? To be accessible to proteins they must lie on the outer surface of the cell membrane proper, or perhaps in some material attached to that surface. The latter possibility is suggested by observations made with the optical microscope. The binding layer for both fluorescent proteins and basic dyes appears to have a definite thickness. But the cell membrane itself is so thin that it can be resolved only with the electron microscope. Therefore the inducers are apparently bound to an extracellular coat.

Mucopolysaccharides (gelatinous compounds composed of proteins and groups of sugars) have been found on the surface of amoebae by several workers who have used chemical techniques on preserved cells. Brandt, who is now at the Columbia University College of Physicians and Surgeons, showed that this material is ingested in the pinosome. My wife and I have confirmed his observation by employing another chemical technique.

We have also induced pinocytosis with toluidine blue and have found that the surface layer of the cells stained pink instead of blue. Known mucopolysaccharides in the extracellular coats of preserved cells stain the same way. Hence the oriented acidic binding-sites appear to be in the mucopolysaccharides. J. M. Marshall and his colleagues at the University of Pennsylvania are now attacking the problem of isolating and analyzing the material of the binding region.

What may be the exact location of the binding sites has turned up in recent electron microscope studies. The surfaces of many cells exhibit a fine fringe outside the cell membrane. In electron micrographs of amoebae the fringe is seen to be composed of discrete fibrils that look like hairs but are so thin they seem to have no internal organization. The fibrils also line new pinosomes, but seem to be broken down in older ones. When amoebae are placed in a solution of ferritin, an extremely dense protein,



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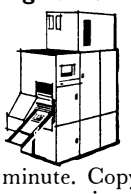
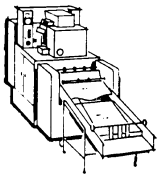
For high-quality offset paper masters:

XeroX Model 1218 copying equipment combines with offset duplicating... and the results are spectacular. This equipment prepares sharp, inexpensive paper masters from original drawings of A to D size. The larger drawings are perfectly reduced to 12″ x 18″ masters, from which multiple prints can be run off in seconds.

Volume reproduction from original drawings or roll microfilm: Just push a button on the XeroX Copyflo® continuous printer for sharp, dry, ready-to-use prints (on ordinary paper, vellum, or offset paper masters up to 12″ wide). Prints are made at the rate of 20 linear feet a minute. Copyflo printers reduce, enlarge, or copy size-to-size from original drawings or roll microfilm (16 or 35mm).



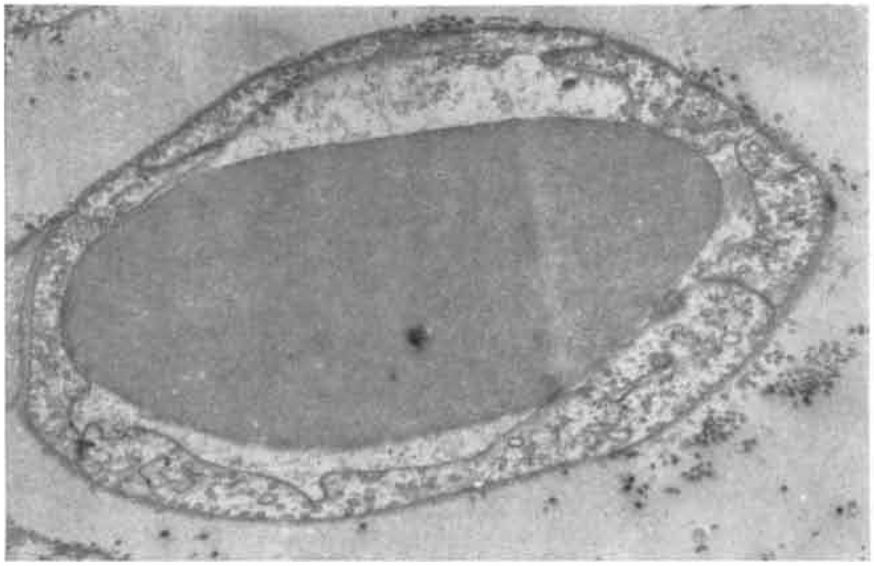
Reproduction from card-mounted microfilm: The XeroX Copyflo 24C and the exciting new Copyflo 1824 automatically produce dry, positive prints on ordinary paper, vellum, or offset paper masters from 35mm card-mounted microfilm. The 24C



produces ready-to-use prints (up to 24″ x 36″) at the rate of 20 linear feet a minute. The new 1824 for small volume users, or large, decentralized users, produces prints from 8½″ x 11″ to 18″ x 24″.

Get all the facts. Write: Haloid Xerox Inc., Dept. 61-367X, Rochester 3, N. Y. Branch offices in principal U.S. and Canadian cities. Overseas: Rank-Xerox Ltd.

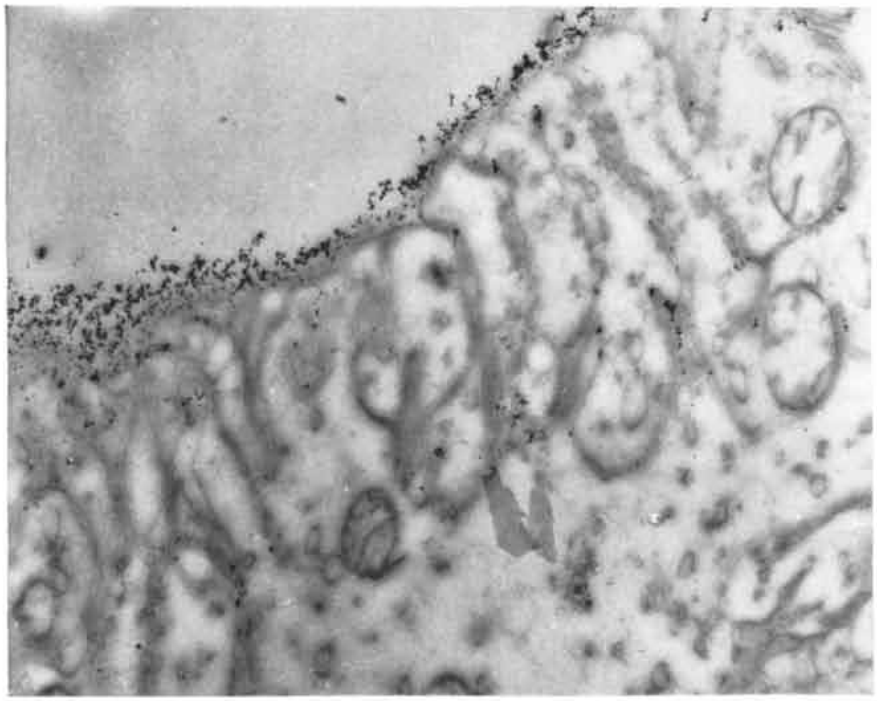
HALOID XEROX®



CROSS SECTION OF BLOOD CAPILLARY with red blood cell (*gray mass*) reveals hundreds of minute pinocytosis vesicles in capillary cells around the red cell. Vesicles can be seen forming along membranes of the capillary cells (*for example, about an inch in from the left, just above bottom*). Magnification here is approximately 20,000 diameters.

the electron microscope shows individual ferritin molecules attached to the fibrils, indicating that the "hairs" are the binding sites. They would be ideal for the purpose, having a vast total area. In cells that have no hairs the sites may lie in extraneous coats that do not show up in electron micrographs.

The studies described so far concern primarily the first stage of pinocytosis. Nothing is known about how the binding induces channel formation. Some work has been done on the later stages, in which the material carried by the pinosome finds its way into the cytoplasm. When the pinosome breaks away from



PORTION OF RABBIT EYE that secretes the aqueous humor that fills the eyeball also shows pinocytosis. This cell was excised 20 minutes after an injection of thorium dioxide into the eye chamber (*top left*). Numerous thorium dioxide particles adhere to surface of cell. Particles are also seen in infoldings of cell membrane and in vesicles within cytoplasm. Rows of vesicles, formed by fragmentation of pinocytosis channels, are also visible. Magnification is 18,000 diameters. Pappas and Brandt made these electron micrographs.

New hydrofoil vessel will literally fly on wings . . . could race from New York to Bermuda in 8 hours at speeds up to 80 mph!

When this 80-ton hydrofoil vessel is launched this summer, a new experience in ocean travel will not be far off. The craft is being built for the Maritime Administration by Dynamic Developments, Inc., an affiliate of Grumman Aircraft Engineering Corporation. It will serve as a sea-going test bed—a possible forerunner of tomorrow's huge passenger hydrofoils.

Supported by its sleek hydrofoils, or underwater wings, the vessel will literally fly. When speeds over 25 miles per hour are obtained, its wings will provide lift to raise the main hull entirely out of the water. To maintain balance, the flaps of the wings will be trimmed automatically to meet changes in speed, sea conditions, and wind force. This will be accomplished by an advanced control system, developed by Hamilton Standard.

Hamilton Standard is now also developing an electronic navigation system for a hydrofoil subchaser being built by Boeing Airplane Company for the U.S. Navy. Advanced stabilization and navigation systems for these hydrofoil vessels typify Hamilton Standard's expanding activities in electronics and new fields.

Today its work includes aircraft engine controls, air-conditioning systems and starters . . . solar power generators . . . missiles and space systems . . . ground support equipment . . . electron beam welding and cutting machines . . . static power systems . . . and new propellers.

UNITED AIRCRAFT CORPORATION

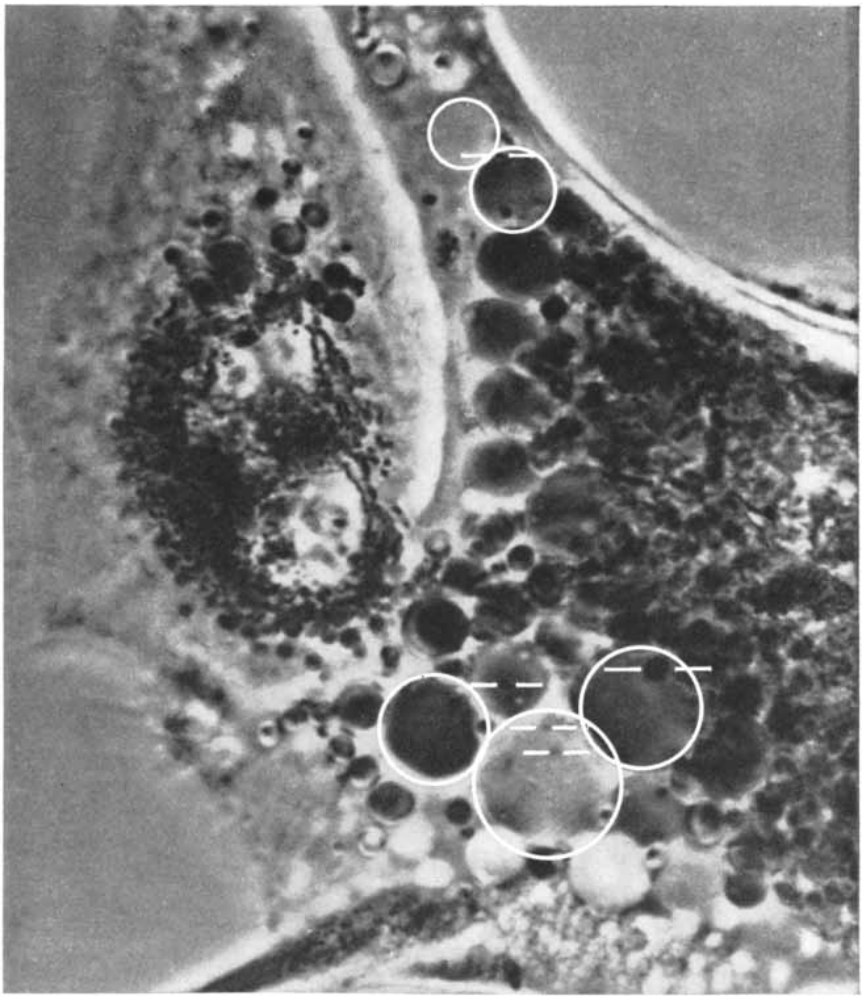
HAMILTON STANDARD DIVISION

ELECTRONICS

its channel, the contents are still separated from the cytoplasm by a bit of impermeable cell membrane. Yet eventually the enclosed substances do cross the barrier, so either they or the membrane must be altered. In the endothelial cells that line blood capillaries the membrane seems to change. When these cells are provided with ferritin, molecules of the protein are found in pinosome-like vesicles and are also found scattered in the cytoplasm.

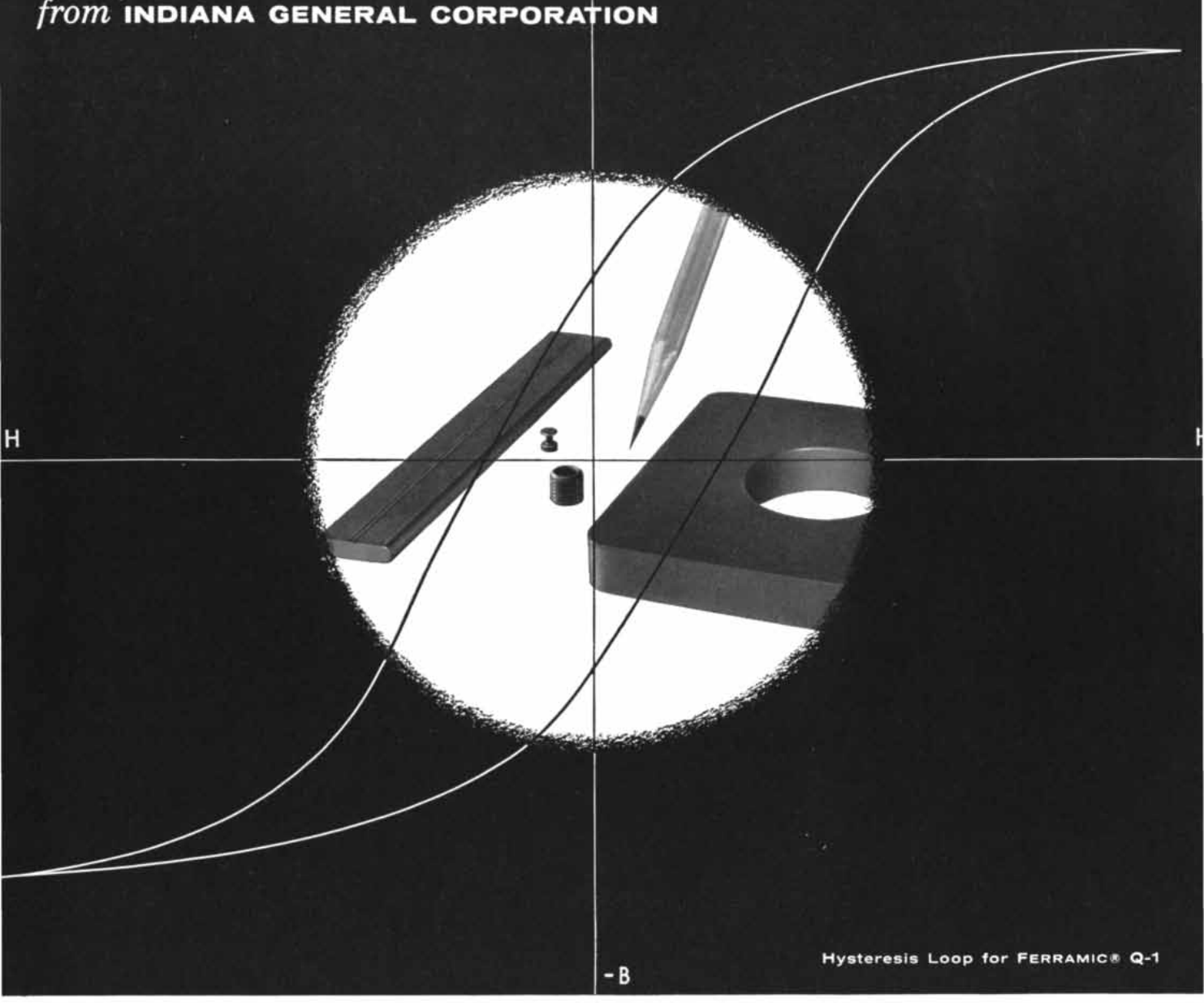
A similar experiment on amoebae failed to show any free ferritin molecules in the cytoplasm. Presumably the material is broken down into smaller molecules—that is, digested—before it can escape through the surrounding membrane. Both amoebae and the phagocytic or scavenger cells of mammals are known to perform a similar process in the digestion of material in vacuoles. The digestion hypothesis has been strengthened by observations of human cells in tissue cultures. By means of time-lapse cinematography George G. Rose of the Hermann Hospital in Houston, Texas, discovered tiny particles bumping into the pinosomes and apparently discharging part of their contents into them. He suggested that the little particles, like the cell bodies known as lysosomes, contain digestive enzymes. If they are discharged into pinosomes, these enzymes could digest the contents and affect the membrane as well.

Although many questions about pinocytosis remain to be answered, it seems from what is already known that pinocytosis is an important form of active transport. It is premature to speculate that pinocytosis is the chief form, even though it is the only one that has been directly visualized. Certainly the study of pinocytosis may be expected to produce information on membrane activities and reactions that can be obtained in no other way.



POSSIBLE DIGESTIVE PARTICLES (*marked by pairs of white lines*) can be seen bumping into pinocytosis vacuoles (*within white circles*) in human cancer cells grown in tissue culture. Particles may inject digestive enzymes into vacuoles. Photomicrograph is one of a sequence made by George G. Rose of the Hermann Hospital in Houston, Texas.

from **INDIANA GENERAL CORPORATION**



Hysteresis Loop for FERRAMIC® Q-1

CREATIVE MAGNETICS

TO SHARPEN ELECTRONIC FIDELITY

Here are three examples of how Indiana General ferrites, technical ceramics and permanent magnets are helping manufacturers improve the eyes, ears and voices of entertainment instruments.

Our General Ceramics Division's research in ferrite materials for radio resulted in FERRAMIC® Q-1. This material made possible the first practical ferrite radio antennas, and is the standard of the industry today. Superiority is due to properties like a Q factor as high as 370, a typical temperature co-efficient of permeability of .04%/°C max., and unequaled resistance to changes in permeability and Q factor due to aging.

The miniature FERRAMIC bobbin and threaded cup core combination is another General Ceramics "first." It is ideal for IF transformers and all miniature inductors requiring high Q (as high as 70 at 200 mc for Q-3 material), high permeability and an adjustable tuning feature which keeps Q variance at a minimum. General Ceramics has also pioneered improvements in low-loss power ferrite materials for flyback transformers used in television receivers.

Permanent magnet materials introduced by our Indiana Steel Products Division have brought major television and radio design improvements. INDOX V ceramic speaker magnets with a guaranteed minimum energy product of 3.25 million BH max. have enabled manufacturers to cut magnet costs by 13%, speaker weight by 25%, speaker length by 46%.

The above is just a sampling of the advanced materials and designs Indiana General offers in the field of entertainment electronics. Our design engineers welcome the opportunity to work directly with you on your development program. Write us outlining your requirements.

INDIANA GENERAL CORPORATION VALPARAISO, INDIANA

Permanent Magnets • Ferrites • Technical Ceramics • Memory Products • Magnetic Separation and Handling Equipment

TIMM Circuits
(Thermionic Integrated Micro Modules)

the most practical solution to problems of micro-miniaturization, heat, and nuclear radiation in military electronic systems

TO MILITARY AND DEFENSE SYSTEMS MANAGEMENT:

An urgent invitation to support the TIMM circuit program in vital electronic systems involving aircraft, space aeronautics, surface weapons, ground support equipment, and data processing.

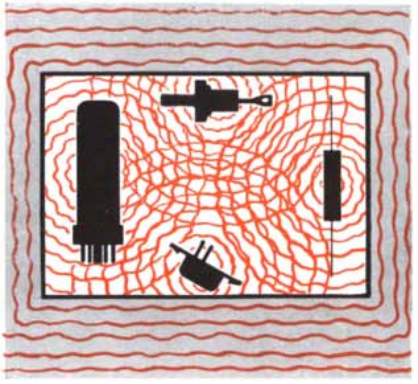
TIMM CIRCUIT FEASIBILITY HAS BEEN DEMONSTRATED

Many military and defense electronics projects currently under development, or pending, will benefit greatly from the practical miniaturization and proven high-temperature performance of TIMM assemblies. Reliability is inherent in TIMM circuits due to the initial choice of materials, processes and interconnection techniques. Logistics are simplified by the use of circuit building blocks made up of standardized TIMM assemblies which can be stored indefinitely, even at elevated temperatures.

TIMM assemblies represent a significant advance in micro-miniaturization techniques in that electronic equipment can now be designed which becomes more efficient and more reliable as packaging densities are increased.

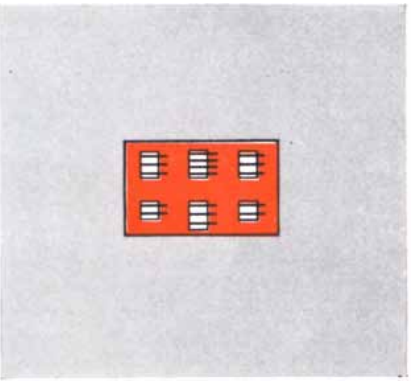
This TIMM circuit for a bistable multivibrator has an operating temperature-limit of 580°C and a component density of 250,000 parts per cubic foot as compared to 250°C and 26,350 parts per cubic foot for the best conventional circuitry. Depending on frequency and output requirements, component densities as high as 1,000,000 parts per cubic foot are possible.

TIMM DEVICES BREAK THE THERMAL BARRIER OF MICRO-MINIATURIZATION



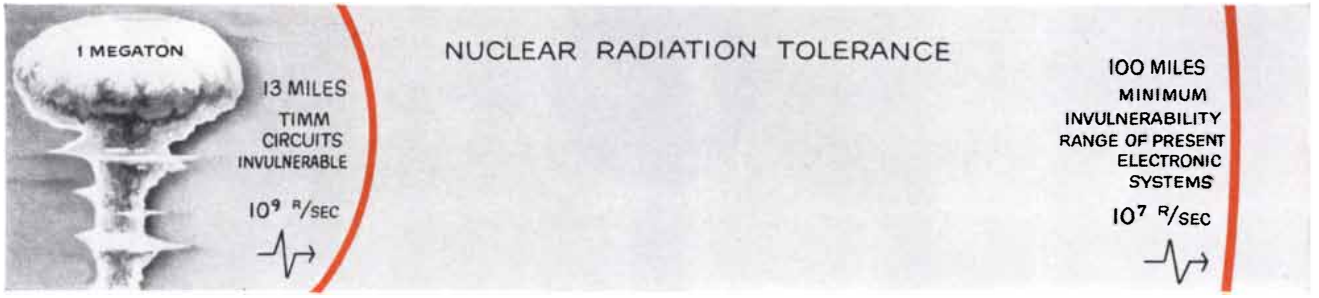
All electronic components give off heat when operating, resulting in lost power and high temperatures inside the electronic package. Progressive miniaturization increases the internal temperature and ultimately creates a thermal barrier (due to the use of temperature-limited components) which prevents further miniaturization.

At some point in the miniaturization process, it is necessary either to remove heat from the equipment package or increase the temperature ratings of the components. Conventional components require bulky cooling equipment to maintain satisfactory operation, thereby sacrificing space, weight, and ultimate system compactness.



TIMM is designed to operate at 580°C and therefore smash the thermal barrier associated with conventional components. By insulating the equipment package to conserve heat, and by increasing component density, very little input power is required. TIMM units eliminate the need for cooling equipment and allow maximum component density.

PREVENTS MALFUNCTION FROM NUCLEAR RADIATION AND HEAT



TIMM circuits, constructed only of metals and ceramics, tolerate more than 10,000 times the nuclear gamma-pulse radiation of circuits employing conventional devices. High-temperature operation of these materials eliminates output transients which normally result from high intensity gamma pulses. All materials used in TIMM circuit construction are at the top of the steady-state nuclear radiation tolerance scale.

TIMM assemblies are the only active components capable of operation at temperatures as high as 580°C. Even in high-temperature ambients, such as in missile nose-cones and re-entry vehicles, increased component and power densities are possible without the use of bulky cooling equipment. Constant high-temperature operation provides outstanding component stability and allows unlimited circuit-design possibilities.

Only a small portion of the TIMM circuit story can be told here. For more complete information, or to arrange a personal visit, write or call:

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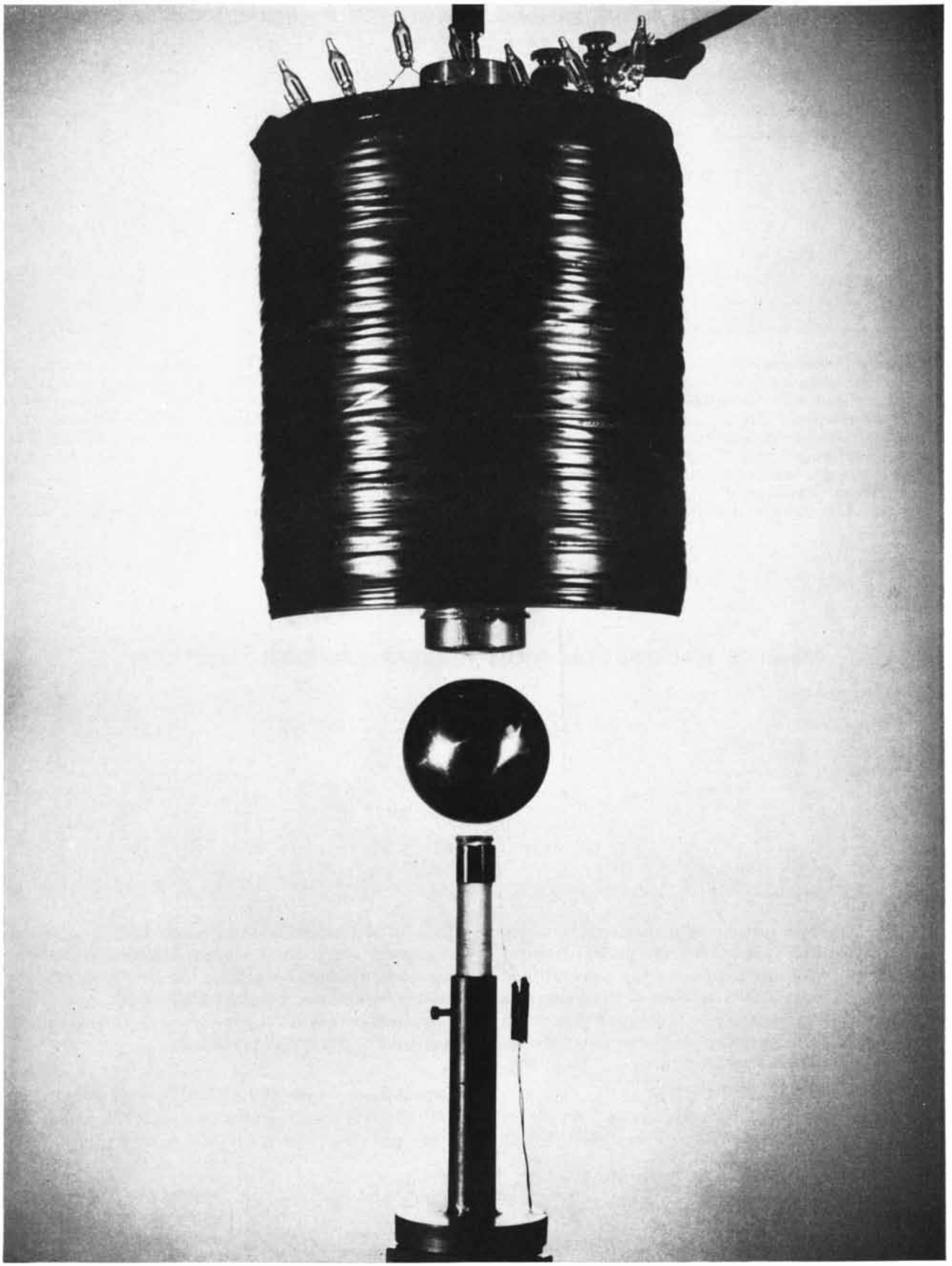


STEEL BALL ROTOR two inches in diameter is supported in mid-air by electromagnet above it. A coil below senses the rotor's position and changes the strength of the electromagnet to hold position constant. In operation the rotor is sealed inside a vacuum chamber and rotated by electromagnetic forces. All photographs accompanying this article were made in the laboratory of the author.

Ultrahigh-Speed Rotation

Centrifuges have now been made that can spin a tiny rotor 1.5 million revolutions per second. The evolution of these machines has provided instruments for a variety of scientific and technological applications

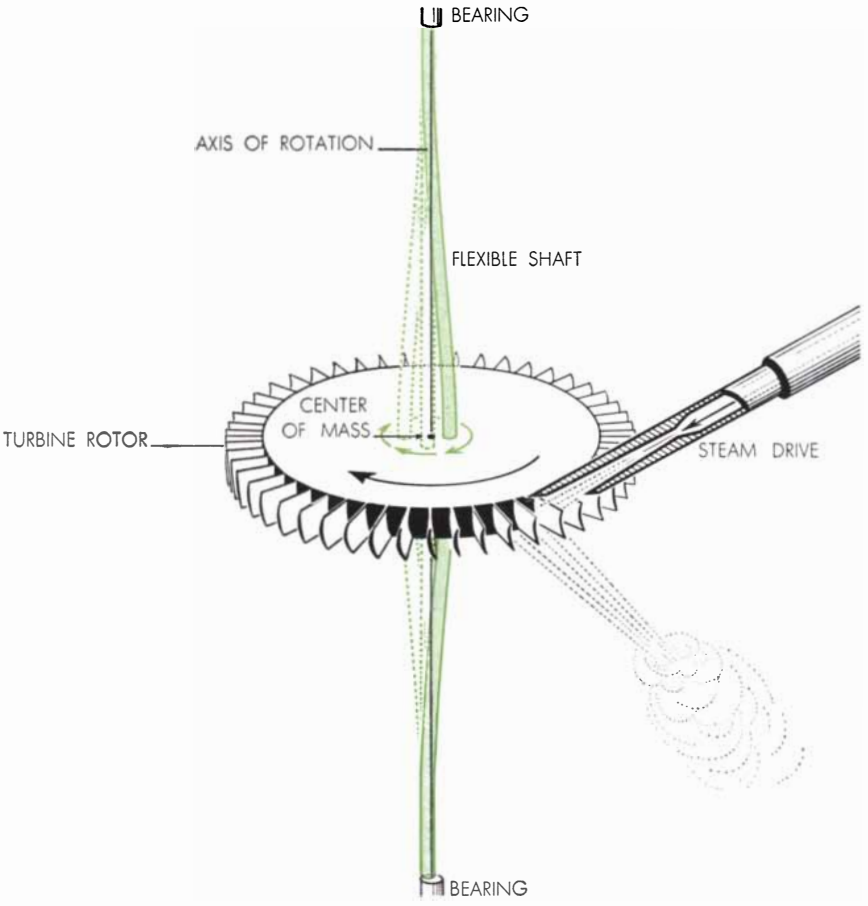
by Jesse W. Beams

To the physicist high-speed rotation is not an end in itself; it is a means for solving scientific or technological problems. But making things spin at ever higher speeds has been fascinating in its own right, and this is the topic of my article. Over the years I have had many able colleagues and students; their ingenuity is reflected in many of the mechanisms I shall mention.

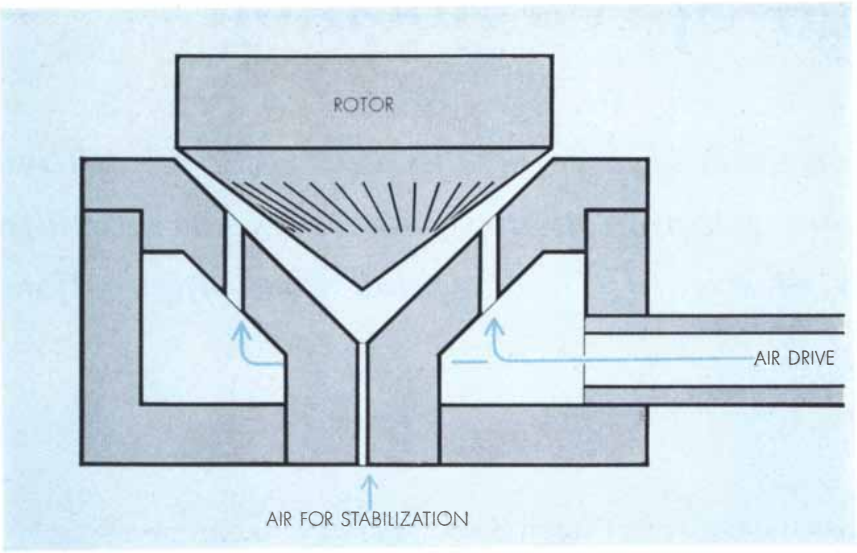
Our fastest machines can spin tiny rotors to speeds of about 1.5 million revolutions per second (not minute). These rotors, which have a peripheral speed of some 2,500 miles per hour, finally explode. Since they are only about a hundredth of an inch in diameter (smaller than the period at the end of this sentence) no serious damage is done. A peripheral speed of about 2,500 m.p.h. seems to be the maximum that can be achieved with ordinary spherical rotors and the strongest steel alloys now available. At top speed the peripheries of these small rotors are subjected to an acceleration of more than a billion times that produced by the earth's gravity. By using still smaller rotors we could obtain a still higher acceleration and for some of our current experiments we may try to achieve it.

Physicists use acceleration in a special sense, which should be explained, along with two other concepts: centripetal force and centrifugal force. When a boy swings a stone on a string, the stone is said to be in a centrifugal field. The force acting on the stone, however, is a centripetal force—it is directed inward to the center of rotation, or inward along the string. The centrifugal force is the equal and opposite force that the boy feels pulling his arm outward.

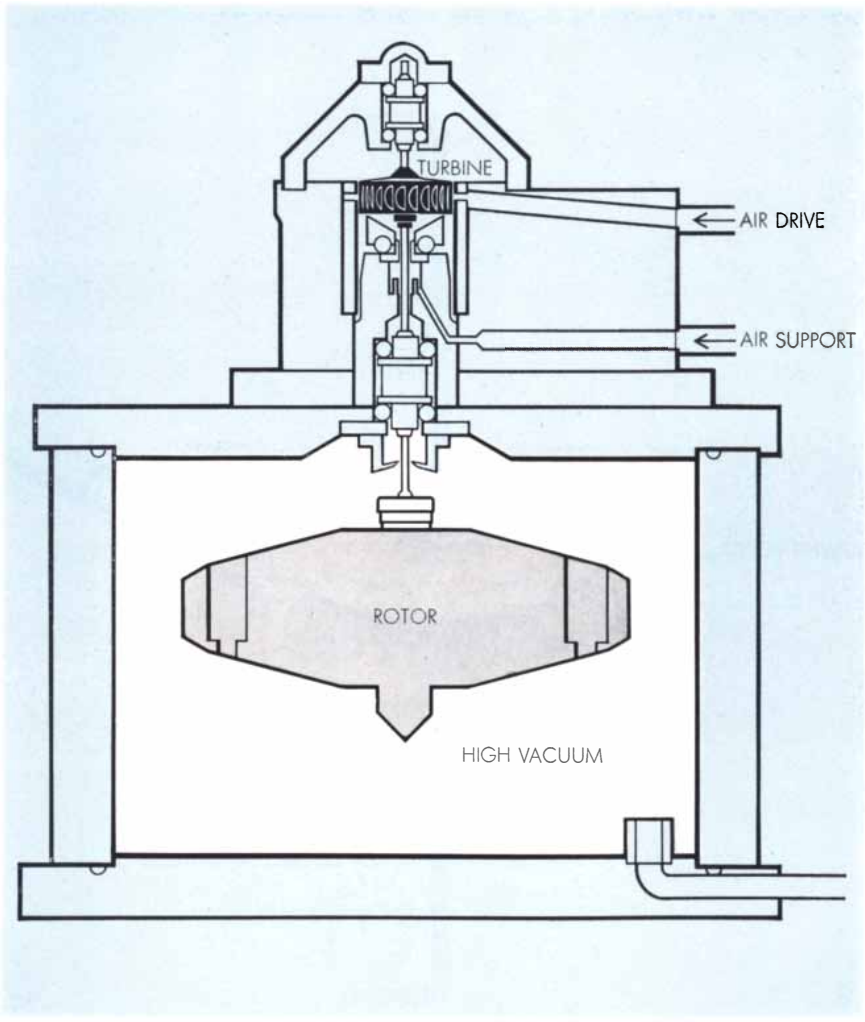
Whenever force is applied to a free object, the object is accelerated. If a body is moving in a straight line and a force is applied in the direction of motion, the body will move faster, or accelerate. But a force is also required to make a body change its direction, even if its speed is unchanged. Thus the physicist also regards a change in direction as an acceleration. In other words, he regards velocity as having both magnitude and direction; a change in either or both represents an acceleration. It is for this reason that a body rotating at constant speed is said to be accelerating constantly; and the acceleration is centripetal. Except at velocities approaching the speed of light, the centripetal acceleration of a mass is proportional to the cen-



FLEXIBLE-SHAFT TURBINE, invented by Carl G. P. de Laval in 1883, overcame problems of lack of balance in the rotor and vibration associated with stiff shafts. The flexible shaft permits the rotor to seek its "own axis of rotation" and spin about its center of mass.



SMALL AIR-DRIVEN ROTOR, designed in 1925 by E. Henriot and E. Huguenard of Belgium, is supported by a jet of air. Flutings milled into the rotor enable air to make it spin. Rotors an inch in diameter can be spun up to speeds of 4,000 revolutions per second.



EARLY ULTRACENTRIFUGE, designed by the author and his students, could spin rotors up to 10 inches in diameter at 1,000 r.p.s. The rotor, housed in a vacuum chamber, is spun by an air-supported, air-driven turbine. Rotor and turbine are joined by a flexible shaft.

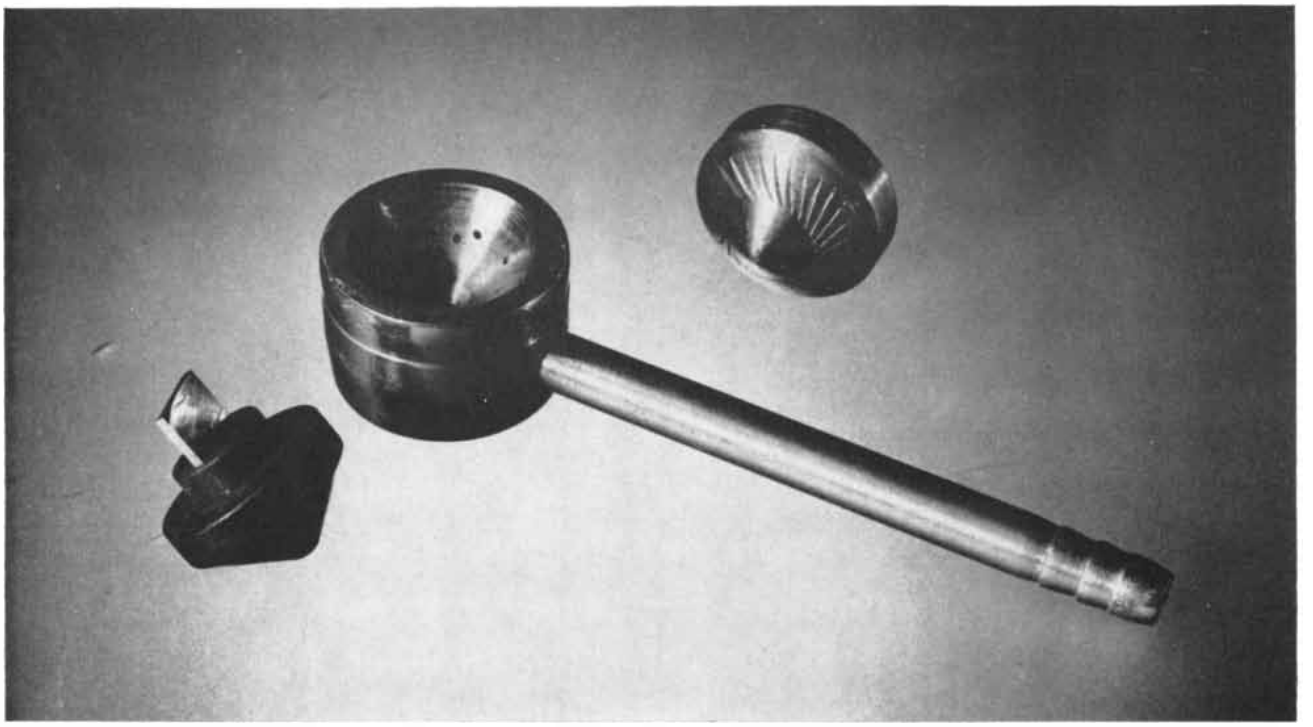
tripetal force. It is convenient to express centripetal acceleration in terms of the standard acceleration of gravity at the surface of the earth. This value, called g, is about 32 feet (or 980 centimeters) per second per second. When the rims of our small rotors are being subjected to a centrifugal field of a billion g, they are undergoing centripetal accelerations of 32 billion feet per second per second.

In the past century the maximum rotational speeds attainable have increased from under 500 revolutions per second (r.p.s.) to the present figure of about 1.5 million. In comparison, the wheel of an automobile traveling 60 m.p.h. rotates at about 12 r.p.s.; the crankshaft of an automobile engine, up to 100 r.p.s.; the turbine rotor of a jet engine, up to about 200 r.p.s.

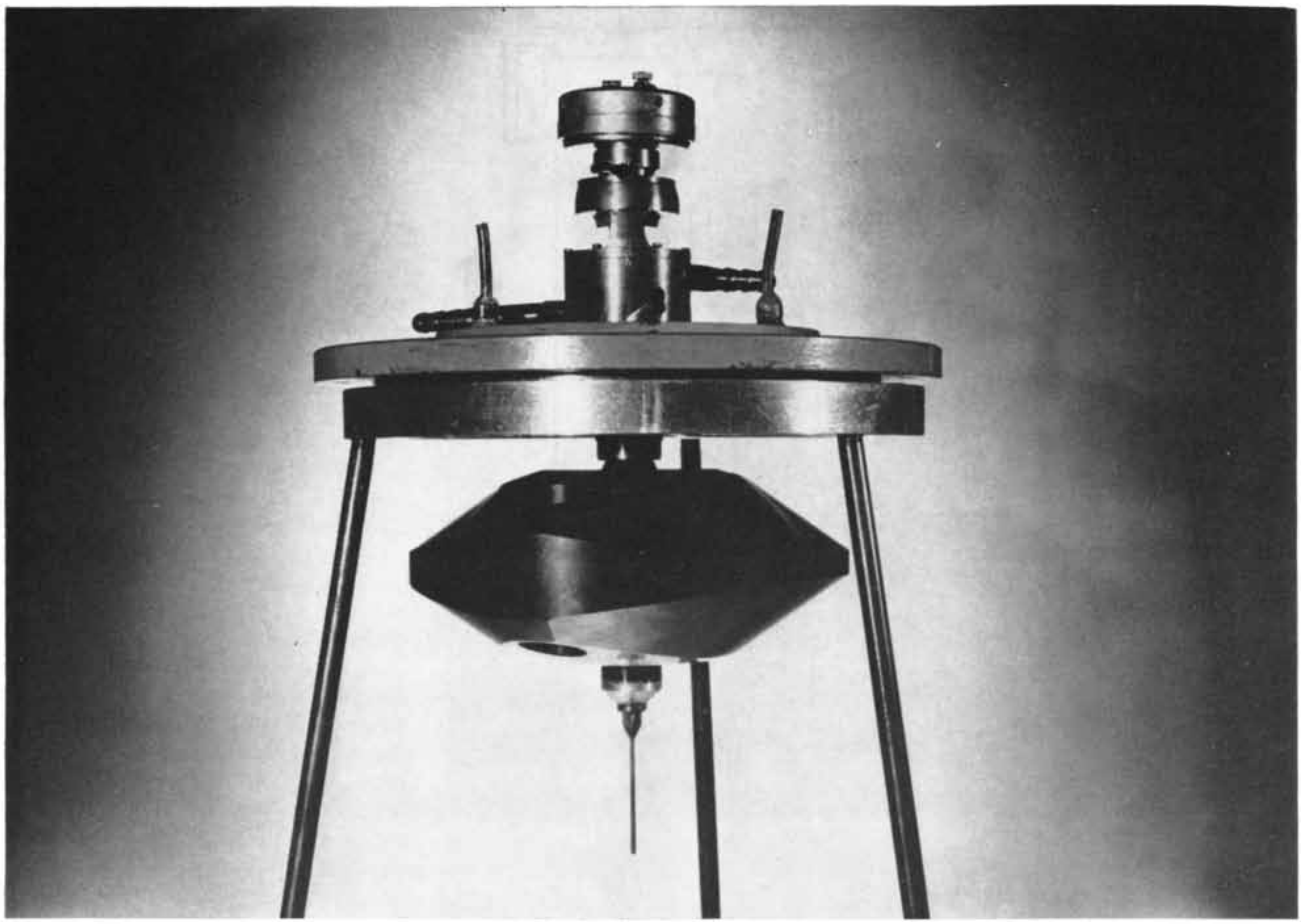
One might think that a rotor mounted on a simple shaft could be driven to almost any desired speed. Actually such a design runs into grave difficulties. If the rotor is even slightly unbalanced, large forces are exerted on the bearings holding the shaft, causing them to fail. More serious still, if the shaft is stiff, the rotor and shaft are easily set to vibrating like a violin string, which also leads to failure. Since it is extremely difficult to damp these vibrations if the imbalance is appreciable, in most practical cases they place a relatively low limit on rotor speeds.

The first designer to find a way around these twin problems was the Swedish engineer Carl G. P. de Laval. In 1883 he substituted a long flexible shaft for the conventional stiff shaft and built a small steam turbine capable of rotating at 700 r.p.s. The complete theory explaining why De Laval's design works is highly complex, but what it amounts to is that a flexible shaft will permit even an unbalanced rotor to spin about a line passing approximately through the rotor's center of gravity. This axis is often referred to as the body's "own axis of rotation."

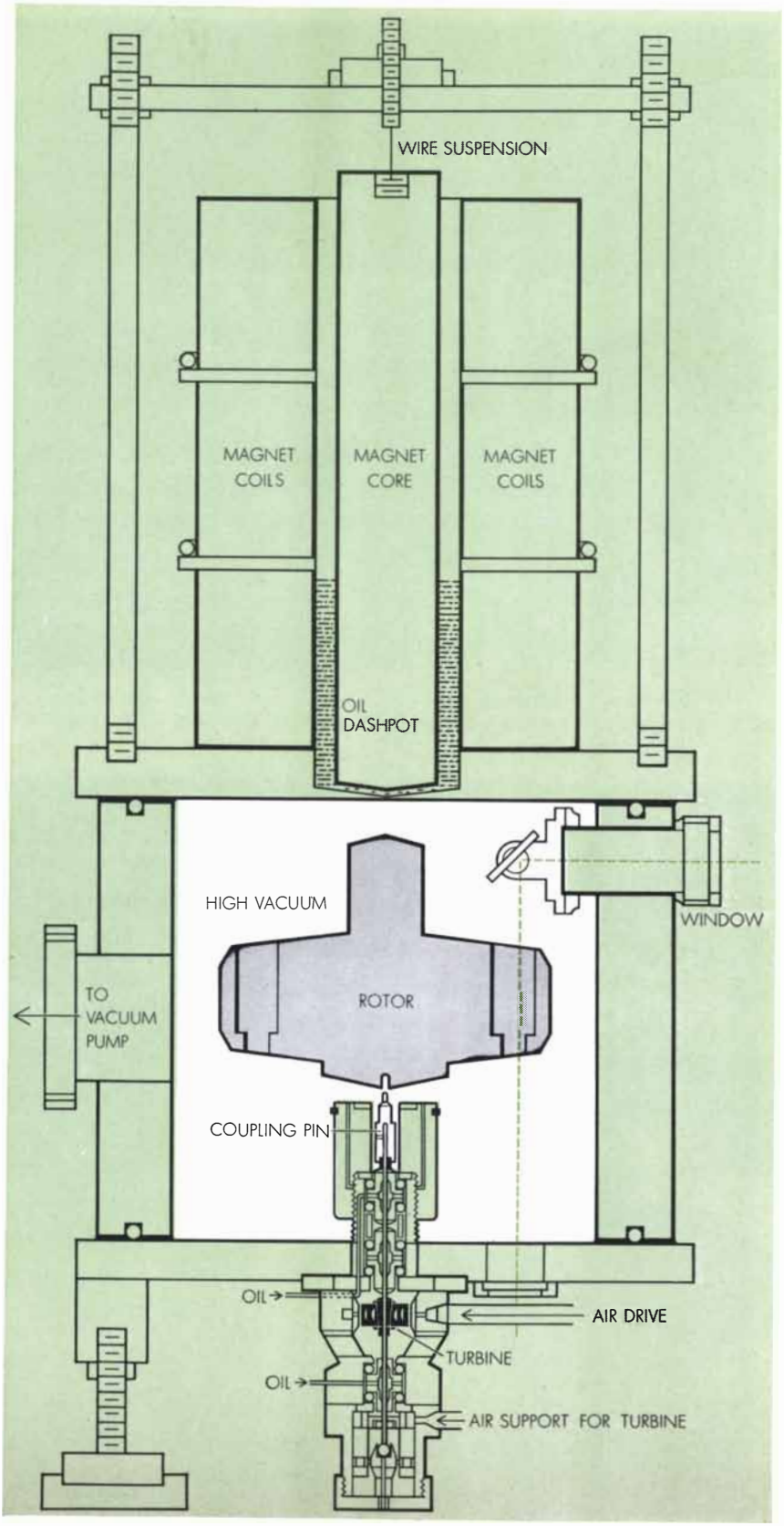
A number of De Laval's small early turbines were used to drive cream separators. Later De Laval used the flexible-shaft principle in his famous single-stage steam turbine [*see illustration on preceding page*]. In these larger machines he obtained rotor speeds of more than 400 r.p.s. and a peripheral speed of 1,300 feet per second, several hundred feet higher than competitive turbines. The extra speed gave De Laval's units a big edge in efficiency, for efficiency increases steadily until the peripheral speed of the



CONE-SHAPED ROTORS designed by Henriot and Huguenard carry a mirror, as at left, for light experiments. Compressed air enters stator (*center*) through a tube. The flutings that cause the rotor to spin can be seen on the underside of the plain rotor.



OLDER ULTRACENTRIFUGE of type shown in diagram at bottom of preceding page has a turbine driven by compressed air. The vacuum housing in which rotor spins has been removed here so that the rotor can be seen. This mechanism was designed in about 1934.



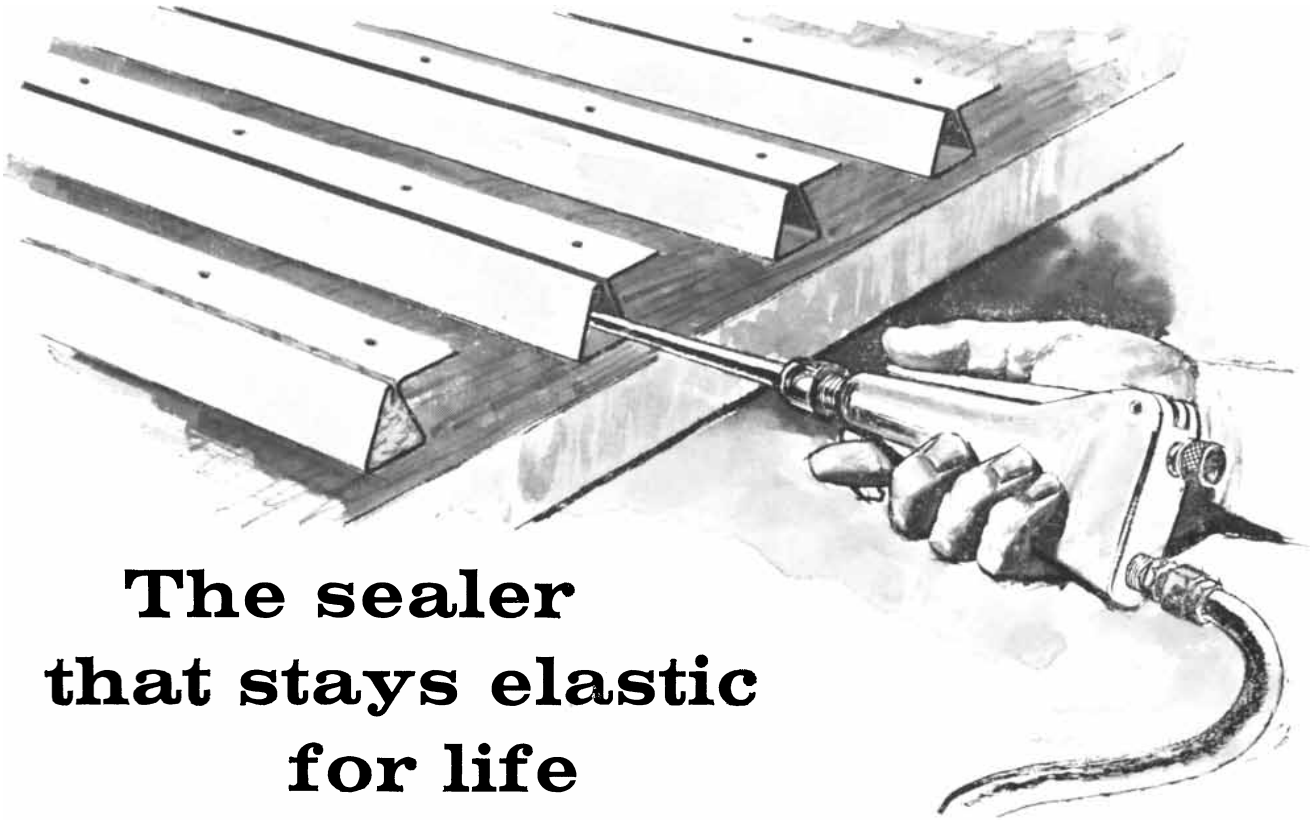
MAGNETIC SUPPORT SYSTEM in an air-driven ultracentrifuge lets the rotor coast freely after it is spun up to full speed and disengaged from drive shaft, as shown here. Unless forcibly decelerated, the rotor would spin for years. Magnetic core in oil dashpot supports rotor and damps drift. Window permits observation of sedimentation of sample in rotor.

turbine reaches about half the speed of the steam jet.

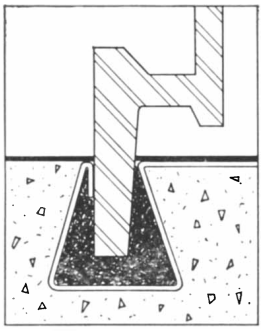
The next significant advances in high-speed rotation came in the 1920's. At the University of Uppsala in Sweden, Theodor Svedberg began building the first of the machines he called "ultracentrifuges," designed to measure molecular weights. The machines incorporated a system of lenses for making photographic records of the sedimentation rate of substances as viewed through a window in the spinning rotor. (A modern system for this purpose is illustrated on page 146.) To reduce friction and minimize the build-up of temperature, the rotors were sealed in a chamber containing hydrogen at a pressure of a few millimeters of mercury (atmospheric pressure is 760 millimeters). The first of Svedberg's ultracentrifuges to give good sedimentation data were electrically driven and rotated at about 170 r.p.s. Over the next few years Svedberg built oil-driven units that turned at more than 1,000 r.p.s. and produced centripetal accelerations as high as 900,000 *g*. Because he never adopted the flexible-shaft principle his machines required the greatest care in design and workmanship. Partly for his investigations of giant molecules, Svedberg was awarded the Nobel prize in chemistry in 1926.

In the previous year two Belgian workers, E. Henriot and E. Huguenard, had conceived the simple idea of spinning a small fluted rotor on a jet of air [*see top illustration on page 136*]. The rotor is raised from its resting place by the airstream and automatically seeks a position in space where its weight is just counterbalanced by the pressure of air from below. The rotor is constrained from flying off to one side or the other, or out of the stator cup, by the operation of Bernoulli's principle, which states that if the speed of a fluid stream is increased, its pressure must decrease. Thus if the rotor should begin drifting to one side, the air velocity would increase on the side opposite and fall in pressure; the rotor would then move back in the direction of reduced pressure. Since the rotor is not connected to a shaft, moreover, it is free to seek its own axis of rotation. By this means Henriot and Huguenard were able to spin small rotors, an inch or less in diameter, to several thousand revolutions per second and to produce centrifugal fields of around a million *g*.

It was this system that came to our attention in the late 1920's, when Ernest O. Lawrence and I were looking



The sealer that stays elastic for life



The sealing compound used in internal, inaccessible joints must give permanent, dependable service.

Sealant failure in such "hidden" joints means trouble. Refilling is costly, if the joint can be reached at all. The only practical answer to such problems is to do the job right the first time with a sealer that never quits—a sealer like Armstrong's new P-606.

A California firm* put this lasting quality of P-606 to good use in developing a new method for installing metal window frames. Metal joint channels, pre-filled with P-606 at the factory as shown above, are imbedded in concrete at the building site. Window frames are then inserted into the channels, forming a lasting, weatherproof seal, and eliminating job site caulking.

The secret of P-606's success in such applications is simple. It stays elastic, eliminating the major cause of sealant failure—drying out and cracking. P-606 does the job right the first time and lasts the life of the joint.

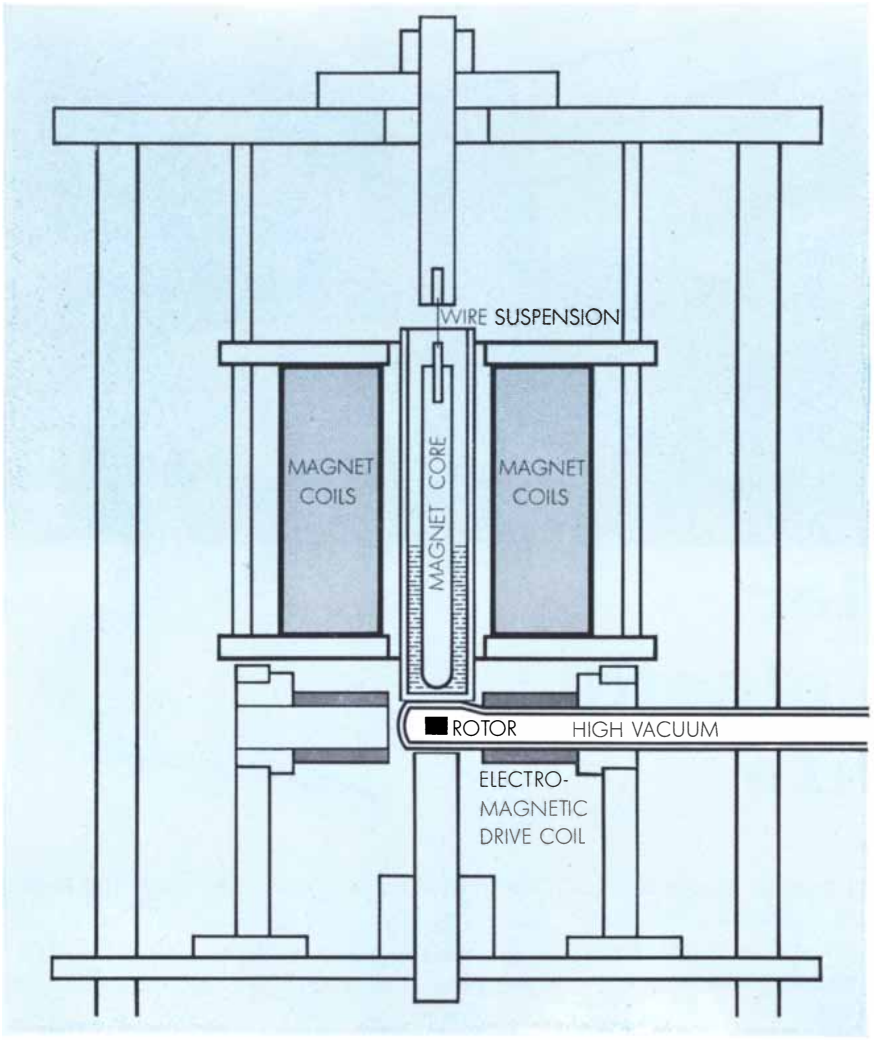
P-606 has excellent adhesion to most materials—metal, glass, rubber, concrete—and it retains this characteristic through extensive aging at temperatures from 160° to −40° F. Shrinkage is negligible since P-606 is more than 90% solids. And P-606 stays where you put it without slumping. Applied with a hand gun or pressure pump system, P-606 forms an effective, permanent seal against air, dirt, dust, and moisture.

These superior properties have made this sealer suitable for a wide range of uses. Voids in air conditioners are filled with P-606 to reduce vibration and prevent air leaks. Riveted truck trailer joints are permanently sealed with P-606. It is even used by a pre-fabricated home manufacturer to seal unexposed joints between concrete wall sections.

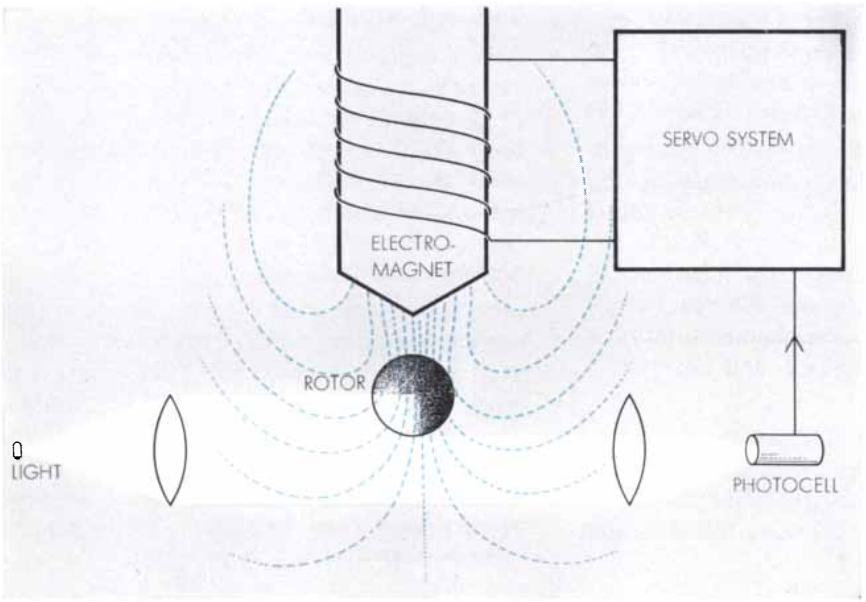
In many cases, P-606 costs less than the sealant previously used. Maybe you have a sealing job that could be done better and more economically with P-606. We will be glad to advise—and furnish samples of P-606—if you will submit full details of the application to the Armstrong Cork Company, 8004 Inland Road, Lancaster, Pennsylvania.

* Name supplied on request

Armstrong ADHESIVES



SHAFTLESS ROTOR made of ferromagnetic material is suspended in magnetic field and is spun, like the armature of an induction motor, by electromagnetic force. Small rotor can reach 1.5 million r.p.s. Magnetic core in oil dashpot prevents horizontal drift of rotor.



OPTICAL CONTROL of vertical drift of rotor is exerted by photocell. If rotor moves up or down, amount of light reaching photocell changes, activating a circuit to change strength of electromagnet that holds rotor up. System works so well rotor cannot be seen to drift.

for a way to make high-speed photographs of the breakdown of electric sparks and of other phenomena of very brief duration. By mounting a mirror on an air-driven rotor we were able to build a high-speed camera that met our needs. This was my introduction to high-speed rotation.

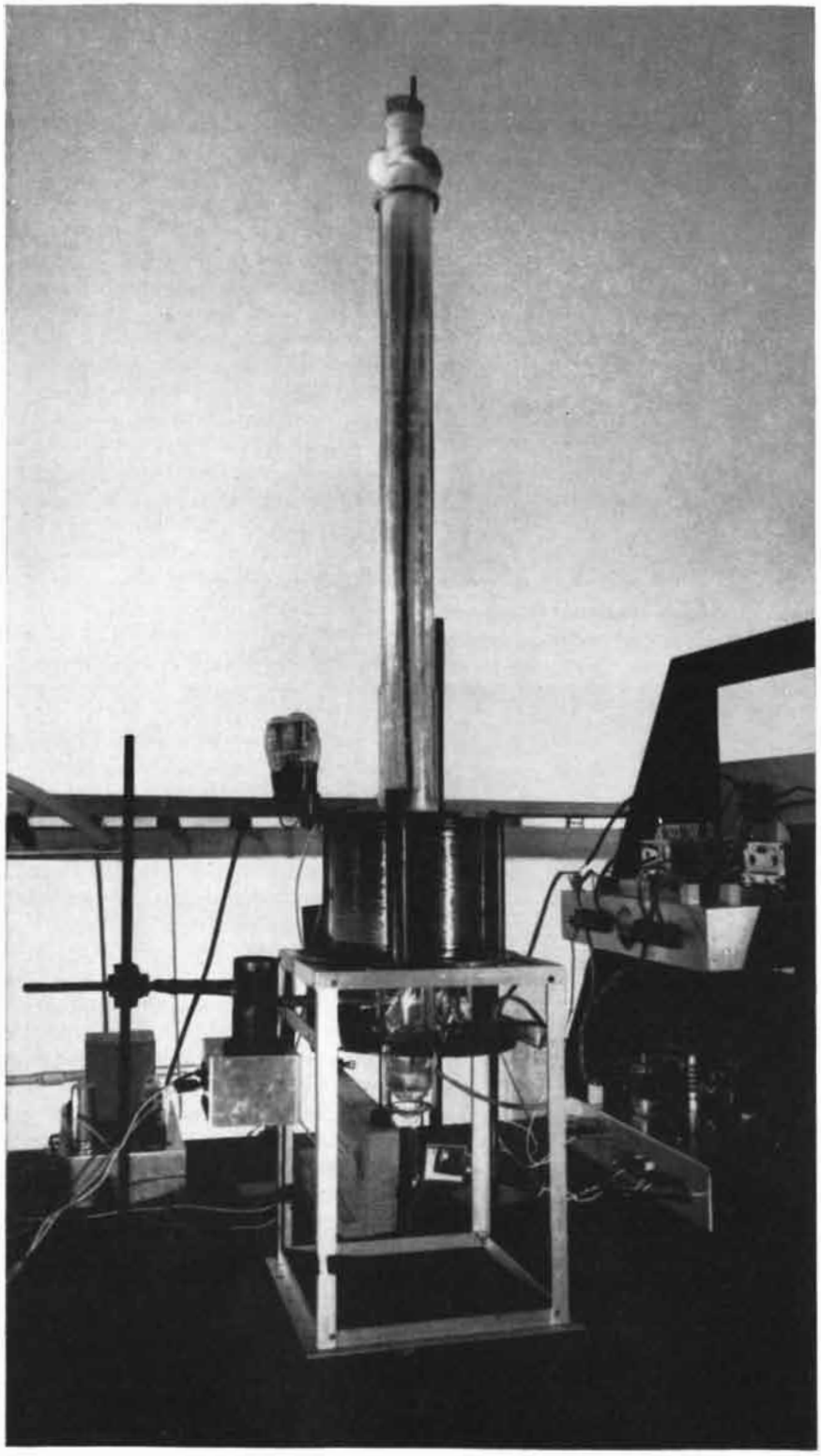
The question naturally arose as to whether we could use a simple air-driven rotor for sedimentation measurements of the Svedberg type. The answer proved to be yes, but the air drive had many drawbacks. If the rotor speed is high, the air or gas friction becomes so great that the rotor will not reach high speeds unless it is small or unless much power is used to drive it. In either case air friction heats the rotor unevenly and tends to set up convection currents in the solution being analyzed, spoiling the results.

We undertook, therefore, to build ultracentrifuges in which the rotor could be spun in a high vacuum. We found we could spin a large rotor (up to a foot in diameter) by sealing it inside a vacuum chamber and driving it by a small air-supported, air-driven turbine located either above or below it [*see bottom illustration on page 136*]. We also adopted De Laval's idea of the flexible shaft to connect the turbine to the rotor. This allowed the rotor to seek its own axis of rotation. One of the most difficult problems in this design, finally solved, was development of a practical vacuum-tight oil gland for the shaft to pass through. The design of our vacuum-type ultracentrifuge has gone through many modifications and, in improved commercial versions, can be found in many laboratories. The usual commercial model spins a seven-inch rotor up to about 1,000 r.p.s., producing a centrifugal field of a few hundred thousand *g*. Ultracentrifuges of this general type have been the principal work horses of molecular sedimentation experiments in this country for the past 25 years.

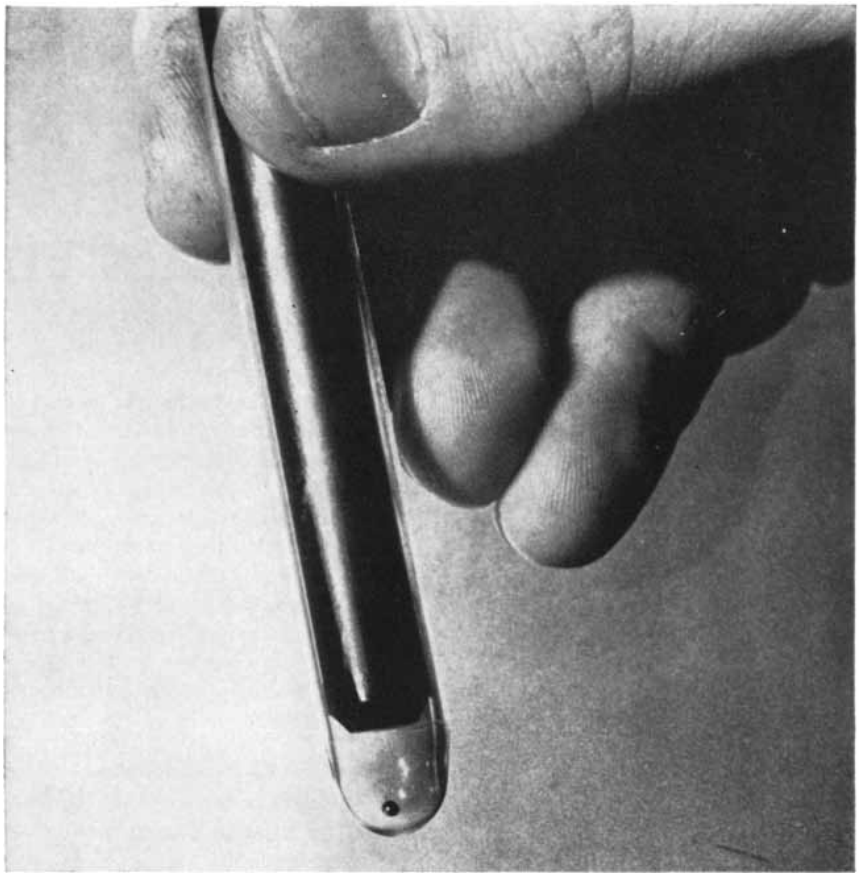
Within the past dozen years many of the air-driven and electrically driven models have incorporated a magnetic-support system [*see illustration on page 138*]. After the rotor is spun up to operating speed, the air or electrical drive coupling is disengaged and the rotor coasts freely, supported only by a magnetic field. It turns out that the friction in this magnetic support "bearing" is too small to be measured. A 30-pound rotor coasting at 1,000 r.p.s. in a high vacuum (a millionth of a millimeter of mercury) will lose only about 1 r.p.s. in a day. Essentially all the slowing down is due to friction with the air remaining in the vacuum chamber.

The ideal rotor drive would be one that did not need a turbine and could therefore be shaftless. The rotor, resting on a friction-free bearing, would freely seek its own axis of rotation at speeds limited only by the rotor's inherent strength. This ideal, of course, cannot be completely achieved. Starting in 1937, however, a number of other workers and I at the University of Virginia began developing magnetically supported, electromagnetically driven rotors that closely approached the ideal.

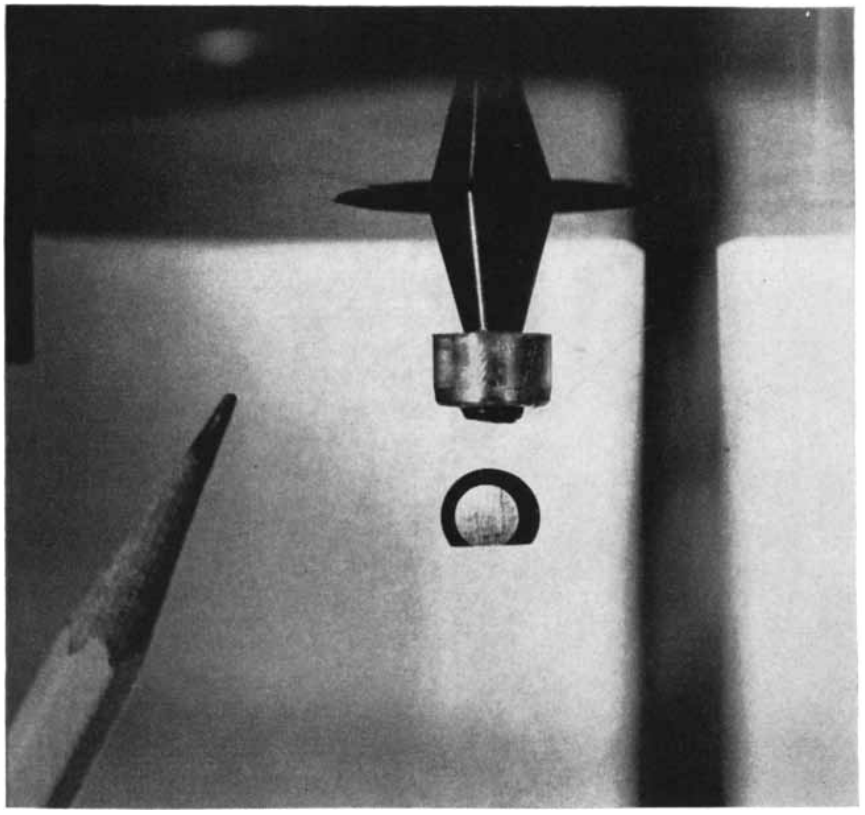
These rotors, made of ferromagnetic



HIGH-SPEED ROTATION DEVICE, currently being used by the author, spins 1/64-inch spheres at a million r.p.s. Liquid helium surrounding the vacuum chamber holds the temperature near absolute zero so that gases freeze out, resulting in a near-perfect vacuum.



PELLET IN VACUUM TUBE, along with ferrite magnetic core, is inserted in apparatus shown on preceding page. There the tube is surrounded by liquid helium to increase vacuum.



ROTOR WITH MIRROR FACE spins at 25,000 to 30,000 r.p.s., the speed being held constant to within one part in 100 million. Rotor is used for ultrahigh-speed photography.

material, are spun by the same electromagnetic forces that turn the armature of an induction or synchronous motor. Housed in a vacuum, the rotors are magnetically stabilized. The lines of force in the magnetic field parallel the axis of the rotor, but they diverge toward the bottom; consequently the rotor will seek the strongest part of the field and will tend to remain centered. Any residual motion is damped by hanging the steel cylindrical core of the supporting magnet in a dashpot of oil; if the rotor starts moving to one side, the core follows it and brings it back into proper position. In one system the vertical position of the rotor is monitored by the shadow the rotor casts on a photocell. A rise or fall in the rotor activates a circuit that makes an appropriate change in the strength of the electromagnet holding the rotor [*see bottom illustration on page 140*]. When everything is adjusted, no movement of the rotor, either horizontal or vertical, can be detected with a 100-power microscope.

The size of the rotor can be varied widely. We have supported and spun rotors ranging from less than a thousandth of an inch in diameter to more than a foot. Their weights have varied from about a billionth of a pound to more than 100 pounds.

The rotational speed at which a rotor will explode depends greatly upon the shape of the rotor and on the precision with which it is made. For carefully made rotors of the same shape, the bursting point is proportional to the mechanical strength of the material divided by its density. For example, when a series of steel spheres of different radii were spun to destruction we found that all exploded at the same peripheral speed, about 3,000 feet per second, or 2,000 m.p.h.

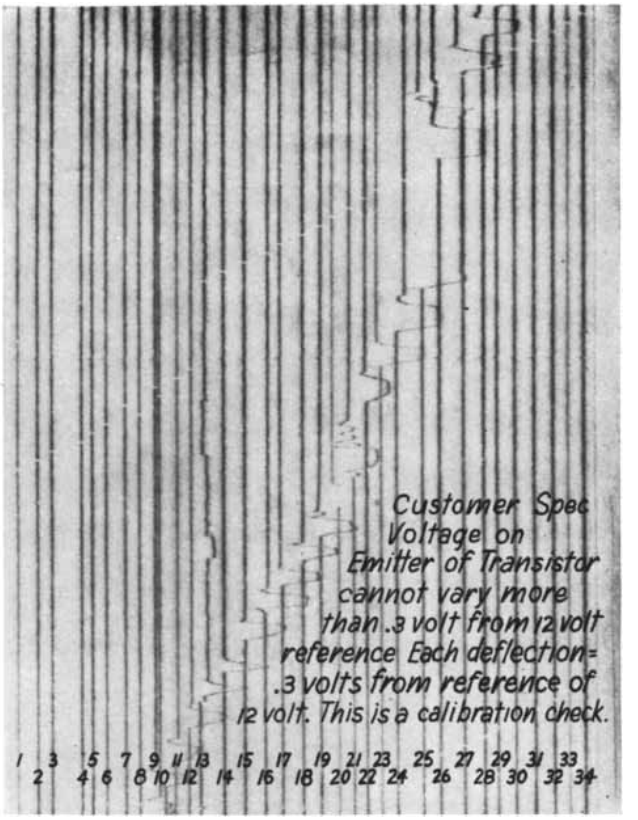
In this article there is room to touch on only a few applications of high-speed rotation. In one series of experiments performed with rotors spun to bursting speed we tested the strength of thin metal films. By electrodeposition we coated small cylindrical rotors with silver films of measured thickness. In some cases we sought maximum adhesion of film to rotor; in others we deliberately spoiled the adhesion by coating the rotors with albumin before the electrodeposition of film. In the latter the observed strength of the film is due solely to its inherent tensile strength.

In the tensile-strength experiments we found that for films thicker than six hundred-thousandths (6×10^{-5}) centimeter, strength is independent of thickness, being about equal to that of bulk

The VISICORDER records transistor torture

Transistors often have to work under incredibly severe environmental conditions. Production-testing them gave engineers at Honeywell's Semiconductor Division a chance to exploit the great versatility of the 36-channel Visicorder oscillograph Model 1012.

A certain order of transistors had to withstand vibrations of 10G at 10 to 2,000 cps without failing during the test or as a result of it. A standard test had been to measure the transistor's performance, next subject it to non-active vibration (not in any circuit), and then re-measure. This approach was obviously deficient as it did not reveal *operating* characteristics during test, nor did it disclose *intermittent*-type failures.



Unretouched record of vibration test on 36 transistors, each active in its own circuit during test.

In this photo, shaker table is at right and amplifier-circuit rack at left, flanking the 36-channel Model 1012 Visicorder.

The customer's quality requirements were stringent (AQL = .4%) and the large test sample required ruled out the use of an oscilloscope. The 3-hour test would have made a battery of scopes and operators necessary; transient defects would be missed due to eyestrain, fatigue, etc.

The Model 1012 Visicorder was chosen for the task as it simultaneously measures and records 36 channels of test information throughout the test period. The Visicorder instantly and directly records transients, no matter how random.

A Visicorder record like this is always a welcome supplement to your test data—your customer will be able to read it quickly and with full understanding. And it is a *permanent* record which *he* can show to *his* customer, if necessary.

For further information on how Visicorders can help to solve your instrumentation problems, contact your nearest Honeywell sales office without delay. Or write for Catalogs HC 906, 1012, 1108 and 1406, to:

Minneapolis-Honeywell, Heiland Division, 5200 East Evans, Denver 22, Colorado, SK 6-3681—Area Code:303

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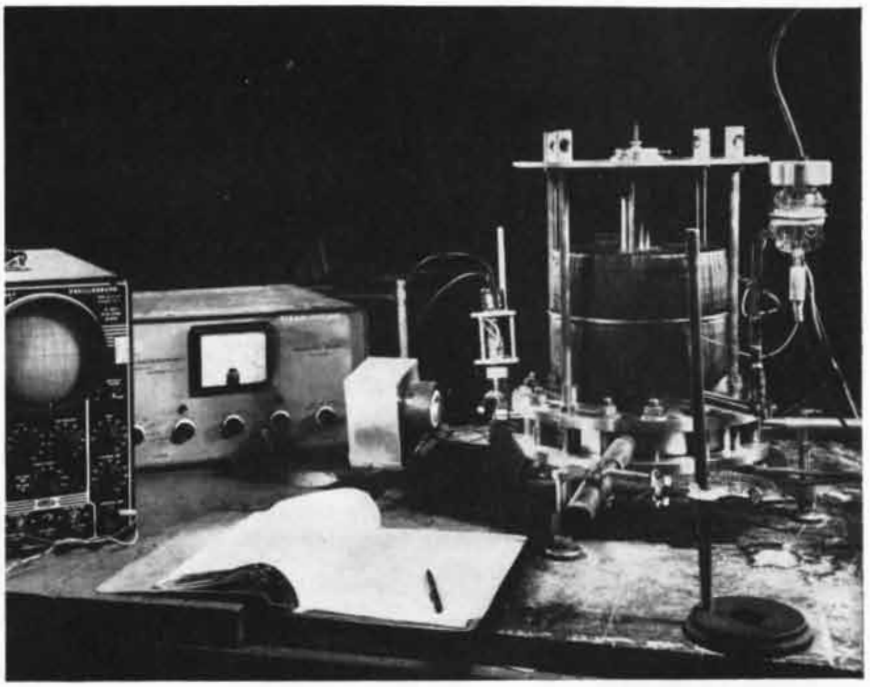
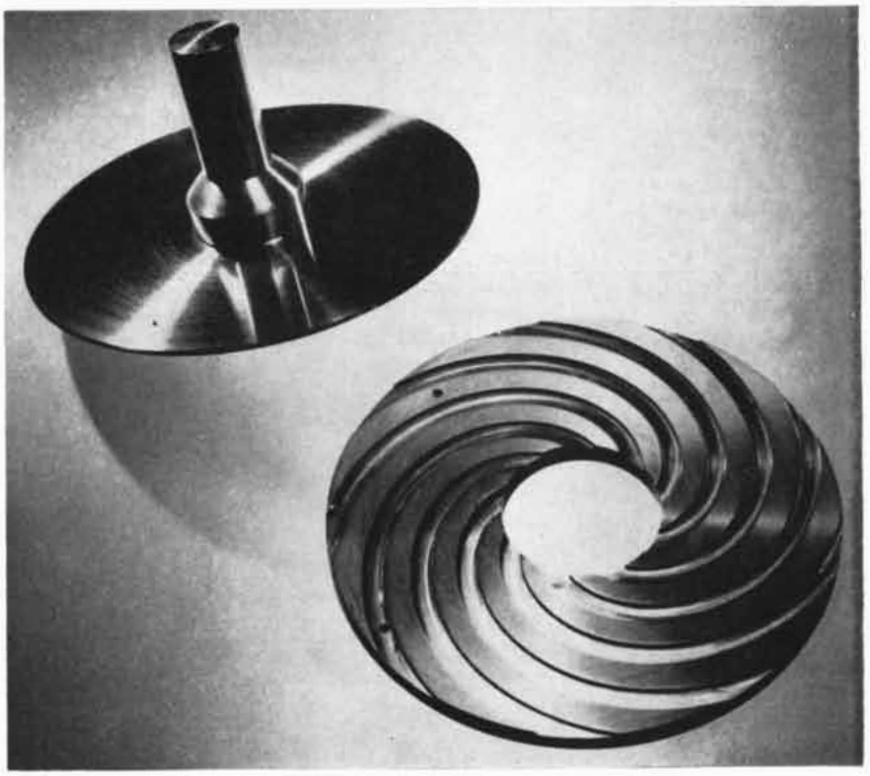
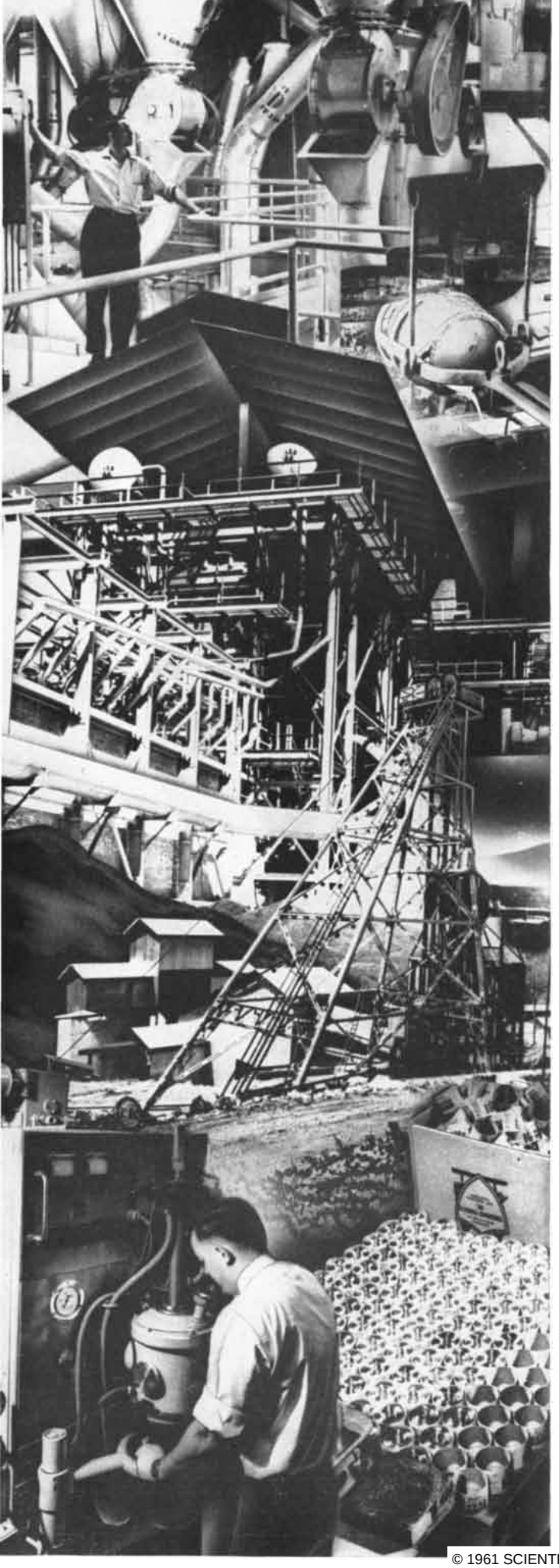
silver. For films thinner than 2.5×10^{-5} cm., the tensile strength rises so sharply that the rotors will explode before the film breaks. The tensile strength of these thin films is at least 30 times that of bulk silver. Their strength seems largely attributable to the locking of crystal dislocations and to the difficulty of generating new dislocations in such thin material.

The widest use of high-speed rotation, of course, is to bring about sedimentation of substances differing either in size or in density. It is common knowledge





HIGH-SPEED CENTRIFUGAL VACUUM PUMP in top photograph achieves a vacuum so nearly perfect that no gauge can measure it. Stator and rotor of the pump appear in bottom photograph. Air molecules are whirled outward along rotor grooves, producing vacuum.



NEW YORK, April 2 -- IN THE 10-DAY PERIOD ENDED MARCH 28, ASARCO FILLED ORDERS FOR 22 BASIC COMMODITIES. THEY RANGED FROM 25 GRAMS OF HIGH PURITY ARSENIC TO 5,000,000 POUNDS OF LEAD. ASARCO ALONE AMONG WORLD PRODUCERS HAS ABILITIES AND FACILITIES TO EXTRACT, REFINE AND DELIVER SO MANY BASIC MATERIALS.

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Sulfuric Acid and Sulfur Dioxide
Tellurium
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Asarco's vast technical knowledge of these and many other basic elements is available to help you solve your materials research and application problems. If you are planning a new product or re-designing one, call Asarco for assistance in producing it better, more economically. Write on your company letterhead to: PR Dept., American Smelting and Refining Company, 120 Broadway, New York 5, N. Y.

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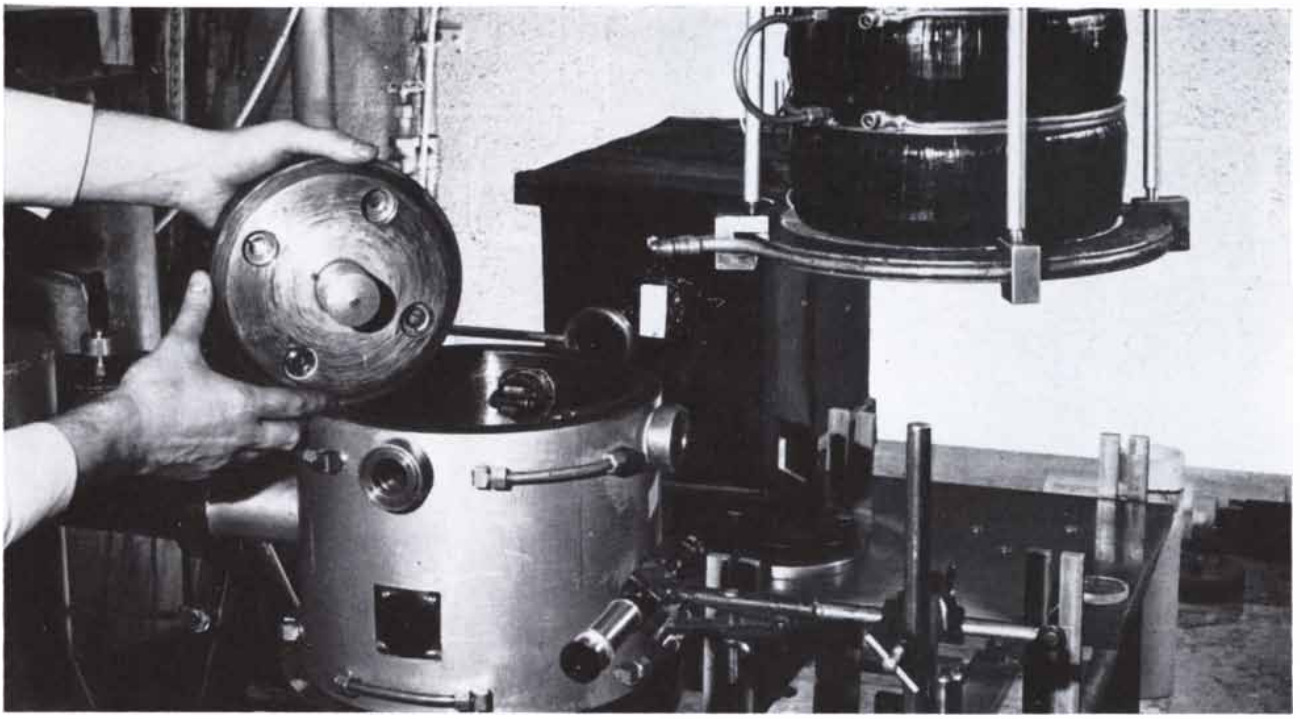
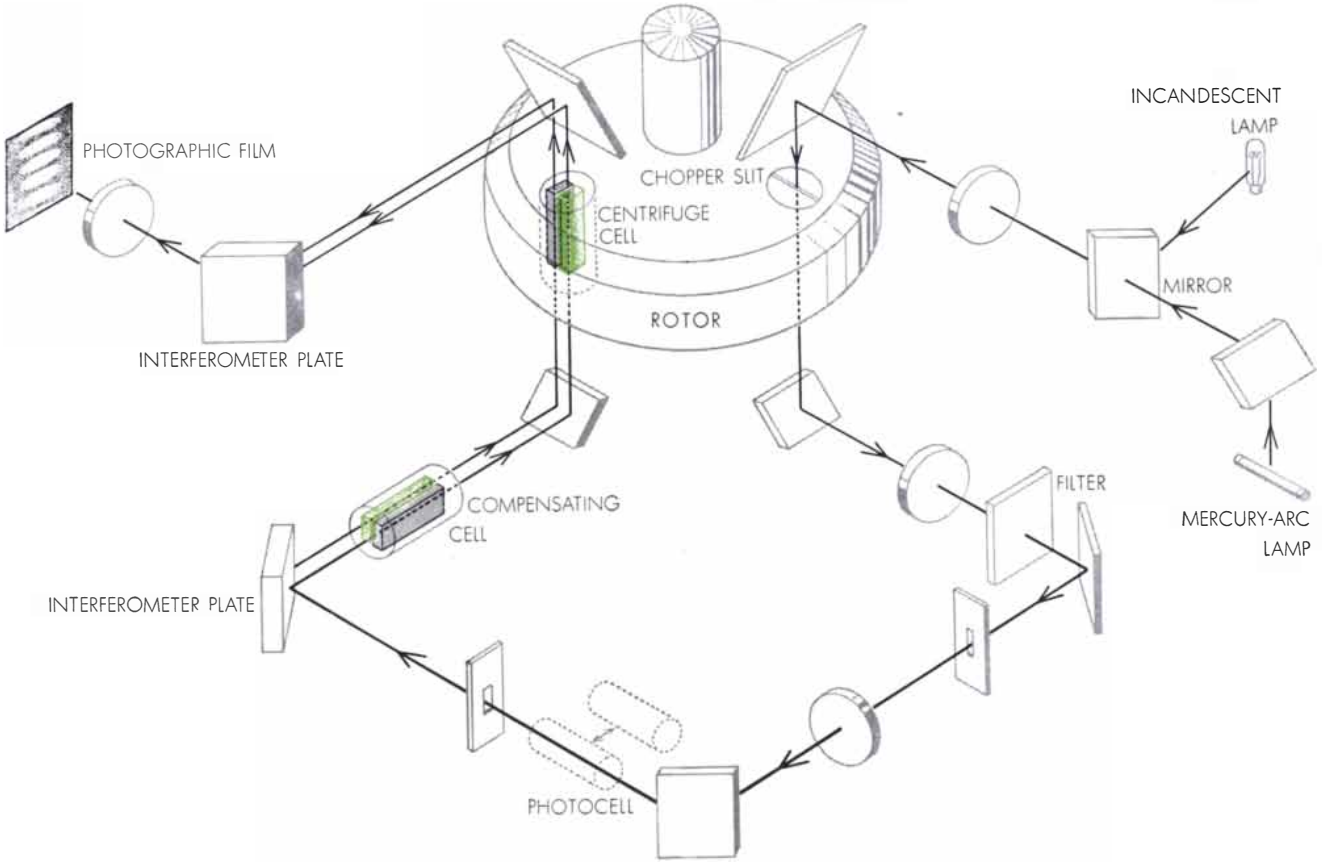


MOLECULAR WEIGHT DETERMINATIONS are made in an ultracentrifuge equipped with a special optical system (*diagramed below*) that reveals sedimentation rate. The rotor has four openings: one sample cell, one light slit and a counterbalance for each.



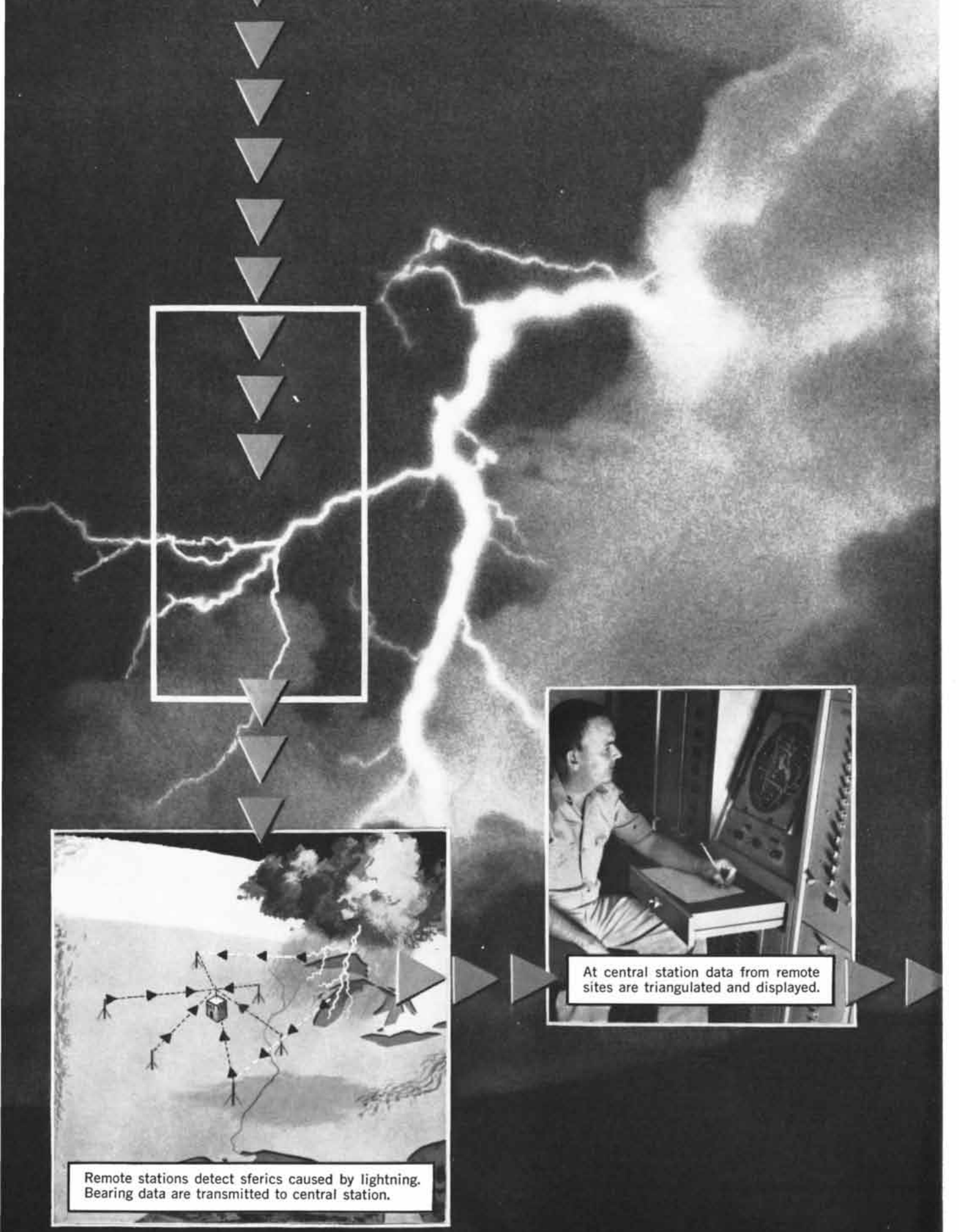
INTERFEROMETER SYSTEM splits one light beam into two, makes both travel through precisely same distance, then reunites them. One beam goes through a cell containing sample being measured (*color*), then through centrifuge cell holding only the solvent sample is dissolved in. Other beam travels first through solvent in compensating cell, then through sample in centrifuge (*color*). Optical path of each beam is the same, except for differences caused by sample undergoing centrifugation. Light is refracted differently in different parts of centrifuge sample cell, producing interference pattern on film. Pattern shows rate of sedimentation, which depends upon molecular weight of sample. The two light sources are not used together; removal of mirror permits use of mercury arc.

that if one mixes up a thin slurry of mud, the heavier particles will settle first, followed by finer ones. If the force causing the particles to settle is doubled, the rate of settling doubles also. With very high centrifugal fields it is possible to throw most ordinary solids out of solution, though this may seem to violate the textbook definition of the term "solution."

Ordinary sugar, for example, stays in solution because it would take more than 100 years for a sugar molecule, suspended in water, to fall one millimeter in the earth's gravitational field. In actuality settling never even starts because the velocity of settling is many orders of magnitude smaller than the average velocity, due to thermal agitation, of all the molecules in the solution. However, if the solution is placed in a centrifugal field of a million *g*, the sugar molecules will have a sedimentation rate of two-thirds of a millimeter per hour. It is this great amplification of sedimentation rate that makes the ultracentrifuge useful for determining molecular weight. Modern ultracentrifuges are capable of determining molecular weights to a precision of much better than 1 per cent over the entire molecular weight region from about 50 to at least 100 million. A recent value obtained for sugar, for example, is 343, which compares very well with the value of 342.3 determined by other means. The centrifuge method is especially useful, of course, for determining the mass of large organic molecules.

As early as 1937 we were able to show at the University of Virginia that the isotopes of elements could be purified by centrifugation. The history of the great uranium separation plants at Oak Ridge testifies to the difficulty of the separation problem. Although a pilot plant for separating uranium 235 from uranium 238 by centrifugation was successfully operated at Bayway, N.J., early in World War II, the electromagnetic and gaseous-diffusion methods were finally selected for use at Oak Ridge. Within the past year, however, reports from Europe indicate a renewed interest in the centrifuge method as a possible way to obtain "cheap" fuel for nuclear reactors.

High-speed rotors provide the highest sustained speeds that can be achieved mechanically inside a small laboratory. They also provide the highest sustained accelerations attainable by any means. These two attributes make it certain that scientists and engineers will continue to find new uses for the techniques of ultra-high-speed rotation.



Now... Forecasting by Lightning

New Lockheed Electronics weather system spots storms up to 2,000 miles away

When a storm is brewing, lightning may send warnings hours before it is detected by weather radar. Lightning flashes (sferics) give valuable clues to weather conditions, but until recently, weathermen had no effective way of detecting and locating sferics at long range.

Now, Lockheed Electronics has produced, in conjunction with the Army Signal Corps and Air Force, a unique system that pinpoints all lightning flashes within a 4,000-mile area.

Flashes of light on kinescope indicate lightning's location.

Remote antennas pick up radio signals generated by sferics. Processing equipment converts the signals into directional data and transmits the information to the Air Force's Severe Weather Warning Center in Kansas City, Missouri. There, after triangulation, the signals are traced on a display which gives the storm's location and path.

Continuing research is leading to use of sferics as an aid in forecasting tornados and for plotting severe storms in mid-ocean where present forecasting devices cannot be used.

LEC is contributing importantly in a variety of ways to development of equipment to advance meteorological knowledge. Among current projects are high performance radiosondes and wind data conversion systems.

MINDING THE FUTURE

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THE ECOLOGY OF FIRE

Fire has played a major role in shaping the world's grasslands and forests. Attempts to eliminate it have introduced problems fully as serious as those created by accidental conflagrations

by Charles F. Cooper

Before Europeans came to North America, fires periodically swept over virtually every acre on the continent that had anything to burn. Along with climate, soil, topography and animal life, these conflagrations helped shape the pattern of vegetation that covered the land.

Civilization brought a tendency to regard fire as pure disaster, together with massive efforts to exclude fire completely from forest and grassland. The attempts frequently succeeded all too well. Over wide regions the pattern of plant life has changed, but not always in a way that users of the land could wish. Paradoxically, in some forest areas fire prevention has greatly increased the destructiveness of subsequent fires.

There is evidence that natural fires have occurred over most of the earth for thousands of years. Buried layers of charcoal testify to prehistoric fires. Historical writings mention great conflagrations witnessed by men. In the narratives of the explorers of North America are numerous accounts of traveling for days through smoke from distant fires, and of passing through burned-over prairies and woodlands.

Tree trunks in forested areas contain a record of past fires. A moderately intense fire often kills an area on one side of a tree, leaving the rest of the tree unharmed. As new layers of tissue grow over the dead spot, they count off the years since the fire. Examining freshly cut stumps of large redwoods, the California forester Emanuel Fritz found evidence of about four fires a century during the 1,100-year history of the stand. The figure is probably conservative, because there must have been many fires not severe enough to leave scars. In the ponderosa pine forests of California and Arizona, fire scars indicate an average of one burning every eight years.

Many forest fires are started by lightning; on the prairies rain immediately extinguishes lightning-set grass fires. Most prehistoric fires were undoubtedly the work of man.

Notwithstanding the popular conception, American Indians were not cautious in using fire. They did not conscientiously put out camp fires nor, unless their villages were threatened, did they try to keep fires from spreading. Often they burned intentionally—to drive game in hunting, as an offensive or defensive measure in warfare, or merely to keep the forest open to travel. A contemporary history of the Massachusetts Bay Colony, dated 1632, relates that "the Salvages are accustomed to set fire of the country in all places where they come; and to burn it twize a year, vixe, at the Spring, and at the fall of the leafe. The reason that moves them to do so, is because it would be otherwise so overgrown with underweedes that it would all be a copice wood, and the people could not be able in any wise to passe through the country out of a beaten path."

In open country fire favors grass over shrubs. Grasses are better adapted to withstand fire than are woody plants. The growing point of dormant grasses,

FIRE MAINTAINS GRASSLAND by holding back spread of mesquite (*shown here*) and other shrubs, which originally constitute small part of vegetation (*a*) but which soon proliferate and reduce areas available to grass (*b*). Fire (*c*) reduces grasses and shrubs alike, but

from which issues the following year's growth, lies near or beneath the ground, protected from all but the severest heat. A grass fire removes only one year's growth, and usually much of this is dried and dead. The living tissue of shrubs, on the other hand, stands well above the ground, fully exposed to fire. When it is burned, the growth of several years is destroyed. Even though many shrubs sprout vigorously after burning, repeated loss of their top growth keeps them small. Perennial grasses, moreover, produce seeds in abundance one or two years after germination; most woody plants require several years to reach seed-bearing age. Fires that are frequent enough to inhibit seed production in woody plants usually restrict the shrubs to a relatively minor part of the grassland area.

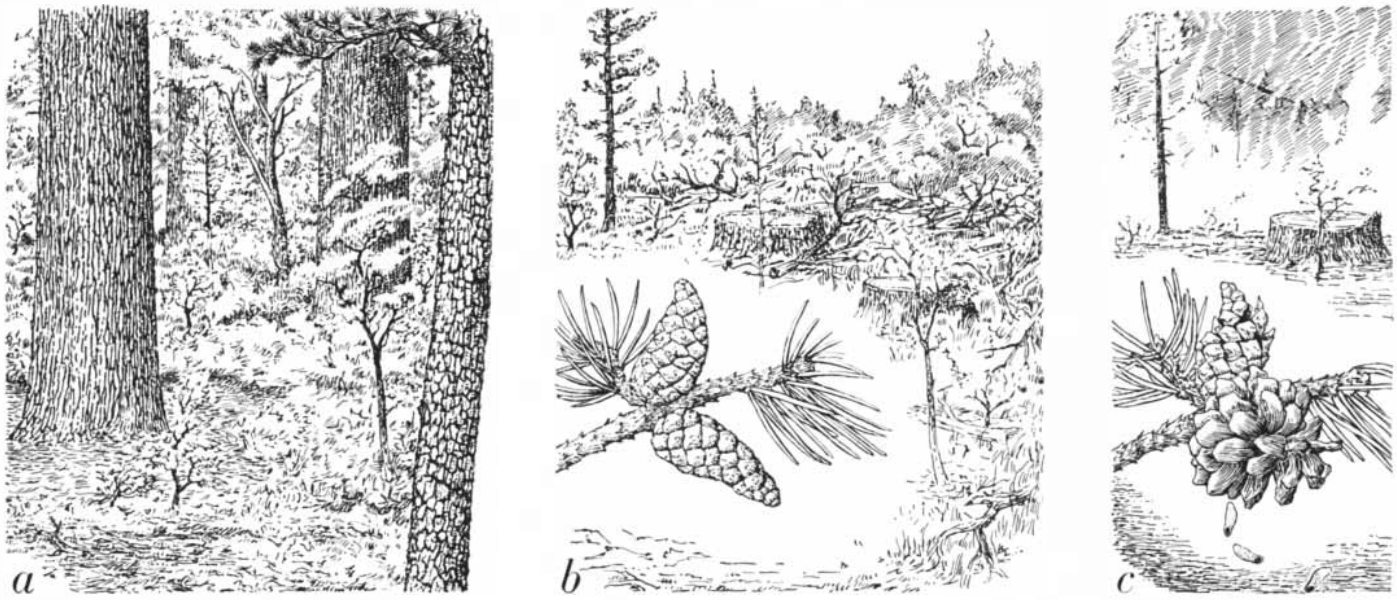
Most ecologists believe that a substantial portion of North American grasslands owe their origin and maintenance to fire. Some disagree, arguing that climate is the deciding factor and fire has had little influence. To be sure, some areas, such as the Great Plains of North America, are too dry for most woody plants, and grasses persist there without fire. In other places, for example the grass-covered Palouse Hills of the southeastern part of the state of Washington, the soil is apparently unsuited to shrub growth, although the climate is favorable. But elsewhere—in the desert grasslands of the Southwest and the prairies of the Midwest—periodic fires must have tipped the vegetation equilibrium toward grasses.

Large parts of these grasslands are now being usurped by such shrubs as mesquite, juniper, sagebrush and scrub oak. Mesquite alone has spread from its former place along stream channels and on a few upland areas until now it occupies about 70 million acres of former grassland. Many ecologists and land managers blame the shrub invasion entirely on domestic livestock; they argue that overgrazing has selectively weakened the grasses and allowed the less palatable shrubs to increase. These explanations do not suffice; even on plots fenced off from animals shrubs continue to increase. A decrease in the frequency of fires is almost surely an essential part of the answer.

Fire has played an equally decisive role in many forests. A good example is found in the forests of jack pine that now spread in a broad band across Michigan, Wisconsin and Minnesota. When lumbermen first entered this region, they found little jack pine; the forests consisted chiefly of hardwood trees and white pines that towered above the general forest canopy. The loggers singled out the white pines for cutting, considering the other species worthless. Their activities were usually followed by fires, accidental or intentional. Supported by the dry debris of logging, the fires became holocausts that killed practically all the remaining vegetation. The mixed forest had little chance to regenerate; even the seeds of most trees were destroyed. But those of the jack pine survived. Unlike most pine cones, which drop off and release their seeds in the fall, jack pine cones stay closed and remain attached to the tree, sometimes so firmly that branches grow right around them. Inside the cones the seeds remain viable for years. When the cones are heated, as in a forest fire, they slowly open and release their seeds. Thus the fires simultaneously eliminated the seeds of competing species and provided an abundant supply of jack pine seed together with a bed of ash that is ideal for germination. The result of the process is a pure stand of jack pine.

The valuable Douglas fir forests of the Pacific Northwest also owe their origin to fire. This species requires full sunlight; it cannot grow in the dense shade cast by a mature fir forest. When old Douglas firs die, their place is taken not by new Douglas firs but by cedars and hemlocks, more tolerant of shade, which therefore constitute the "climax" vegetation of the region. Forest fires, however, arrest the succession by creating openings in the forest into which the light, winged seeds of Douglas firs can fly from adjacent stands. The seedlings

while growing point of grass lies near or beneath ground (*root system at right in "c"*) and is left unharmed, buds and growing tissue of shrub stand fully exposed and are destroyed. Balance is further tipped toward grasses (*d*) because they produce abundant seed a year or two after germination; as a result they lose only one or two years' growth in fire. Shrubs lose several years' growth.



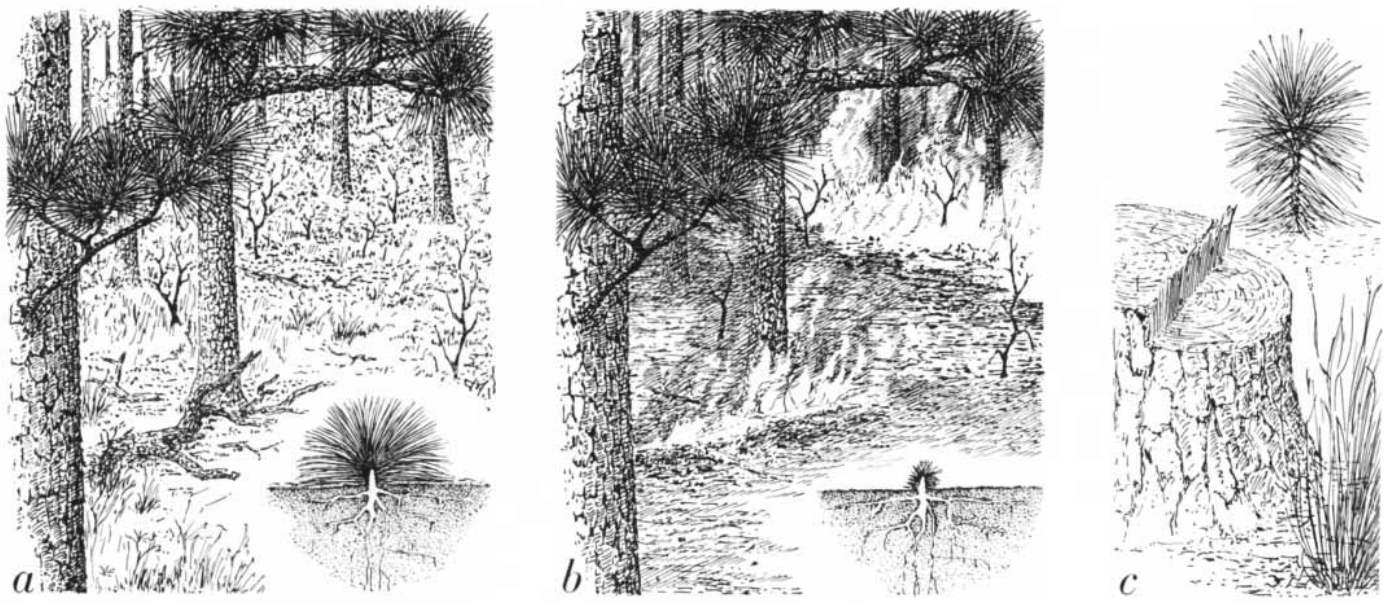
**ORIGINAL FORESTS of Great Lakes region were of mixed hardwoods, some jack pines (*at right in "a"*) and white pines (*middle distance and background*). Early loggers cut white pines and left other species standing (*jack pine cone is in foreground of*

take advantage of the sunlight in the openings: they flourish and top competing vegetation; ultimately they grow into pure stands of uniform age.

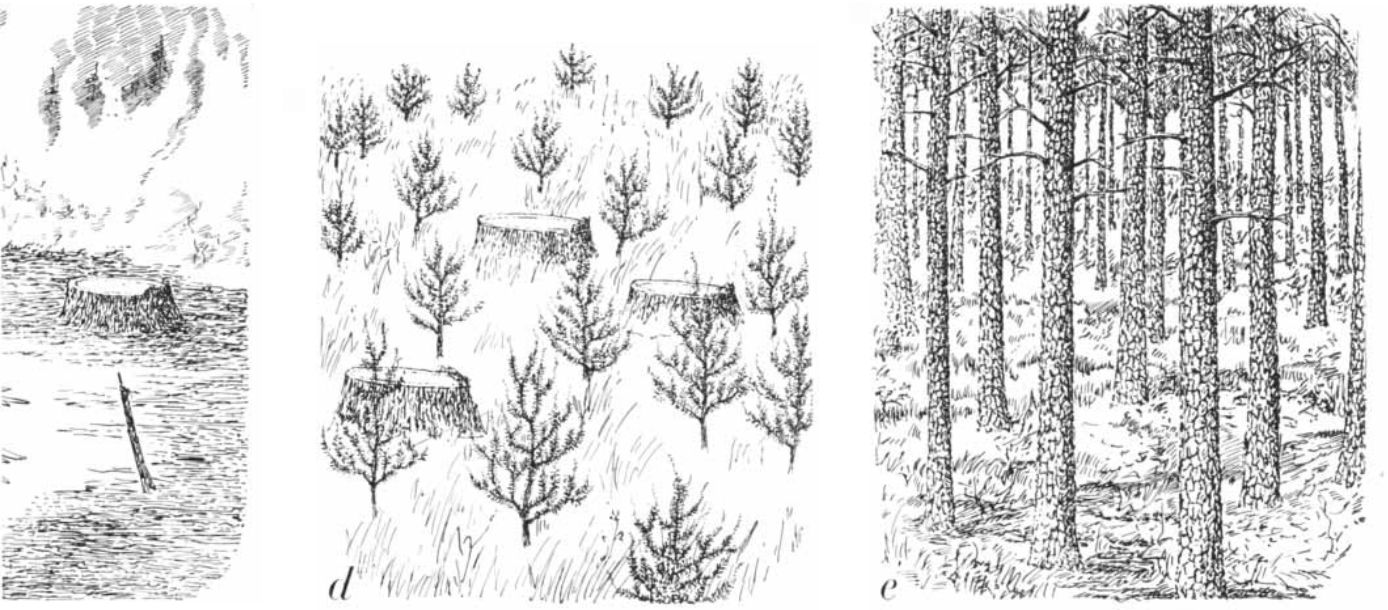
Jack pine and Douglas fir are dependent on fire for their establishment but cannot endure frequent burning thereafter. In other forests fire is a normal part of the environment during the whole life of the stand. The longleaf pine of the southeastern U. S. is a striking example. This species is almost ideally adapted to recurring fires.

Unlike most pines, the young longleaf does not grow uniformly after germination. The seedling reaches a height of a few inches in a few weeks. Then it stops growing upward and sprouts a grasslike ring of long drooping needles that surrounds the stem and terminal bud. During this so-called grass stage, which usually lasts from three to seven years, the plant's growth processes are concentrated in forming a deep and extensive root system and in storing food reserves.

Longleaf pine is easily shaded out by



FIRE-RESISTANT FORESTS of longleaf pine in southeastern U. S. are well adapted to recurrent fires. Long, green needles of seedling longleaf (*lower right in "a"*) protect central stem and bud against surface fires that burn out forest debris and saplings of competing hardwoods (*middle distance and background in "b"*). Rapid vertical growth of tree after seedling stage carries



"*b*"). Debris of logging supported holocausts that consumed remaining vegetation. Although jack pines were destroyed, their cones survived and released seeds (*c*). Seedling jack pines (*d*) grew in fertile ashes, giving rise to pure jack pine stands today (*e*).

competing hardwoods and is susceptible to a serious blight known as brown spot. The brown spot fungus multiplies during the dry summer, and the autumn rains splash its spores onto the needles of the low seedlings. Unless overtopping vegetation is cleared away and brown spot is controlled, the young pines may remain in the grass stage indefinitely.

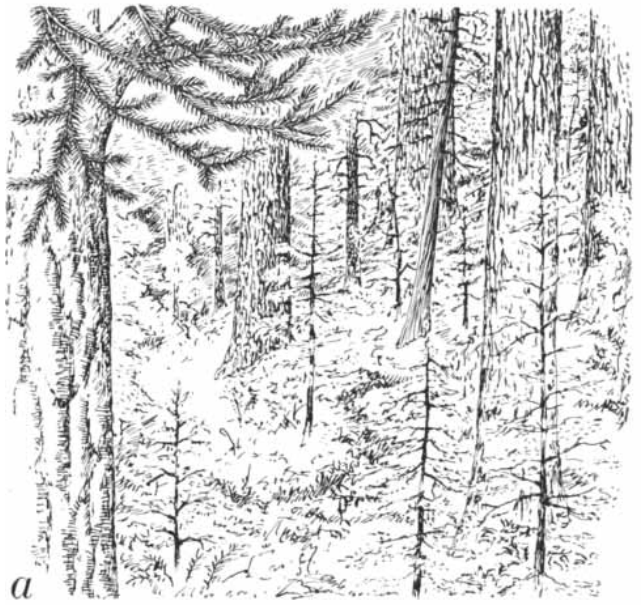
One of America's first professional foresters, H. H. Chapman of Yale University, perceived in the early 1920's that periodic fires were essential to the life of longleaf pine. Protected by its canopy of needles, the longleaf seedling can withstand heat that kills the aboveground portions of competing hardwoods and grasses. At the same time the flames consume dry needles infected with brown spot, destroying the principal source of fungus spores. After the young pine emerges from the grass stage, its phenomenal growth—often four to six feet a year for the first two or three years—quickly carries the buds beyond the reach of surface fires. The thick, corky bark of the sapling protects its

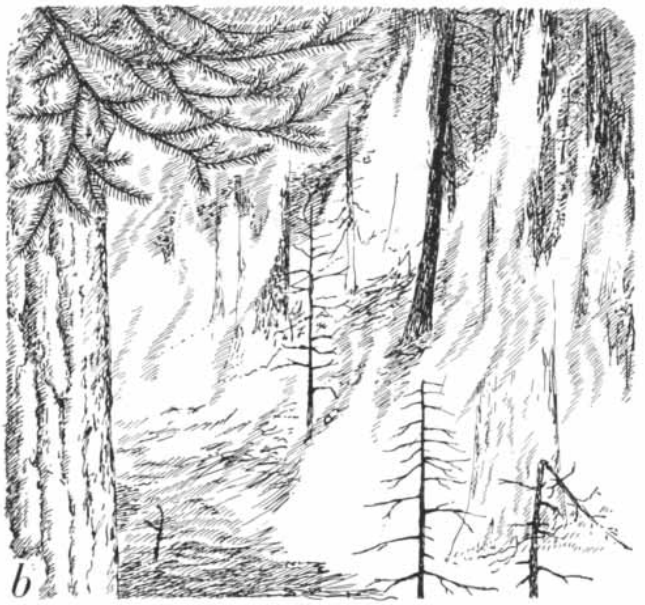
vulnerable bud beyond reach of bigger fires (*c*); thickening bark affords increasing insulation for delicate cambium against hotter fires. At the same time the tree drops more needles, supporting hotter fires that clear out larger saplings (*d*). Self-governing mechanism keeps forest open (*e*). Illustrations follow single tree from seedling ("*a*" *and* "*b*") to sapling ("*c*" *and* "*d*") to maturity (*e*).

sensitive growing tissue. As the tree grows and the bark thickens, it becomes resistant to any but the most intense fires.

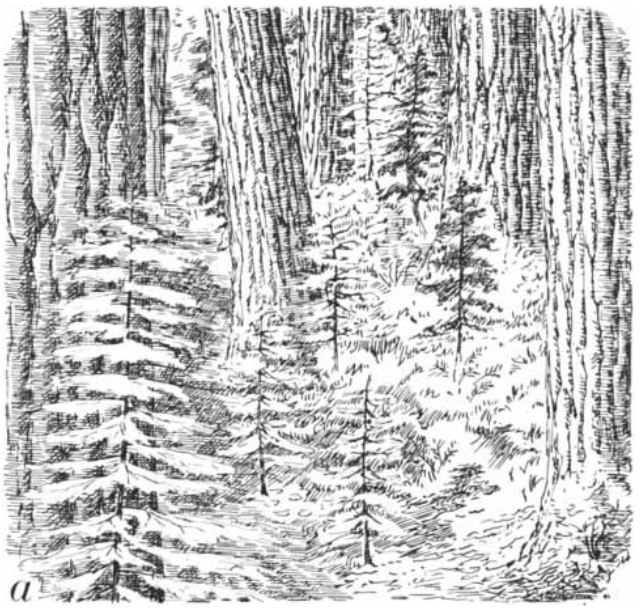
Largely at Chapman's urging, prescribed fire has become an accepted management tool in the southeastern longleaf pine forests. Before a stand is harvested a fire is run through during the dry summer, when it will burn fairly hot. This clears out most of the undergrowth without killing the trees and prepares a good seedbed. The old trees are cut during the following winter, after the seeds have fallen. About three winters later, when burning conditions permit only a relatively cool fire and the seedlings have entered the grass stage, the area is burned again. Fires at regular three-year intervals thereafter keep down the worthless scrub oaks and help control brown spot. They hold back the normal succession, which would lead to a climax oak-hickory forest. Moreover, a regime of periodic fires reduces the accumulation of dry fuel on the ground that might otherwise lead to an uncontrollable holocaust.

My own work has dealt with the ponderosa pine forests of the Southwest. As





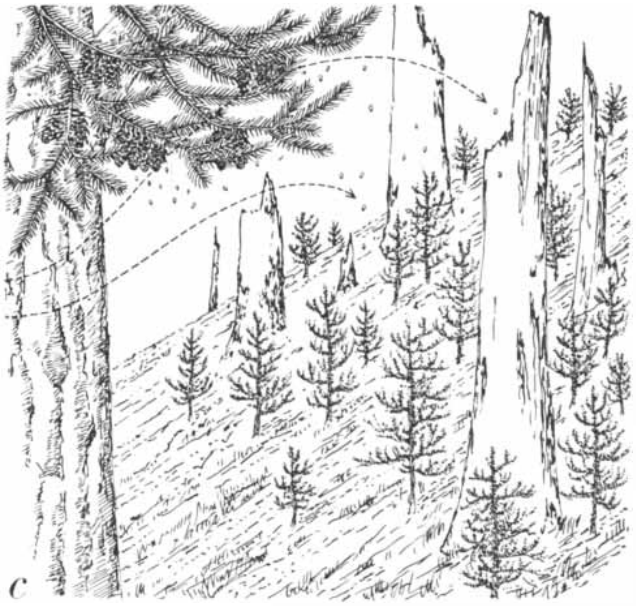
PRIMEVAL DOUGLAS FIR FORESTS of western U. S. have origin in fires of previous centuries. Young Douglas firs, which are intolerant of shade, cannot grow beneath mature Douglas fir forest (*a*), yield to cedars and hemlocks, which make up the climax

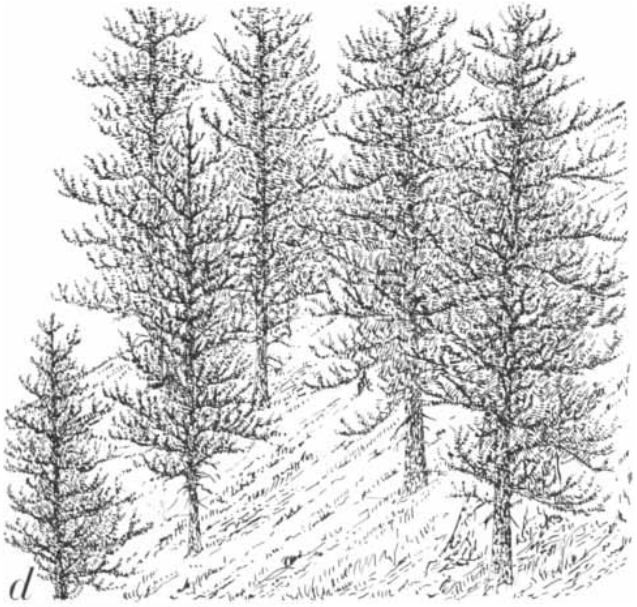


REPLACEMENT OF DOUGLAS FIRS by hardwoods is in part attributable to exclusion of fire. Cedar and hemlock saplings (*a*), unlike young Douglas firs, grow well in shade of mature Douglas fir forest, take over as older firs die (*b*). As cedar and hemlock

19th-century chronicles attest, they used to be open, parklike forests arranged in a mosaic of discrete groups, each containing 10 to 30 trees of a common age. Small numbers of saplings were dispersed among the mature pines, and luxuriant grasses carpeted the forest floor. Fires, when they occurred, were easily controlled and seldom killed a whole stand. Foresters in other regions envied the men assigned to the "asbestos forests" of the Southwest.

Today dense thickets of young trees have sprung up everywhere in the forests. The grass has been reduced, and dry branches and needles have accumulated to such an extent that any fire is likely to blow up into an inferno that will destroy everything in its path. Foresters have generally blamed the overproduction of trees on a period of unusually favorable weather conditions, or on removal of competing grasses and exposure of bare soil through past trampling and grazing by domestic animals. But it is becoming increasingly apparent that a vigorous policy of fire exclusion, too long followed, is at least partly responsible.

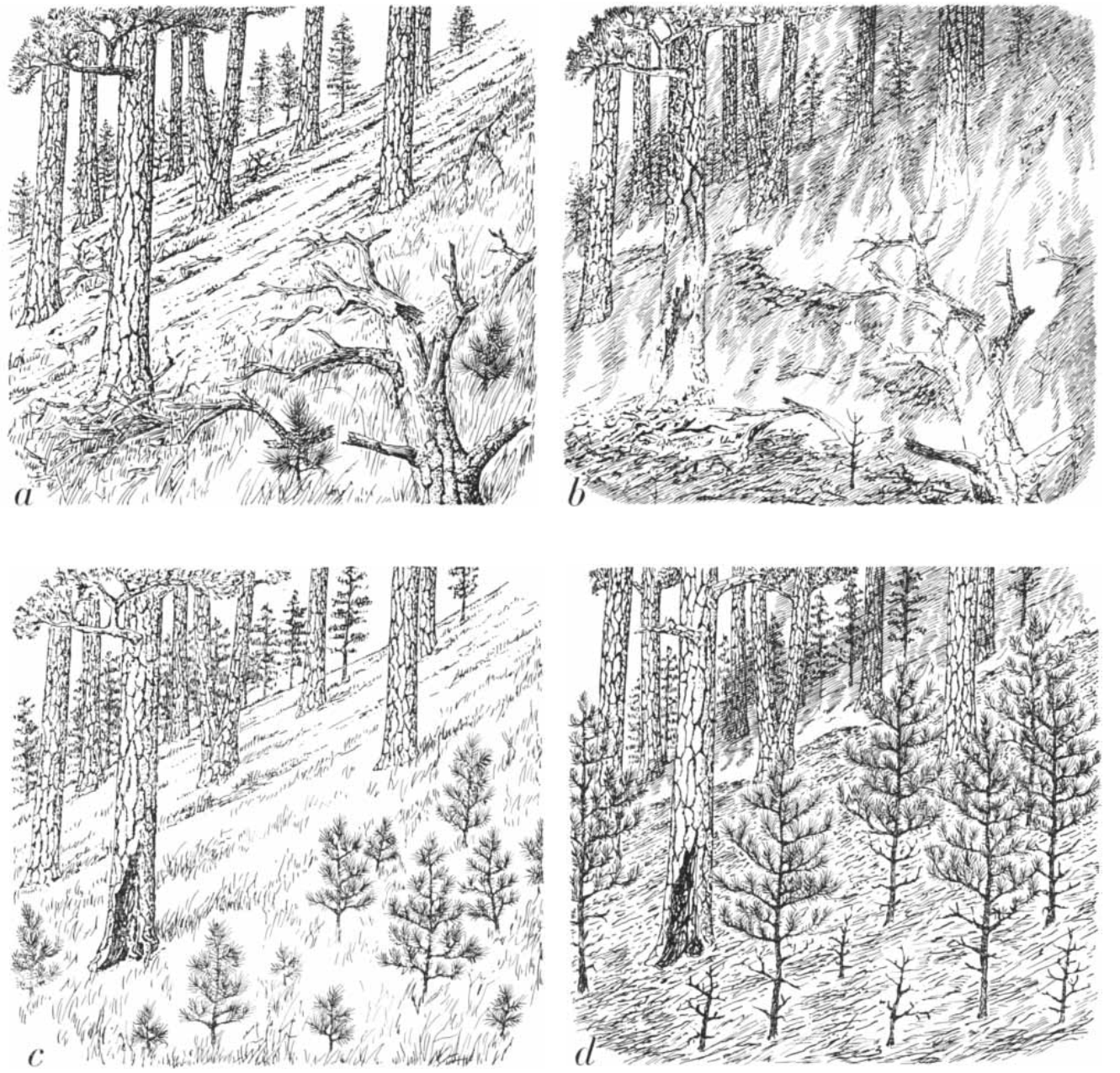




vegetation of the region. Succession was interrupted by frequent small fires that burned out cedar and hemlock trees (*b*). Douglas fir seeds from adjacent stands blew into new openings (*c*), grew well in seedbed of ashes and became pure stands of Douglas fir (*d*).

trees grow (*c*), they diminish remaining opportunities for Douglas fir seedlings to survive. Climax vegetation that results is composed of cedar and hemlock (*d*). These illustrations, like those on preceding and following pages, are drawn from same point of view.

Lightning is frequent in the ponderosa pine region, and the Indians set many fires there. Tree rings show that the forests used to burn regularly at intervals of three to 10 years. The mosaic pattern of the forest has developed under the influence of recurrent light fires. Each even-aged group springs up in an opening left by the death of a predecessor. (After remaining intact for 300 years or more, groups break up quite suddenly—often in less than 20 years.) The first fire that passes through consumes the dead trees, and leaves a good seedbed of ash and mineral soil, into which seed drifts from surrounding trees. Young ponderosa seedlings cannot withstand even a light surface fire, but in the newly seeded opening they are protected by the lack of dry pine needles to fuel such fires. Consequently the young stand escapes burning for the first few years. Eventually the saplings drop enough needles to support a light surface fire, which kills many smaller saplings but leaves most of the larger ones alive. The roots of the survivors quickly appropri-



PARKLIKE PONDEROSA PINE FORESTS of Southwest were typically a mosaic of even-aged groups (*mature stand in middle distance of "a"; young stand in background*). Frequent fires kept forest debris from accumulating (*b*); thus the fires were mild and created openings for seedlings (*c*), which cannot grow in shade. As new trees matured, they dropped more needles, providing more fuel for hotter fires, which killed new seedlings (*d*). Mosaic and parklike character of the forest was thereby maintained.

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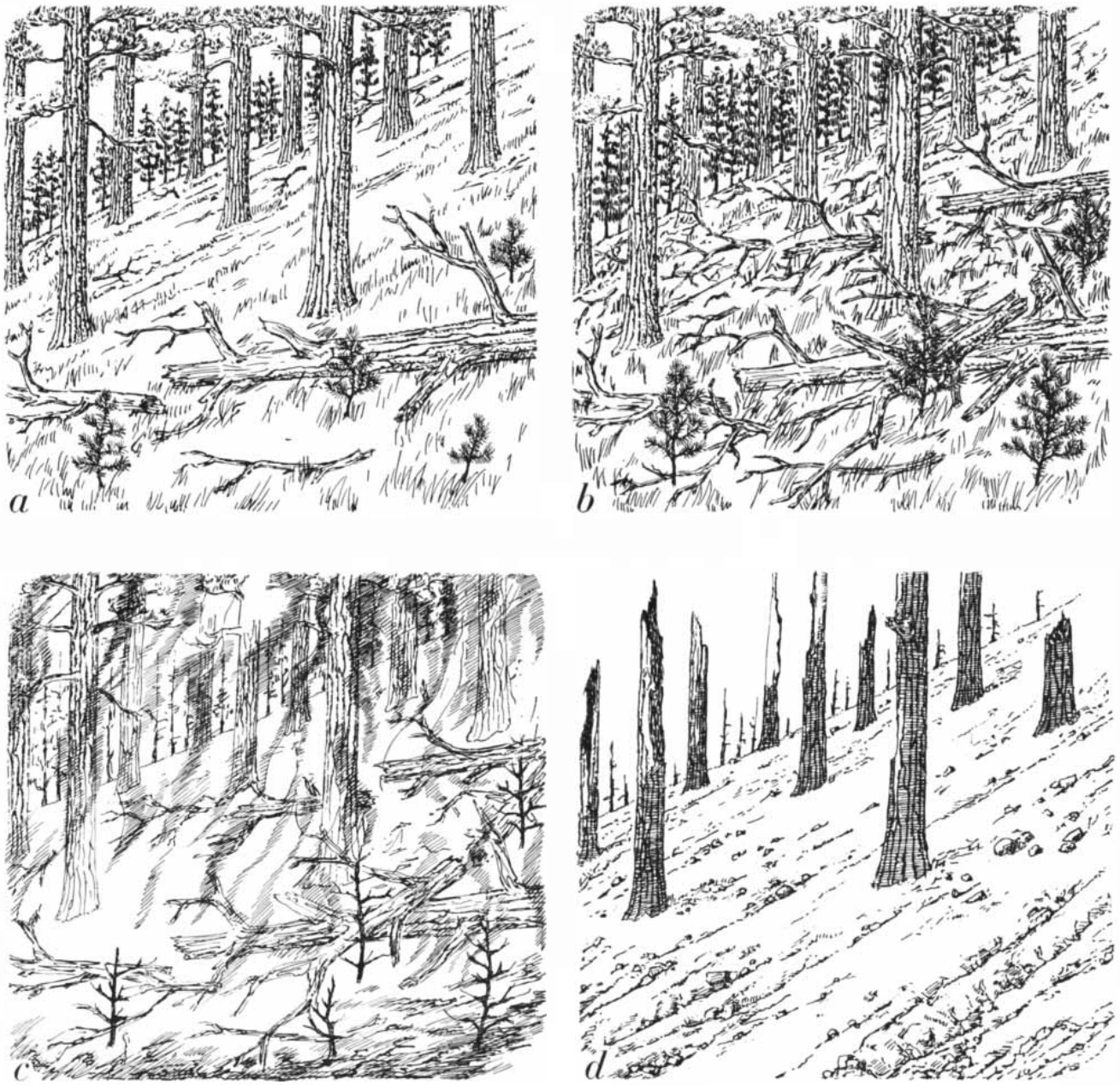
ate the soil made vacant, and their growth is stimulated.

The degree of thinning accomplished by a fire depends upon the quantity of fuel on the ground. The denser the sapling stand, the more needles it drops and the hotter the fire it will support. The process is thus a sort of self-regulating feedback mechanism governed by the density of the stand. Thinning by fire is less efficient than the forester might wish, but it does help to prevent the stagnation resulting from extreme overcrowding.

As a group of trees grows toward maturity, new seedlings germinate beneath it. The volume of dry fuel dropped by the older trees, however, supports fires hot enough to eradicate the seedlings entirely. Fire and shade together prevent younger trees from developing; the even-aged character of the group is maintained throughout its life.

Wild-land managers have historically, and properly, concentrated on suppressing accidental fires in forests and grasslands and on discouraging deliber-



CLUTTERED PONDEROSA PINE FORESTS (*a*), in contrast to those illustrated on page 156, result from the elimination of the periodic fires that occurred naturally. Saplings that would have been thinned out by fire now vie for space in the formerly open avenues between trees, the grass cover is reduced and forest debris and undergrowth have accumulated to the point (*b*) that fires that formerly would have been mild and easily controlled often explode into holocausts (*c*) that destroy the entire stand of trees (*d*).

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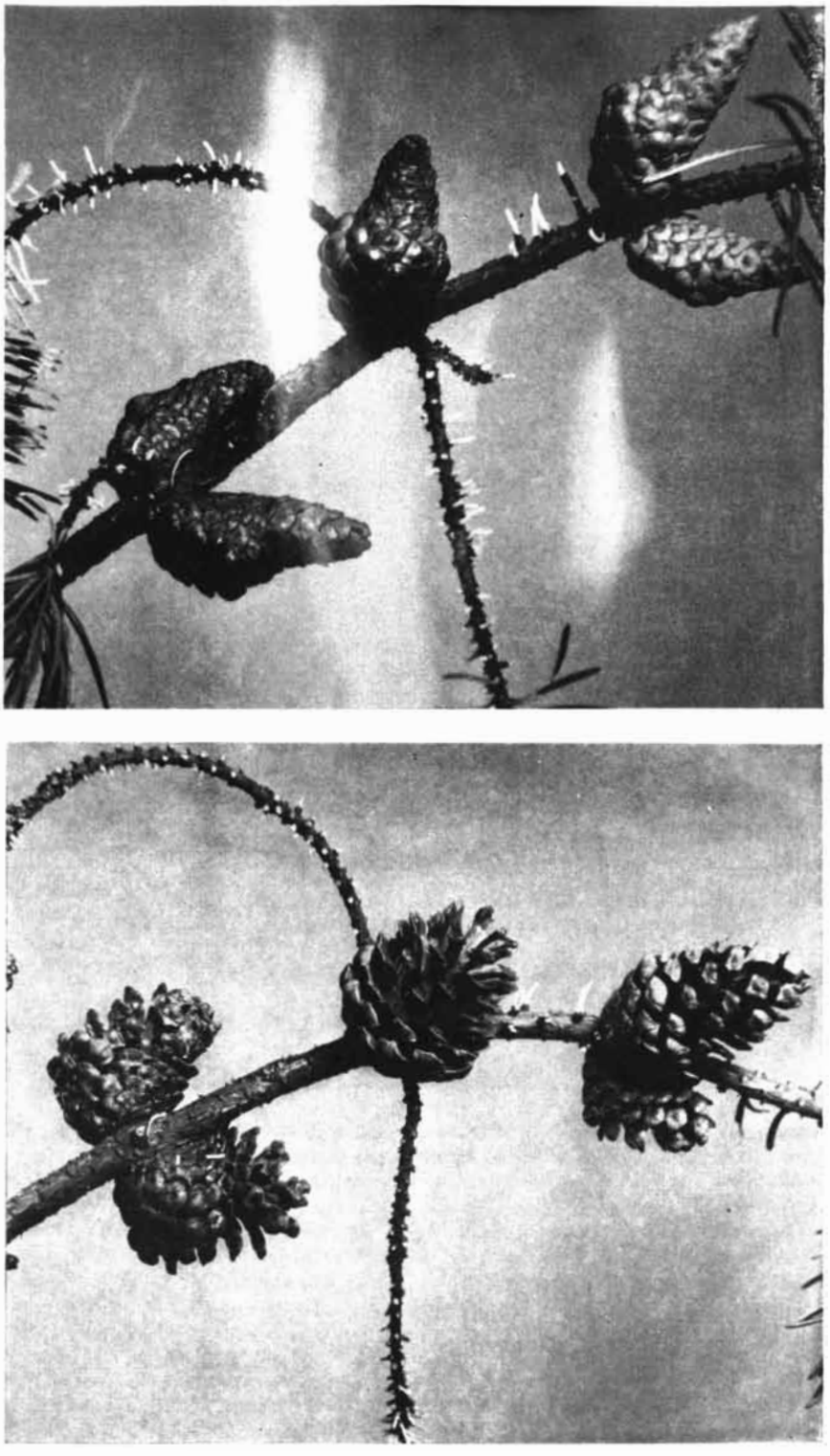
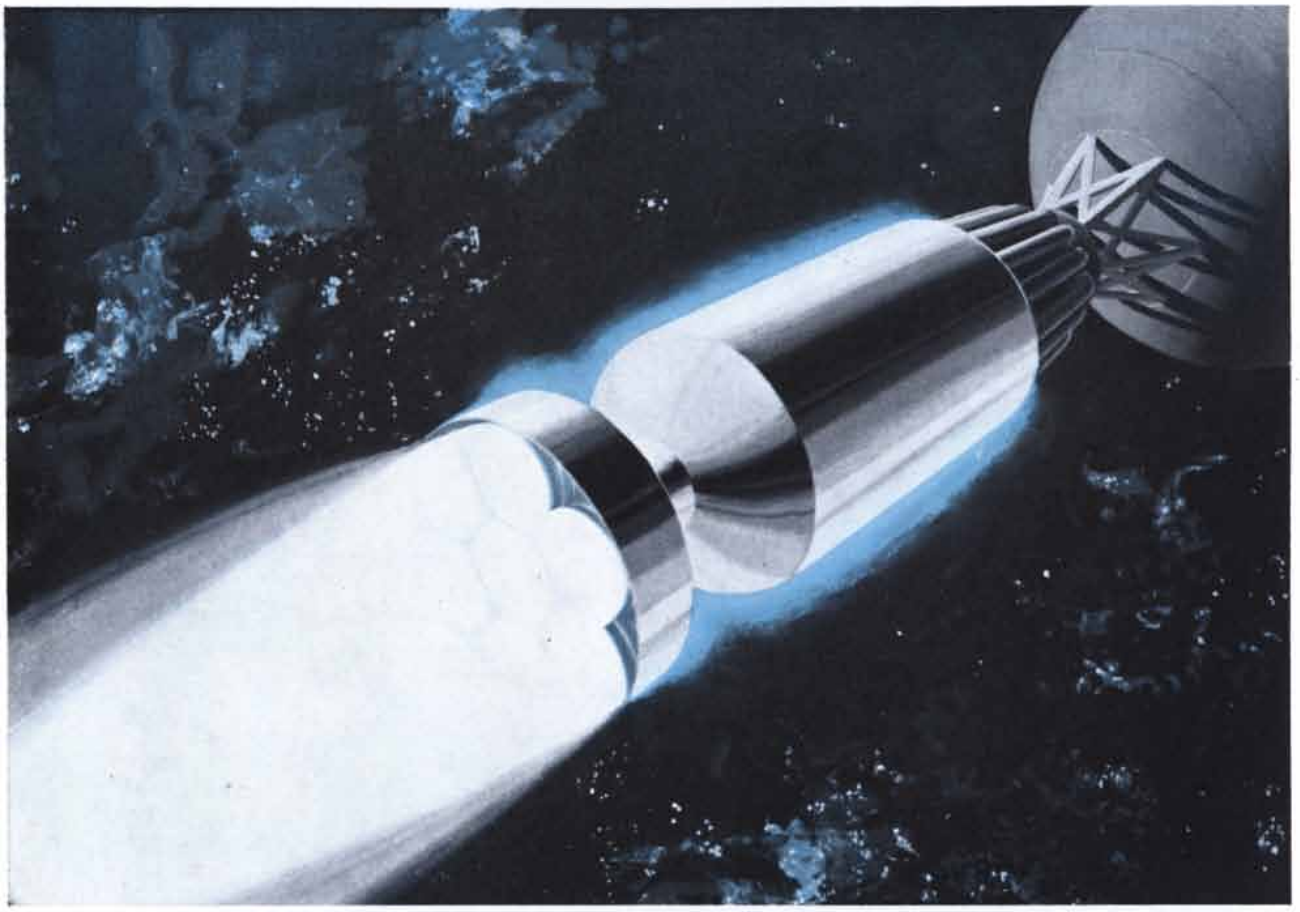
ate overburning by man. While fire may favor the establishment of jack pine forests, the annual burning long practiced in the South will prevent the growth of any forest at all. By the same token, occasional fires may be needed to maintain African grasslands, but deliberately setting fire to the country every few months has unquestionably damaged them seriously. In many cases the time has come to relax the ingrained prejudices against fire and to utilize it, judiciously, as a tool in the management of both forests and grasslands.



SEROTINOUS JACK PINE CONES resist fire (*top*). Unlike other pine cones, which open and release their seeds in the fall, jack pine cones open after being heated (*bottom*).

NUCLEAR ROCKET PROPULSION AT AEROJET-GENERAL



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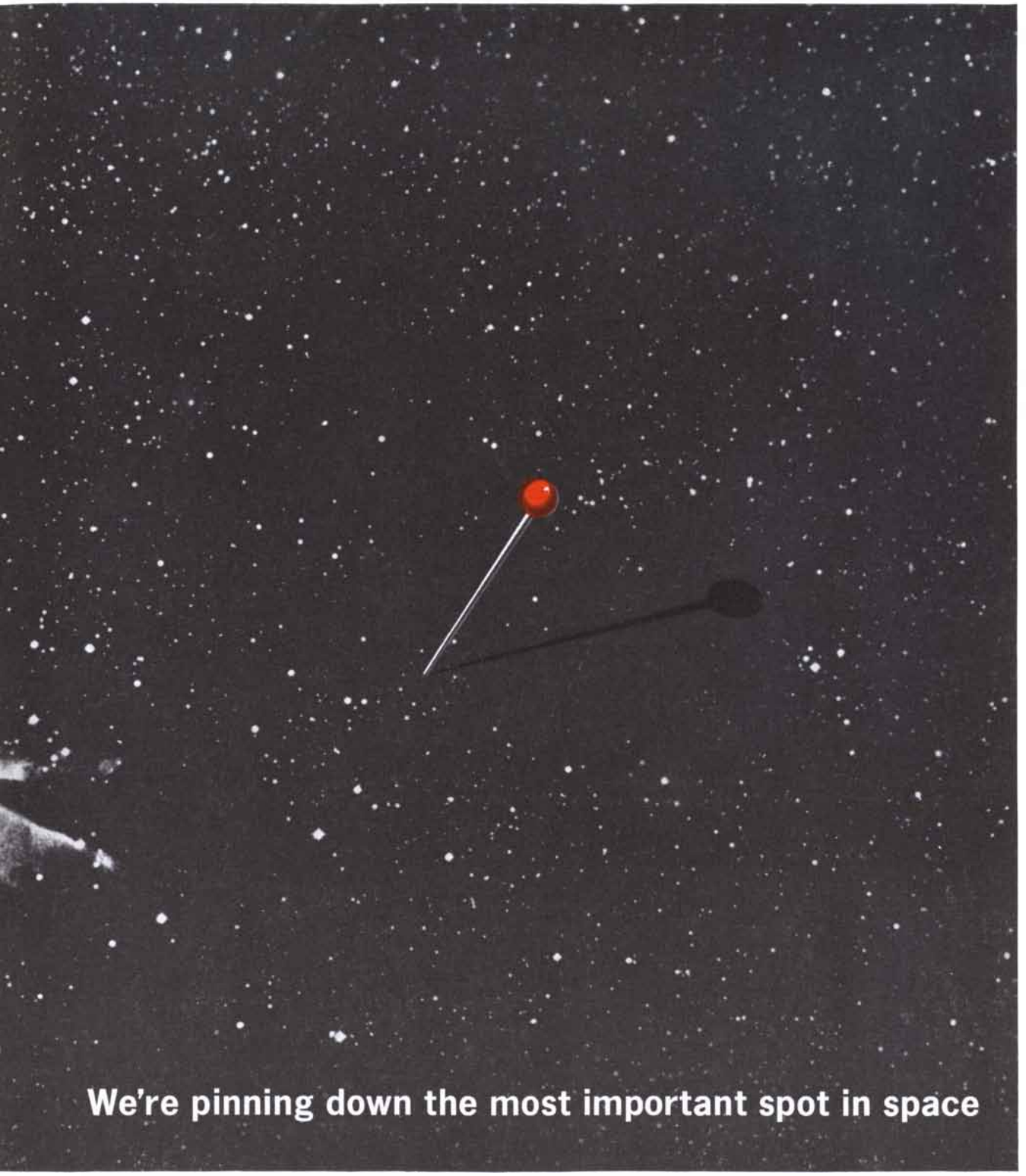

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MATHEMATICAL GAMES

Concerning the diversions in a new book on geometry

by Martin Gardner

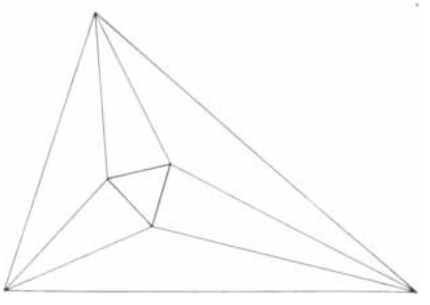
Most professional mathematicians enjoy an occasional romp in the playground of mathematics, in much the same way that they enjoy an occasional game of chess: it is a form of relaxation that they avoid taking too seriously. On the other hand, many creative, well-informed puzzlists have only the most elementary knowledge of mathematics. H. S. M. Coxeter, professor of mathematics at the University of Toronto, is one of those rare individuals who are eminent as mathematicians and as authorities on the not-so-serious side of their profession.

Harold Scott Macdonald Coxeter was born in London in 1907 and received his mathematical training at Trinity College, Cambridge. On the serious side he is the author of *Non-Euclidean Geometry* (1942), *Regular Polytopes* (1948) and *The Real Projective Plane* (1955). On the lighter side he has edited and brought up to date W. W. Rouse Ball's classic work *Mathematical Recreations and Essays,* and has contributed dozens of articles on recreational topics to various journals. This month John Wiley & Sons will publish his *Introduction to Geometry,* a book that is the topic of this article.

There are many ways in which Coxeter's new book is remarkable. Above all, it has an extraordinary range. It sweeps through every branch of geometry, including such topics as non-Euclidean geometry, crystallography, groups, lattices, geodesics, vectors, projective geometry, affine geometry and topology —topics not always found in introductory texts. The writing style is clear, crisp and for the most part technical. It calls for slow, careful reading but has the merit of permitting a vast quantity of material to be compressed between the volume's covers. The book is touched throughout with the author's sense of humor, his keen eye for mathematical beauty and his enthusiasm for play. Most of its sections open with apt literary quotations, many from Lewis Carroll, and close with exercises that are often new and stimulating puzzles. A number of sections deal entirely with problems and topics of high recreational interest, some of which have been discussed, on a more elementary level, in this department: the golden ratio, regular solids, topological curiosities, map coloring, the packing of spheres and so on.

Amusing bits of off-trail information dot the text. How many readers know, for example, that in 1957 the B. F. Goodrich Company patented the Möbius strip? Its patent, No. 2,784,834, covers a rubber belt that is attached to two wheels and is used for conveying hot or abrasive substances. When the belt is given the familiar half-twist, it wears equally on both sides—or rather on its single side.

And how many readers know that at the University of Göttingen there is a large box containing a manuscript showing how to construct, with compass and straightedge only, a regular polygon of 65,537 sides? A polygon with a prime number of sides can be constructed in the classical manner only if the number is a special type of prime called a Fermat prime: a prime that can be expressed as $2^{(2^n)} + 1$. Only five such primes are known: 3, 5, 17, 257 and 65,537. The poor fellow who succeeded in constructing the 65,537-gon, Coxeter tells us, spent 10 years on the task. No one knows whether there is a prime-sided polygon larger than this that is in principle constructable with compass and straightedge. If there is such a polygon, its act-



Morley's theorem

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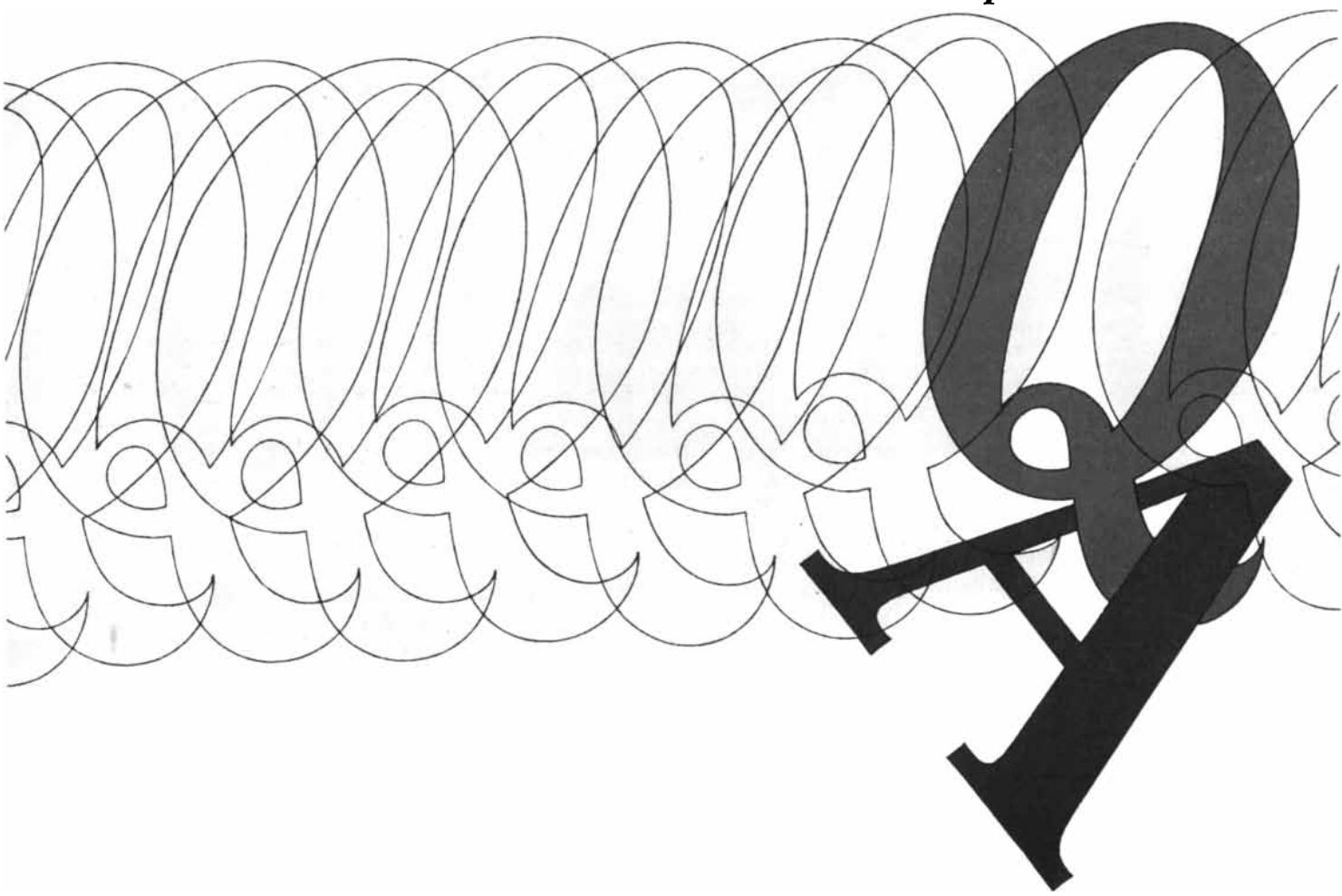
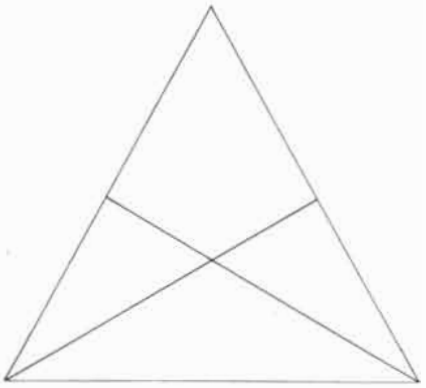
When a communications system must reply to 150 questions a second, how can it find time to line up the answers?





The internal bisector problem

ual construction would be out of the question, since the number of sides would be astronomical.

It might be supposed that the lowly triangle, studied so thoroughly by the ancients, would contain few new surprises. Yet many remarkable theorems about the triangle—theorems that Euclid could easily have discovered but didn't—have been found only in recent times. One outstanding example, discussed by Coxeter, is Morley's theorem. It was first discovered about 1899 by Frank Morley, professor of mathematics at Johns Hopkins University and father of the late Christopher Morley. It spread rapidly through the mathematical world in the form of gossip, Coxeter writes, but no proof for it was published until 1914. When Paul and Percival Goodman, in Chapter 5 of their wonderful little book *Communitas*, speak of human goods that are not consumed while being enjoyed, it is Morley's beautiful theorem that provides a happy illustration.

Morley's theorem is illustrated on page 164. A triangle of any shape is drawn, and its three angles are trisected. The trisecting lines always meet at the vertices of an equilateral triangle. It is the appearance of that small equilateral triangle, known as the Morley triangle, that is so totally unexpected. Professor Morley wrote several textbooks and did important work in many fields, but it is this theorem that has earned him his immortality. Why was it not discovered earlier? Coxeter thinks that perhaps mathematicians, knowing the angle could not be trisected within the classical limitations, tended to shy away from theorems involving angle trisections.

Another triangle theorem that has achieved widespread notoriety in this century is illustrated on this page. If the internal bisectors of the two base angles of a triangle are equal, it seems intuitively obvious that the triangle must be

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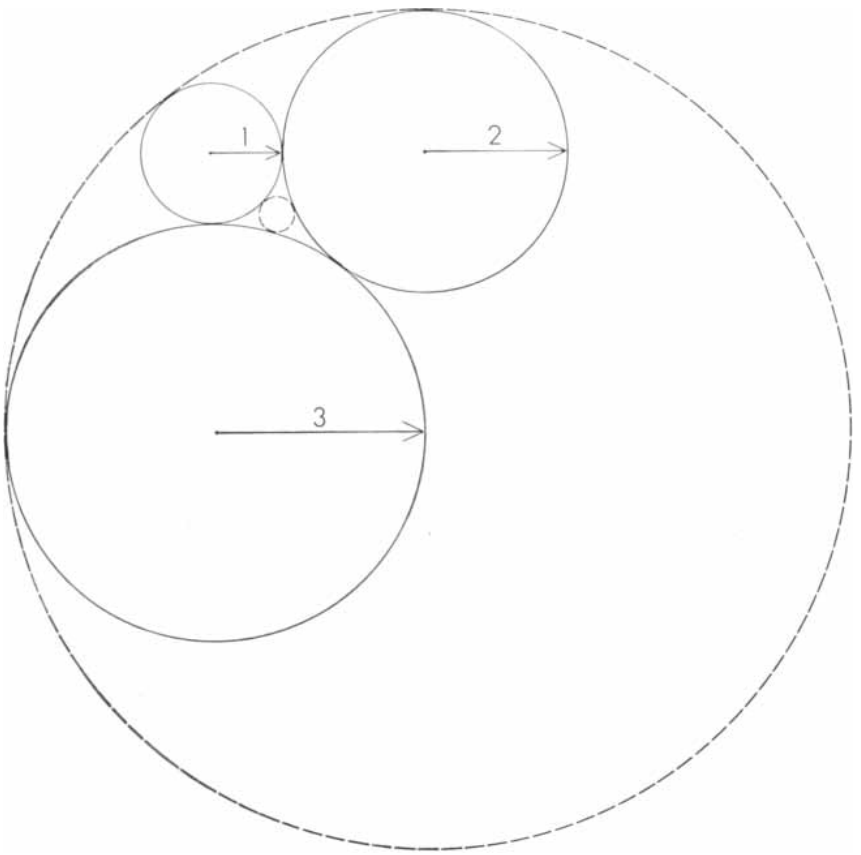
isosceles. But can you prove it? No problem in elementary geometry is more insidiously deceptive. Its converse—the bisectors of the base angles of an isosceles triangle are equal—goes back to Euclid and is easy to prove. This one *looks* as if a proof would be just as easy, when in fact it is incredibly difficult. Every few months a tormented reader of this department sends me a plea for a proof of this problem. I usually reply by citing an article by Archibald Henderson that appeared in the *Journal of the Elisha Mitchell Scientific Society* for December, 1937. Henderson calls his paper, almost 40 pages long, "an essay on the internal bisector problem to end all essays on the internal bisector problem." He points out that many published proofs, some by famous mathematicians, are faulty; then he gives 10 valid proofs, all long and involved. It is a pleasant shock to find in Coxeter's book a new proof, so simple that all he need do is devote four lines to a hint from which the proof is easily derived.

Now and then, when someone discovers an elegant new theorem, he is moved to record it in verse. An amusing modern instance is "The Kiss Precise," a poem by the distinguished chemist Frederick Soddy, who coined the word "isotope." If three circles of any size are placed so that each touches the other two, it is always possible to draw a fourth circle that touches the other three. Usually there are two ways to draw a fourth circle; sometimes one is a large circle enclosing the other three. In the illustration on this page, for instance, the two possible fourth circles are shown as broken lines. How are four mutually tangent circles related to each other in size? Soddy, as the result of a procedure that he later confessed he never really understood, chanced upon the following beautifully symmetrical formula, in which a, b, c and d are the reciprocals of the four radii:

$$a^2 + b^2 + c^2 + d^2 = \tfrac{1}{2}(a + b + c + d)^2$$

The reciprocal of a number n is simply $1/n$, and the reciprocal of any fraction is obtained by turning the fraction upside down. The reciprocal of a radius is the measure of a circle's curvature. A concave curvature, such as that of a circle enclosing the other three, is considered a negative curvature and is handled as a negative number. In his poem Soddy uses the term "bend" for curvature.



Frederick Soddy's "kiss precise"

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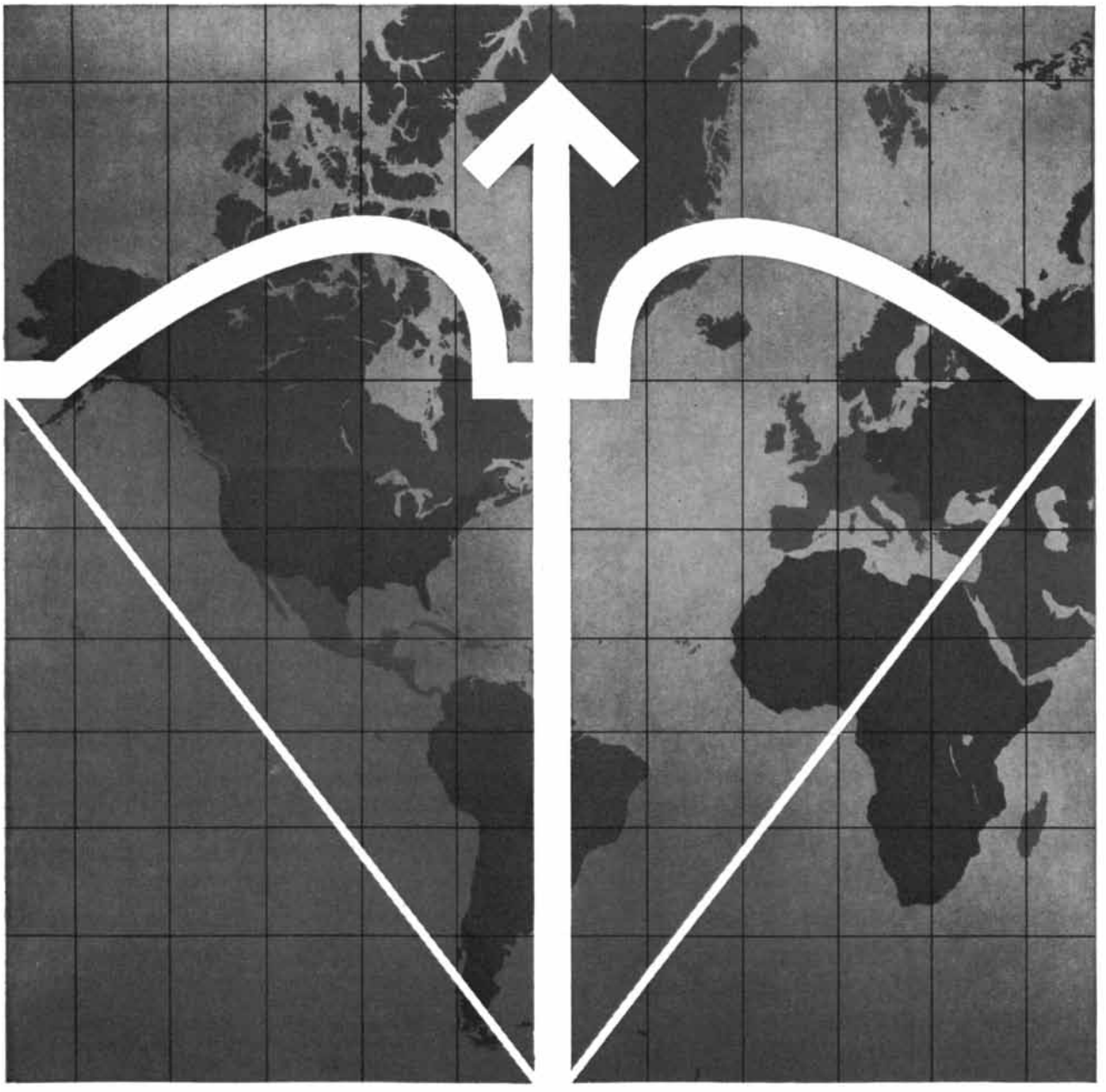
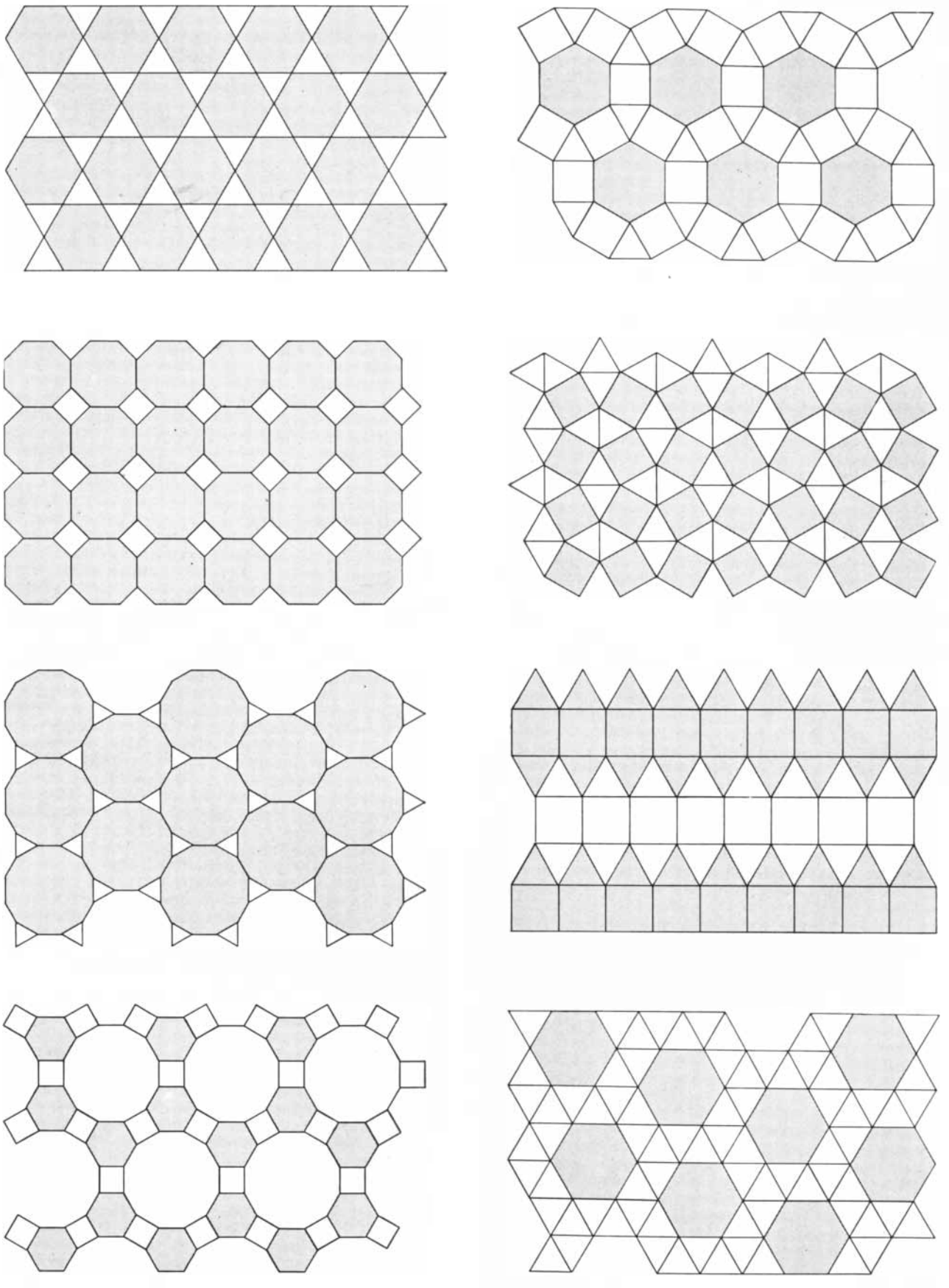




The eight "semiregular" tessellations

Coxeter quotes the second stanza of the poem as follows:

Four circles to the kissing come,
The smaller are the benter.
The bend is just the inverse of
The distance from the centre.
Though their intrigue left Euclid dumb
There's now no need for rule of thumb.
Since zero bend's a dead straight line
And concave bends have minus sign,
The sum of the squares of all four bends
Is half the square of their sum.

Soddy's formula is a great timesaver for puzzlists; problems involving kissing circles, often found in puzzle books, are tough to crack without it. For example, if the three solid circles in the illustration on page 168 have radii of one, two and three inches, what are the radii of the broken circles? This can be answered by drawing a large number of right triangles and doggedly applying the Pythagorean theorem, but Soddy's formula gives a simple quadratic equation with two roots that are the reciprocals of the two radii sought. The positive root gives the small broken circle a curvature of 23/6 and a radius of 6/23 inches; the negative root gives the large broken circle a negative curvature of $-1/6$ and a six-inch radius.

Readers who care to test the formula's power on another problem can consider this situation. A straight line is drawn on a plane. Two kissing spheres, one with a radius of four inches, the other with a radius of nine inches, stand on the line. What is the radius of the largest sphere that can be placed on the same line so that it kisses the other two? Instead of Soddy's formula one can use the following equivalent expression, supplied by Coxeter, which makes the computation much easier. Given the three reciprocals, a, b and c, the fourth reciprocal is:

$$a + b + c \pm 2\sqrt{ab + bc + ac}$$

The answer to the problem will appear in this space next month.

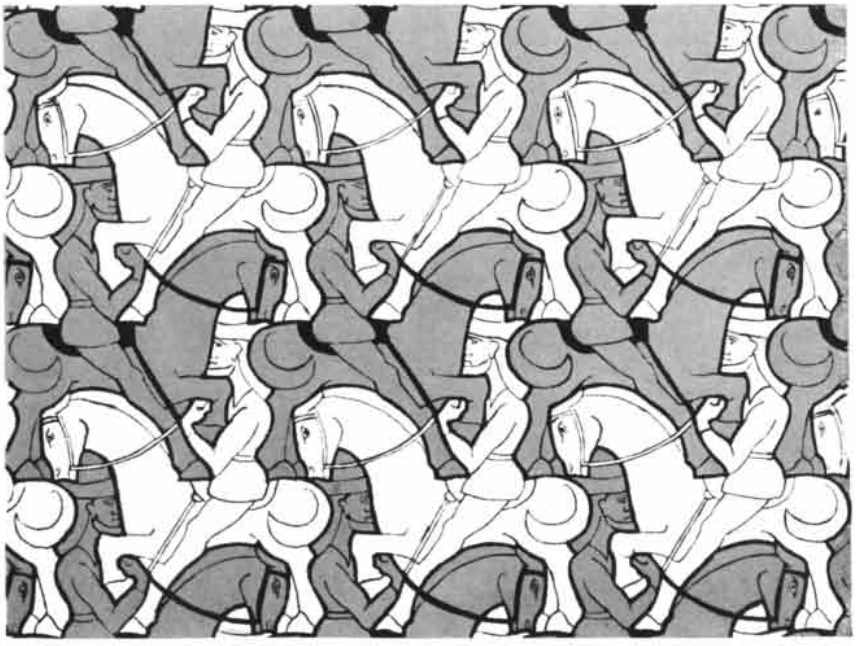
From an artist's point of view, some of the most striking pictures in Coxeter's richly illustrated volume accompany his discussions of symmetry and the role played by group theory in the construction of repeated patterns such as are commonly seen in wallpaper, tile flooring, carpeting and so on. "A mathematician, like a painter or a poet, is a maker of patterns," wrote the English mathematician G. H. Hardy in a famous passage quoted

by Coxeter. "If his patterns are more permanent than theirs, it is because they are made with *ideas*." When polygons are fitted together to cover a plane with no interstices or overlapping, the pattern is called a tessellation. A regular tessellation is one made up entirely of regular polygons, all exactly alike and meeting corner to corner (that is, no corner of one touches the side of another). There are only three such tessellations: a network of equilateral triangles, the checkerboard pattern of squares, and the hexagonal pattern of the honeycomb, chicken wire and bathroom tiling. The squares and triangles can also be made to fill the plane without placing them corner to corner, but this cannot be done with the hexagons.

"Semiregular" tessellations are those in which two or more kinds of regular polygons are fitted together corner to corner in such a way that the same polygons, in the same cyclic order, surround every vertex. There are precisely eight of these tessellations, made up of different combinations of triangles, squares, hexagons, octagons and dodecagons [*see illustration on page 170*]. All of them would, and some do, make excellent linoleum patterns. All are unchanged by mirror reflection except the tessellation in the lower right-hand corner, a pattern first described by Johannes Kepler. It has two forms, each a mirror image of the other. An enjoyable pastime is to cut a large number of cardboard polygons of the required sizes and shapes, paint them various colors and fit them into these tessellations. If the restriction about the vertices is removed, the same polygons will form an infinite variety of mosaics. (Some striking examples of these nonregular but symmetrical tessellations are reproduced in Hugo Steinhaus' *Mathematical Snapshots*, recently reprinted by the Oxford University Press.

All tessellations that cover the plane with a repeated pattern belong to a set of 17 different symmetry groups that exhaust all the fundamentally different ways in which patterns can be repeated endlessly in two dimensions. The elements of these groups are simply operations performed on one basic pattern: sliding it along the plane, rotating it or giving it a mirror reversal. The 17 symmetry groups are of great importance in the study of crystal structure; in fact, Coxeter states that it was the Russian crystallographer E. S. Fedorov who in 1891 first proved that the number of such groups is 17. "The art of filling a plane with a repeated pattern," writes Coxeter, "reached its highest development in thirteenth-century Spain, where the Moors used all seventeen groups in their intricate decorations of the Alhambra. Their preference for abstract patterns was due to their strict observance of the Second Commandment ['Thou shalt not make thee any graven image . . .']."

It is not necessary, of course, to limit the fundamental shapes of such patterns to abstract forms. Coxeter goes on to discuss the ingenious way in which the Dutch artist Maurits C. Escher, now living in Baarn, has applied many of the 17



One of Maurits Escher's mathematical mosaics

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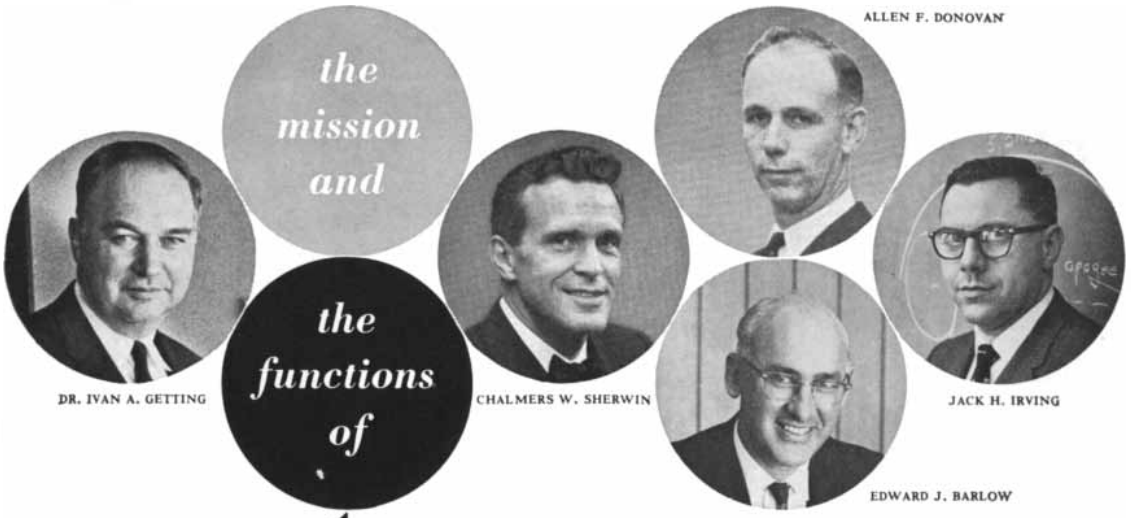

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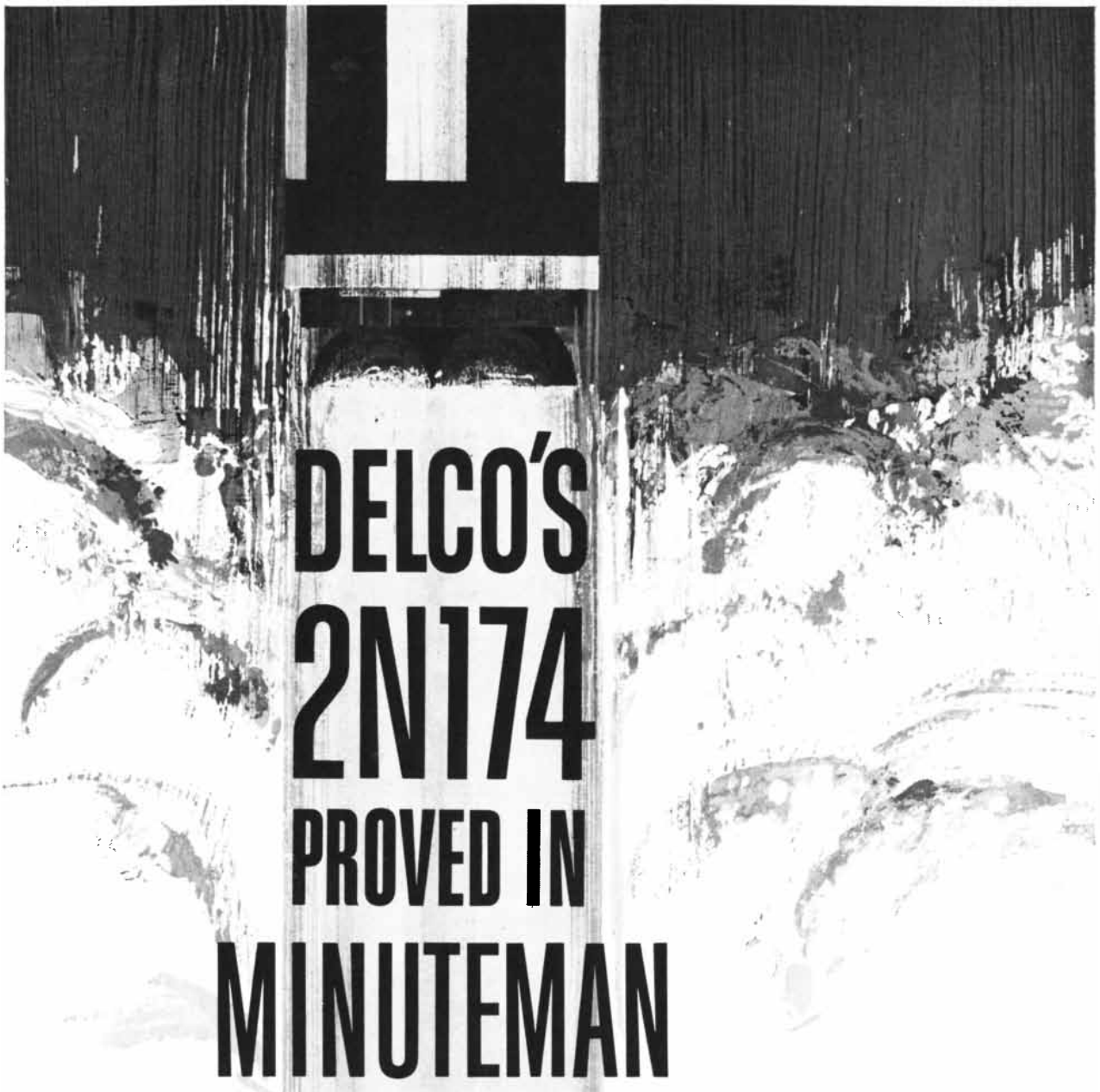
symmetry groups to mosaics in which animal shapes are used for the fundamental regions. One of Escher's amazing mosaics, reproduced in Coxeter's book, is the knight on horseback shown in the illustration on page 172; another is reproduced on the cover of this issue of SCIENTIFIC AMERICAN. At first glance, Coxeter points out, the knight pattern appears to be the result of sliding a basic shape along horizontal and vertical axes; but on closer inspection one sees that the same basic shape also furnishes the background. Actually, the more interesting symmetry group for this pattern is generated by what are called glide reflections: sliding the shape and simultaneously giving it a mirror reversal. Strictly speaking, this is not a tessellation because the fundamental region is not a polygon. The pattern belongs to a curious class of mosaics in which irregular shapes, all exactly alike, lock together like pieces in a jigsaw puzzle to cover the plane. Abstract shapes of this sort are not hard to devise, but when they are made to resemble natural objects, they are not so easy to come by.

Escher is a painter who enjoys playing with mathematical structure. There is a respectable school of aesthetics that views all art as a form of play, and an equally respectable school of mathematics that looks upon all mathematical systems as meaningless games played with symbols according to agreed-upon rules. Is science itself another kind of game? On this question Coxeter quotes the following lines from John Lighton Synge, the Irish mathematical physicist:

"Can it be that all the great scientists of the past were really playing a game, a game in which the rules are written not by man but by God?. . . When we play, we do not ask why we are playing—we just play. Play serves no moral code except that strange code which, for some unknown reason, imposes itself on the play. . . . You will search in vain through scientific literature for hints of motivation. And as for the strange moral code observed by scientists, what could be stranger than an abstract regard for truth in a world which is full of concealment, deception, and taboos?. . . In submitting to your consideration the idea that the human mind is at its best when playing, I am myself playing, and that makes me feel that what I am saying may have in it an element of truth."

This passage strikes a chord that is characteristic of Coxeter's writings. It is one reason why his new book is such a treasure trove for students of mathematics whose minds vibrate on similar wavelengths.



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THE AMATEUR SCIENTIST

Various experiments for a rainy weekend

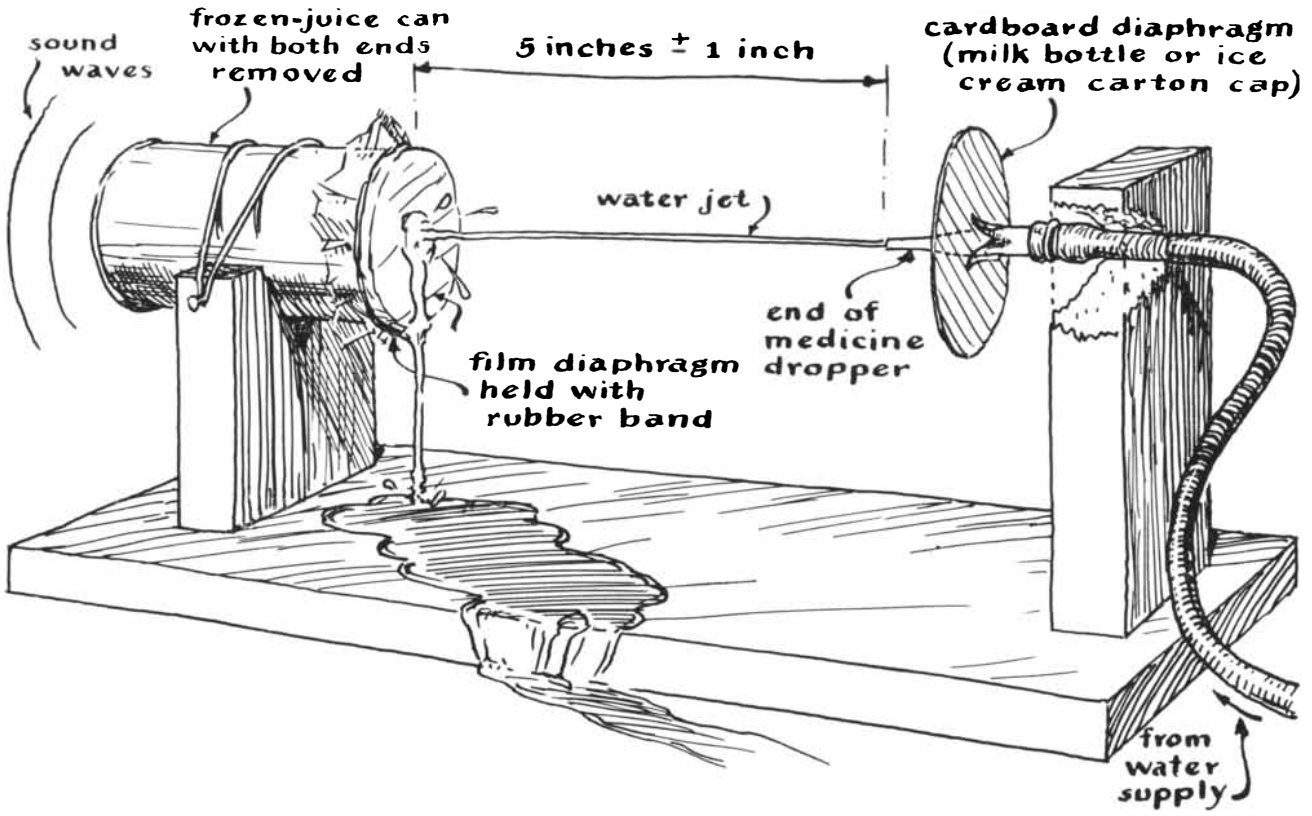
Conducted by C. L. Stong

Now and again, especially on a rainy weekend, it is fun to set up one or another of the so-called string and sealing wax experiments. These reached the peak of their popularity among amateurs of the last century, when phenomena such as sound and heat were under vigorous investigation. Many of the experimental devices can be constructed in minutes from simple materials ordinarily found in the house. Not all can be made to work on the first try, but therein lies much of their charm.

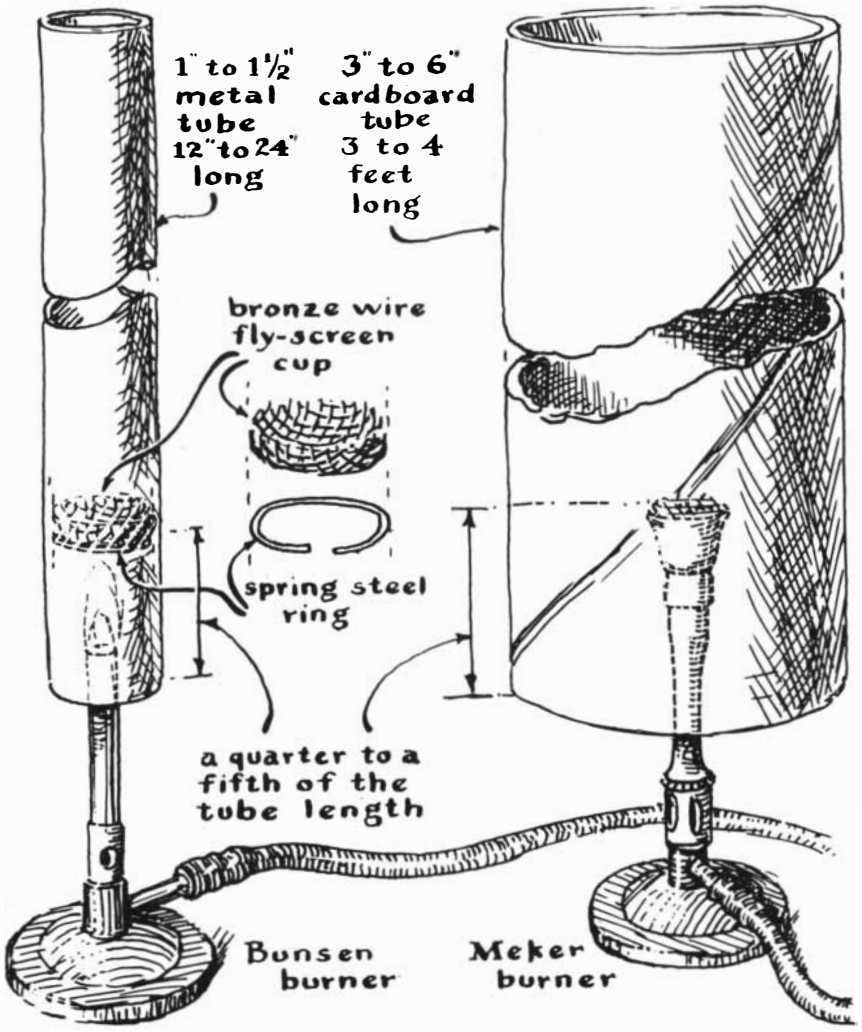
An elegant example is the hydroacoustic amplifier devised by Chichester Bell, a cousin of Alexander Graham Bell. With only a thin stream of water playing against a flexible diaphragm, Bell generated continuous sound waves and amplified faint sounds such as the ticking of a watch. In short, his apparatus performed at least two basic functions of the electronic amplifier.

In making his amplifier Bell exploited surface tension: the tendency of a liquid to take the shape that minimizes its ratio of surface to volume. A solid stream of water tends to break into spherical drops—the shape of minimum surface-to-volume ratio. Assume, for example, that a solid stream about the thickness of a pencil lead proceeds from a nozzle for a distance of six inches. It has the form of a long, thin cylinder. Cylinders present minimum surface when their length and diameter are in the ratio of four to three. Accordingly the stream first breaks into a succession of small cylinders of this proportion, to develop a series of deepening constrictions that at one stage resembles a string of sausages. After the water has proceeded for a distance that depends upon the velocity and diameter of the stream, the constrictions develop and the stream breaks into a series of elongated drops. These oscillate in three dimensions with diminishing amplitude until their kinetic energy is transformed into heat, at which point they become spheres.

Bell observed that the constrictions do not necessarily start to develop the instant the water leaves the nozzle. Although the shape of the stream is highly unstable, the forces associated with sur-



An acoustic amplifier that works on a stream of water



Singing pipes actuated by heated screening (left) *and a Meker burner* (right)

face tension tend to remain in equilibrium. But they are easily disturbed. Equilibrium can be upset, for instance, if the apparatus is vibrated. If the nozzle is displaced abruptly as little as a millionth of an inch, a corresponding constriction will travel down the stream and initiate the formation of a drop. Random vibrations of at least this intensity are normally present everywhere. For this reason jets of water characteristically break into drops of random size.

Bell insulated the jet from random vibrations by inserting the nozzle in a soft rubber tube that also supplied the water. Under a pressure of five to 10 pounds an unbroken stream .05 inch in diameter would proceed for a distance of roughly five inches. Bell then directed the jet against the middle of a thin, flexible diaphragm about an inch in diameter and spaced the nozzle at a distance such that constrictions in the stream were on the verge of developing at the point where the water struck the diaphragm. The force of the jet caused the diaphragm to bow inward slightly. This force was constant. Accordingly the diaphragm, though bowed, did not vibrate. With the apparatus adjusted to this sensitive state a faint vibration communicated to the nozzle would be reproduced as an amplified movement of the diaphragm. Each disturbance of the nozzle caused a constriction to develop that deepened as it traveled down the stream. Upon arriving at the diaphragm the constriction exerted less force than the full stream. Moreover, the depth attained by the constriction and the force exerted on the diaphragm by it varied in proportion to the intensity of the initiating vibration through a significant range of frequencies. As a result of the diminished force the diaphragm would move in the direction of its unstressed position and communicate its movement to the surrounding air as a sound wave. Bell maximized the acoustic efficiency of the apparatus by coupling a horn to the diaphragm.

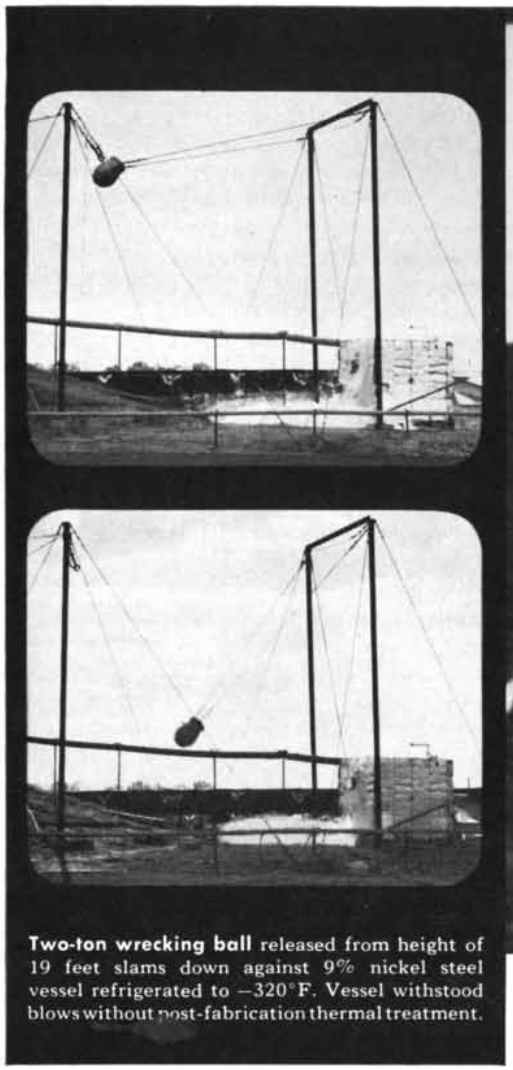
To make the apparatus oscillate, or sing, he attached a second diaphragm to the nozzle. A random mechanical vibration initiated the first constriction and resulting sound vibration. Part of the acoustic energy would feed back and impinge on the diaphragm at the nozzle, start a second constriction, and so on. The pitch of the resulting sound was determined largely by the resonance of the diaphragm-and-horn assembly.

Complex sounds were amplified by coupling the vibrating source or input signal to the nozzle mechanically. Speech could be reproduced by directing the voice against a diaphragm linked to the nozzle by a stiff wire. The input diaphragm was shielded acoustically from the output to prevent feedback and oscillation. The ticking of a watch could be amplified to fill a room merely by resting the case of the watch lightly against the side of the nozzle.

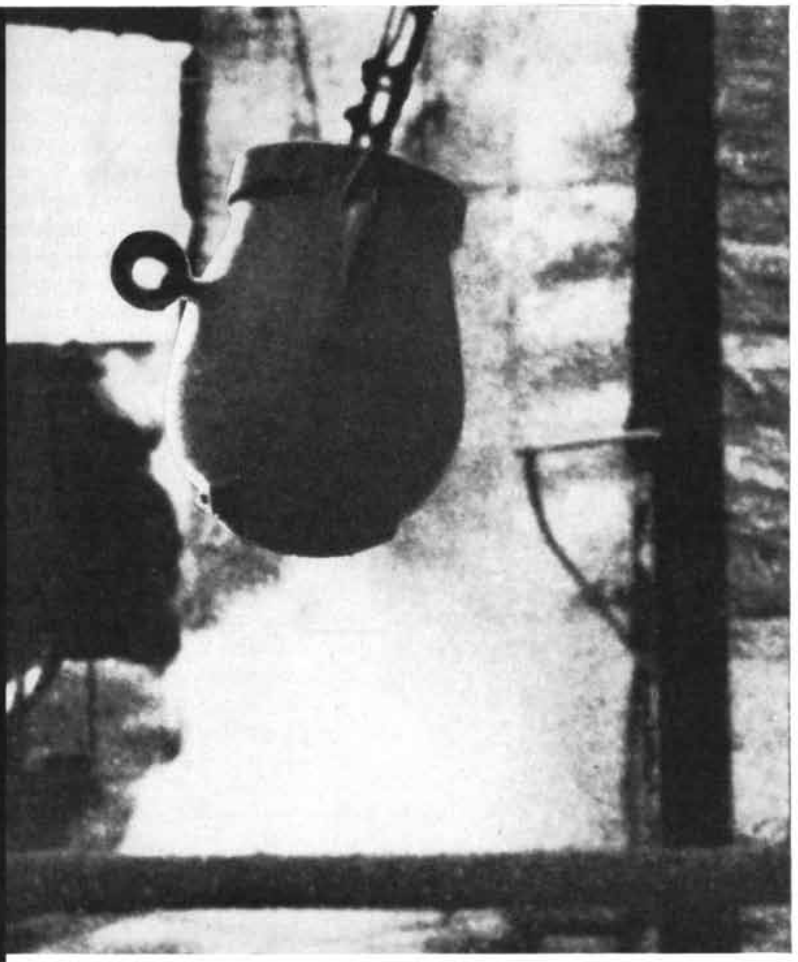
A simple version of the apparatus calls for a tin can with the ends cut out for supporting the output diaphragm, and a nozzle made from the glass tip of a medicine dropper. The nozzle is pushed into the end of a quarter-inch rubber tube connected to a water tap. The can and tube are mounted on wooden supports attached to a base as depicted in the illustration on page 177. If the apparatus is to be used more than once, the wooden parts should be waterproofed by a coat of melted paraffin or shellac.

The diaphragm may be made of any thin plastic sheet, such as Saran Wrap. The material is placed over one end of the can like a drumhead and is secured by a tight rubber band. After the band is in place the edges of the material are pulled down uniformly until the diaphragm is tight enough to ring when the side of the can is tapped lightly.

Some medicine droppers end in a small bulb. These will not work. To remove the bulb hold the tip in a gas flame until the glass softens uniformly. Then grasp the bulb with a pair of tweezers, remove from the flame and pull the glass straight out about an inch. Nick the extended part with the edge of a file at the point where the tapered bore is about the diameter of the lead used in mechanical pencils (.05 inch) and break by bending the glass in the direction that exerts tension on the nick. Insert the modified nozzle in the rubber tubing and assemble on the wooden support, allowing about half an inch of rubber between the inner end of the nozzle and the wood.



Two-ton wrecking ball released from height of 19 feet slams down against 9% nickel steel vessel refrigerated to −320°F. Vessel withstood blows without post-fabrication thermal treatment.



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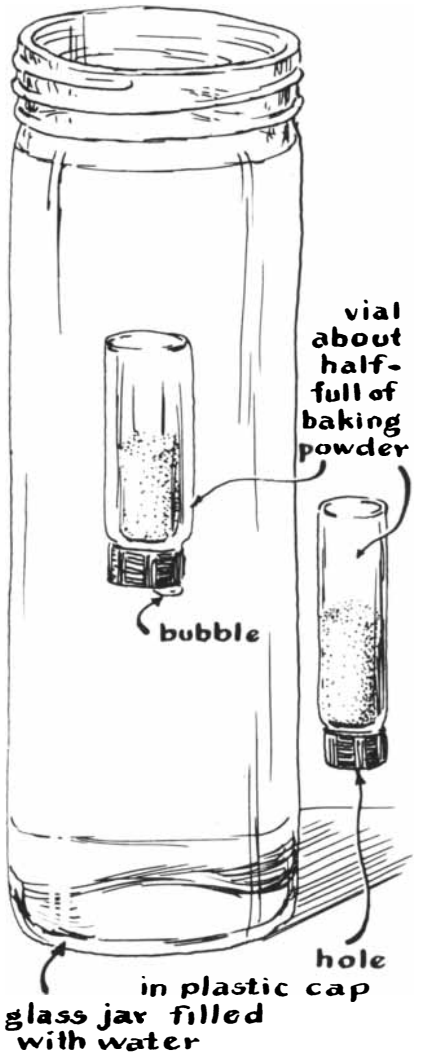
If possible, equip the rubber tubing with a needle valve for adjusting the flow of water. The system can be "tuned" by regulating the amount of water admitted to the nozzle. A needle valve provides fine control. The apparatus will operate for about 10 minutes on a quart of water. It can be set in a rectangular cake pan to catch the runoff.

A hydroacoustic amplifier made in this way is not likely to take prizes in a hi-fi contest. The frequency response is comparable to that of early acoustic phonographs. That it works at all, however, is astonishing.

Another fascinating oscillator, one that is activated by heat, is described by Julius Sumner Miller, professor of physics at El Camino College in California. "Push a cup of fly screening about a quarter of the way into a 15-inch length of metal pipe an inch and a half in diameter," he writes. "The screening can be held in place with a spring steel ring, as shown in the accompanying illustration [*page 178*]. Now hold the pipe vertically (with the screen end down) over a Bunsen flame, the burner of a gas stove or even a large candle, so that the screen is heated. This takes only a few seconds. Remove the pipe from the flame but continue to hold it vertically. It sings! Shift the position of the screening and try the experiment again. With repeated trials a position can be found that causes the pipe to sing loudest. The critical location will be found to lie somewhere between a fifth and a quarter of the length of the pipe—between three and four inches in the case of a 15-inch pipe. Make a second pipe of other dimensions, say 12 inches long and an inch in diameter. Fit it with screening and heat both pipes simultaneously. When the pipes are removed from the flame, each will sing at its characteristic pitch, and a wavering beat note will be generated.



An oscillating Cartesian diver

"Now let us explore the physics of this astonishing business. The physics of sounds maintained by heat is not simple, but in general the requirement is that energy be applied intermittently to the air. In the case of the screened pipes, heat is applied to produce periodic convection currents in the air. Consider the situation at the instant the pipe is removed from the flame. The screening is red hot, and heat is radiated to the air in the immediate vicinity. As this air expands it sends a wave of compression up the pipe. But the density of the heated air is reduced. Consequently a rarefaction is formed. The void is promptly filled by an upward rush of cold air from beneath the screening. This air is similarly heated and the cycle repeats. If the heat is maintained (for example, by passing an electric current through the screening), the pipe will sound continuously. When the screen is heated in the manner suggested, however, the sound is heard only briefly.

"Why is the location of the screening important? As mentioned, the operation of the device depends on the fact that heat can set air in motion. In this case the air moves in two ways. First, the entire column drifts slowly up the pipe by convection, just as hot gases move up a chimney. Second, sound waves are generated in the pipe, with the result that the molecules of air oscillate at the ends of the pipe but stand still in the middle, where the node of the sound wave (the point of varying compression) is situated. The node of sound vibration in the pipe is precisely the reverse of the node associated with a vibrating string. In the latter the nodes (points of maximum compression) are situated at the ends, where the string is attached, and the antinode (point of maximum excursion) is in the middle of the string. The most favorable position for the screening in our pipes is in the middle of an antinode. This is an acoustic position and does not necessarily correspond to the physical geometry of the pipe. It must be found experimentally.

"What kind of pipe and screening should be used? The material is not critical. Ordinary water pipe will work, or aluminum tubing. The latter is easy to cut. Copper or bronze fly screening works well, as do the various metal gauzes. There is no need to measure the initial position of the screening. Just push it into the pipe a little way. If the pipe does not sing on the first try, push the screening in a little farther and try again. The same effect, incidentally, can be observed by using an alternate scheme, one rather more difficult to make work. If hot air is fed into the bottom of the pipe and a piece of screening in the upper part of the pipe is left cold, the pipe will also sing.

"A comparable effect, although one caused by a different mechanism, can be observed by holding a cardboard tube (of any length, diameter and wall thickness) over a gas burner of the Meker type [*see illustration on page 178*]. These burners resemble the more familiar Bunsen burner but have a heavy wire grid across the top. The flame is short, intense and situated above the grid. The tube sings as long as the flame persists. Here the physics of this action differs somewhat from that of the metal pipes fitted with screening. As in the case of the pipes, however, the addition of heat to the air in the immediate neighborhood of the flame gives rise to a pressure change, and a sound wave is set up in the tube. The pulse of high pressure reduces the convective flow of gas through the grid of the burner and so starves the flame momentarily. When the pressure wave has passed, convection carries a fresh supply of gas through the grid, the flame regains its former intensity and the cycle repeats. Heat energy is thus developed discontinuously. Depending upon the size of the burner and the resonant frequency of the pipe, the oscillations can acquire enough intensity to extinguish the flame. As with the screened metal pipes, the most effective position for the burner is found experimentally. If the tube is lowered over the burner too quickly, however, the flame is almost certain to

Photo by Frank Cowan

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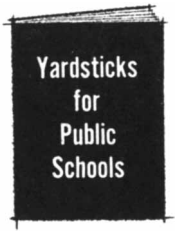

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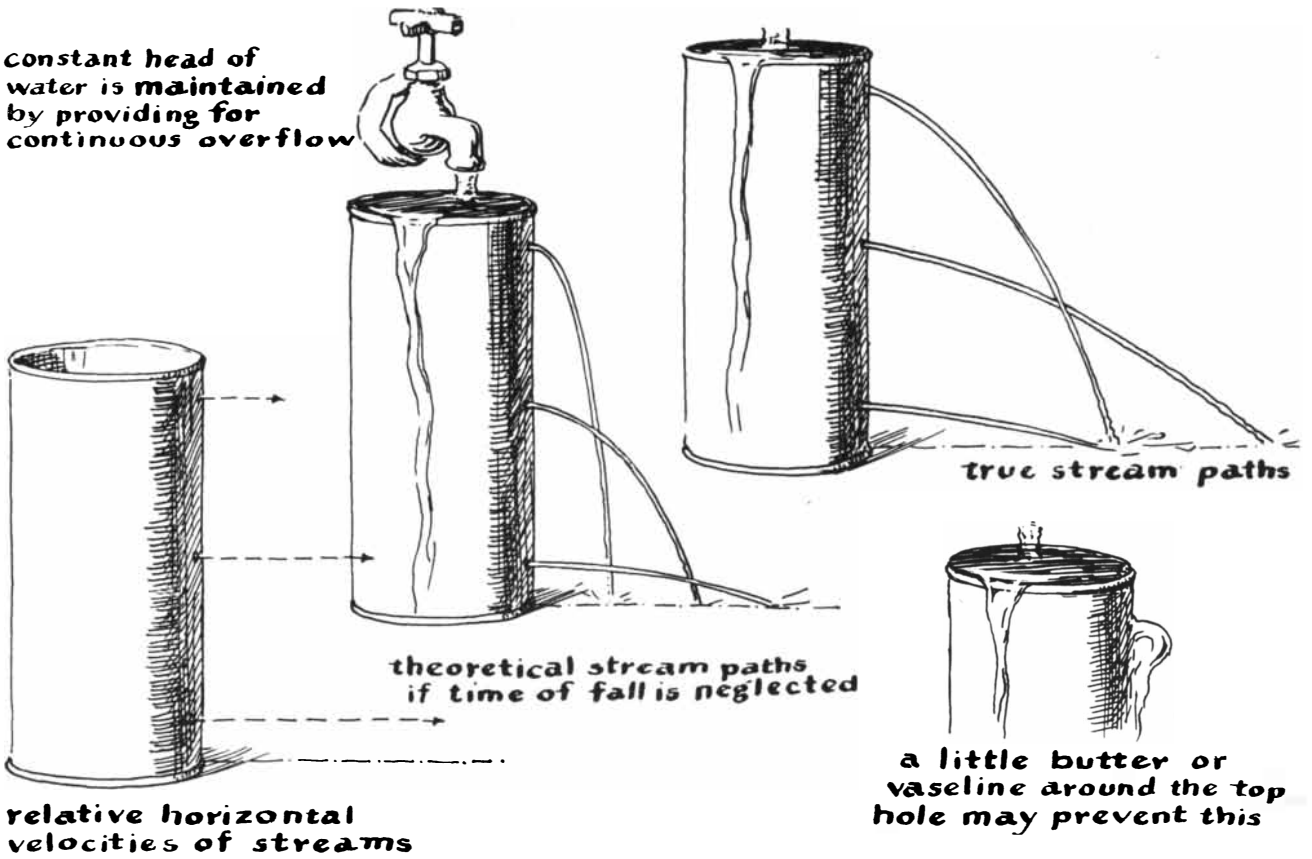
go out. Incidentally, a stovepipe, a gutter pipe and even a cast-iron water pipe can be excited this way and made to emit a surprising volume of sound.

"Another amusing oscillator, one that involves buoyancy rather than acoustics, can be set up with one or more small vials, some baking powder and a jar of water. It is a new version of the Cartesian diver, the device that is encountered as a toy or as an apparatus by which biologists measure the metabolism of minute living systems such as microorganisms. The conventional Cartesian diver consists of a vessel that contains a bubble just large enough to make the diver float. Any change in atmospheric pressure at the surface is communicated to the liquid inside the diver and compresses the bubble or causes it to expand. This alters the specific gravity of the diver and it sinks or rises accordingly.

"How is this principle used by biologists? In one kind of study an investigator wishes to know the rate at which a microorganism evolves gas in the process of respiration. To measure the rate at which gas is evolved a culture of the organism is incubated inside a minute diver that has been balanced at an intermediate level between the top and bottom of a glass vessel containing a transparent liquid. The evolved gas displaces liquid in the diver, thus altering its specific gravity, and the diver rises proportionately.

"The effect can be approximated on a large scale by putting enough baking powder in a stoppered vial to make the vial sink at the rate of about an inch per second. A 10-milliliter vial with a diameter of one centimeter and a screw-on plastic cap works well. Unless the precise displacement and weight of the vial is known, the amount of baking powder required must be determined by trial and error. After the vial has been charged with baking powder, a hole approximately .05 inch in diameter is drilled through the center of the plastic cap. Then the vial is placed upside down in a jar of water [*see illustration on page 180*].

"After the vial has rested on the bottom for a moment, a bubble of gas forms at the hole and continues to grow until the bottle and attached bubble acquire enough buoyancy to rise to the surface. (Baking powder contains sodium bicarbonate mixed with either an acid or a salt; it liberates carbon dioxide when water is added to it.) Watch the bubble carefully when the diver begins to rise. (We say that it 'rises.' Actually it is pushed up by the surrounding water, which is pulled down by the force of gravity.) As the diver proceeds upward, the water exerts progressively less pressure on the bubble, which, obedient to Boyle's law, expands at an increasing rate. The bottle therefore picks up speed and, because of turbulence, gyrates a little. The motion is violent enough to detach most of the bubble when the diver breaks through the surface. The diver then sinks. Be sure to observe the small bubble that remains attached to the cap. On the way down the bubble disappears into the bottle, demonstrating that hydrostatic pressure increases with depth. After the diver rests on the bottom for a moment, the pressure of the accumulating gas overcomes the hydrostatic pressure, the bubble appears and the diver makes another round trip to the surface. Its up-and-down motion will



An experiment with hydrostatic pressure

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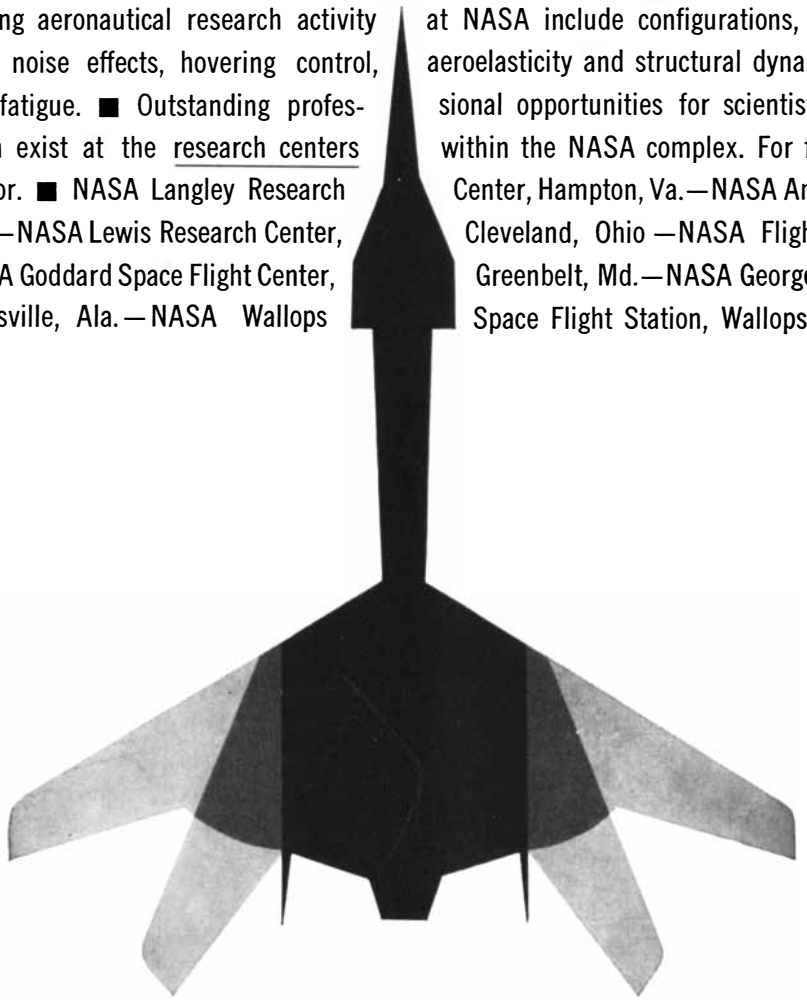


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

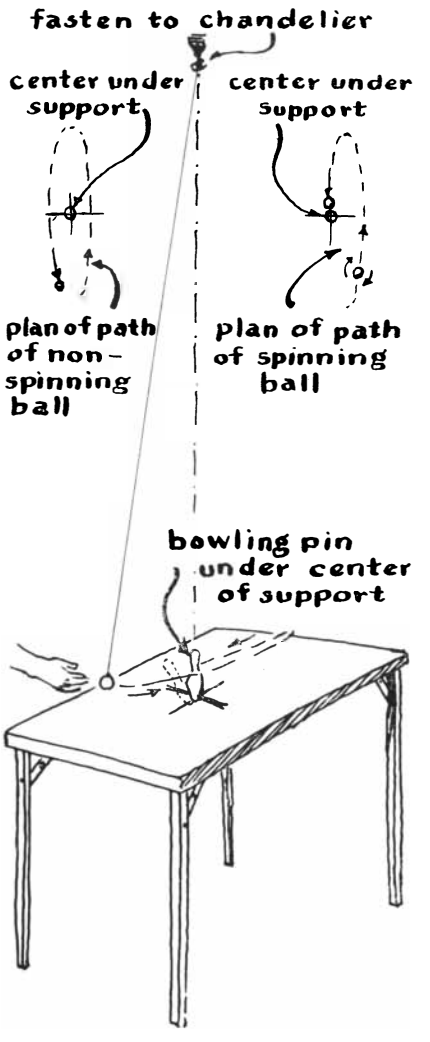
continue for half an hour or more, depending on the size of the bottle.

"Not all the effects that arise from hydrostatic pressure are easy to visualize. About a century ago, for instance, a natural philosopher who saw little point in confronting theory with experiment drew a picture in his mind's eye of how water would flow from a container with three holes in its sides: one hole near the bottom, a second hole above the first and a third hole the same distance above the second. He concluded that the stream from the bottom hole would squirt farthest because the hydrostatic pressure would be greatest at the bottom. The middle stream, according to his reasoning, would not travel quite so far as the bottom one before striking the surface on which the container rested, and the uppermost stream would land closest to the can. He thereupon proceeded to publish his 'observation,' together with a diagram similar to that second from the left in the accompanying illustration [*page 182*]. His view won wide acceptance and has been perpetuated down through the years in physics books, including one that received worldwide distribution as recently as 1957. When the question is put to nature in the form of an experiment, however, the streams are found to behave as depicted by the diagram third from the left in the illustration. Where did the philosopher make his mistake?

"It is, of course, easy to overlook the obvious. Consider the game, sometimes offered at carnivals, in which a bystander is invited to knock down a bowling pin with a wooden ball that is suspended by a string [*see illustration on this page*]. The carnival barker demonstrates the game and explains the ground rules. The bystander is instructed to swing the ball so that it misses the pin on the forward swing but knocks it down on the return swing. It all looks very easy, because the barker knocks the pin over every time. The innocent who pays a dime for a try never succeeds because he observes only one of the ball's two motions as it leaves the barker's hands. He sees it swing but he fails to note that the barker first winds up the string so that the ball unwinds in transit and therefore spins in addition to swinging. When swung without spin the ball follows an elliptical path with the pin inside it. When the ball is spun, it responds to the Magnus effect, the aerodynamic force that is exerted on a spinning sphere (or cylinder) at right angles to its trajectory through the air. The same effect explains why a spinning baseball curves. In the case of the carnival game the spin warps the elliptical path just enough to bring the ball into contact with the pin on the return swing, as experiment will convincingly demonstrate.

"One can similarly go astray by failing to take all factors into account when interpreting even the most obvious laws of physics. Consider the law established by Galileo that states in effect that bodies of various masses fall at the same rate. Is it possible for an object that moves solely under the force of gravity to exceed the velocity of free fall? An entertaining apparatus can be constructed to prove that the answer is yes.

"Consider a stick standing on end on a table top. If it falls over, all points on it describe circular paths and all points on it have the same angular velocity. Clearly, however, all points do not have the same linear velocity. (It is assumed that the lower end of the stick does not skid but remains fixed as though



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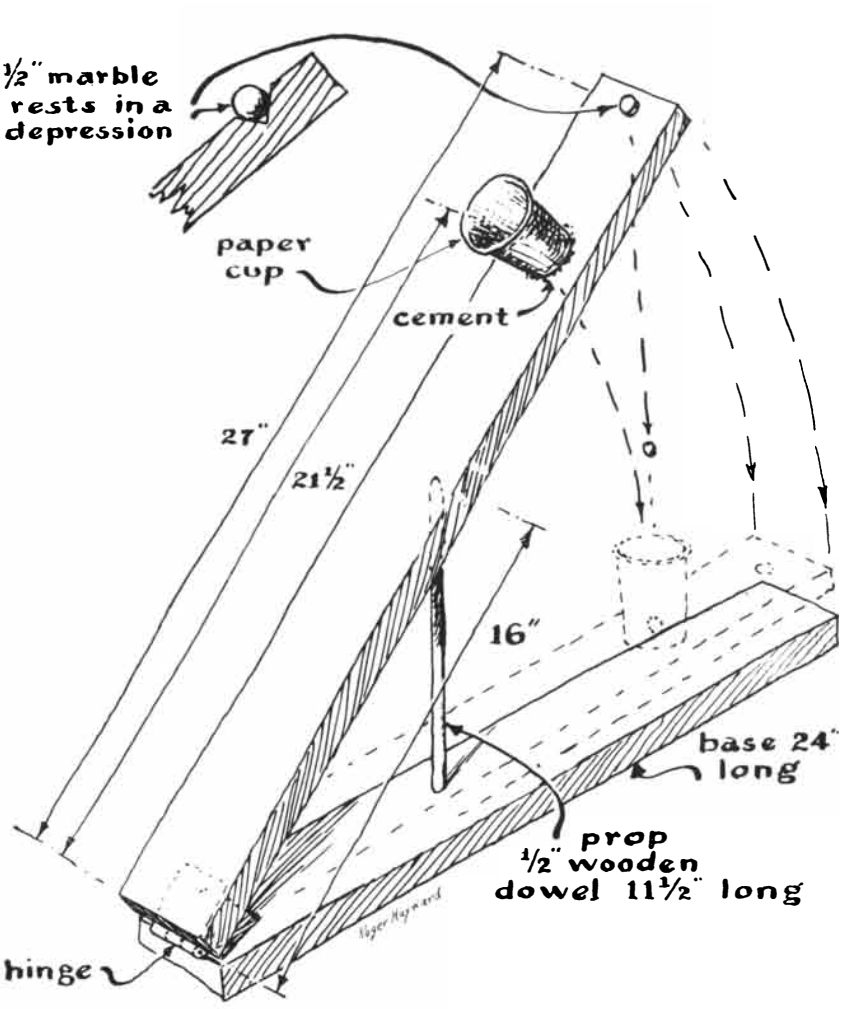

An apparatus for investigating free fall

on a hinge.) Because all points on the stick have the same angular velocity at all times, it is obvious that all points have the same angular acceleration at all times. But if the angular acceleration is everywhere the same, then the linear acceleration is everywhere different.

"Hence if some point on the stick falls at the velocity of free fall, other points must fall at either a greater or lesser velocity. The velocity of fall at the hinged end is obviously zero. It is reasonable to assume that some point between the hinged end and outer end would attain the velocity of free fall. If so, however, the outer end would necessarily exceed the velocity of free fall.

"To test this assumption hinge a pair of sticks as shown in the accompanying drawing [*above*]. Open them to an angle of more than 35 degrees and cut a prop to support the upper stick at this angle. Make a small depression in the top of the upper stick near the end to support a small weight such as a marble or a steel ball. Then find the point on the lower stick directly below the depression and mark it with an *X*. Measure the distance between the *X* and the outer end of the lower stick. Cement a paper cup to the upper stick at this distance from the outer end. (When the sticks are closed, the cup should be centered over the *X* on the lower stick.)

"To make the experiment, open the sticks and insert the prop. Place the weight in the depression and quickly remove the prop. The outer end of the upper stick will drop away from the weight as the cup moves into position to catch the weight at the end of the fall. The end of the stick has dropped faster than the weight, which was in free fall. What is observed here, incidentally, explains why tall smokestacks usually buckle as they fall."

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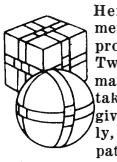

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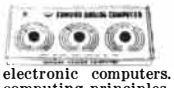

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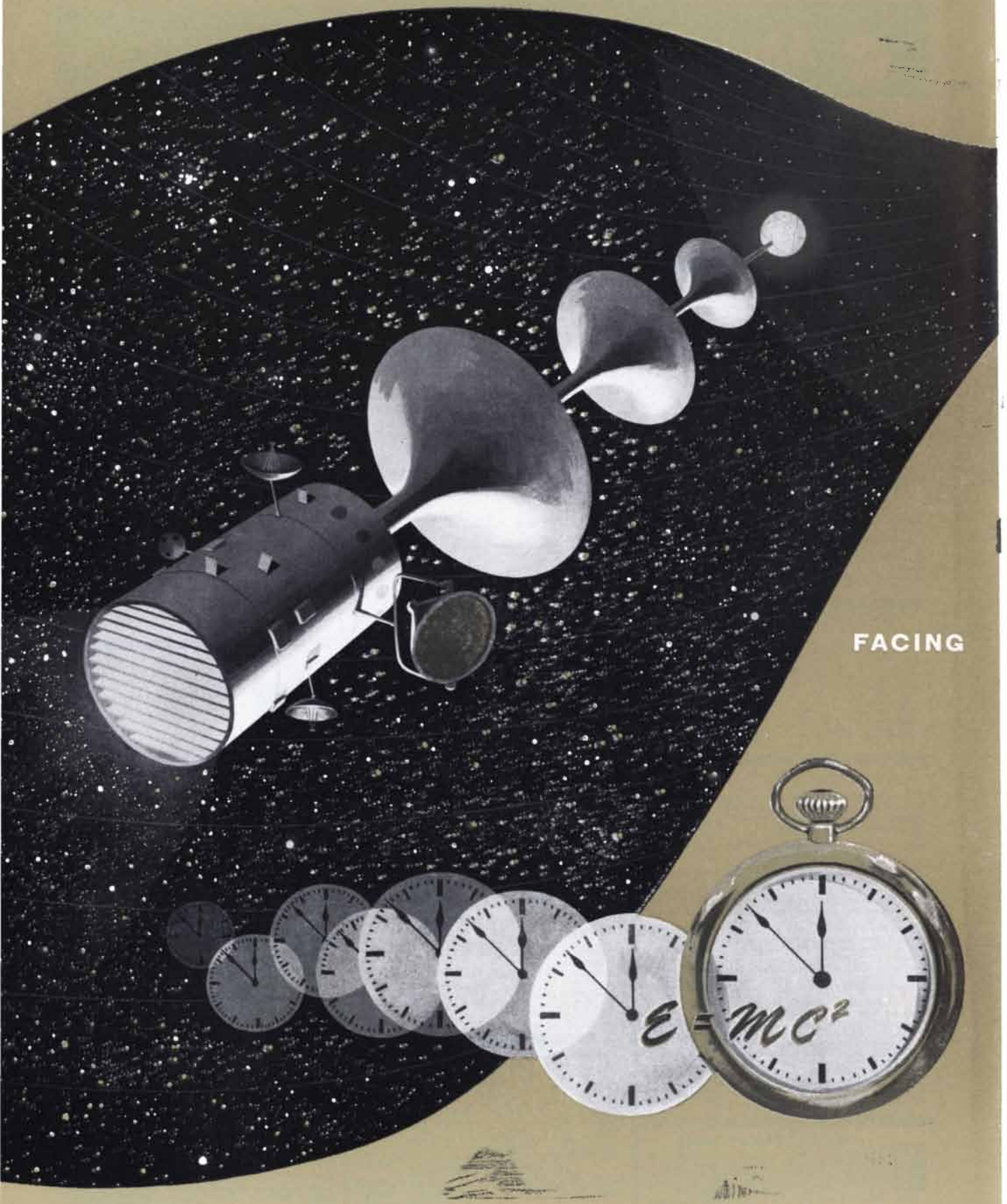

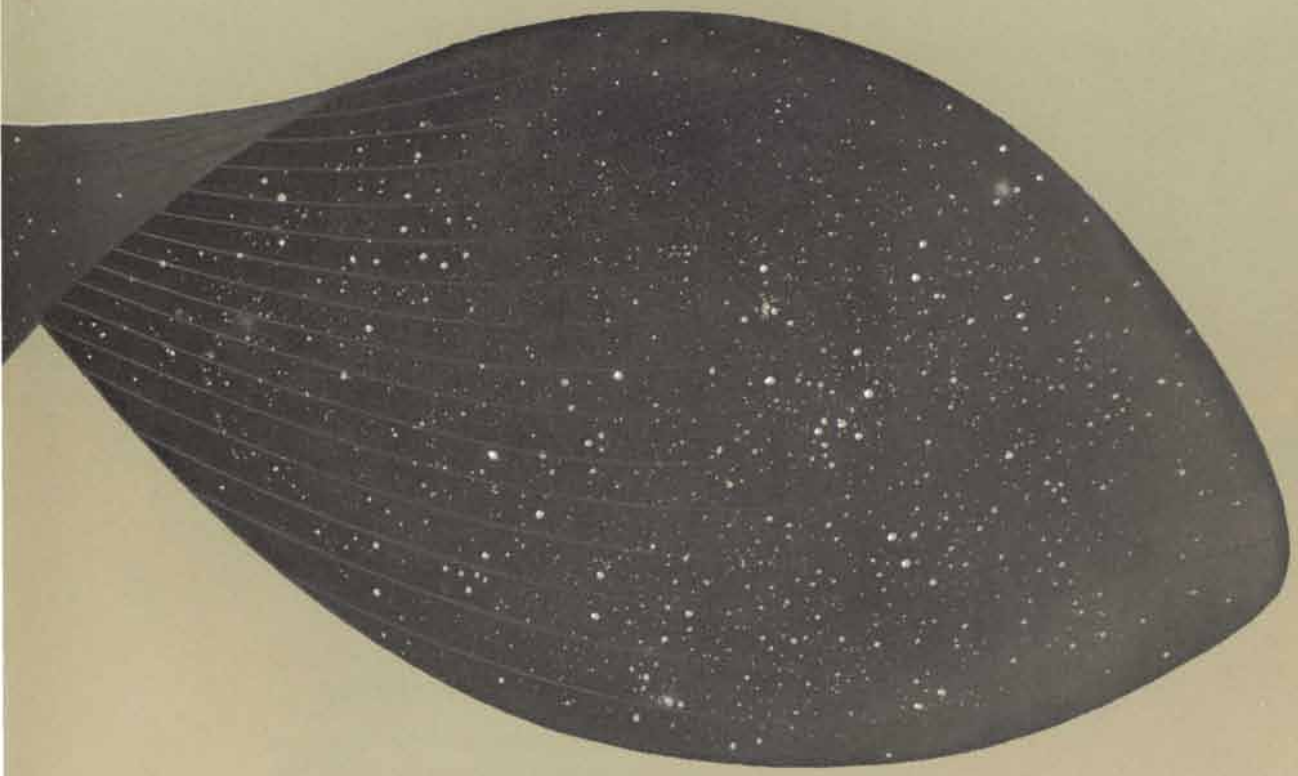

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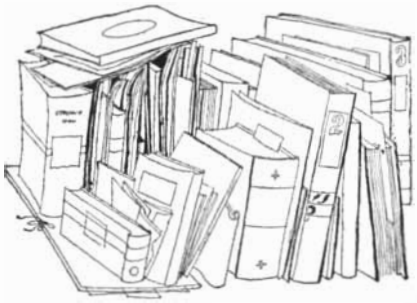

BOOKS

C. P. Snow's account of the role of two scientists in government

by P. M. S. Blackett

SCIENCE AND GOVERNMENT, by Sir Charles Snow. Harvard University Press ($2.50).

To the people making it, history is a long series of decisions: whether to do this or to do that; whether to take one road or another; whether to be bold or whether to be cautious; whether to make war or to make peace; or, in this nuclear age, whether to live or to die. H-bombs have made us all decision-conscious. All decisions must start with an analysis of the past, for without understanding the past it is not possible to predict the future, and without some prediction of the future no rational decisions can be made. The decision to take one course of action rather than another implies the prediction that the one chosen will produce more favorable results than the one rejected. Unless one can make some such prediction, one has to rely on a guess; when this is successful, history calls it inspired.

How have the important decisions of the tumultuous past three decades actually been made? What sort of people made them? How much part did calm and detached thought play, and how much instinctive feelings or plain emotion? To what extent did personal loyalties and personal hates dictate the pattern of world events? To what extent did the decision makers think out the complex consequences of their actions and plan accordingly? Or did they stake their country's—or indeed mankind's—future on a gamble? Or were the decision makers perhaps more like players of chess than of poker?

All these questions came into my mind as I read C. P. Snow's *Science and Government,* originally presented at Harvard University as the Godkin Lectures. Snow is primarily concerned with understanding how some of the important decisions of our time were in fact made. His training as an experimental scientist, his years as a civil servant in close touch with the British scientific effort during the war and after, his experience as a director of a major engineering firm and finally his authorship of many successful novels—have given him a background that no contemporary, either in Britain or the U. S., has had. Moreover, his main interests as a novelist have been concerned less with the relationship between men and women than with the relationship between men and men, as they live their professional lives in government departments, in scientific laboratories, in the board rooms of industry or the common rooms of universities. The interplay of personalities and policies, of abilities and ambitions, the actual functioning of that remarkable abstraction, the so-called British Establishment, were among the interests that have made Snow the novelist of committees and court politics in this scientific age.

Snow analyzes in detail two major decisions of British war policy: the decision made between 1935 and 1937 to give the development of radar the highest possible priority, and the decision in 1942 to make the bombing of German cities a major part of the British war effort. In the conflicts that preceded these two fateful decisions, two outstanding and very different scientists, Henry Tizard and Frederick Lindemann, played a major role. Much of Snow's book is concerned with the clash between these two strong personalities. By various accidents I was personally involved in both conflicts, and I can vouch for the fundamental truth of Snow's account of what went on. Moreover, I think that his description of the conflicts and his penetrating insight into the characters of the two men is brilliantly carried out: this is a first-rate piece of writing. One quotation must suffice here:

"Judged by the simple criterion of getting what he wanted, Lindemann was the most successful court politician of the age. One has to go back a long way, at least as far as Père Joseph, to find a gray eminence half as effective. Incidentally, there exists a romantic stereotype of the courtier—as someone supple, devoid of principle, thinking of nothing except keeping his place at court. Now Lindemann was, in functional terms, a supreme courtier; and yet no one could be more unlike that stereotype. Life is not as simple as that, nor as corrupt in quite that way. Throughout his partnership with Churchill, Lindemann remained his own man. A remarkable number of the ideas came from him. It was a two-sided friendship. There was admiration on Lindemann's side, of course, but so there was on Churchill's. It was a friendship of singular quality—certainly the most selfless and admirable thing in Lindemann's life, and in Churchill's, much richer in personal relations, it nevertheless ranked high. It is ironical that such a friendship, which had much nobility and in private showed both men at their human best, should in public have led them into bad judgments."

There is no doubt that Tizard must be given a major part of the credit, and Lindemann none, for the radar chain. When war came, Britain had an operational early-warning radar system all around its east and south coasts; moreover, it had fighter squadrons trained to intercept the German bombers by using radar plots. Our edge over the enemy was more in massive deployment and operational training than in the basic knowledge of electronics. Tizard, above all others, was responsible for the high priority that led to the rapid development and installation of the radar system. Without it the Battle of Britain in 1940—a near thing at best—might have been lost, with incalculable historic consequences. As Snow points out, this particular decision was not technically a difficult one, being in effect a choice of doing something that might work as against doing nothing. The conflict over the decision, which was very real and in slightly different circumstances might have gone the wrong way, appears in retrospect to have been at the bottom purely personal. At that time Lindemann opposed anything suggested by his former friend Tizard.

Tizard's second vital contribution related directly to the U. S. In the sum-

mer of 1940, soon after the fall of Paris, he persuaded a reluctant British Government to send to the U. S. a mission headed by himself with the famous black box containing samples, blueprints and reports on nearly all important new British war devices, including the magnetron. The contents of this box were later called by an American writer "the most valuable cargo ever brought to our shores." This imaginative act of trust, which Tizard initiated and forced through (Tizard described it as "bringing American scientists into the War before their Government"), had immensely beneficial effects on the scientific aspects of the Allied war effort.

By 1941 Tizard was widely recognized as the ablest British scientist to apply himself to the problems of war. He was popular both with scientists and with the armed services; he had two major achievements to his credit—the radar chain and the American mission—and in addition he had done much to make the services scientifically minded. Two years later he was effectively out of the war effort. How this came about is a major theme of Snow's book. The cause of this disastrous turn of fortune—in my view disastrous for the whole British war effort—was another conflict of judgment on priorities, this time about the bombing offensive. As I was deeply involved in this, I can add something to Snow's vivid account. I will also say something of the historic background and of the aftermath of the decision to concentrate a major part of the British war effort on the destruction of German housing. So far as I know, it was the first time that a modern nation had deliberately planned a major military campaign against the enemy's civilian population rather than against his armed forces. During my youth in the Navy in World War I such an operation would have been inconceivable. Incidentally, the German air attacks on London from September, 1940, to May, 1941, were undertaken with little serious planning, and they were called off when the Germans attacked the U.S.S.R.

I remember fire-watching on the roof of a block of flats in Westminster in September, 1940, on the evening of the day the "blitz" began. We were watching the glow from the burning East London docks, and bombs were falling on central London. A young bomber pilot by me said: "I can hardly bear to wait till we can do it back to them." Such understandable sentiments do not necessarily make good strategy, nor does the commonly used argument: What else could we have done?

The origin of the Allied bombing offensive goes much further back. It was a product of the rise of the air forces of the world and of their determination to evolve a strategic role for air power that would make them independent of the two older services, the army and the navy. Since this requirement excluded co-operation with either of these two services as its major role, the Air Force sought the strategic role of attacking the sources of economic and military power in the enemy country. When this policy was first put into effect in the early summer of 1940, it was gradually realized that the accuracy of navigation was far too poor to allow our night bombers to hit anything smaller than a fair-sized town—and generally not even that. So the attempt to hit military installations, factories and transport centers was abandoned for a general attack on the centers of civilian population. Until 1943 the effort was on such a small scale and was so ineffective as to have negligible military effect. The decision to make the dehousing of the German working-class population, with the object of lowering its morale and will to fight, a major part of the British war effort was made in the spring of 1942, as Snow relates.

In March, Prime Minister Churchill asked the Air Staff how they thought they could best help our Russian allies, then engaged in desperate land battles, by stepping up the bombing offensive against Germany. The Air Staff report to the Prime Minister was sent to the Admiralty, and they sent it to me for comment. I was then Director of Operational Research at the Admiralty. Since the Air Staff estimates in this paper of what the bombing campaign had hitherto accomplished seemed to me to be based on very flimsy evidence, I set about checking the claims by the simple method of noting what the German blitz on England had accomplished and calculating from this what our much weaker attack should have done to Germany. The result was startling. It seemed probable that the German casualties from our bombs could not have been much more than the loss of trained air crews. Further, I estimated that the reduction of industrial production was less than 1 per cent. So on these two counts the direct effect of the British bombing offensive of 1940 to 1942 seemed nearly a dead loss. I took these calculations personally to Lindemann, then Churchill's personal adviser. In effect he accepted my calculations and realized that neither by the casualties inflicted nor by the interruption of production was our

bombing offensive likely to bring much relief to the Russians. So he switched the objective to the destruction of German housing. Together with the Air Staff a new paper was prepared claiming that, if all possible priority were given to bomber production and training, it should be possible in the next critical 18 months to destroy some 50 per cent of all houses in all towns with a population of more than 50,000. In April a Cabinet paper setting out these estimates was prepared and contained the recommendation that this strategy was the best available to help the Russians.

This was the paper which Snow mentions as having come to both Tizard and me; we independently agreed that the claims of destruction of houses was probably about five times too high. Our forebodings went unheeded and the bombing policy was adopted. After the war we learned that the estimates were 10 times too high.

From my talks with Lindemann at this time I became aware of that trait of character which Snow so well emphasizes: this was his almost fanatical belief in some particular operation or gadget to the almost total exclusion of wider considerations. Bombing to him then seemed the one and only useful operation of the war. He said to me (unfortunately I have no record of this conversation, but he probably said the same to others) that he considered any diversion of aircraft production and supply to the antisubmarine campaign, to army cooperation or even to fighter defense—in fact, to anything but bombing—as being a disastrous mistake. Lindemann even suggested that the building up of strong land forces for the projected invasion of France was wrong. Never have I encountered such fanatical belief in the efficacy of bombing.

The high priority given thereafter to everything pertaining to the bombing offensive made it very difficult to get adequate air support for the vital Battle of the Atlantic. If this had got worse there would have been no more bombing offensive for lack of fuel and bombs, and no invasion of France in 1944. I remember that during the winter of 1942 and 1943 the Admiralty had to enlist President Roosevelt's personal influence to ensure that a squadron of that admirable antisubmarine aircraft, the B-24, was allocated to Coastal Command (where they were brilliantly successful) and not, as the Air Staff wanted, sent to bomb Berlin, for which they were not very suitable. However, at the Casablanca Conference in January, 1943, a combined American and British bomb-

ing offensive was formally adopted as a major part of the British war strategy.

No part of the war effort has been so well documented as this campaign, which had as its official objective "the destruction and dislocation of the German military, industrial and economic system and the undermining of the morale of the German people to the point where their capacity for armed resistance is fatally weakened." Immediately after the war the U. S. Strategic Bombing Survey was sent to Germany to find out what had been achieved. A very strong team (which included two men who are now advisers to President Kennedy, J. K. Galbraith and Paul Nitze) produced a brilliant report, which was published in September, 1945. Without any doubt the area-bombing offensive was an expensive failure. About 500,000 German men, women and children were killed, but in the whole bombing offensive 160,000 U. S. and British airmen, the best young men of both countries, were lost. German war production went on rising steadily until it reached its peak in August, 1944. At this time the Allies were already in Paris and the Russian armies were well into Poland. German civilian morale did not crack.

Perhaps it is not surprising that the report of the Strategic Bombing Survey seems to have had a rather small circulation; it is to be found in few libraries and does not appear to have been directly available, even to some historians of the war.

If the Allied air effort had been used more intelligently, if more aircraft had been supplied for the Battle of the Atlantic and to support the land fighting in Africa and later in France, if the bombing of Germany had been carried out with the attrition of the enemy defenses in mind rather than the razing of cities to the ground, I believe the war could have been won half a year or even a year earlier. The only major campaign in modern history in which the traditional military doctrine of waging war against the enemy's armed forces was abandoned for a planned attack on its civilian life was a disastrous flop. I confess to a haunting sense of personal failure, and I am sure that Tizard felt the same way. If we had only been more persuasive and had forced people to believe our simple arithmetic, if we had fought officialdom more cleverly and lobbied ministers more vigorously, might we not have changed this decision?

Snow devotes the last part of his book to extracting from these two cautionary tales, as he calls his accounts of the radar and the bombing conflicts, some lessons for the future. He wisely warns us of the danger of what he calls the euphoria of gadgets, meaning by this the tendency on the part of some scientists—and not only scientists—to believe that a new device, or a new tactic, is a solution of all our defense problems. This was fundamentally the error behind the overconcentration during the war on the area bombing of enemy cities. It is worth remembering that Germany never did this. Her remarkable military successes of the first years of the war were achieved by brilliant co-ordination of armor, artillery, infantry and close air support. The same was true of Russia. When she finally drove the German armies back from Stalingrad into Germany, this was achieved by the co-ordinated use of land and air power. In fact, Germany was eventually defeated primarily by the methods that had brought her such startling successes earlier. Of the three million German war dead and missing up to November, 1944, 75 per cent were on the Russian front. This is an indication of the extent to which World War II was primarily a land war. The air operations of the bombing offensive carried on independently of military operations did begin to have an important effect during the summer of 1944. However, by this time the German armies had been decisively defeated both in the East and in the West.

This is not the place to attempt to apply in detail some of these lessons to postwar defense problems. There is, however, one comment that must be made. Never have Snow's twin warnings, of the danger of thinking that one weapon will solve our problems, and of the illusion that one can rely on maintaining technical superiority, been more vividly illustrated by the early years of nuclear weapons. Here the euphoria both of gadgets and of secrecy reached their highest and most disastrous intensity. Through a blind obeisance to a single weapon the West let down the strength of its conventional forces and failed even to develop prototypes of modern weapons for land warfare. In spite of the vast technological strength of the Western world, its ground armies in Europe are not only much smaller but also much inferior in equipment to those of the Soviet army. This has led the West to a reliance on nuclear weapons that is certainly dangerous and could be suicidal. A calm contemplation of the last 15 years makes one remember the cynical comment that the only lesson ever learned from history is that no one ever learns from history. But unless we do, there will be no more history. Snow's

little book, with its wisdom and penetration, should do much to stimulate serious thought on these vital problems of decision making.

Short Reviews

ATTENUATED INFECTION, by Harold J. Simon. J. B. Lippincott Company ($10). The old song warned that "some little bug is going to get you someday" but by the 1920's scientists generally believed that microbiology had most of the bugs cornered and that the rest would soon come to terms. A notable dissenter was the biologist Theobald Smith, who thought it incorrect to regard infectious diseases as "pathologic deviations from the normal processes of nature." Parasites may at times threaten man, but parasitism, Smith maintained, is an altogether normal phenomenon, and it will not do to study infectious diseases entirely in terms of the classic formula that "balances the virulence of the parasite, the susceptibility of the host and the immunologic response." Simon's book is concerned with the further exploration of this theme, with the many aspects of the host-parasite relationship, and in particular with the phenomena of latent, dormant infectious processes which occur in all forms of life and which may be regarded as "manifestations—even though temporary—of the ideal form of parasitism." Simon has searched a large literature and has brought together and critically interpreted much scattered information on the "changing pattern" of microbial disease; the problems of drug-resistant bacterial infections and the elusive adaptability of microbes; the transformation, under conditions which may often be man-made, of attenuated to progressive infection (and finally infectious disease); and the concept of "peaceful coexistence" with parasites (rather than extirpation) as a clue to reducing infectious disease.

THE INFORMED HEART: AUTONOMY IN A MASS AGE, by Bruno Bettelheim. The Free Press of Glencoe, Illinois ($5). Bettelheim is convinced that he and others who survived concentration camps in the late 1930's, before the prisoners were systematically murdered, did so largely by maintaining an essential link with themselves. He demonstrates that Nazism waged internal war not only against Jews, political enemies and intellectuals but also against all expressions of human uniqueness. Gradually the plan to erase individuality among the Germans, party members in-

cluded, became a clear part of policy, just as the story told in smoke from the furnaces of the camps made clear the extermination of the Jews. Bettelheim says that he survived as an intact person by reflectively observing his own and other people's responses to the methodical onslaught against human maturity. This attack was made not only by cruelty but also by treating prisoners as children, as animals, as objects, as nothings. Other men chose ways different from Bettelheim's to keep intact a core of self. To fail in this task was to participate in one's own extinction. To adapt too well was as dangerous as to defy without hope. In the camps, where all past values were stripped away—economic or professional achievement, social status, possessions, family structure, social regard—nothing was left but the naked self. And often, with these gone, no self remained. Yet this book is not primarily a history of the horrors of concentration camp life. It is a tale of the present, not the past. Its thesis is that the same forces that led to the Nazi ideal of making men into a mass machine exist in our society today. These forces can, if we let them, destroy our essential identity and leave us with a shell of self too weak to determine our own course in life or its meaning to us. By seducing us with comfort and conformity, these mass forces can insidiously make us relinquish our selves without our becoming aware of what is happening. Bettelheim warns of the need for vigilance, the need to use all the tools at our disposal, to modify and re-evaluate the methods of science and social science so as to prevent the obliteration of the boundaries between the outside world and the self, which is equivalent to disintegration. Since suffering the experiences reported in this book, Bettelheim has devoted his life to the extraordinarily painstaking process of creating an awareness of identity in the damaged and destroyed, or never-born, selves of mentally ill children. He is a teacher, an informer of hearts, a teacher who has taught himself, a physician who has healed himself.

HUMMINGBIRDS, by Crawford H. Greenewalt. Doubleday & Company, Inc. ($22.50). The schizognathous anisodactyle apodiformes known to the French as *oiseau-mouche* (fly-sized bird), the Portuguese as *beija flor* (kiss the flower), the Cubans as *zum-zum* and to us as hummingbirds are tiny, often brilliantly colorful, iridescent creatures with eight pairs of ribs, a long and slender bill, a "gape not deeply cleft," an extensible tongue, no gall bladder and no adult down. They live in the Western Hemisphere, adapt themselves to many altitudes and climates, run to at least 319 species, do not migrate (there are rare exceptions), vary in length from two and a quarter to eight inches, are unique among birds in their ability to hover and to fly backward, have the highest energy output per unit weight of any living warm-blooded animal (the daily output of a hummingbird, if calculated for a 170-pound man, is equivalent to about 155,000 calories), have a food intake at a rate comparable to a normal man's eating 285 pounds of hamburger a day (hummingbirds prefer nectar), beat their wings less—not, as is commonly supposed, more—than ordinary birds, have no song (although they chatter unmusically), are courageous and aggressive with their enemies, touchy and disagreeable with their own kind, do not practice marital fidelity or grow old together, build beautiful nests and have an egg quota of two. They had the good fortune a century ago to attract the attention of John Gould, who wrote and illustrated six imperial folio volumes about them, and now they are lucky in finding another biographer, scientifically trained, patient, skillful, dedicated, commanding large resources, who has used ultrahigh-speed photography to catch his subjects on the wing and has made other additions to our knowledge of their behavior and characteristics, in particular their property of iridescence. An engaging book with some stunning pictures.

THE LONG RESCUE, by Theodore Powell. Doubleday & Company, Inc. ($4.95). In July, 1881, an expedition under the command of Lieutenant Adolphus W. Greeley, U. S. A., sailed from St. John's in Newfoundland in the barkentine-rigged steamer *Proteus*. The objective of the expedition was to establish a site on Ellesmere Island, between the 81st and 83rd parallels, from which to study arctic phenomena and, if a favorable chance presented itself, from which to make a dash for the North Pole. The undertaking was partially successful: for two years observations were taken, explorations and mapping conducted, collections made of vegetable and animal life. Sledge parties got to the northern shore of Greenland, farther north than anyone had ever got before, but the North Pole remained unapproachable. According to plan the expedition was to be relieved in 1882, but the relief ship failed to penetrate the ice and another failed in 1883. In Au-

gust of that year Greeley decided that he and his men could wait no longer. They would make a run for it in a small launch and catch the relief ship farther south. Thus began one of the cruelest journeys in the history of arctic exploration. The launch missed the relief ship and the Greeley party was forced to spend a third bitter winter on Ellesmere Island. Finally, in July, 1884, Commander Schley of the U. S. Navy pushed his vessels, the *Thetis* and the *Bear*, through the ice across Melville Bay and Smith Sound to Greeley's winter camp at Cape Sabine and rescued seven pitiful living skeletons, all that remained of the original 25 members of the expedition. One more died on the return voyage, so that only six returned alive. Greeley lived to become Chief Signal Officer of the Army and one of the founders of the National Geographic Society. He died in 1935. The story of the expedition is the subject of this book by a journalist who has examined large masses of records, reports and diaries on deposit in the U. S. Archives and elsewhere. He admits using "literary devices" to "round out the story," and he has created dialogue. The story is of course tremendously dramatic—including the shocking business of having to execute one of the members of the expedition, shortly before the rescue, for repeatedly stealing food—but the imaginary dialogue is wholly unnecessary. Powell would have done better to forgo the literary devices, identify his sources and let the record speak starkly for itself.

TELEGRAPHS IN VICTORIAN LONDON, by John Durham. The Golden Head Press (15 shillings). This little historical essay tells the story of the two telegraph companies formed in London in 1859 and 1860 to give service by over-the-house-wires, one company simply by connecting the business places of subscribers, the other by setting up many local offices—some in the corners of grocers' or tobacconists' shops—which the public could patronize and from which telegrams could be sent to the office lying nearest their destination and then delivered by messenger to the addressee. The details are delightful: battles with houseowners to get permission to string wires over the roof, the training of lady telegraphers for employment at 10 shillings a week, the mishaps caused by falling wires (in one case a wire torn down by a gale yanked a man from his seat on the top of an omnibus crossing Blackfriars Bridge and deposited him in the roadway on his head, with unhappy results), the delays and mistakes

in transmission (for example, the telegraphic likeness between "one" and "hog" caused distress to a man who simply wanted his family "to expect one for dinner"), the misconceptions as to the working principles of telegraphy which caused parents to explain to their children that the writing on a telegram "traversed the wires in a fluid state," and led an old lady whose house was a wire carrier to inform the company that she tolerated the "continual babble of voices in the wires but wished to make a very serious complaint about the disgraceful nature of the conversations." The price of this 30-page booklet is ridiculous, but the contents are almost worth it.

THE BIRDS OF THE BRITISH ISLES: VOL. IX, by David Armitage Bannerman; illustrated by George E. Lodge. Oliver and Boyd (63 shillings). The ninth volume of this splendid work deals with a part of the family Scolopacidae: godwits, curlews, whimbrels, sandpipers, woodcocks, snipes, phalaropes, turnstones, knots, dunlins, stints, ruffs. Many of these species of shore birds are not indigenous to the British Isles but are wanderers and visitors from distant lands. Whenever Bannerman knows little about a species from personal experience, he has enlisted—in this as in earlier volumes—leading specialists to write about the bird. The text keeps to the high mark which this great natural history has set, as do the paintings by the late George E. Lodge.

THE SCIENCE OF MECHANICS: A CRITICAL AND HISTORICAL ACCOUNT OF ITS DEVELOPMENT, by Ernst Mach. The Open Court Publishing Company ($6). The sixth U. S. edition of this famous and profoundly influential book (Einstein was among those who early fell under its positivist spell), first published in German in 1883, incorporates revisions through the ninth German edition (1933) and carries an introduction by Karl Menger, which affords him the opportunity not only to assert the continuing vitality of the work and to describe its relation to later positivist thought, in particular the doctrines of the Vienna Circle, but also to raise certain critical points bearing on mathematical concepts with which he has long concerned himself. A paperback of this edition is also available.

AËDES AEGYPTI (L.), by Sir Richard Christophers. Cambridge University Press ($14.50). A comprehensive monograph by a foremost specialist on *Aëdes aegypti,* a notorious little creature,

world-wide within the tropical and subtropical zones, carrier of yellow fever and dengue and still the object of control measures on an immense scale. *Aëdes aegypti* has partially repaid the enormous injury and damage it has inflicted by serving extensively as a test animal for investigation in many fields. Christophers' masterly work brings together all that is known about this species: the history of early research on mosquitoes, beginning in the 18th century with Robert Hooke's description of the *Culex* larva; the species' systematics, distribution, natural enemies and parasites; its relation to disease and measures taken in its control; structure and changes undergone by the egg and mosquito embryology; physical characteristics of the adult; the use of *Aëdes aegypti* in the laboratory. An ornament of scientific literature and a finely made book.

READABLE RELATIVITY, by Clement V. Durell. Harper Torchbooks ($1.25). This book, unquestionably the best introduction to relativity for the plain reader, was first published in London in 1926. Unaccountably and unfortunately, it never attracted the attention of a U. S. publisher until now, when it appears as a paperback. Durell's explanation of the theory is beautifully carried through with the help of the simplest algebra (early high school level), a lucid and humorous style and a sure feeling for the intellectual snarls the beginner is likely to get himself into. There are many helpful illustrations and exercises at the end of each chapter which you can try if you want to be sure you are not fooling yourself when you claim to understand the main questions. Highly recommended.

AN ILLUSTRATED HISTORY OF RUSSIA, by Joel Carmichael. Reynal & Company ($20). A general reader's survey, emphasizing the 19th and 20th centuries. The story is engrossing—though it contains assertions, especially on controversial matters, which specialists will challenge with characteristic glee—and the more than 300 illustrations (36 in full color) cannot fail to enlarge one's understanding of the Russia that was and the Russia that is.

MANUAL OF PHOTOGRAPHIC INTERPRETATION, edited by Robert N. Colwell. Society of Photogrammetry ($15). This co-operative work, on a comparatively new technique which has already proved itself enormously useful in both military and nonmilitary spheres, con-

tains articles on the development of photographic interpretation, how aerial photographs are made, photographic interpretation in geology, soil studies, engineering, forestry, wildlife and range management, hydrology, agriculture, urban area analysis, archaeology, geography and other fields. More than 600 photographs (16 pages in full color), many of which are of striking interest.

THEORIES OF SCIENTIFIC METHOD: THE RENAISSANCE THROUGH THE NINETEENTH CENTURY, by Ralph M. Blake, Curt J. Ducasse and Edward H. Madden. University of Washington Press ($6.50). A collection of papers on ideas about scientific method, beginning with theories of hypothesis in the Renaissance and including Francis Bacon's philosophy of science, Newton's hypothetic-deduction concepts, David Hume's views on causation, John Herschel's method of experimental inquiry, John Stuart Mill's system of logic, W. S. Jevons' principles of induction and probability, Charles Sanders Peirce's search for a method. There is interesting historical material in this book, and it affords a useful perspective of one of the main lines of philosophical development.

PECOS, NEW MEXICO, by Alfred Vincent Kidder. Phillips Academy ($7.50). This publication of the Robert S. Peabody Foundation for Archaeology is based upon field work carried on in the Upper Pecos Valley between 1915 and 1929, many of the results of which have been reported by Kidder and others in past years. In this volume are gathered notes on the Forked Lightning Ruin and other sites in the valley, on the history of Pueblo occupancy, on household arrangements, occult and material aspects of kivas (ceremonial rooms), mortuary practices. Photographs and diagrams.

THE UPPER ATMOSPHERE, by H. S. W. Massey and R. L. F. Boyd. Philosophical Library, Inc. ($17.50). An account of the phenomena of the upper atmosphere studied during the International Geophysical Year. Among the topics considered are research by balloons and rockets, probing with sound waves and radio waves, the ozonosphere and ionosphere, the aurora, aerial tides and magnetic effects, solar and magnetic disturbances, meteors, cosmic rays, artificial satellites. Photographs (some in color) and diagrams.

THE MCGRAW-HILL ILLUSTRATED WORLD GEOGRAPHY, edited by Frank Debenham and William A. Burns. Mc-

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BECAUSE two-thirds of the world's people are now underfed;

BECAUSE *each day* nearly 140,000 more people are added to the world's population, and *each year* 50,000,000 more people;

BECAUSE unless a favorable balance of population and resources is achieved with a minimum of delay, there is in prospect a Dark Age of human misery, famine and unrest;

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*Signers are from the United States unless otherwise designated.

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Graw-Hill Book Company, Inc. ($15). This attractive, well-illustrated book presents a wide amount of information about the peoples of the world, where they live and the work they do. It contains 24 full-color maps, 31 color photographs, hundreds of black-and-white photographs and small two-color maps of every country. The text, though necessarily succinct and telegraphic, covers for each country information on physical features, climate, flora and fauna, history, character of the people, languages, industry and agriculture, government and administration, cities and ports, transportation. A sound job which succeeds in enlightening the reader both as to the extraordinary diversity of the world and the interdependence of its people.

Notes

THE CLONAL SELECTION THEORY OF ACQUIRED IMMUNITY, by Sir Macfarlane Burnet. Vanderbilt University Press ($5). The 1958 Abraham Flexner lectures, in which the author interprets the phenomenon of acquired immunity and antibody production in terms of a group or family of cells which have multiplied asexually and so have identical genetic constitutions.

CONCEPTS OF SPACE, by Max Jammer. Harper Torchbooks ($1.40). Paperbacked reissue of an excellent history of the theories of space in physics. Foreword by Albert Einstein.

WATER SUPPLY, by Jack Hirshleifer, James C. De Haven and Jerome W. Milliman. University of Chicago Press ($7.50). A study of the economics, technology and basic policy questions of U. S. water supplies.

THE ANCIENT GODS, by E. O. James. G. P. Putnam's Sons ($7.50). A survey of the religions of the ancient Near East, from the Indus Valley to Italy, from the Paleolithic era to the rise of Christianity.

LECTURES ON ERGODIC THEORY, by Paul R. Halmos. Chelsea Publishing Company ($2.95). A series of informal lectures delivered at the University of Chicago in 1955 designed "to rekindle interest in a useful but currently not fashionable part of mathematics."

THE DISCOVERY OF THE CIRCULATION OF THE BLOOD, by Charles Singer. Wm. Dawson and Sons, Ltd. ($2.50). A reprint, with minor changes and correc-

tions and a revised bibliography, of a historical essay by the late Charles Singer, originally published in 1922. Illustrations.

THE MECHANICS OF THE ATOM, by Max Born. Frederick Ungar Publishing Co. ($6.50). Republication of a translated, revised version of a series of lectures on the mechanical principles of atomic physics, delivered by Born in Göttingen in 1923.

QUALITATIVE THEORY OF DIFFERENTIAL EQUATIONS, by V. V. Nemytskii and V. V. Stepanov. Princeton University Press ($12.50). An English translation of the latest edition of an important Russian mathematical treatise.

TABLES OF HIGHER FUNCTIONS, by Eugen Jahnke and Fritz Emde, revised by Friedrich Lösch. McGraw-Hill Book Company, Inc. ($14). Sixth edition of a standard work which describes and gives tables of a wide variety of mathematical functions. In its new dress, with the beautiful illustrations for which the book has long been known, this edition will be indispensable to engineers and scientists.

AN INTRODUCTION TO GENETICS, by C. M. M. Begg. The Macmillan Company ($6). A better than average introduction to the science of heredity, designed to meet the needs of undergraduates who are easy in their algebra.

EXPLAINING THE ATOM, by Selig Hecht. The Viking Press, Inc. ($1.25). A paper-backed reprint of one of the best popularizations of atomic physics, as revised and expanded by Eugene I. Rabinowitch.

SPACE AND GEOMETRY, by Ernst Mach. The Open Court Publishing Company (95 cents). Paper-backed reissue of three essays by Mach which appeared in *The Monist* almost 60 years ago. They deal with physiological space as distinguished from geometrical space; psychology and the natural development of geometry; space and geometry from the point of view of physical inquiry.

THE PLASMA PROTEINS: VOL. II, edited by Frank W. Putnam. Academic Press, Inc. ($14.50). The contributors to this volume treat the physical aspects and metabolic interrelationships of the plasma proteins in the normal state and in disease. This is the second and concluding volume of a treatise, the first of

which considered the plasma proteins as a physicochemical system.

FREEDOM AND CIVILIZATION, by Bronislaw Malinowski. Indiana University Press ($2.25). The noted anthropologist Bronislaw Malinowski began this book after the outbreak of World War II and died before the final revisions on the manuscript could be made. His wife was able to prepare the material for publication. It deals with the nature of freedom and its relation to human nature and culture.

THE LIFE OF SCIENCE, by George Sarton. Indiana University Press ($1.50). A collection of Sarton's essays in the history of civilization. They deal with such topics as the history of medicine versus the history of art, Leonardo da Vinci and the birth of modern science, Evariste Galois, Ernest Renan, Herbert Spencer. Paperback.

HYDRODYNAMICS OF OCEANS AND ATMOSPHERES, by Carl Eckart. Pergamon Press, Inc. ($9). A systematic introduction to the hydrodynamics of the earth's atmosphere and oceans, under the action of gravitation and the Coriolis force.

THE FERRARI, by Hans Tanner. Robert Bentley, Inc. ($5.50). The story of one of the world's great racing and sports cars, designed and built by Enzo Ferrari: evolution of the engine through various models, mechanical features and specifications, performance data, competition results. For the aficionado.

CONTRIBUTIONS TO PROBABILITY AND STATISTICS: ESSAYS IN HONOR OF HAROLD HOTELLING, edited by Ingram Olkin, Sudhish G. Ghurye, Wassily Hoeffding, William G. Madow and Henry B. Mann. Stanford University Press ($6.50). Forty-two papers on statistics, probability theory, economics and biostatics celebrating the 65th birthday of a noted teacher and mathematical statistician.

PROGRESS IN BIOPHYSICS AND BIOPHYSICAL CHEMISTRY: VOL. X, edited by J. A. V. Butler and B. Katz. Pergamon Press, Inc. ($15). The 10th volume in this series includes papers on the high-energy chemical-bond concept, the molecular structure and contact relationships of cell membranes, the structure and physical chemistry of nucleic acids and nucleoproteins, oxygen tension and oxidation, the tobacco mosaic virus, thermodynamics and the interpretation of biological heat measurements.

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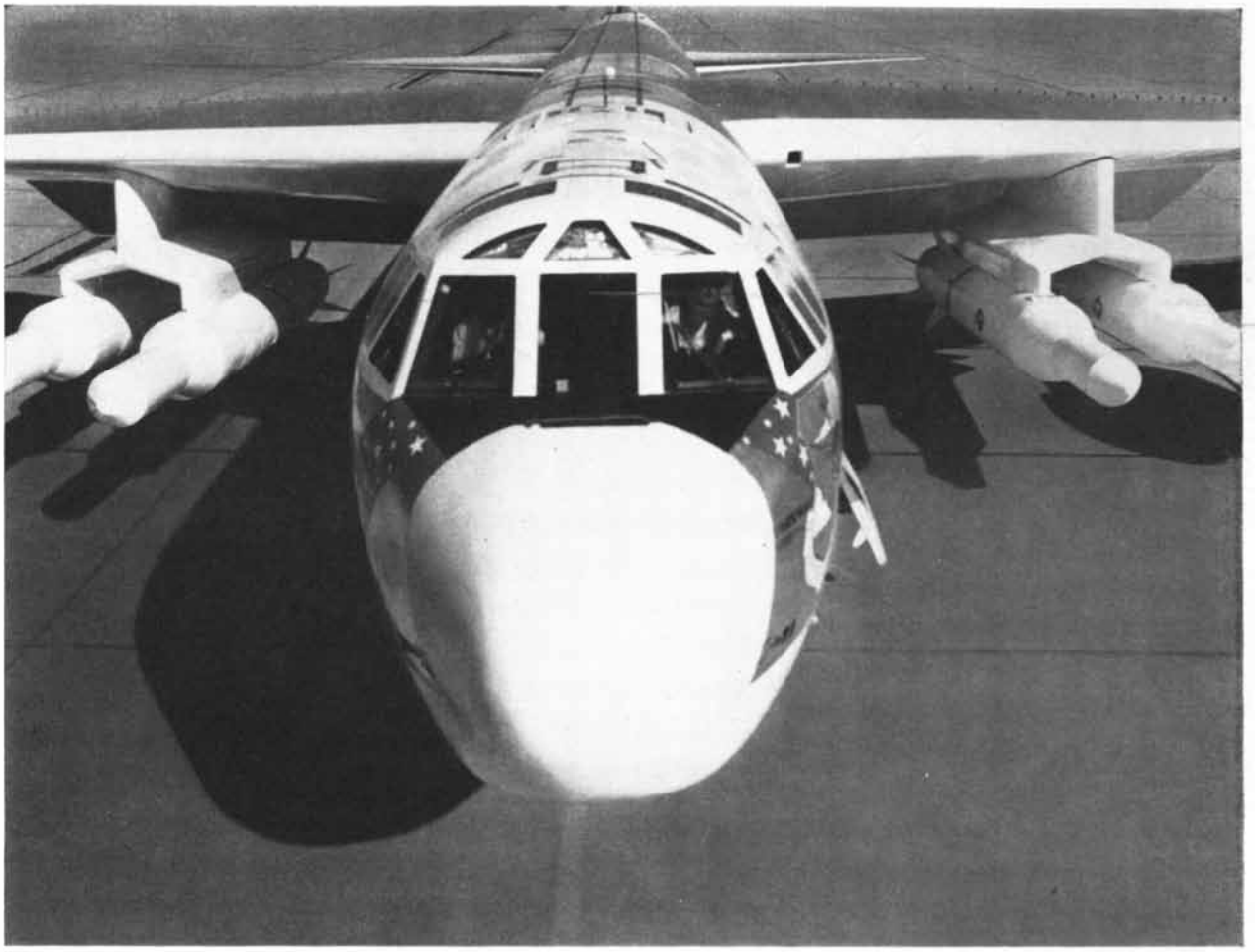
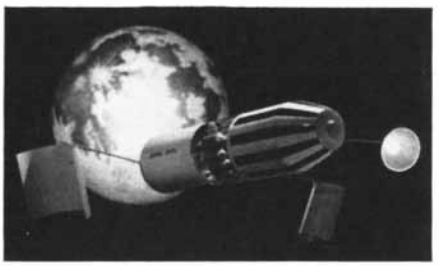


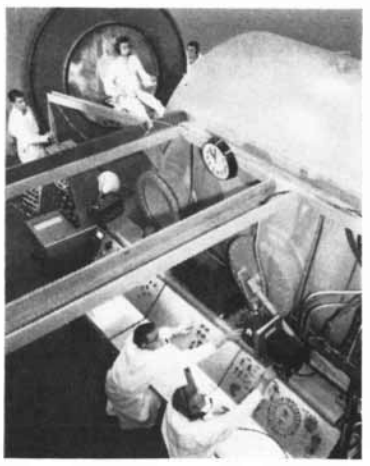
MISSILE BOMBER. New "H" model is latest version of famous Boeing B-52 missile bomber, most versatile long-range weapon system in U.S. Air Force arsenal. B-52H here carries mock-ups of four Skybolt air-launch ballistic missiles. B-52s can also carry supersonic Hound Dog missiles for in-flight launching toward distant targets. Flying high or low, B-52s will provide an almost undetectable launch pad for missiles. They can also carry regular load of gravity bombs, and strike up to five targets on single mission.

Capability has many faces at Boeing



RESEARCH STATION. Model of space research station designed by Boeing to accommodate12 men and remain in earth orbit, serving as research station or interplanetary launch site.

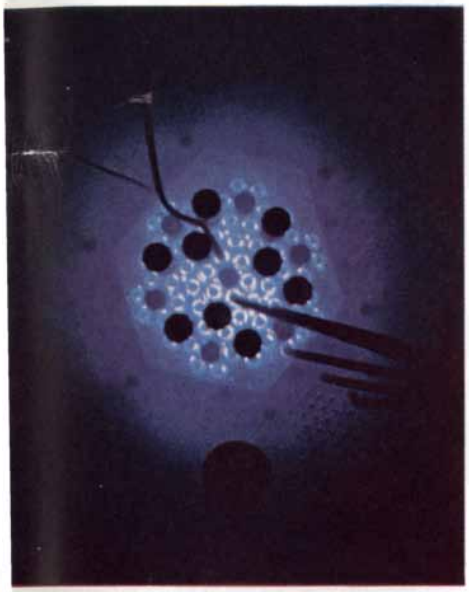
SPACE CHAMBER. Boeing multi-stress chamber simulates six conditions of space travel in research to develop protective environments required for space vehicle crews. Chamber will also be used to test conditions in moon stations.



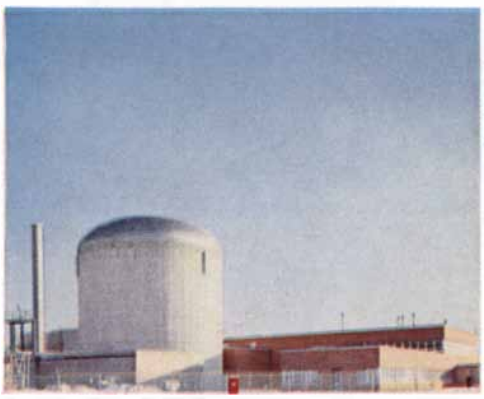
"FLYING" BOAT. Drawing of 115-foot hydrofoil craft Boeing is building for U.S. Navy. Riding out of water, hydrofoil will "fly" on underwater wings at speeds up to 45 knots. Powered by two 3000-hp gas turbine engines, craft will be the biggest hydrofoil ever built.

BOEING

60,000 kw Westinghouse testing reactor speeds radiation tests for industry and government

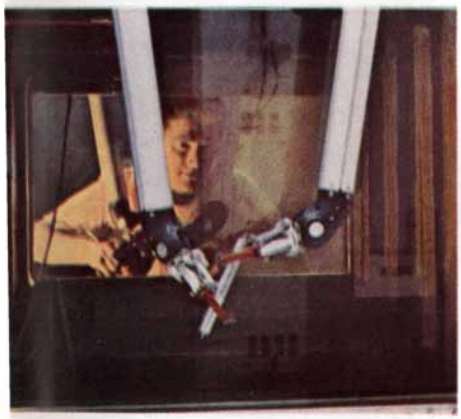


Reactor Core. Nuclear fuels and other materials can be tested inside cylindrical fuel elements.



Testing Reactor Facility. Most powerful privately-owned complete facility in U.S. Available to serve industry and government.

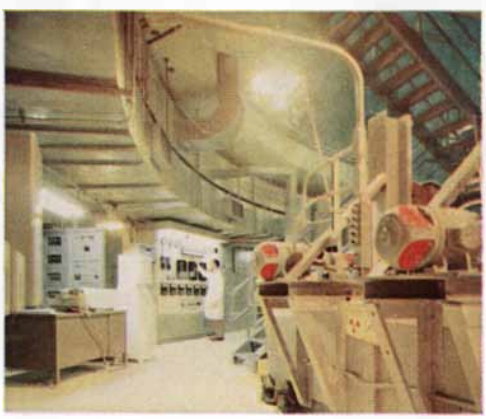
Critical Experiment Station. Low power test facility used to confirm physics of experiments before exposure in the reactor.



Remote Handling Facility. Hot cells and metallographic cells are available for post-irradiation examination of samples.

Master Control Room. This is focal point of the operating facility; providing remote indication of reactor performance and experimental conditions.

Complete Laboratory Facilities. Chemical, analytical and counting laboratories are used to make post-irradiation tests.



Test Loop Control Center. Loops are available to provide a variety of environmental conditions during irradiation.

J-59502

Westinghouse

Westinghouse Testing Reactor
Box 868, Pittsburgh 22, Pa.

Electronic Intelligence . . . Guide a plane. Spot a marauder. Interrogate a thunderhead. Electronic sentinels — gathering, analyzing and integrating information — will enhance man's dominion over his environment . . . and help preserve him from his follies.