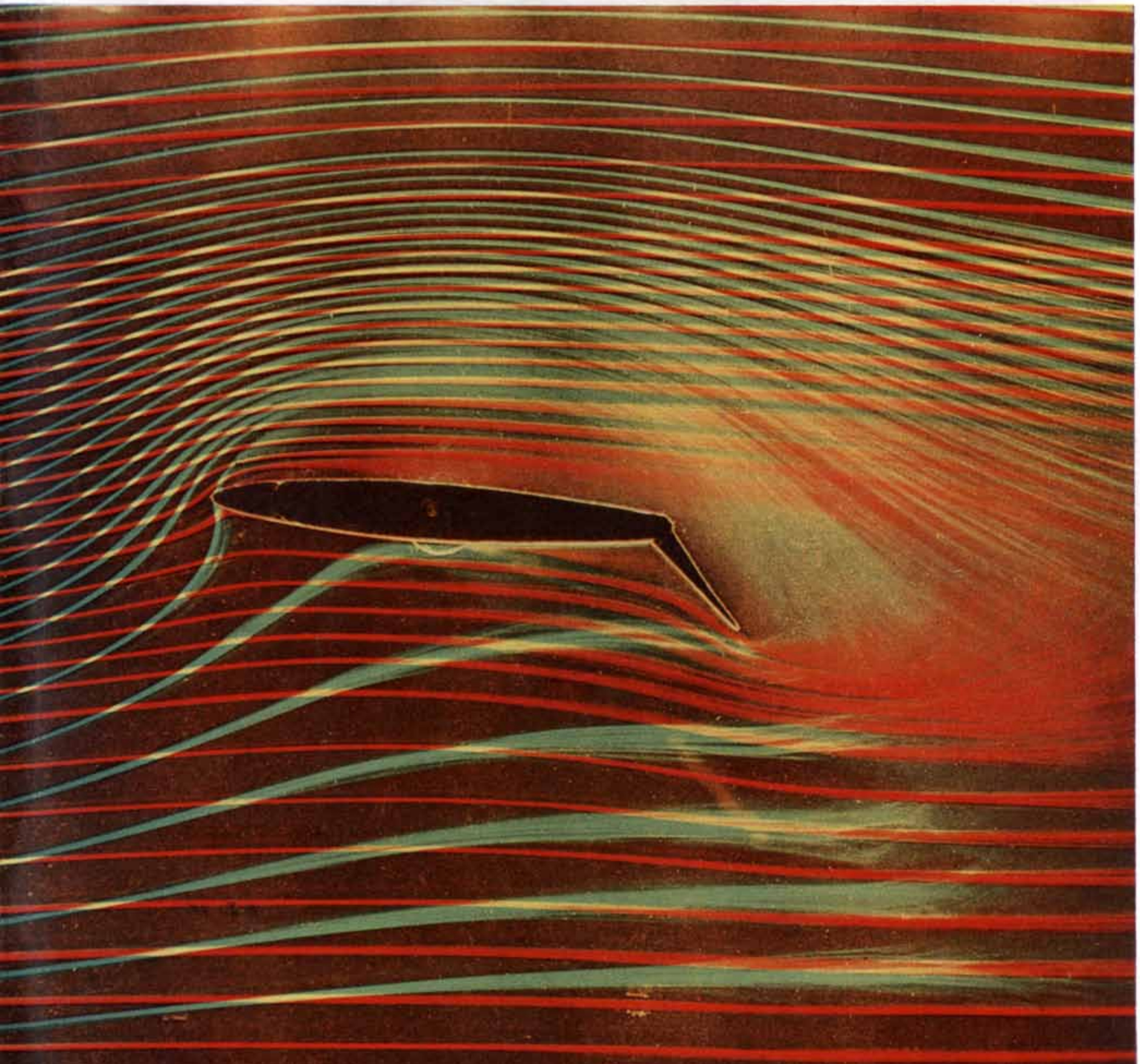
SCIENTIFIC AMERICAN



LOW-SPEED FLIGHT

FIFTY CENTS

April 1956

Wanted:
Compressible painter to work <u>inside</u> a 6-inch pipeline!

TODAY, this improbable plea is answered by an unusual combination. A revolutionary process puts a coating of Epon® resin enamel inside a pipe line that is *already in the ground!*

Epon resin liner stops corrosion in a pipe line carrying crude oil, salt water or natural gas, and so prevents product contamination by rust or scale. It greatly increases the useful life of a pipe line. This means great saving of time and dollars for pipe line operators. Smooth and durable Epon resin coating sticks to steel pipe wall with a tenacity never before attained without baking.

Use of Epon resin in pipe line paint is but one application of a Shell Chemical product in the field of industrial transportation.

Shell Chemical Corporation

Chemical Partner of Industry and Agriculture

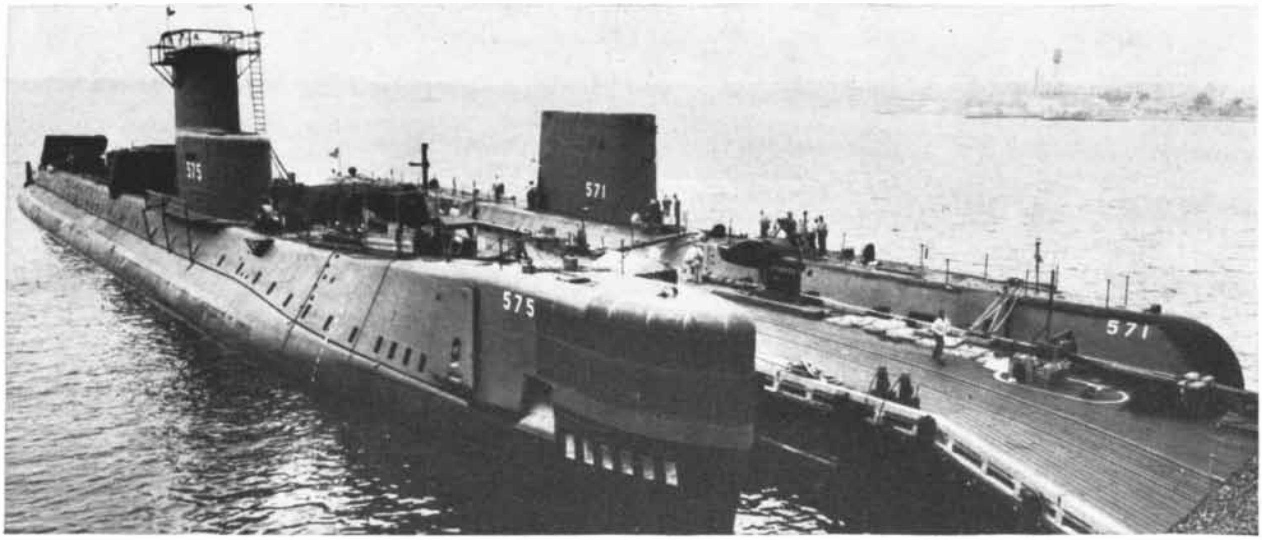
NEW YORK

SHELL

On the USS Forrestal

Built by the Newport News Shipbuilding and Drydock.

On the USS Nautilus and Seawolf



Built by the Electric Boat Division of General Dynamics Corp.

Unibestos insulates vital pipe systems

Guardians of today's security and tomorrow's future—these are the ships of electronic devices and nuclear power...the products of advanced engineering and modern materials.

Aboard these ships, where dependability is a must, Unibestos pipe insulation protects intricate and vital pipeline systems against crucial heat loss. Unibestos makes a clean sweep in its contribution to this important Navy development program.

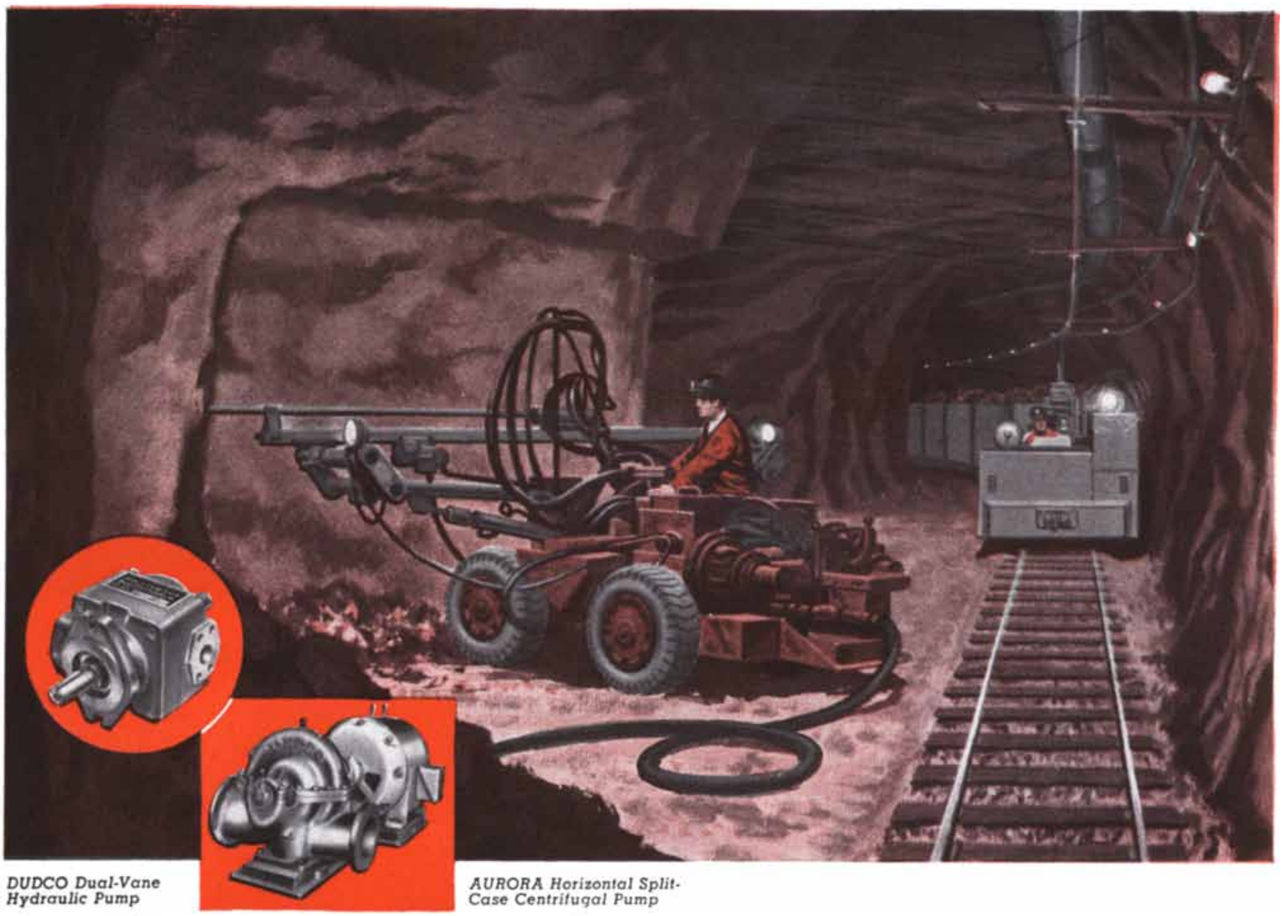
In fact, Unibestos is fast becoming the preferred insulation for an increasing number and variety of applications. Whether it's a ship, a refinery or a power plant, *single-layer* Unibestos combines high thermal efficiency with superior strength and unmatched ease of installation.

Unibestos® pipe insulation is available in sectional form through 44″ O.D. For further information without obligation, write for the free descriptive bulletin 109C.

UNARCO

UNION ASBESTOS & RUBBER COMPANY

1111 West Perry Street • Bloomington, Illinois



DUDCO Dual-Vane Hydraulic Pump

AURORA Horizontal Split-Case Centrifugal Pump

Find It . . . Get to It . . . Dig It Out . . . Save Time With Power

FLUID POWER

KALAMAZOO DIVISION
Kalamazoo, Mich.
HYDRECO Gear-Type Hydraulic Pumps, 3 to 120 gpm; Fluid Motors, 3 to 52 hp; Cylinders; Control and Auxiliary Valves; 1500 psi. DUDCO Dual-Vane Hydraulic Pumps, 3 to 120 gpm; Fluid Motors, 7 to 140 hp; 2000 psi operation.

WATERTOWN DIVISION
Watertown, N. Y.
Railroad air brake equipment of all types, STRATOPOWER Hydraulic Pumps for Aircraft, to 3000 psi.

AURORA PUMP DIVISION
Aurora, Ill.
Liquid Handling Pumps, Centrifugals and deep well Turbines, 7000 gpm, 500 ft. heads. Turbine-type, 150 gpm, 600 ft. heads. Condensate Return Units.

KINNEY MANUFACTURING DIVISION
Boston, Mass.
Rotating Plunger and Heliquad Liquid Handling Pumps, to 3000 gpm. Vacuum Pumps, 0.2 micron, evacuate 1800 cfm.

Mining, from strike to full operation, measures profits in time, because time saved can be as important in the profit picture as the grade of ore.

Consider the products made by Divisions of The New York Air Brake Company as the means for saving time, raising efficiency and lowering costs. DUDCO Dual-Vane Pumps and Motors . . . HYDRECO Gear Pumps and Motors, Valves and Cylinders provide the Hydraulic equipment for drilling, cutting, collecting, loading and transfer of ore as well as for Hydraulic Power on conveyors, grinders and shakers at the mill.

The AURORA PUMP and KINNEY MFG. DIVISIONS produce the "right" pump for every Liquid Handling requirement . . . Turbine-type Pumps for water supply . . . Centrifugal Pumps for handling drainage and liquids containing solids . . . Gear and Rotating Plunger Pumps for sludges, slurries and heavy flotation liquids.

KINNEY High Vacuum Pumps bring another vital tool to the refinery. Developing pressures to 0.0001 mm Hg., vacuum processing opens up entirely new vistas to the metallurgist . . . and new economies in refining and the reclaiming of many metals.

More and more, engineers reach for improved techniques by employing the versatility, dependability, time and money-saving performance that distinguish Fluid Power.

Engineers of The New York Air Brake Company are a well-spring of "know-how" on Fluid Power. Get to know more about N.Y.A.B. products and the many new developments in Power Hydraulics, Liquid Handling and High Vacuum Equipment.

Write today for literature on AURORA, KINNEY, DUDCO, HYDRECO and STRATOPOWER products.

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230 PARK AVENUE • NEW YORK 17, N. Y.

INTERNATIONAL SALES OFFICE, 90 WEST ST., NEW YORK 6, N. Y.

Established 1845 **SCIENTIFIC AMERICAN** April, 1956 Volume 194 Number 4

ARTICLES

DEPARTMENTS

THE COVER

The photograph on the cover shows an airfoil with a flap in a smoke tunnel at Princeton University. The photograph is described in detail by the article beginning on page 46.

THE ILLUSTRATIONS

Cover by Rudolf F. Lehnert

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KANIGEN®

a chemically-unique coating

Number 2 In A Series

Kanigen is a uniform, hard, corrosion-resistant nickel-phosphorus coating. It can be applied to iron, copper, nickel or aluminum and their alloys as well as ceramics, glass and thermo-setting plastics. This is achieved through a chemical bath without the use of electricity. The coating (probably a solution of nickel phosphide in nickel) exhibits many desirable properties not normally associated with metals or metal plating.

Kanigen coatings, chemically as well as metallurgically unique, provide protection against iron and copper pick-up in moderately corrosive substances.

Kanigen coatings are most strongly indicated in alkaline or neutral media at most temperatures and concentrations. They may be recommended in slightly acidic (pH 4.0) media under special circumstances. They are rarely recommended to resist acid attack.

One or 2 mils of Kanigen will protect many basis materials in many applications. If, however, extended service life is required under relatively extreme conditions such as hot, concentrated caustic or dilute solutions of strong electrolytes, coatings of 3 to 5 mils may be needed. In the case of Kanigen-coated aluminum components exposed to corrosive attack by dilute, strong electrolytes, a minimum of 2 mils is indicated. Where performance is more important than cost, 3 mils is usually recommended. Although Kanigen itself may not be affected by the corrosive media, the widely separated electropotentials of Kanigen and aluminum will accelerate the dissolution of the basis material in the event of a macroscopic break in the coating.

When it is metallurgically feasible for the basis material to permit the heat treatment of the Kanigen coating at 1400° F (760° C), an exceptional gain in corrosion resistance is achieved.

The ability of Kanigen to deposit uniformly on complex shapes is an additional tool for the design engineer and a means to realize extensive savings over expensive alloys.

Then, too, in some cases Kanigen—because of its peculiar combination of properties—may perform a unique function not obtainable in any alloy at any cost.

CORROSION STUDIES OF KANIGEN

Where indicated, heat treatment carried out at 1400° F (760° C) for 5 hours in controlled atmosphere

MATERIAL	PENETRATION Mils (0.001") per year
Acetic acid, 5% (rm. temp.)	0.79
Acetic acid, 5% (rm. temp.-aerated)	5.12
Acetic acid, 5% (rm. temp.-aerated-heat treated Kanigen)	0.13
Acetic acid, 10% (rm. temp.-heat treated Kanigen)	0.07
Acetic acid, 50% (rm. temp.-heat treated Kanigen)	0.08
Acetic acid, glacial (rm. temp.-heat treated Kanigen)	0.001
Acetylene bromide (rm. temp.)	no attack
Alcohol (rm. temp.)	no attack
Allyl chloride (rm. temp.)	0.04
Aluminum sulfate, satd. (rm. temp.)	0.26
Ammonium chloride, satd. (rm. temp.)	0.46
Ammonium hydroxide, 30% NH_3 (rm. temp.)	2.30
Ammonium hydroxide, 30% NH_3 (rm. temp.-heat treated Kanigen)	no attack
Ammonium hydroxide, 30% NH_3 (rm. temp.-heat treated Kanigen—partly immersed)	no attack
Ammonium nitrate, 63% (rm. temp.-heat treated Kanigen)	no attack
Ammonium nitrate, 63% (rm. temp.-heat treated Kanigen-partly immersed)	no attack
Ammonium phosphate, 5% (140° F)	0.80
Ammonium phosphate, 5% (140° F-heat treated Kanigen)	0.45
Ammonium phosphate, 5% (rm. temp.)	0.71
Ammonium phosphate, 5% (aerated)	not recommended
Ammonium phosphate, 5% (aerated-heat treated Kanigen)	0.02
Ammonium sulphite, satd. (rm. temp.)	0.02
Ammonium thyocyanate (rm. temp.)	0.19
Amyl acetate (rm. temp.)	0.002
Amyl chloride (rm. temp.)	0.01
Benzol (rm. temp.)	no attack
Benzyl chloride (rm. temp.)	1.44
Calcium chloride, 3% (rm. temp.)	0.21
Calcium chloride, 48.5% (rm. temp.)	no attack
Calcium chloride, 48.5% (aerated)	no attack
Citric acid, 5% (rm. temp.)	0.97
Citric acid, 5% (aerated)	3.60
Citric acid, 5% (aerated-heat treated Kanigen)	0.15
Citric acid, satd. (rm. temp.)	0.05
Cresylic acid (rm. temp.)	no attack

MATERIAL	PENETRATION Mils (0.001") per year
Dibutyl phthalate (rm. temp.)	0.006
Fluorophosphoric aeid (rm. temp.)	1.56
Formaldehyde (rm. temp.)	0.15
Glucose (rm. temp.)	no attack
Lactic acid, 45% (rm. temp.)	0.13
Lactic acid, 45% (rm. temp.-heat treated Kanigen)	0.005
Lactic acid, 45% (aerated)	1.57
Lactic acid, 80% (rm. temp.)	0.07
Lactic acid, 80% (rm. temp.-heat treated Kanigen)	0.03
Lactic acid, 80% (aerated)	0.46
Lemon juice (rm. temp.)	0.23
Oleic acid (rm. temp.)	0.01
Orange juice (rm. temp.)	0.01
Petroleum sour crude oil (rm. temp.)	0.001
Phenol, conc. (178° F)	0.08
Phosphoric acid, 85% (140° F)	not recommended
Phosphoric acid, 85% (rm. temp.-heat treated Kanigen)	0.01
Refinery brine solution (rm. temp.)	no attack
Sherry wine (refrigerated)	not recommended
Sherry wine (refrigerated-heat treated Kanigen)	no attack
Sodium carbonate, 10% (rm. temp.)	no attack
Sodium Cyanide, 5% (rm. temp.)	0.52
Sodium hydroxide, 10% (rm. temp.)	no attack
Sodium hydroxide, 72% (240° F)	0.07
Sodium hydroxide, 72% & mercury 240° F)	not recommended
Stearic acid (158° F)	0.02
Sulfuric acid, 1% (rm. temp.)	1.12
Sulfuric acid, 1% (aerated)	not recommended
Sulfuric acid, 1% (aerated-heat treated Kanigen)	0.35
Sulfuric acid, 5% (rm. temp.)	1.83
Sulfuric acid, 5% (rm. temp.-heat treated Kanigen)	0.56
Tall oil (rm. temp.)	0.04
Tanning solution, 50% (KOREON) (rm. temp.)	0.05
Thionyl chloride, anhydrous (rm. temp.)	0.03
Water, chlorine (5ppm Cl_2) (rm. temp.)	0.02
Water, distilled (rm. temp.)	0.03

If you have a problem that a Kanigen application might solve or if you'd like further information, write:

KANIGEN DIVISION, GENERAL AMERICAN TRANSPORTATION CORPORATION

135 South LaSalle Street, Chicago 90, Illinois.

PERHAPS YOU SAW THIS NEWSPAPER STORY

D. J. Haughton, Lockheed vice president and general manager of the Georgia Division, has disclosed to all employees four important new phases of the Company's plans for the Division in 1956:

1. Lockheed's major nuclear-powered aircraft preliminary design study projects will be transferred to the Georgia Division around mid-year.

2. Plans are underway for a modern, new engineering building for the Georgia Division.

3. Corporate approval is being sought for expenditure during 1956 of $8,500,000 in company funds for fixed assets (machinery and facilities). This would mean a total of $11,500,000 in company funds to be invested in the Marietta facility in a two-year period. Expenditure of Lockheed funds for improving the aircraft facilities is being done with Air Force approval.

4. 140 acres of land adjoining the plant facilities to the southwest have been purchased by the company. This was done with a view to future expansion.

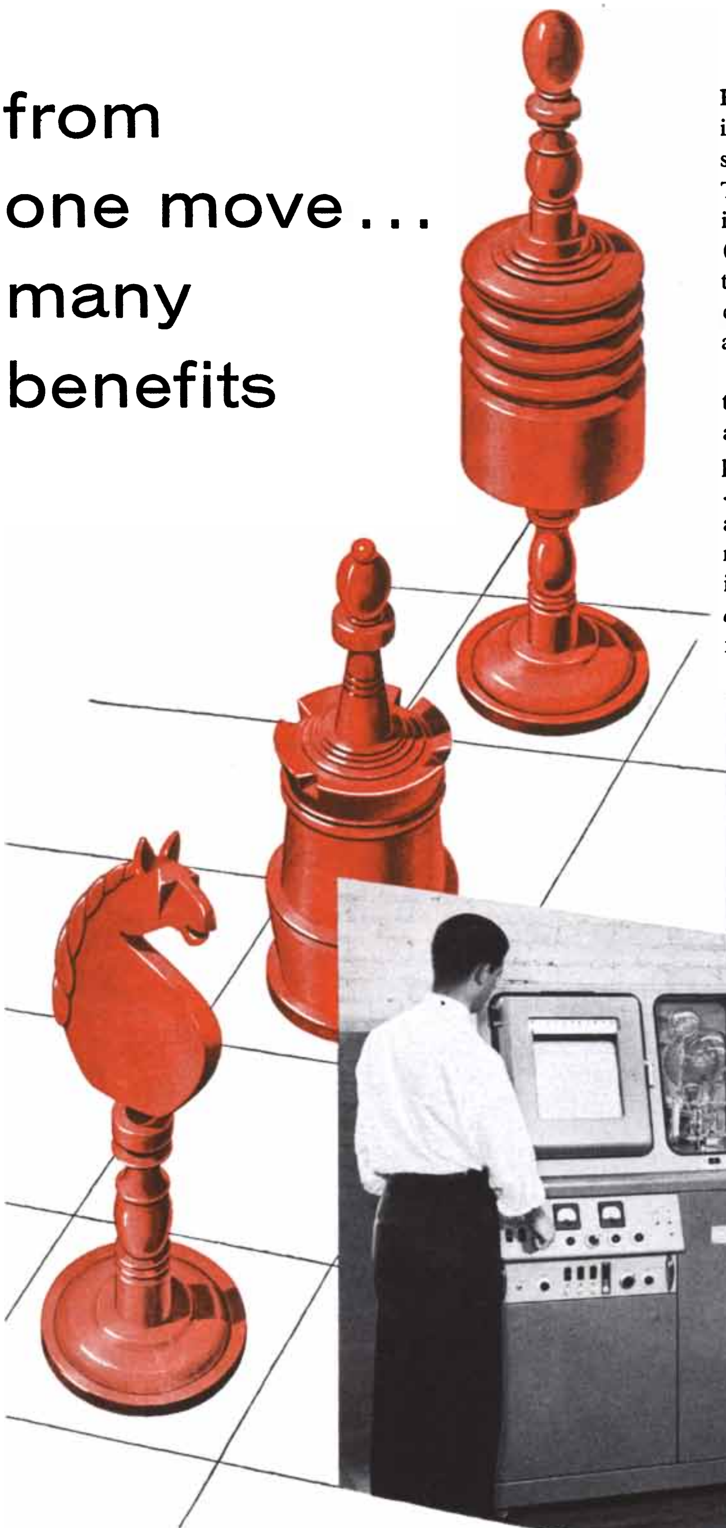
"We want to continue rounding out our research and development facilities in order to make this a completely integrated aircraft facility," Mr. Haughton said.

In this Project, Lockheed will need a number of qualified Engineers and Nuclear Scientists. The opportunities, and other compensations, we believe to be exceptional.

Little more, on the subject, can be put into print because it is classified information. However, if you are interested in the possibility of joining us in this expansion program, please write to Jim Wade, Dept. SA-4,

LOCKHEED

AIRCRAFT CORPORATION
GEORGIA DIVISION
761 Peachtree St., N.E.
Atlanta, Georgia



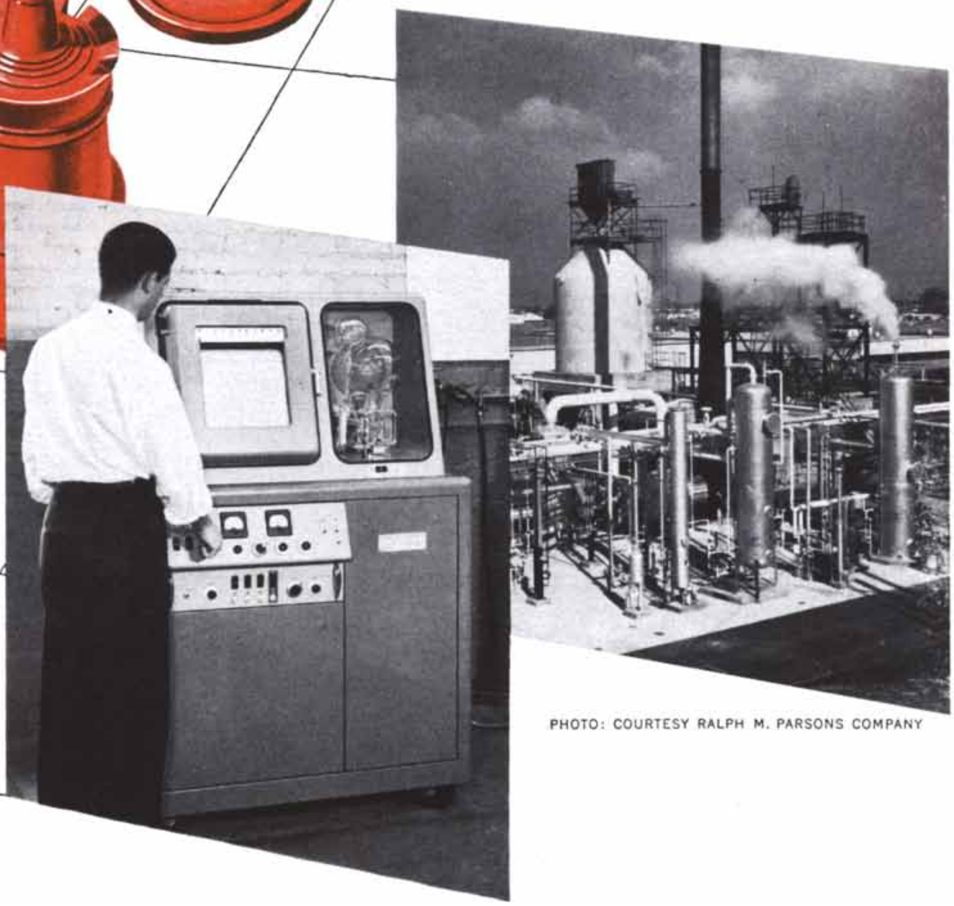


PHOTO: COURTESY RALPH M. PARSONS COMPANY

Airborne Mule Skinner for today's Defense

Now to the service of supply comes a new idea in military logistics—air transports that rival the train in ton-mile cost. Newest and largest, now on the way, is the turbo-prop Douglas C-133.

About to undergo flight tests, C-133 packs the load of *five freight cars* into its huge hull, loads 96% of military or construction equipment—fully assembled and ready for action—through an adjustable platform ramp in its tail section.

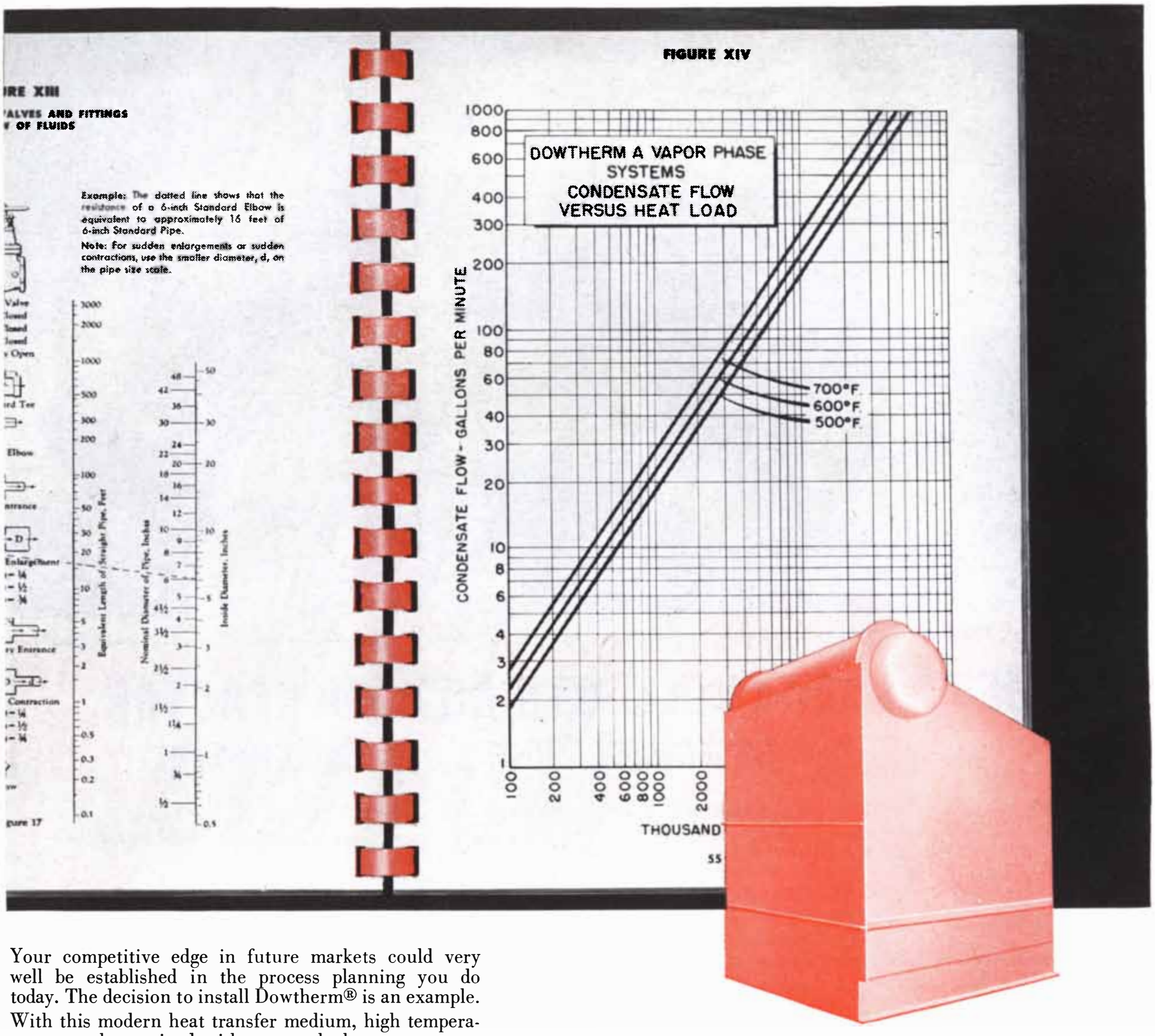
Speed and range are still secret but C-133's ability to shuttle back and forth across oceans gives it the cargo potential of a 7000-ton ship. Cost drops drastically because C-133 gets material into action in hours, rather than weeks or months.

Biggest cargo transport—the Douglas C-133A

Development of the Douglas C-133 shrinks supply lines and bolsters America's armed strength. But the core of that strength is the personnel manning posts and aircraft. Ask your local recruiting officer about the opportunities in the U. S. Air Force.

Depend on *DOUGLAS* **First in Aviation**

Process Heat Of The Future — *available today!*



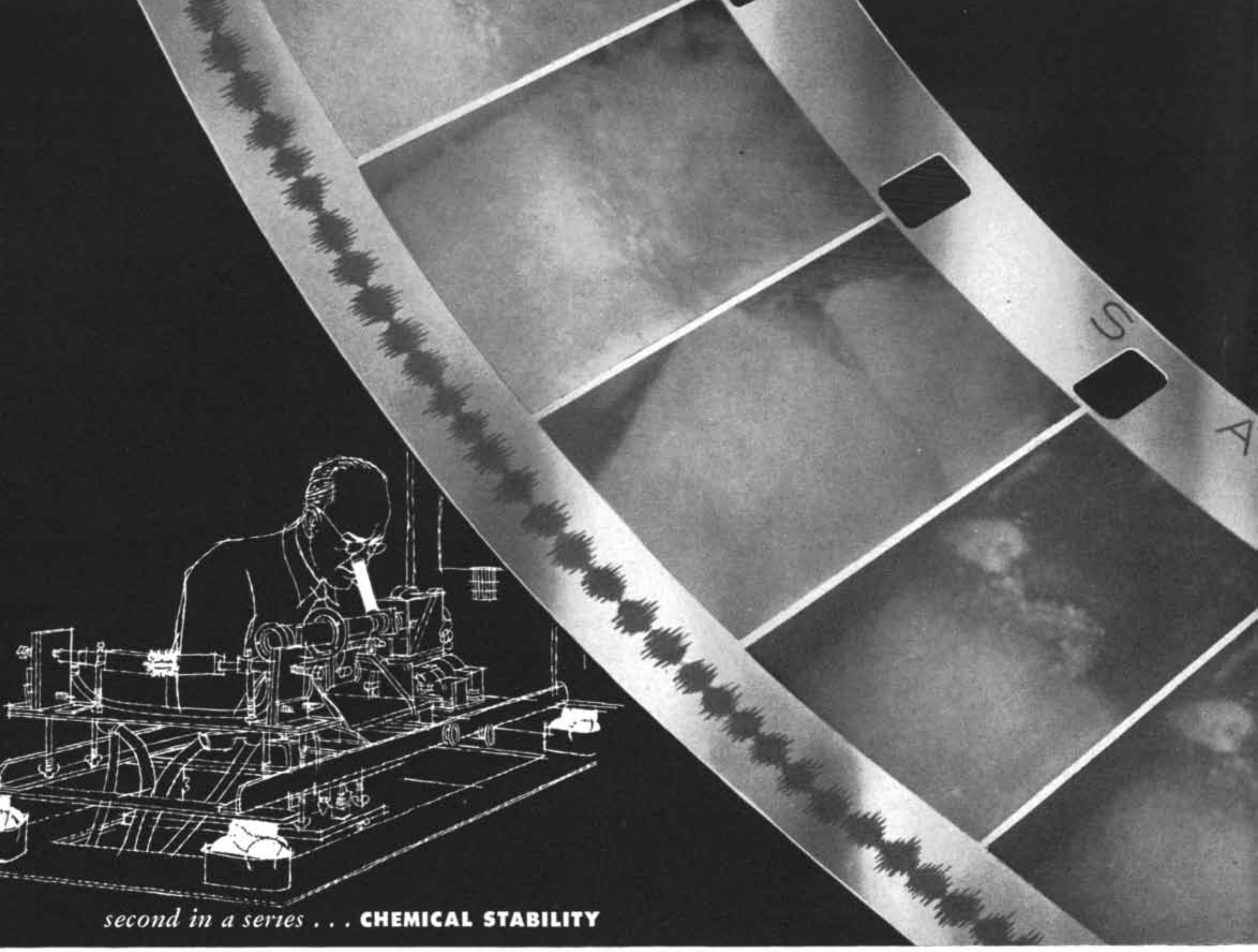
Your competitive edge in future markets could very well be established in the process planning you do today. The decision to install Dowtherm® is an example. With this modern heat transfer medium, high temperatures can be attained with extremely low pressures—permitting the use of thinner-walled, more compact equipment. Temperature control is precise, too, and easily maintained through simple pressure regulation. Resulting elimination of hot spots and varying temperatures assures quality of product and reduction in waste. The extraordinary thermal stability of Dowtherm makes it a natural for those applications demanding liquid phase heating.

Dowtherm is an accepted "tool" for the process engineer. You'll find all the facts in the "*Dowtherm Handbook*", a valuable technical guide of process heat information. A request on your letterhead will bring it to you promptly. THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 730F.

DOWTHERM

solves problems of pressure, control and maintenance for informed management in many process industries.

you can depend on DOW CHEMICALS



Comparative stability of MONOFRAX® fused cast refractory (left) vs. fireclay (right) . . . under attack by molten glass, as viewed through the high temperature microscope — one of Carborundum's most useful test facilities. (16 mm. frames shown are not consecutive.)

Unusual Properties of Refractory Materials

Chemical stability — Even under high temperature attack by gases, acids, corrosive solutions, molten salts and molten metals — the chemical stability of CARBORUNDUM'S super refractories enables them to fill industrial requirements that other refractories are unable to meet. For this reason, they are being used with increasing frequency in critical applications: i.e. as linings in controlled-atmosphere furnaces, in the production of muriatic acid, as radiant tubes, in the submerged combustion of liquids containing free acid — such as mixed chlorides and sulphates of iron, zinc, mercury and tin; in retorts for reducing and refining zinc, melting copper alloys and for hundreds of similar applications.

CARBORUNDUM'S laboratories are constantly developing new super refractories to meet specialized application problems. Current research projects include refractory materials for guided missile components, for atomic reactors, and for applications where wear and corrosion are unusually severe.

The forthcoming issue of CARBORUNDUM'S new magazine "Refractories" treats the subject "Chemical Stability of Refractories" in detail. Send for your copy today.

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VALUABLE INFORMATION FOR USERS OF:

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The Carborundum Company, Perth Amboy, N. J.

Please send me the forthcoming issue of "Refractories".

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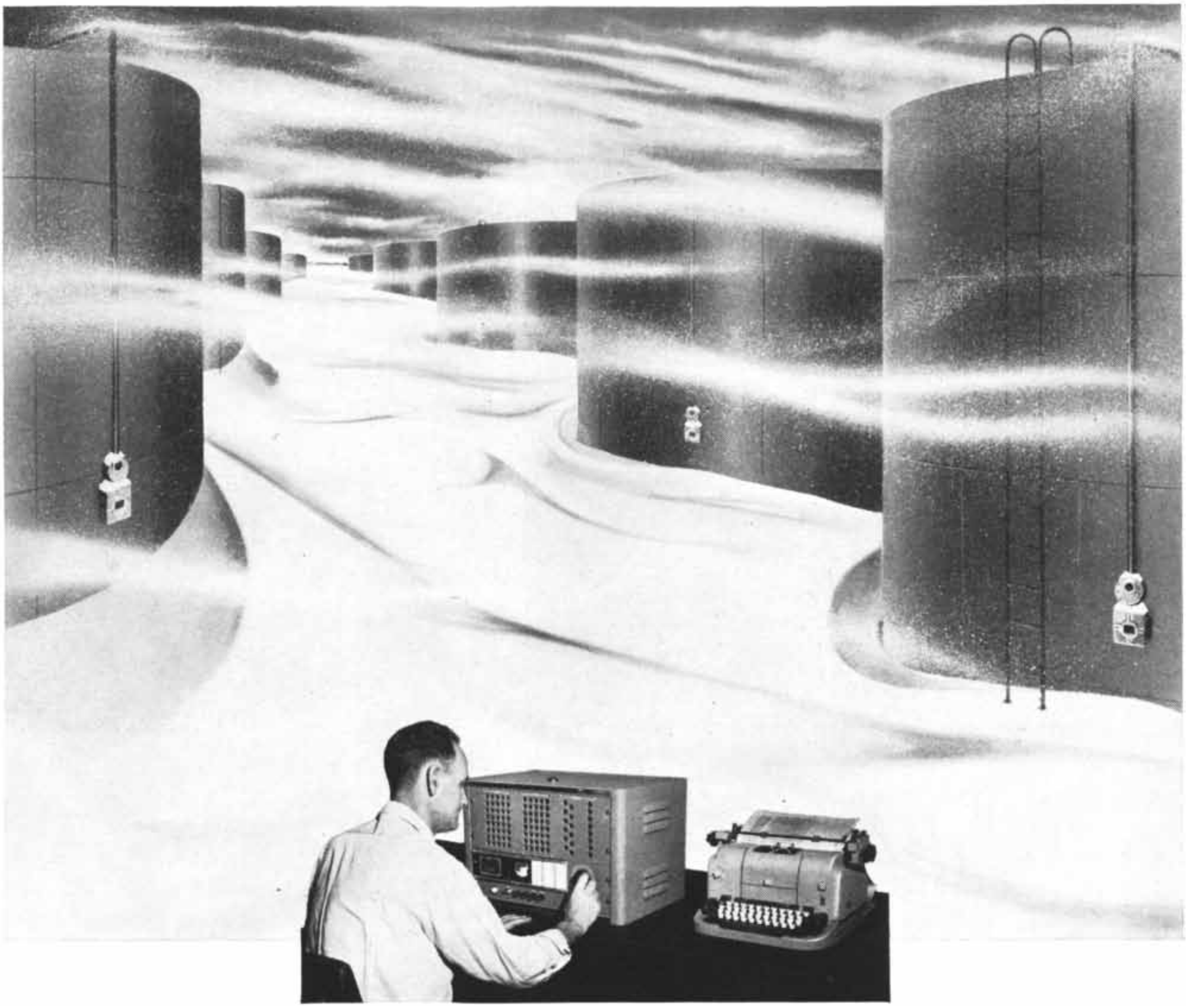


Liquid levels monitored hundreds of miles from your central office by Bendix ELECTRO-SPAN!

Important storage reservoirs for water, crude oil, gas, brine and other liquids are located in many remote and isolated sections of this country. It takes crews of men stationed at these points to keep a constant check of volumes and to open and close valves to balance supply and demand. The work is lonely, expensive to maintain, and sometimes dangerous.

Licks many problems

Now Bendix ELECTRO-SPAN can take over the entire job. It's a completely automatic remote measuring and control system that makes measurements in oil storage tanks, controls flow in water systems, completely operates unattended power and weather observation stations—all from a central location. Liquid level, flow, temperature, electrical quantities, pressure or shaft position are types of information ELECTRO-SPAN delivers immediately.

Controls as well

The system also acts in reverse, enabling the operator to control pumps, valves, motors and circuit breakers at remote locations. ELECTRO-SPAN can be used over any communication link such as telephone or telegraph lines or by radio or microwave. For further information contact our Pacific Division, 11600 Sherman Way, North Hollywood, California.

This particular device conceivably could be outside your field of endeavor but there are well over a thousand other Bendix systems and products just as ingenious, some of which may well solve particular problems you have. Write for our informative brochure "Bendix and Your Business"—it's bound to be helpful.

Bendix
AVIATION CORPORATION
FISHER BLDG., DETROIT 2, MICHIGAN

Application courtesy of Pennsylvania Salt Manufacturing Company

against calcium hypochlorite attack

TITANIUM *boosts service life over 1500%*

These filter press parts demonstrate the remarkable service life titanium can bring to chemical processing equipment.

Both parts are shown after use in the same application —pressing solid cakes from slurries of calcium hypochlorite. *But there the similarity ends.* Badly pitted, the part on the left made from one of the best corrosion-resisting metals lasted two weeks. The gleaming REM-CRU titanium part on the right is still going strong after seven months—without a trace of pitting or other corrosion.

Replacement savings vs. cost

No wonder titanium is justified in so many applications! The extra service life made possible *by its corrosion resistance alone* often makes titanium the most economical selection. Furthermore, as titanium's downward price trend continues, the "pay-out" time for titanium parts becomes progressively shorter.

Other titanium properties

While titanium's corrosion resistance is often its most important characteristic, don't overlook its other excellent properties. Titanium is unusually resistant to erosion by high-velocity fluids . . . is entirely free from stress-corrosion cracking . . . withstands abrasion, shock and fatigue . . . has a uniquely high strength-weight ratio that means substantial reduction in weight and cost of material needed for a given use.

When the going's tough for ordinary metals—try REM-CRU titanium. For specific recommendations, call or write REM-CRU today.

To keep abreast of the latest developments on this vital metal, write to Dept. S-4 for the Rem-Cru Review—a free periodical presenting the latest technical data on titanium alloys.

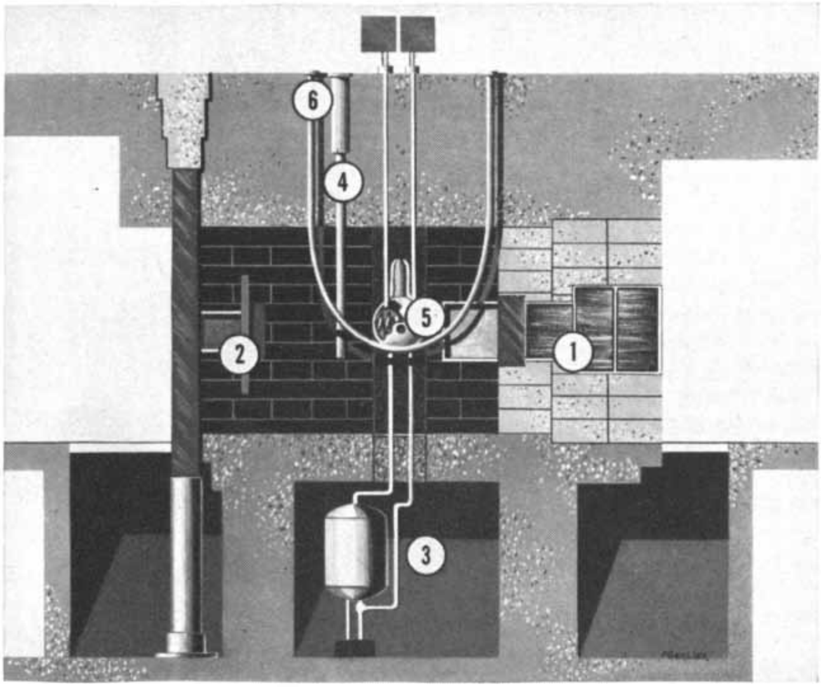
REM-CRU TITANIUM

REM-CRU TITANIUM, INC., MIDLAND, PENNSYLVANIA

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

Nuclear Reactor for Cancer and Other Medical Research

This new reactor utilizes the proven homogeneous solution design based on the SUPO unit at Los Alamos—modified and adapted to the special needs of cancer and other medical research and therapy. To be built by ATOMICS INTERNATIONAL for a prominent southern California university Medical Center, the reactor will provide a variety of radiological facilities—primarily high purity neutron and gamma beams with controlled exposure times in each. The thermal neutron flux at the central exposure tube is 1.7×10^{12} n/cm^2-sec. at a power of 50 Kw.



Medical Reactor Test Facilities

1. Gamma and Fast Neutron Facility—Gamma intensities of 1.3 reb/min/Kw and fast neutron intensities of 4 reb/min/Kw are available.
2. Thermal Neutron Facility—Provides neutron flux of 3.8×10^7 n/cm^2-sec. per kilowatt.
3. Gamma Radiation Area—Activity of the fission gases provides a radiation source in the gas handling equipment room.
4. Multiple Specimen Irradiation Tube—One or more in the reflector. Each accommodates 16 samples.
5. Central Exposure Tube—A 1-inch internal diameter tube through the center of the core permits access to maximum neutron flux.
6. Pneumatic Tubes—Tangential to core. Also (not shown) are Beam Tubes—Radial to core, or through reflector tangential to the core.

Gas handling system assembly for nuclear research reactor. This component, developed by Atomics International, contains facilities for circulating the reactor atmosphere, recombining the radiolytic gases, condensing the water vapor and returning water to the reactor core, in a closed cycle operation. Additionally, the tank at top which contains fission product gases, provides an intense source of neutron-free gamma radiation.

One Configuration of the thermal neutron facility provides a neutron flux of 3.8×10^7 n/cm^2-sec/Kw with a gamma ray intensity of only 0.1 reb/min./Kw (reb—roentgen equivalent biological). The fuel is Uranium enriched in the U^{235} isotope in the form of UO_2SO_4 dissolved in light water. This fuel-moderator solution, cooled by chilled recirculated water, is contained in a stainless steel core tank surrounded by a graphite reflector and dense concrete shield. Radiolytic and fission gases produced in operation are handled in a closed-cycle, water recombination and return system, which eliminates any discharge of radioactive core effluents and permits the re-utilization of materials.

Atomics International is a major reactor builder—experienced in the design, construction and operation of nuclear reactors for research and the production of power. If you are interested in any phase of our activities, ATOMICS INTERNATIONAL is staffed and equipped to help you. Please write: Applications Engineering Service, Dept. SA-N1, ATOMICS INTERNATIONAL, P.O. Box 309, Canoga Park, California. Cable address: ATOMICS.

ATOMICS INTERNATIONAL

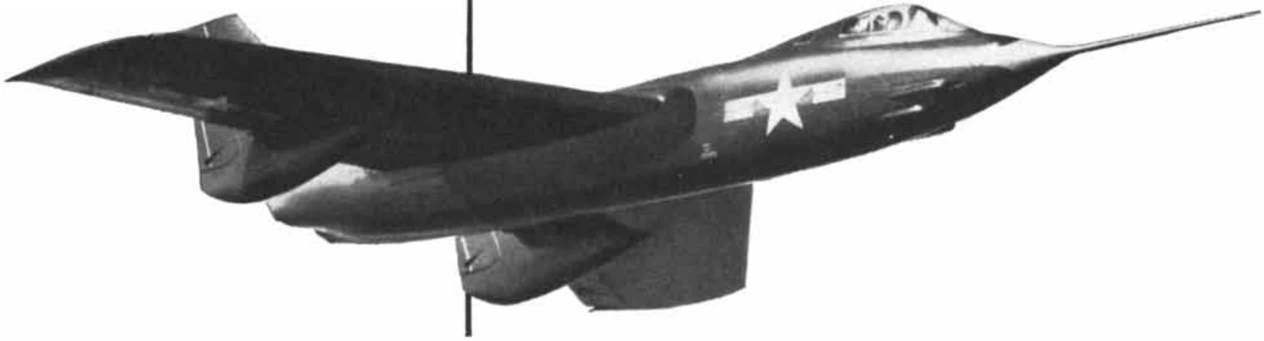
A DIVISION OF NORTH AMERICAN AVIATION INC.

PIONEERS IN THE CREATIVE USE OF THE ATOM

ALTEMP

For your selection

HIGH TEMPERATURE SUPER ALLOY STEELS



ALTEMP A-286 . . . an austenitic iron-nickel-chromium alloy made heat-treatable by the addition of titanium. Designed to maintain high strength and corrosion-resistance up to the 1350 F range, and to afford satisfactory scale resistance up to 1800 F.

A-286 was developed in the A-L Research Laboratory in Watervliet, N.Y., in the 1949-51 period. Among the high-strength, heat-resisting alloys, it has exceptionally low strategic alloy content, improved hot-working and machining qualities, and good center ductility in large sections. Currently used in jet engines and superchargers for such applications as turbine wheels and blades, frames, casings, after-burner parts, bolting, etc.

This alloy is readily produced in large quantities without the need of special steel-making equipment. It is available in the form of billets, bars, forgings, sheet, strip, tubing and hot-extruded shapes.

ALTEMP S-816 . . . a chromium-nickel-cobalt base alloy, strengthened by additions of molybdenum and tungsten, and with a columbium-carbon ratio of ten to one to insure its structural stability. Designed for high strength and corrosion-resistance service in the 1200-1500 F range, and at higher temperatures under lower stress conditions. Developed in the A-L Research Laboratory at Watervliet, N.Y. in the years of 1940-43, and engine-tested and proved for periods of over 30,000 hours.

S-816 is used currently for turbine blades in two of the production jet engines, also in a number of experimental aircraft and commercial gas turbines. Except for seamless drawn tubing, it is available in practically all forms and shapes in which stainless steels are processed, including hot extrusions.

ALTEMP S-590 was designed for service in the range of 1100-1400 F temperatures where high strength and corrosion resistance are required, and where cost is also a factor. Unlike S-816, which is practically a non-ferrous alloy, S-590 has a chromium-nickel-cobalt-iron base. However, it employs the same molybdenum and tungsten additives, and the same columbium-carbon ratio.

S-590 was developed at the Watervliet Laboratory and field-proved during the same years as S-816. It is available in the same shapes and forms, and is currently being used for turbine blades and wheels in experimental commercial gas turbines.

OTHER GRADES . . . among the many other Super Alloys made by Allegheny Ludlum are V-36, M-252, 19-9 DL, 19-9 DX and Waspaloy.

Do you have a high temperature problem? The services and experience of our Research Laboratories and Technical Staff are completely at your command. ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.***

WSW 8310 B

WRITE FOR INFORMATION

Certified laboratory data on the properties of Allegheny Ludlum high temperature Super Alloy Steels are yours on request.

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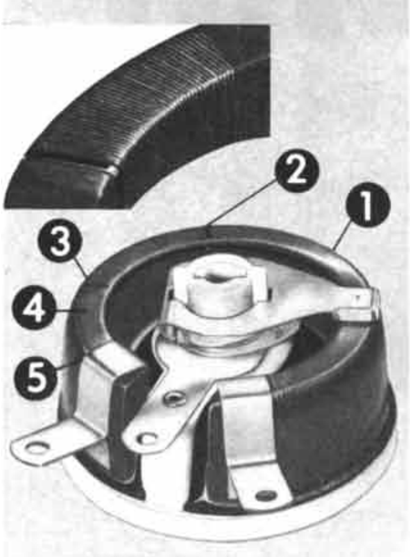

LETTERS

Sirs:

Richard C. Pinkerton's suggestion in his article "Information Theory and Melody" [Scientific American, February] that "a set of tables could be constructed which would compose Mozartian melodies" is not as fanciful as it may have seemed to some of your readers, for this very thing was done by none other than Mozart himself. His *Musikalisches Würfelspiel* (K. Anh. 294d), published in this country as *The Dice Composer* (Guild Publications of Art and Music, 1941), consists of a set of alternative groups of notes for each measure of a standard-form minuet. The particular choice for each measure is determined by throwing a pair of dice. There are some duplications, but a surprising amount of variety is possible in the resulting compositions. . . .

Which just goes to show that some of our "new" ideas aren't so new after all!

Morton S. Raff

Silver Spring, Md.

Sirs:

. . . Alexander Laszlo, who edited *The Dice Composer*, refers to other attempts at mechanical composition by Joseph Haydn, Maximilian Stadler and Karl Philipp Emanuel Bach. These attempts were, of course, prior to our background of information theory.

Subsequently, J. J. Coupling has discussed stochastic composition of music in an article "Science for Art's Sake" in *Astounding Science Fiction* for November, 1950. Dr. D. Slepian of the Bell Telephone Laboratories has also experimented in the stochastic composition of music, using not statistics derived from a study of particular compositions, but such ideas of probability as have accumulated in the minds of a group of experimenters. Thus, he had each of a group of men add to a "composition," after examining only one or more preceding half measures. Tape recordings of the resulting music have been played as a part of a number of talks on information theory.

J. R. Pierce

Murray Hill, N. J.

Sirs:

Some years ago, while trying to unravel a crystal structure by means of Fourier series at Cal Tech, I would relax, like Richard C. Pinkerton, by investigating the nature of melodies, and arrived at the point where I felt that certain mathematical parameters existed which had constant values for satisfying melodies.

While I started along lines similar to Dr. Pinkerton's, I soon found that the harmonic context of a note was of primary importance in assessing its statistical value. Thus in the key of C the note C has more "tonic value" than it would if accompanied by the subdominant or F triad, which in turn has greater affinity with the key chord than the same C when it appears as the seventh of the dominant seventh chord D, F sharp, A, C.

Thus in the slow portion of Schubert's "Tod und das Mädchen" the same note is repeated by the voice 17 times in six measures. Without the varied harmonic accompaniment of the piano the sequence would be monotonous and meaningless, and I fear Dr. Pinkerton would have rejected the sequence in his analysis.

Another case in point is the spooky opening melody of the finale of Brahms's third symphony, where the first eight measures are mostly in a completely foreign key, but given stability and meaning by the reiteration of the tonic triad in the succeeding eight measures.

Thus mere concern over the frequency of occurrence of certain melody notes without reference to the harmonic context can produce meaningful results only in the trivial case where the entire

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melody is accompanied by the same tonic triad, this despite the invocation of such a potent talisman as the Second Law of Thermodynamics.

It is my hope ultimately to derive the now purely empirical laws of harmony and counterpoint as developed by Palestrina and Bach. When the necessary parameters of my equations are determined I hope to extrapolate and out-Schönberg the atonalists!

GUSTAV ALBRECHT

Music Editor
The Pasadena Independent
Pasadena, Calif.

Sirs:

James Newman concludes his excellent review of Morton White's *The Age of Analysis* [SCIENTIFIC AMERICAN, February] by quoting Wittgenstein's famous remark to the effect that his views are like a ladder. By means of it one can climb to the summit from which all philosophy is meaningless, including the philosophy out of which the ladder is constructed. Therefore the ladder may be thrown away. I have heard this statement cited so often as an example of Wittgenstein's wit that I think it is time someone pointed out that the remark goes back at least to the second century. Sextus Empiricus, the greatest of the Greek skeptics, was often accused of using arguments to prove that all arguments are false. He replied by citing two possibilities: (1) Perhaps the proof that all proofs are false is the one exception, as Zeus is the father of all gods except himself. (2) Perhaps the proof may abolish itself, as a fire destroys its fuel and then itself, as a laxative purges the stomach of food and is thereby also purged, and, finally, as a man climbs to a high place on a ladder, then overturns the ladder with his foot. (See Loeb Classical Library edition of Sextus Empiricus, Volume 2, page 488.)

MARTIN GARDNER

New York, N. Y.

Sirs:

Readers of "Flowers in the Arctic" by Rutherford Platt [SCIENTIFIC AMERICAN, February] would probably be interested in some of the history of McGarry's Rock. This appears to be the same small island Dr. E. K. Kane mentioned as having been named in 1853 for its discoverer, Mr. James McGary of

He figures in MUSIC as well

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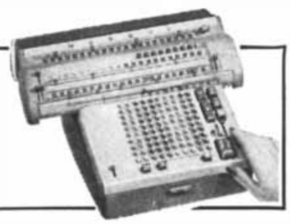


see the MAN from **MONROE**

for CALCULATING • ADDING • ACCOUNTING MACHINES

New London, second officer of the Second Grinnell Expedition (*Arctic Explorations: The Second Grinnell Expedition*, 1853, 1854, 1855, by E. K. Kane; Volume I, pages 137-139).

The island was first occupied about October 10, 1853, by a party which Dr. Kane had sent out from the expedition base at Rensselaer Bay (about 80 miles to the southwest) to establish supply caches for future exploration parties. The island is located by Kane at about 79 degrees 10 minutes North, 65 degrees 40 minutes West and described as a "low island at the base of the large glacier which checked further march along the coast." The cache consisted of "six hundred and seventy pounds of pemmican, forty of Borden's meat biscuit, and some articles of general diet; making a total of about eight hundred pounds."

In spite of the efforts which were made to keep the polar bears out of the cache, when it was revisited in June of the following year (1854) it had been entirely destroyed. Its destruction was a severe blow to the expedition's hopes for their summer's exploration in 1854.

The story of this expedition is one of continual battle against what would seem to be insuperable odds, but when they finally walked and dragged their way home in the summer of 1855, among the baggage was Dr. Kane's collection of botanical specimens.

The botanical specimens represent only a part of the contributions made to the knowledge of our time by the Kane expedition. His studies of this Arctic area included, besides botany and geographical exploration, meteorology, terrestrial magnetism, glaciology, geology, and the customs and nature of the Eskimos.

ELMER ROBINSON

Associate Meteorologist
Stanford Research Institute
Stanford, Calif.

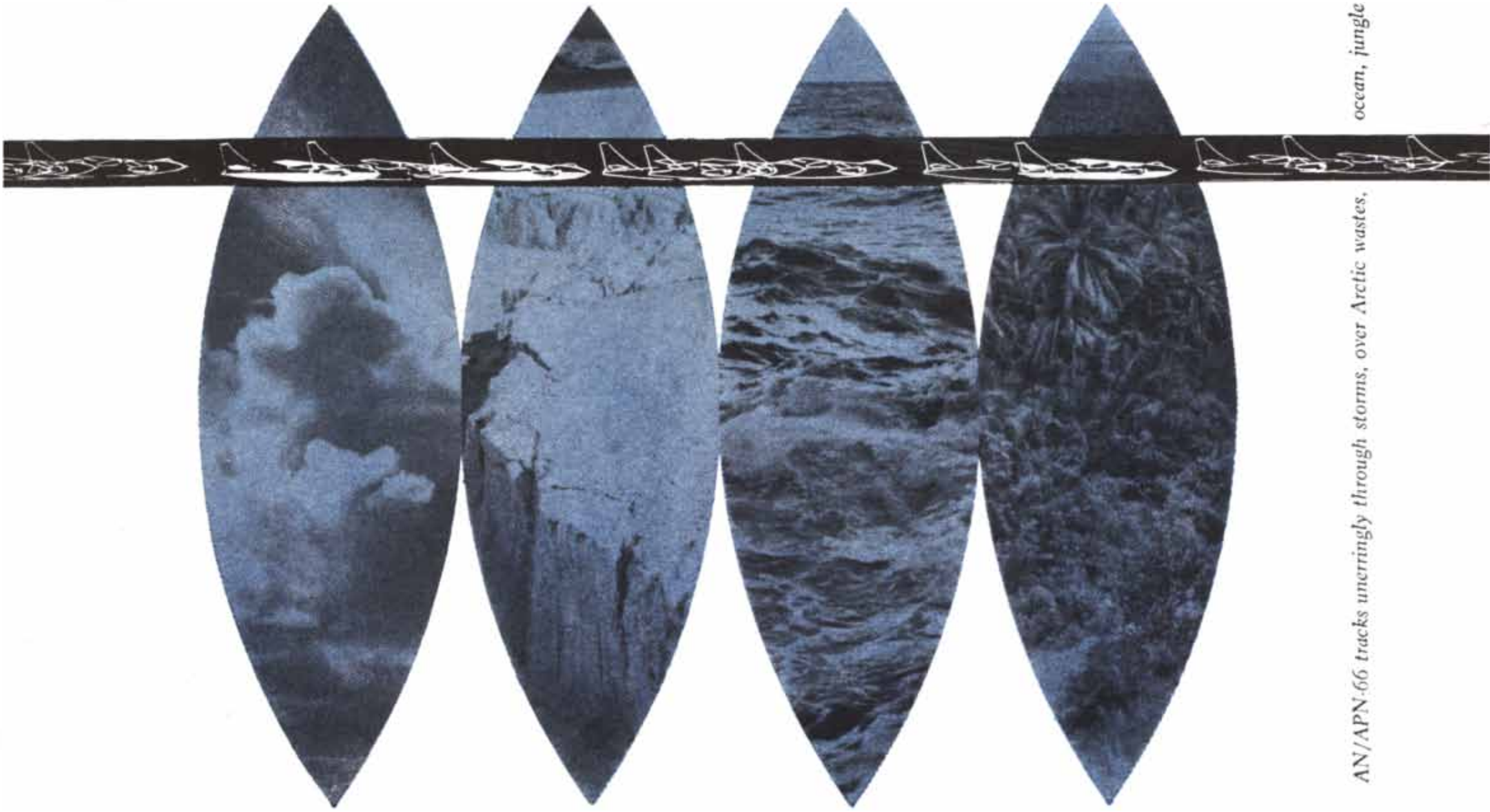
Sirs:

This bit of philosophy takes *pi* out to 31 places ["Letters," SCIENTIFIC AMERICAN, January *et seq.*]:

"Why a chap, I query,—scientist or layman—takes the hours probably necessary finding sentences for *pi* (and hundreds most likely do), always will irk and irritate all my medulla oblongata."

JOHN KLEMPNER

Reed College
Portland, Ore.



AN/APN-66 tracks unerringly through storms, over Arctic wastes, ocean, jungle

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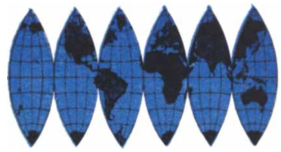

GPL — in conjunction with Air Force Weapons Guidance Laboratory — has produced the most advanced automatic air navigation system in operational use — AN/APN-66.

This GPL system guides an airplane to its destination under any conceivable conditions. It is completely self-contained; needs no ground guidance, no search radar, no optical observation. It works equally well anywhere in the world. Virtually instantaneously, and with unprecedented accuracy and speed, AN/APN-66 will always tell exactly where a plane is and where it must go to reach its goal.

The military application of a system of such capabilities is far reaching. To achieve these capabilities, GPL mobilized scientific manpower and facilities on a large scale. Four other GPE companies took part. Even so, development of AN/APN-66 took 8 years, for it required a seemingly impossible engineering achievement: the harnessing of the "Doppler effect."

The Doppler effect is the shift in the frequency of waves, sound or electrical, transmitted from a moving object to a stationary one. It is most familiar as the shift in the pitch of a train whistle as it approaches and passes. AN/APN-66 measures a similar shift in the frequency of electro-magnetic waves it bounces off the earth's surface below. From the difference in frequency between the original wave and its echo, the system computes the plane's speed and direction, then uses this data to keep continual track of the plane's position.

AN/APN-66 and its variations, AN/APN-81, 82 and 89, have flown millions of operational miles in transports, hurricane hunters, patrol craft, bombers. They are steadily going into more types of aircraft as standard equipment. When put to civilian use, they will guide air liners to the remote corners of the world.

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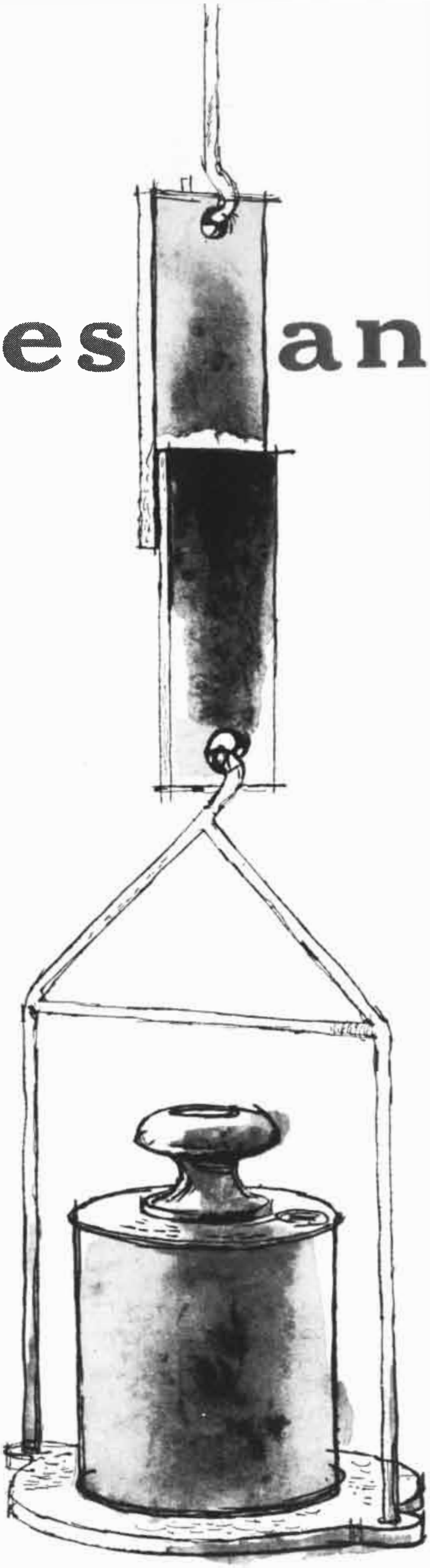
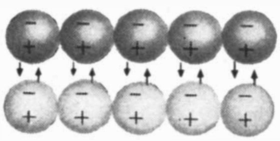


3 theories of adhesion

These theories describe what most research chemists agree are the important factors in bonding. As yet there is no agreement on a general theory of adhesion that would explain why all adhesives work.

Molecular attraction

Adhesive molecule

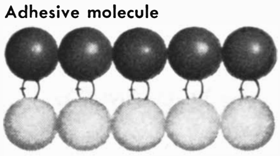


Surface molecule

All matter contains electrical forces in excess of those needed to hold the atoms within a molecule together. These tiny electrical forces are capable of providing a very strong attraction between the adhesive film and the surfaces to be bonded.

Chemical reaction

Adhesive molecule

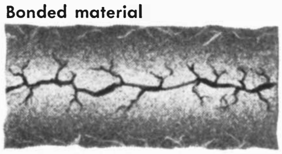


Surface molecule

In some instances, the adhesive reacts chemically with the surfaces of the materials to be bonded. A chemical bridge is formed which knits the two materials together.

Mechanical tie

Bonded material



Bonded material

With porous materials, the adhesive (dark line) fills the pores of the materials being bonded. When the adhesive hardens, it interlocks or "hooks" the two materials together as pictured above.

adhesive stick?

Researchers don't agree on the answer . . .
but they keep on turning out amazing new adhesives

Wherever you look on the industrial horizon, adhesives are replacing nuts and bolts, rivets, and other mechanical fastenings. Materials like metals, glass, plastics, and ceramics are being bonded together with a speed and effectiveness that would have been impossible a few years ago.

When you consider this amazing progress, it's a little surprising to find that research chemists don't agree upon a basic theory that explains why adhesives stick. It seems that in some bonds, chemical reaction does the trick. In others, it may be molecular attraction, a mechanical tie, or possibly some combination of these and other still unknown factors.

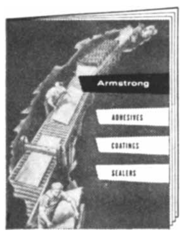
None of these theories, however, seems to explain fully why adhesives like asphalt emulsion or putty will stick only as long as they remain "liquid." By contrast, most adhesives must pass through a liquid stage, then harden or change to a solid to form a bond.

It's easy to understand why a comprehensive theory has not been evolved. Research chemists have been tied to their benches by the pyramiding demand for new and better industrial adhesives. They have had to keep pace both by improving established adhesives and by exploiting the advantages of promising new basic materials.

This practical work, of course, has tended to confirm some theories and disprove others. Up to now, however, no complete proof of a fundamental theory of adhesion has been established. Even so, it seems reasonable to expect that before too long the final mystery of why adhesives stick will be solved.

For practical solutions to bonding problems, many manufacturers today turn first to the Armstrong Cork Company. Because of our 35 years of experience in making and using adhesives, we've been able to help a lot of fabricators find better ways to join things. For instance, Armstrong's new and stronger air-drying adhesives are bringing the speed and economy of assembly-line production to operations where overnight drying has been necessary.

If you're using adhesives, or would like to, get in touch with us. We'll be glad to study your problem and suggest a practical, economical solution.



For helpful information on using adhesives, send for our new 36-page illustrated manual, "Adhesives, Coatings, and Sealers." It's free to industrial users. Write on your letterhead to Armstrong Cork Company, Industrial Division, 8204 Inland Road, Lancaster, Penna.

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50 AND 100 YEARS AGO

Scientific American

APRIL, 1906: "Prof. Pierre Curie, whose researches have earned for him a worldwide reputation, was killed in Paris last month by a wagon as he crossed the Place Dauphine."

"When the flights of the Wright brothers were first announced last December in France, it was incredible to many people that so novel a device as a flying machine could be operated frequently for nearly six months in the vicinity of a large city without the fact becoming generally known. The Wrights refused to make a statement, and they gave the names of but a few persons who had seen them fly. In order to dispel any lingering doubt regarding the flights, the reported accounts of which the leading German aeronautical journal, *Illustrirte Aeronautische Mitteilungen*, characterized as *'ein amerikanischer bluff,'* a list of questions was sent to the witnesses. In all we received eleven replies. Mr. Chanute, in answer to our telegrams, writes: 'The Wright brothers have for the past two years been in possession of a successful flying machine driven by a motor, to my certain knowledge, and have been gradually perfecting it. On the 15th of October, 1904, I witnessed a flight of 1,377 feet performed in 23⅘ seconds. After the machine had gone some 500 feet and risen some 15 feet, a gust of wind struck under the right-hand side and raised the apparatus to an oblique inclination. The operator, who was Orville Wright, endeavored to recover an even transverse keel, was unable to do so, and concluded to alight. One side of the machine struck the ground first; it slewed around and was broken but the operator was in no wise hurt. This was flight No. 71 of that year (1904). I visited Dayton in November, 1905, and verified the absolute accuracy of the statements which the Wrights have since made to the Aérophile of Paris and to the Aero Club of New York. There is no question in my mind about the fact that they have solved the problem of man-flight by dynamic means. Believing that this so-

An intrstng exprmnt in spch

Some day your voice may travel by a sort of electronic "shorthand" when you telephone. Bell Laboratories scientists are experimenting with a technique in which a sample is snipped off a speech sound—just enough to identify it—and sent by wire to a receiver which rebuilds the original sound. Thus voices can be sent by means of fewer signals. More voices may economically share the wires.

This is but one of many transmission techniques that Laboratories scientists are exploring in their search for ways to make Bell System wire and radio channels serve you more efficiently. It is another example of the Bell Telephone Laboratories research that keeps your telephone the most advanced on earth. *The oscilloscope traces at right show how the shorthand technique works.*

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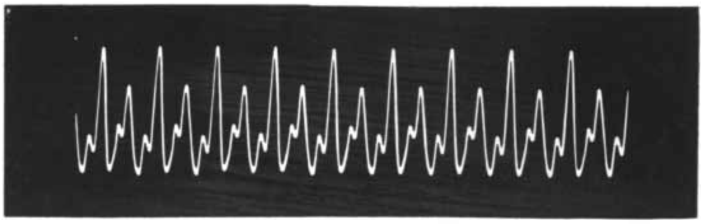
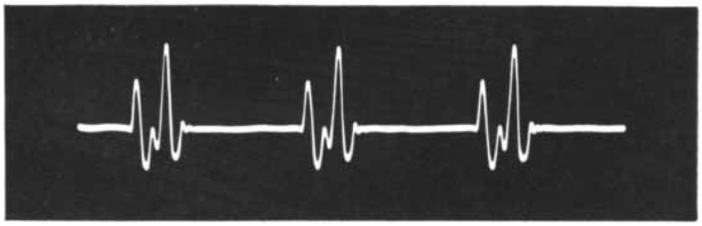
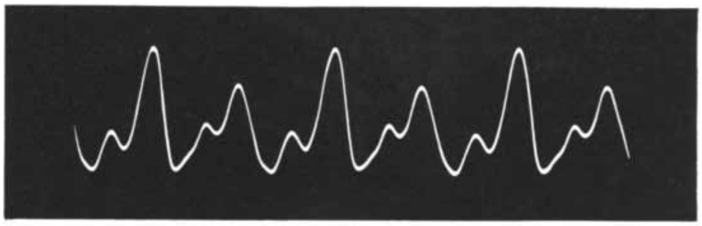
Largest industrial laboratory in the United States



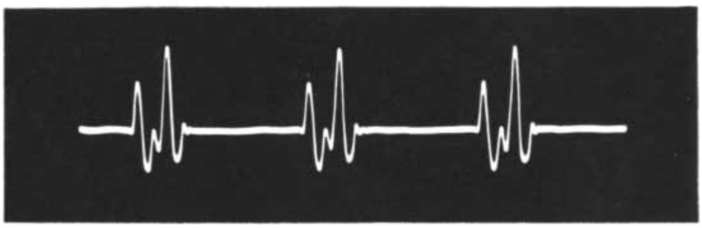
Vibrations of the sound "or" in the word "four." Pattern represents nine of the "pitch periods" which originate in puffs of air from the larynx when a word is spoken.



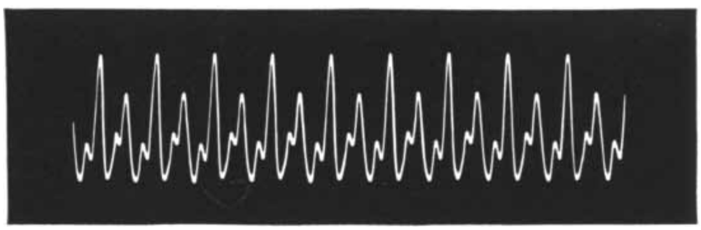
An electronic sampling of the "or" sound. One "pitch period" in three has been selected for transmission. This permits great naturalness when voice is rebuilt. Intelligible speech could be sent through a 1 in 6 sampling.



The selected samples are "stretched" for transmission. They travel in a narrower frequency band than complete sound.



Using the stretched sample as a model, the receiver restores original frequency. In all speech, sounds are intoned much longer than is needed for recognition—even by the human ear. Electronic machines perform recognition far faster than the ear.



The receiver fills in gaps between samples, recreating total original sound. Under new system, three or four voices could travel at once over a pair of wires which now carries only one—and come out clearly at the end!

lution had a money value, they have, until recently, preserved whatever secrecy they could. As the first use will be in war, it is my belief that the various purchasers will desire to preserve such secrecy as may be practicable concerning the further developments. In addition to the great feat of inventing a practical flying machine the Wright brothers have, in my judgment, performed another improbable feat by keeping knowledge of the construction of a machine, which can only be operated in the open, from the incredulous but Argus-eyed American press.'—O. Chanute."

"It is unfortunate that a project for the construction of a railroad in Siberia, to run from Behring Sea to a junction with the Siberian Railroad, should be handicapped at the very outset by identifying it with the absurd and impossible proposal to build the railroad tunnel beneath Behring Strait. The Behring Sea suggestion is one that seems to have taken a firm hold on the mind of what might be called the engineering romanticists, and it takes only a very slight occasion to open the flood gates to a mass of rhapsodical outpourings about 'engineering triumphs.' It would be located at a distance of 3,000 miles from the Siberian Railroad, and about 2,000 miles from the nearest point on the most northerly of the transcontinental railroads in America. If Alaska fulfills its great promise of unexplored mineral wealth, no doubt the Alaskan railroads will be carried up to Behring Strait. The prospects of a connecting railroad in Russian territory are at present apparently dependent upon the success of an American company, which offers to construct a tunnel and build a road 3,000 miles long from East Cape to Kansk, where it will join the Siberian Railroad. That there will ever be a considerable amount of through travel by way of Behring Sea is very unlikely. The construction of the tunnel would be an enormously costly undertaking. With its approaches it would be not far from 40 miles in length; and since the depth of the water is variously stated at from 160 to 170 feet, the subgrade of the tunnel would have to be at minus 200 feet."

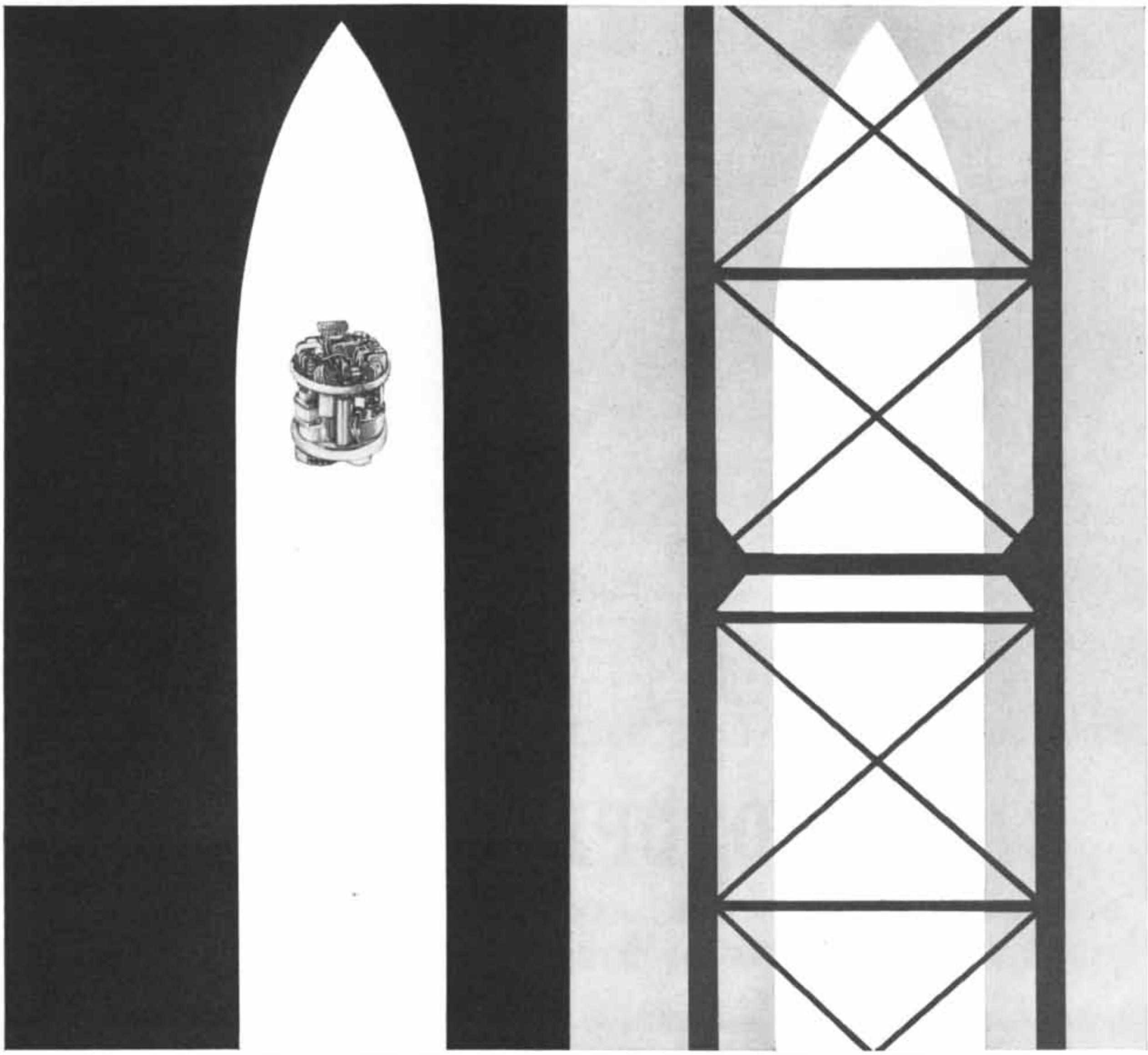
"The first instance, doubtless, of the use of a phonograph as evidence in a court of this country occurred, according to the newspapers, in a recent trial in the United States Court at Boston. It is said that the phonograph was put in evidence to show the court the noise of the elevated cars, for which the plaintiff

claimed damage to his business block. The evidence was objected to, of course, and, in support of its admission, the plaintiff's counsel contended that a phonograph is one of the most accurate scientific recorders, and that it is admissible in evidence on the same ground that photographs are admissible."

APRIL, 1856: "Liebig recently delivered a lecture at Munich, Bavaria, on the nature and uses of beer—a beverage for which Bavaria has long been pre-eminently distinguished. He stated that it did not contain matter for supplying the waste of muscle, it only was a supporter of combustion to supply warmth. The nitrogenous portion of the barley—the muscle constituent—is separated by boiling and fermentation."

"Recently on one of the Prussian railroads a barrel which should have contained silver coin was found, on arrival at its destination, to have been emptied of its precious contents and refilled with sand. When Professor Ehrenberg of Berlin was consulted on the subject, he sent for samples of sand from all the stations along the different lines of railway that the specie had passed, and by means of his microscope, identified the station from which the interpolated sand must have been taken. The station once fixed upon, it was not difficult to hit upon the culprit in the small number of employees on duty there."

"A canal across the Isthmus of Suez which, for many years, has seemed a visionary project, is likely to be realized. The commission of engineers and scientific men whom the Viceroy of Egypt appointed to examine and determine upon the practicability of it, have made a report, in which they declare that the canal could be built on nearly a direct route from Suez to the Gulf of Pelusium on the Mediterranean, with a branch to the Nile. The estimated cost is $8,000,000, and the construction will take six years. It is estimated that this canal will effect a saving in distance between the respective places and Bombay, as follows: Constantinople, 12,900 miles; Liverpool, 8,550; New York, 7,317; New Orleans, 8,178. More than one half the distance is abridged between the principal ports of Europe and Asia, by the proposed canal."



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THE AUTHORS

MICHAEL EVENARI and DOV KOLLER ("Ancient Masters of the Desert") are botanists at Hebrew University in Jerusalem. Evenari was born in 1904 at Metz in Lorraine, then part of Germany. He took a Ph.D. in botany at the University of Frankfurt in 1926. Until 1933 he was engaged in teaching and research in Germany and Czechoslovakia. He made two botanical trips to Bulgaria as a guest of King Boris, "an enthusiastic botanist." Evenari became a refugee to Palestine in 1933 and later served in the Jewish Artillery Unit of the British Army and in the Jewish Brigade. "Shooting with pieces of artillery," he notes, "is an old invention of the plants; I had always been interested in the shooting fungi, which throw their sporangia and spores with great ballistic exactness." In 1945 he was elected vice president of Hebrew University. Dov Koller was born in Palestine in 1925. During World War II he served in the Royal Air Force and later joined the Israeli Infantry. He obtained a Ph.D. at Hebrew University after the war.

DAVID C. HAZEN and RUDOLF F. LEHNERT ("Low-Speed Flight") are at the Subsonic Aerodynamics Laboratory of Princeton University. Hazen was born in New York City and was educated at the Choate School in Connecticut and at Princeton, from which he graduated in 1948. He became an assistant professor there in 1953. He spent two years working under A. A. Nikolsky in the field of helicopter stability and control. Hazen now heads Princeton's program of boundary-layer investigations for the Navy. Lehnert was born of American parents in Munich in 1929; he attended the Lawrenceville School and Princeton, from which he graduated in 1952. He is in charge of the experimental work in Hazen's laboratory. Hazen and Lehnert have organized a group known as the Institute of Utterly Worthless Research. This group, says Hazen, "investigates in an informal but rigorously scientific manner anything that seems to be of interest to any of its members. Topics so far covered have included the performance of kites, flow fields around automobiles, model airplane performance and the performance of swimmers."

GERARD DE VAUCOULEURS ("The Clouds of Magellan") is a French

USING BERYLLIUM COPPER TO DESIGN A VIBRATION MOUNT THAT HAS A DAMPING EFFICIENCY OF 95%

SOURCE: K. W. Johnson, former chief engineer of the Mechanical Section, Wright Air Development Center, and president of K. W. Johnson & Company, Dayton, Ohio

Objective:

To obtain an all-weather, all-altitude metal mount which will provide maximum damping and stability for electronic instruments in shock conditions up to 30 g, and in-flight vibration conditions through the range of 1-500 cps.

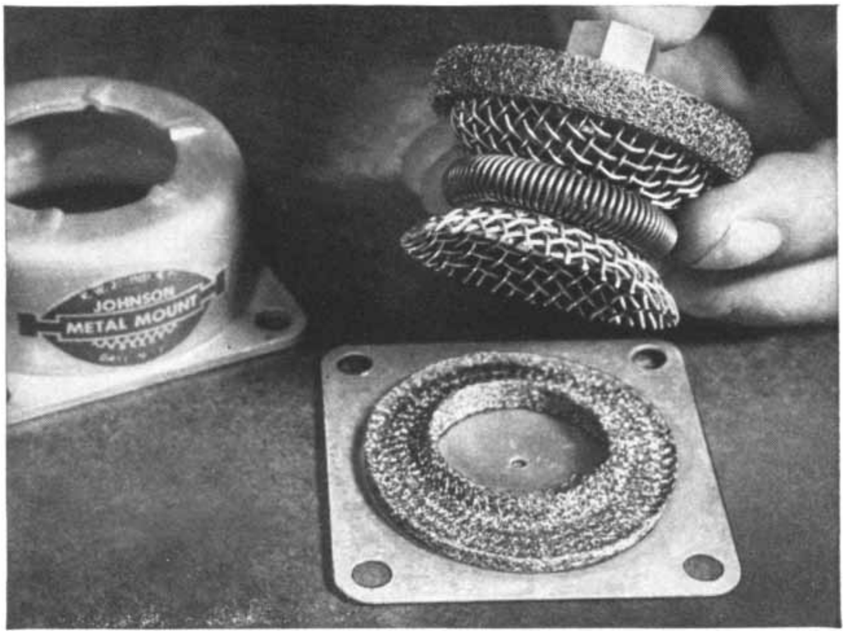
Metal Requirements:

In addition to the stringent load requirements, the metal used must pass test conditions of temperature differentials ranging from —65°C. to +200°C., high salt spray concentrations, extreme humidity, and long storage. It must have excellent fatigue life and metallic compatibility.

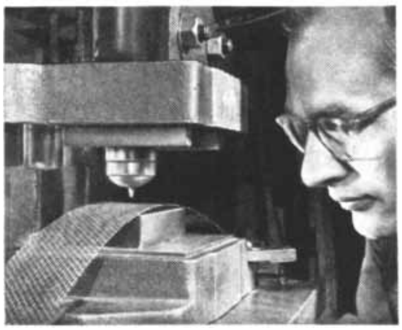
Procedure:

A convexed spring is fabricated of beryllium copper wire cloth, formed and cut on a punch press, then heat treated. Two of these discs are fastened together back-to-back with the convex surfaces facing each other. A circular coil spring is fitted around the assembly in the "V" made by the joining of the discs.

The concave-convex beryllium copper assembly absorbs the shock in a vertical and radial pattern. This spring alone would produce a bouncing action, causing the unit to move in uncontrolled prolonged cycling. To regulate this effect, the motion of the beryllium copper spring is resisted by the friction of the coil spring against the convex surface of the concave-convex spring. It cushions the downward action as it expands, and contracts to level the upward surge. The end result is a double damping system where the coil spring moderates the concave-convex system, and, at the same time, is damped by it. Consequently, magnification at resonance is controlled on the order of 1.5.



The mount uses a double reacting spring arrangement—a beryllium copper concave-convex spring and a circular coil spring provide a damping efficiency up to 95%.



Forming and cutting the concave-convex spring from "BERYLCO" brand #25 wire cloth.

Test Results:

In the 50-hour salt test, stainless steel cloth failed completely—the stainless convexed springs could be broken apart and disintegrated by handling. A shift was made to "BERYLCO" #25 beryllium copper alloy to obtain a cloth which had superior spring characteristics over stainless, and gave much greater fatigue life. The beryllium copper spring holds up without failure or setting tendencies, and it is unaffected by a salt atmosphere. It has proven to be over 200% better from a life and service standpoint.

Many metals and alloys cannot be used together in applications of this type because they are inducive to an electrolytic action. Localized corrosion resulting from a coupling of dissimilar metals does not occur in this mount, because beryllium copper is compatible with the other alloys which are used.

Summary

"Beryllium copper is the heart of our vibration control unit," asserts K. W. Johnson, president of the K. W. Johnson Company. "It has given us the qualities of high strength, resistance to temperature extremes and severe shock, increased fatigue life, and eliminated the danger of corrosion. Without it, we could not have passed the service qualification test."

A technical bulletin (#33), with specific details on the design and use of beryllium copper in the Johnson Metal Mounts, is available on request without charge. Write to

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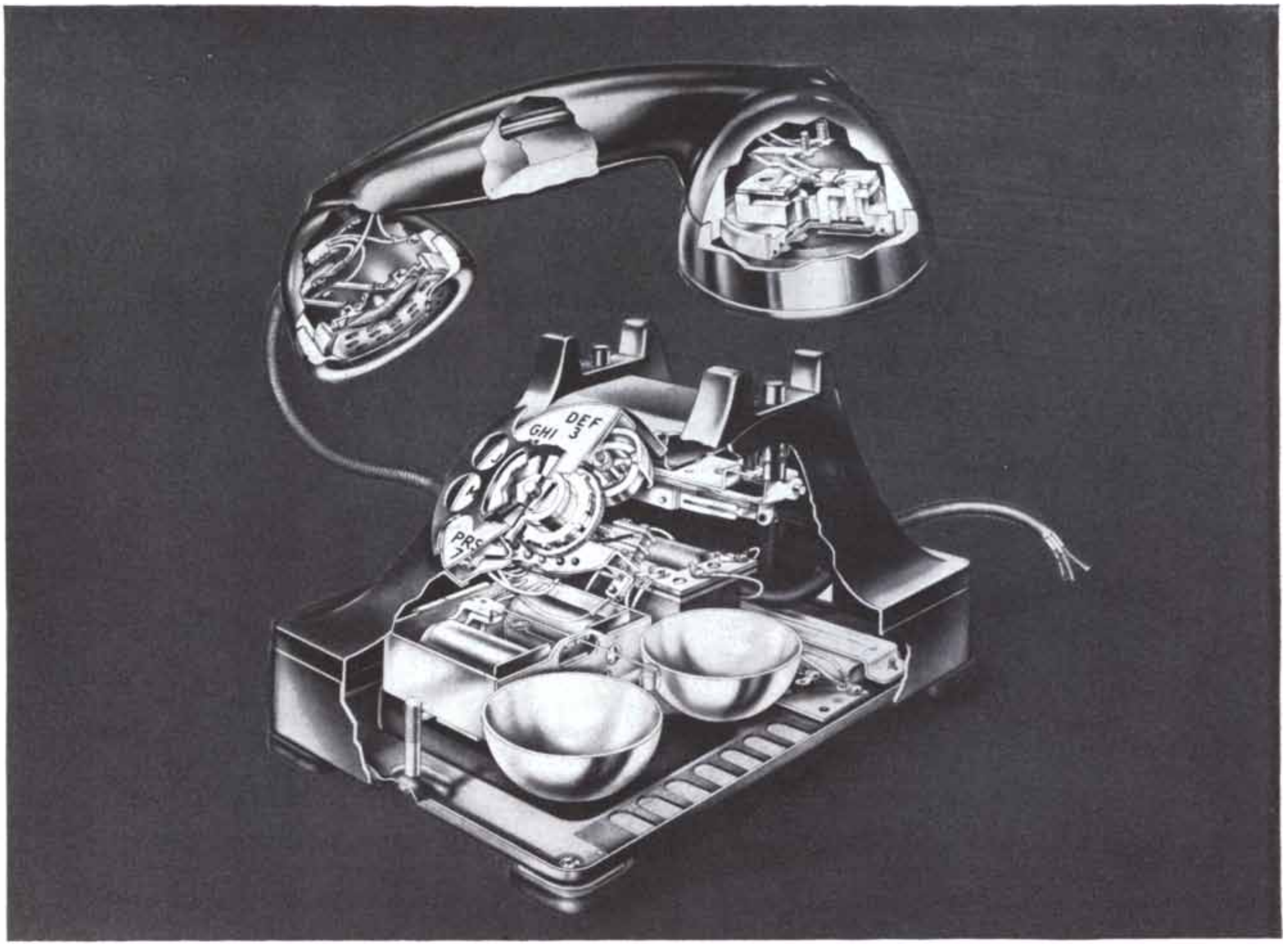
astronomer who has been observing the Southern skies from Mount Stromlo in Australia, at the Yale-Columbia Southern Station. He has previously written for SCIENTIFIC AMERICAN articles on Mars and on the "supergalaxy."

ARTHUR M. BUSWELL and WORTH H. RODEBUSH ("Water") are chemists who have been doing research on water together since the 1930s. Buswell, now research professor at the University of Florida, was chief of the Illinois State Water Survey and research professor of chemistry at the University of Illinois until last September. He graduated from the University of Minnesota and took his Ph.D. at Columbia University in 1917. At Illinois, from 1920 to 1955, he developed methods of water and waste treatment. Rodebush joined the University of Illinois in 1921 as an associate professor of physical chemistry, becoming professor of chemistry in 1924. With Wendell M. Latimer he invented the concept of the hydrogen bond to explain in part the properties of water. The work of Buswell and Rodebush has been supported by grants-in-aid from the National Institutes of Health.

MARIE POLAND FISH ("Animal Sounds in the Sea") is a biological oceanographer at the Narragansett Marine Laboratory of the University of Rhode Island. At Smith College, from which she graduated in 1921, she planned a medical career, but she married an oceanographer instead and soon started studying the embryology of fishes. In 1925 she was a member of William Beebe's *Arcturus* expedition. This enabled her to describe the first known specimens of the egg and early larva of the American eel. From 1928 to 1931, while curator of ichthyology at the Buffalo Museum of Science, she described the developmental stages of 62 species of lake fishes, about which very little had been known. In 1937 she became a research associate of the Narragansett Marine Laboratory, which her husband had just founded. Her work in underwater sounds began in 1946.

EDWARD S. DEEVEY, JR. ("The Human Crop") is associate professor of biology and director of the Geochronological Laboratory at Yale University. His specialty is ecology. He has published several articles in SCIENTIFIC AMERICAN, "The End of the Moas" (February, 1954) being the most recent. He spent the year 1953-1954 in Europe, mainly Denmark, on Guggenheim and



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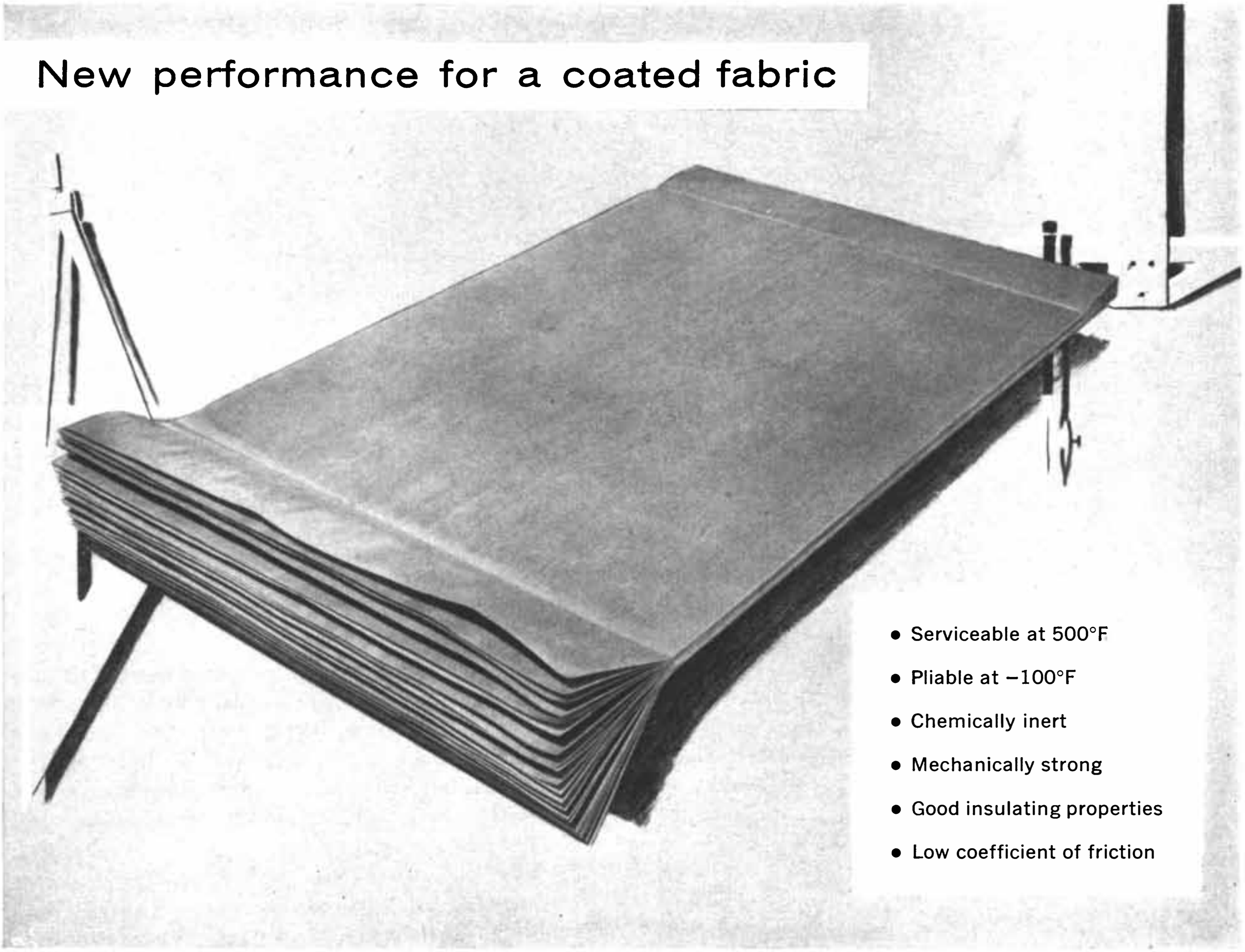
Fulbright grants. Deevey recently received a National Science Foundation award to help him continue his research in dating lake sediments.

WARREN WEAVER ("Lewis Carroll: Mathematician") is vice president for the natural and medical sciences of the Rockefeller Foundation and director of its division of natural sciences and agriculture. This is his second career; his first was as a mathematician at the University of Wisconsin, where he was chairman of the mathematics department until 1932. He has one of the largest private collections of Lewis Carroll's works; it includes mathematical manuscripts as well as editions in many languages of *Alice's Adventures in Wonderland* and *Through the Looking-Glass.* Weaver has contributed several articles to SCIENTIFIC AMERICAN.

WILLIAM G. VAN DER KLOOT ("Brains and Cocoons") is an instructor in biology at Harvard University. He was born in Chicago in 1927 and graduated from Harvard in 1948, hoping to go into mammalian physiology. "I was alarmed," he writes, "when an insect physiologist, Carroll M. Williams, was assigned as my adviser. When I first entered Williams' laboratory, I found him, apparently by coincidence, with a cocoon in his hand. When I left that day, I was a convinced comparative physiologist." Van der Kloot did the work he reports in this article as a Lalor fellow at Harvard and as a National Research Council fellow at the University of Cambridge. This spring he plans some experiments on frog muscle. Next year he will offer a course on the physiology of behavior at Cornell University.

ROBERT P. KNIGHT, who reviews Ruth L. Munroe's *Schools of Psychoanalytic Thought* in this issue, is medical director of the Austen Riggs Center at Stockbridge, Mass. He graduated from Oberlin College in 1923, taught school for a few years, then went to Northwestern University Medical School, taking his M.D. in 1932. He joined the Menninger Sanitarium as a resident and stayed on as a staff member of the Clinic and of the Sanitarium until 1947, when he went to the Austen Riggs Center. He is also a clinical professor of psychiatry at the Yale University School of Medicine and an instructor and training analyst at the Western New England Institute for Psychoanalysis. Knight was president of the American Psychoanalytic Association from 1951 to 1953.



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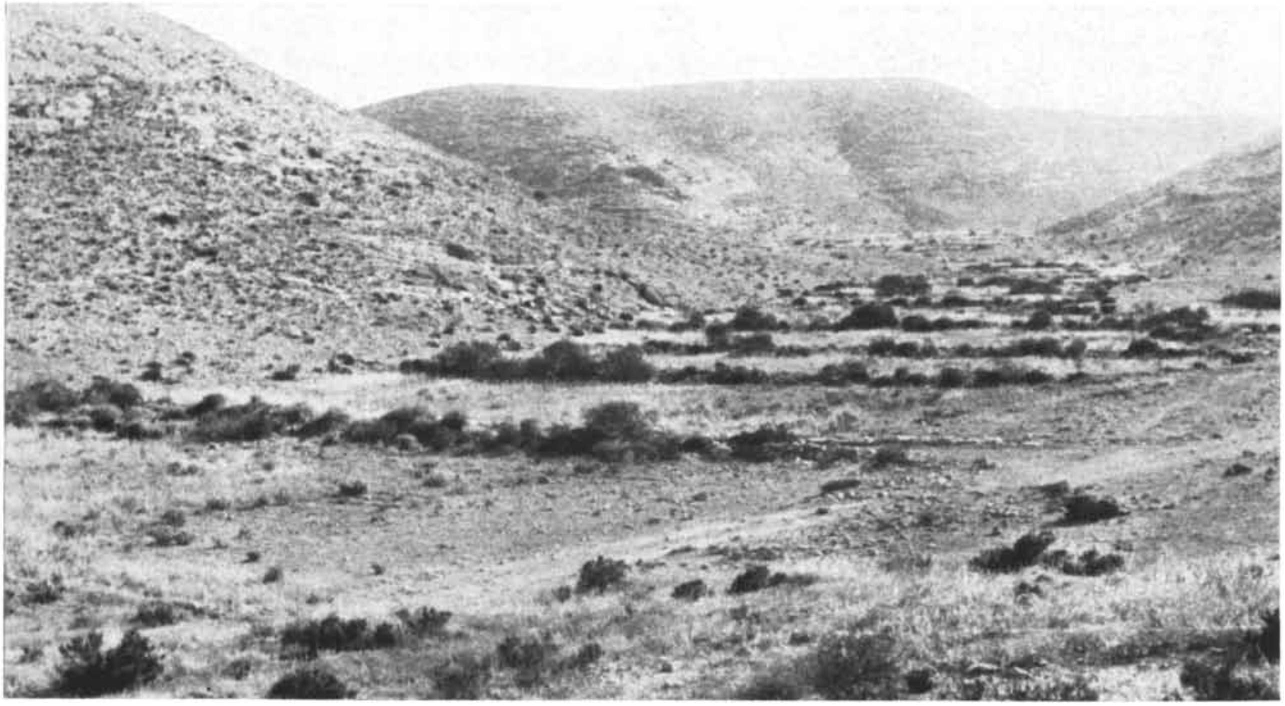
Ancient Masters of the Desert

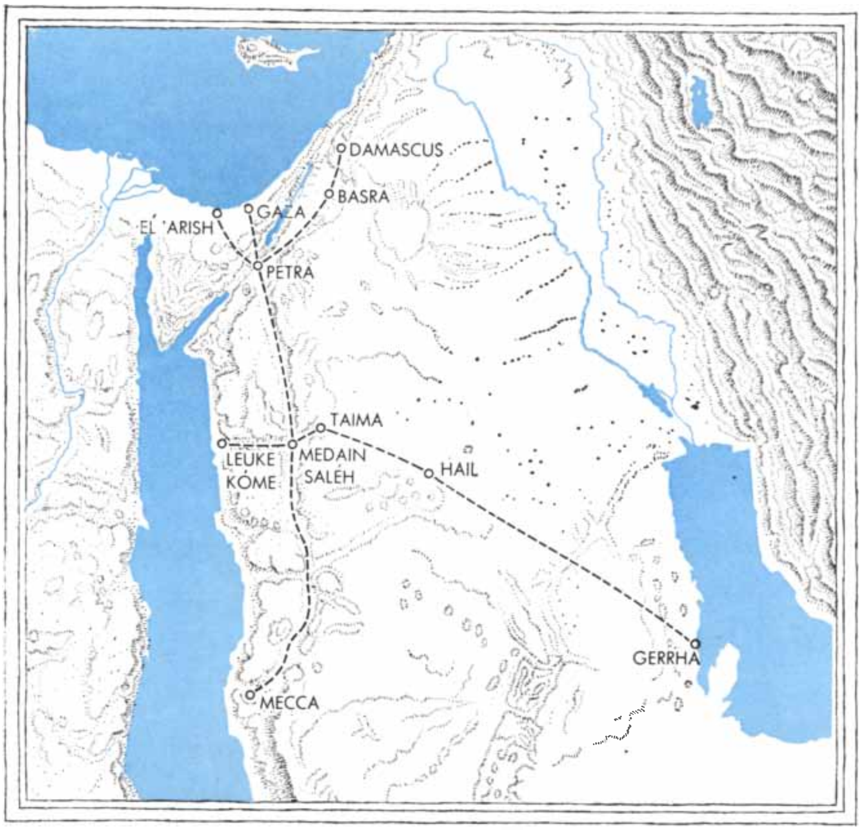
In the Negev of Israel are the structures of a remarkable people who tilled the soil on an average of only four inches of rain per year. Their works are helping to revive agriculture in the region

by Michael Evenari and Dov Koller

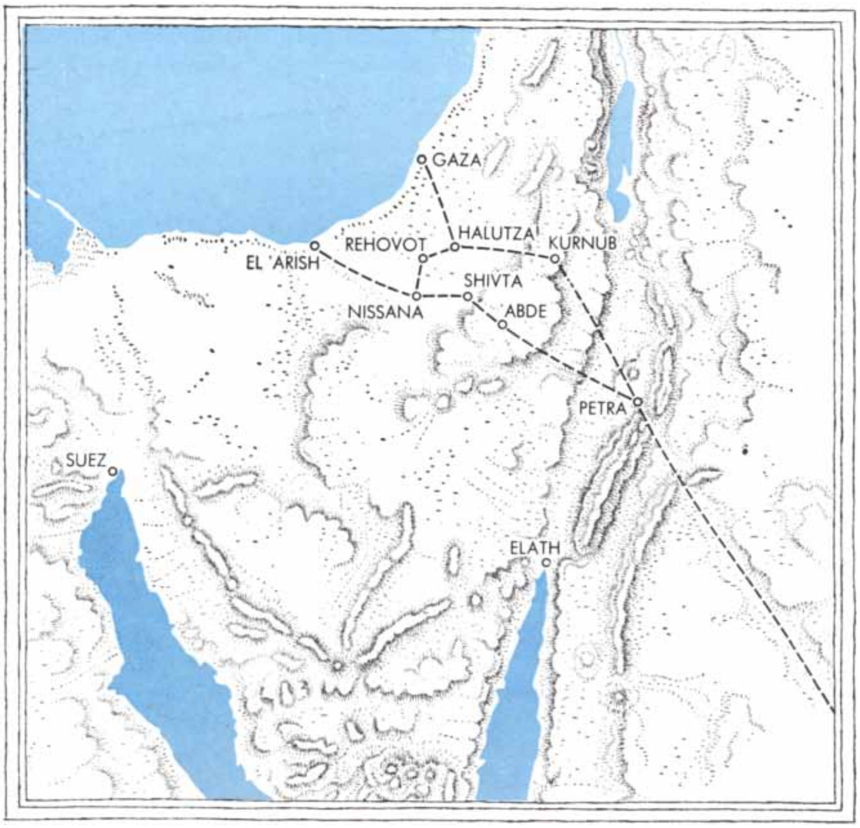
South of the Dead Sea lies one of the earth's most desolate lands. To the west stand the naked highlands of the Negev. Ahead stretch the endless deserts of Transjordan and Arabia, over which caravans maintained a frail and slender link between the ancient Mediterranean world and Asia. A traveler journeying through these deserts today finds no human occupation except a few tiny Bedouin settlements. But tucked away in the rocky hills of southern Transjordan is a stunning surprise. You enter a deep, narrow gorge in the rock—so narrow that in places you can almost touch both walls with your outstretched hands. The walls tower 200 to 300 feet high, and in this cool, shady place wild fig trees and garlands of ivy grow in the rock fissures. Toiling over the gravelly floor of the gorge, you trudge on for nearly a mile and then suddenly, rounding a bend in the dark passage, you burst upon an enormous monument hewn out of the rock. Bathed in sunlight, the great facade of pillars and friezes carved out of the rose-red Nubian sandstone looks like a creation of dreamland. The monument is called Khaznat Firun (Pharoah's treasure house). It is but a portal, how-



WADI was terraced by the Nabataeans, an Arab people whose civilization flourished in the Negev 2,000 years ago. Bordering each terrace is a wall which retards the water that pours down the wadi in a rainstorm. The walls are reinforced with perennial bushes.



NABATAEAN KINGDOM extended from Damascus in Syria to Medain Saléh in Saudi Arabia. At left is the Gulf of Suez; at right, the Persian Gulf. The lines mark caravan routes.



PRINCIPAL CITIES of the Nabataean kingdom lay south and west of the Dead Sea (*upper right*). At upper left is the Mediterranean Sea; at bottom, the two arms of the Gulf of Suez.

ever, to a greater sight, for a little farther on the gorge opens into a wide circular valley in which stand the ruins of a large city. Hewn into the valley's towering walls of rock are hundreds of houses, temples, tombs and monuments—a rainbow metropolis drenched in rose-red with bands of yellow, purple and violet.

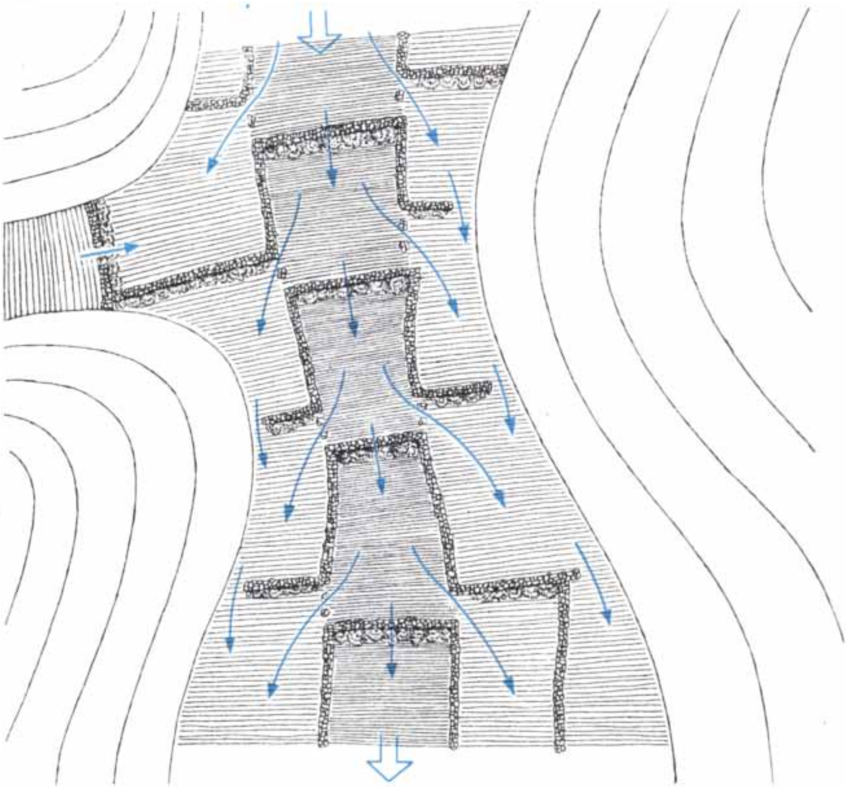
The city is Petra, the capital of one of the great kingdoms of ancient times. Two thousand years ago, at the height of its power, this kingdom of the Nabataeans, an Arab people, extended from Damascus in Syria to Medain Saléh in Saudi Arabia [*see map at the left*]. But the center and mainstay of its power lay in Petra and a surrounding group of settlements, among them six flourishing cities in the Negev.

The empty shells of these cities, which have stood abandoned in the desert for more than 1,000 years, long puzzled archaeologists. Why did the Nabataeans build their monumental capital here in the middle of nowhere? How could they have lived and built a mighty empire in the barren desert?

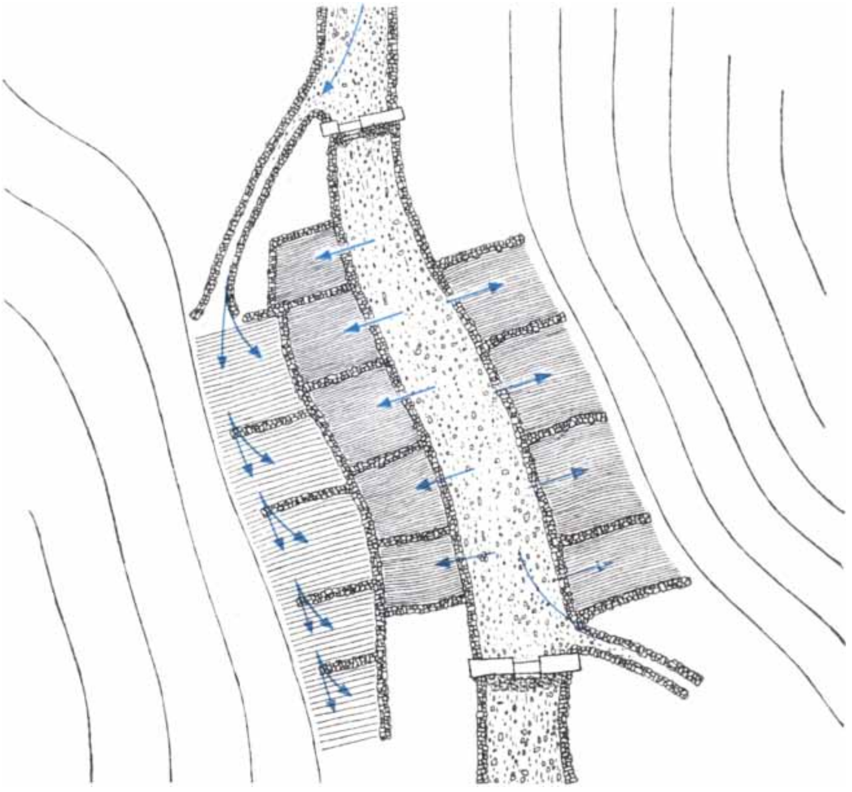
Historical accounts of their kingdom might seem to suggest an answer. The Nabataeans were traders who organized caravans to carry incense, myrrh and other precious commodities from the Far East across the deserts to the Mediterranean. Petra was a major crossroads of the caravan traffic, and the Nabataeans gained wealth from trade and taxes. Modern scholars who rediscovered their cities and history therefore supposed at first that the inhabitants of this rich ancient empire in the desert simply imported their food. But it soon became evident that the Nabataeans must have raised their own food, for there were many signs that they had practiced agriculture on a large scale.

The idea that anyone could have farmed a desert as arid as the Negev is today seemed so incredible that many authorities concluded the climate of the region must have been more lush in the time of the Nabataeans. The explorer Ellsworth Huntington put forward this theory in his study, *Civilization and Climate*, published in 1915. But in the 1930s Nelson Glueck, the noted Biblical scholar and archaeologist (now president of Hebrew Union College in Cincinnati), went to Palestine and Transjordan to re-explore the Nabataean culture, and what he found led him to acclaim the Nabataeans of old as "one of the most remarkable people that ever crossed the stage of history." Their cities did indeed bloom in the midst

AERIAL PHOTOGRAPH made by the Israeli Air Force suggests the great extent of Nabataean agriculture. The short dark lines are the bush-reinforced walls of terraces in wadis. The black and darker gray patches are small areas which are still under cultivation.



MAIN WADI was more elaborately terraced than tributary wadis. The bottom of the wadi was blocked by low dams which raised the water so it flowed into terraces along the sides.



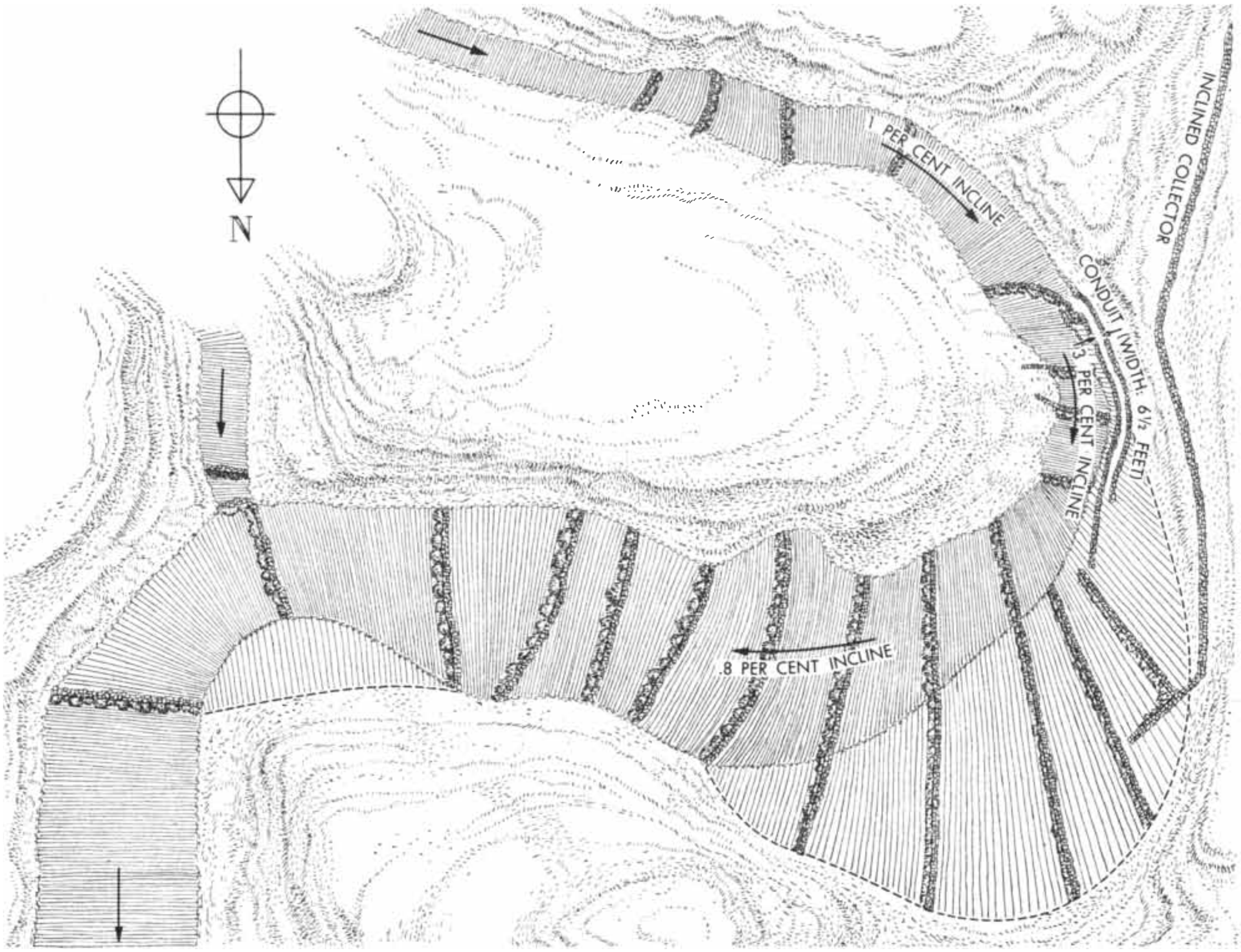
DEEP WADI, in which simple terraces would not have been sufficient to control the flow of water, was blocked by dams which diverted the water along spillways to higher ground.

of a seemingly hopeless desert. Nowhere in all their houses was there a stick of wood to show that any trees had ever grown in the region, and in the ruins of the Nabataean settlements Glueck found an elaborate and intricate system of rain-catching and irrigation devices which proved beyond doubt that they had made a living in a land of the scantiest rainfall. In his famous book, *The Other Side of the Jordan*, Glueck observed that the Nabataeans had pushed the boundaries of agriculture farther into the desert than any other people in this part of the world.

Up to about 10 years ago the Nabataeans and their agriculture interested only historians and archaeologists. But when the new state of Israel began its attempt to push agriculture into the Negev desert, the Nabataean methods of farming became a matter of highly practical interest. We felt that an intense study of their agricultural system could teach us a great deal to help our own endeavor to recreate fertility in those areas of the desert where the Nabataeans had created it once before.

To see what the natural conditions are and how the Nabataeans made the most of them, let us take for illustration a city such as Abde (which was named for one of the mightiest Nabataean kings, Ovdath, a contemporary of King Herod the Great in the first century B.C.). Abde stands in the Negev highlands, where wadis (dry watercourses) cut through steep-sided, stony hills. The summers are hot and the winters fairly cool. Rainfall occurs only in winter and averages only four inches a year. It is not spread over the season but is likely to come in sudden, violent bursts. The water rushes over the bare, almost impermeable soil without sinking in, and it carries along some of the surface soil. Even after a light rainfall a heavy wash of soil-laden water flows from the high ground into the wadis. Its volume is usually so large as to take the form of raging floods, lasting a few hours. The result is that for a few hours each year the wadis become swift torrents of muddy water. Year by year more soil from the hillsides is deposited in the wadis and catchment basins.

The ancient engineer-farmers recognized the agricultural possibilities of this aspect of the desert. They realized that the wadis could serve as collectors of both soil and water, and they therefore concentrated on efforts, in partnership with nature, to make farming plots of the wadis. The scheme they adopted was



CURVED WADI was studied by N. Tadmor and E. Rawitz of the Israeli Ministry of Agriculture. The dotted line marks the edge of the ancient watercourse. This system includes a long wall (*right*) which controls water flowing down the side of the wadi.

essentially to slow and control the flow of water by means of terraces and walls, thus trapping the water and its freight of soil, spreading the water over plots it would not otherwise reach, and collecting some reserves of drinking water in storage basins, shielded from the sun to reduce evaporation loss.

It is a truly remarkable fact that the Nabataeans avoided the mistake of trying a more obvious system of water conservation which present-day engineers have found, to their disappointment, is impracticably expensive and less effective in deserts: namely, building dams to hold the runoff of rains in storage reservoirs. The Nabataean scheme was not only far less costly but also enabled them to irrigate a larger area, for it spread the water over the soil along the whole course of a wadi and its banks.

Their constructions started on the slopes of the hills, where rain water flowed down by way of tributary wadis into the broad main wadi in the valley. In feeder wadis which were not too narrow and steep they terraced the watercourse by building a series of shelves, using stones—the most abundant building materials of our deserts—to form each shelf. Thus instead of rushing down the wadi the rain water cascaded gently down the series of steps, part of it sinking into the ground at each step and depositing some of its suspended soil and organic debris. Often the Nabataean farmers left shrubs growing on the steps, partly to reinforce the shelf construction and partly to help slow the water and hold plant debris to enrich the soil. The shrubs were of inedible varieties, so that cattle would not eat them. Each of these terraces in the tributary wadis, accumulating soil year after year, became a farming plot, primarily for growing field crops.

The broad main wadi similarly was converted into a series of terraces, but in a more elaborate fashion. Masonry walls divided the wadi area into level plots. The walls of the central plots served to divert some water to higher plots along the sides [*see upper diagram on the opposite page*]. During a rainstorm all the walled plots became small ponds, so that water was distributed uniformly over the plot.

Some of the wadis were eroded with deep channels where control of the flow of water by terraces would have been impossible. The Nabataean engineers here worked out an ingenious solution. They built a series of thick dams, not to stem the flow of water but simply to raise its level a few feet, so that part would spill over to terraces along the sides [*see lower diagram on the opposite page*]. To divert water to still higher ground they built stone conduits upstream from the dams. Close study of their system gives still further evidences of their ingenuity. Realizing that the slightest change in the dimensions or direction of the watercourse would throw the entire system out of gear, they built strong masonry walls along its entire length to fix its boundaries perma-

STONE WALLS controlled the flow of water in the wadis. The photograph at the left shows a low dam with a damaged spillway. The bottom of the dam is built up in steps. The photograph at the right shows a relatively high wall which kept water in the wadi.

nently [*see diagram on the preceding page*]. Among the other refinements in the system here illustrated was a low stone wall along the higher slopes which acted as an "inclined collector," diverting runoff water from plots already well watered and conducting it to otherwise unreachable plots.

The more one examines the Nabataeans' elaborate systems, the more impressed he must be with the precision and scope of their work. Engineers today find it difficult enough to measure and control the flow of water in a constantly flowing river, but the Nabataean engineers had to make accurate flow estimates and devise control measures for torrents which rushed over the land only briefly for a few hours each year! They anticipated and solved every problem in a manner which we can hardly improve upon today.

As we have remarked, the primary objective of the Nabataean system was to irrigate plots for raising field crops, chiefly grain. Next came the growing of vegetables and fruit and the raising of livestock; water was allotted to these purposes from the surplus beyond the main crop needs. The cisterns where drinking water was stored had the lowest priority of all.

These cisterns, most of which are still in use today, are caverns dug in limestone strata in the hillsides. In the larger ones the roof is supported by strong stone pillars. The cistern has a narrow opening for the entry of water, and some have a small, round opening in the roof for the drawing of water by means of buckets. Shielded from sunlight and held in the almost watertight limestone, the water lasts for a long time. Rain water was conducted to the cisterns via a conduit or an inclined collector, often draining an entire hill; some were filled by the overflow from a wadi. To remove silt from the water, sedimentation basins were placed at the cistern entrance.

Some of the Nabataeans' structures still baffle investigators. For example, spread over large areas near their cities are low mounds or long, patterned rows of stones, called "vine-mounds." We must suppose that a people whose waterworks so dramatically demonstrate their ingenuity and common sense would never have gone to all the trouble of collecting stones and arranging them in

BARLEY GROWS on two ancient terraces. Although this photograph was made in 1955, which was a year of drought in the Negev, the barley is knee-high and well-developed. The bushes reinforcing the wall between the two terraces are visible in the middle.

STONE CISTERNS collected water for drinking purposes. The photograph at left shows cistern openings at the bottom of a cliff.

The photograph at the right is another view of the same cliff. In the foreground is the channel which conducts water to the cisterns.

these geometrical patterns without good reason. Two theories have been suggested. One argues that the mounds of stones were laid next to grape vines to reduce evaporation from the soil and collect dew. The other theory suggests that the stones were gathered from the soil surface to expose part of it to "controlled erosion," so that the neighboring wadis would be enriched in both water and soil. Experiments may enable us to decide which of the theories is right.

We have comparatively little writing left from the Nabataean civilization. The Roman Emperor Trajan occupied their capital in 106 A.D., and from that date their written records disappear entirely. We know that their cities survived, under Roman and then Byzantine rule, until about the seventh century, and that after the Moslem Arabs destroyed the Byzantine Empire the desert cities were gradually abandoned.

However, there are inscriptions, wall paintings and other records which tell us that the Nabataean water system enabled the Nabataean and Byzantine farmers to practice a highly successful agriculture. According to papyri found in one of the ancient Negev cities, Nissana, their desert farming produced barley, wheat, legumes, grapes, figs and dates. The parchments even tell the yields: the barley sowings gave more than eight times the amount of seed sown, and the wheat yield was about seven times. Today in the northern Negev, which has considerably more rainfall than the southern part, the barley yield is between nine- and elevenfold and the wheat yield about eightfold. Thus the Nabataeans do not suffer by comparison with the most intensive kind of modern cultivation in an arid area.

The Nabataeans' conquest of the desert remains a major challenge to our civilization. With all the technological and scientific advances at our disposal, we still must turn to them for some lessons. To be sure, the age of the machine calls for somewhat different techniques (*e.g.*, mechanical earth-moving and construction instead of laborious stone-laying by hand), but when all is said and done, the best we can do today is no more than a modification of the astute and truly scientific methods worked out more than 2,000 years ago by the Nabataean masters of the desert.

STONE MOUNDS were built by the Nabataeans for an unknown purpose. One theory is that the stones were piled up to promote erosion that would carry soil into the wadis. The two mounds in the middle were built recently for experimental purposes.

LOW-SPEED FLIGHT

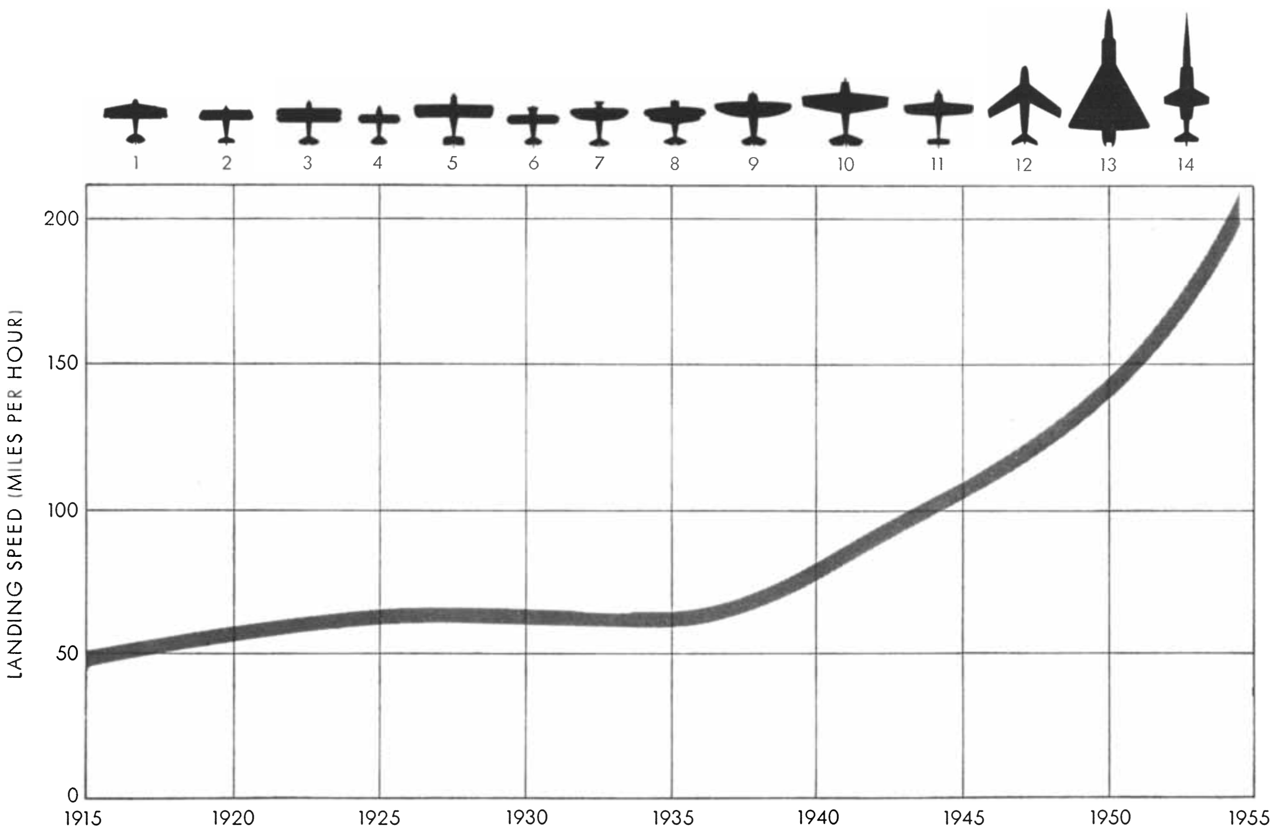
As airplanes fly faster, they also land faster. New techniques of reducing landing speed are studied by means of a wind tunnel in which the flow of air is made visible by filaments of smoke

by David C. Hazen and Rudolf F. Lehnert

The developments in aviation that excite the most interest and attention are, naturally, the peak performances—faster and faster speeds, higher and higher altitudes, longer and longer flights. In recent years the public has heard a great deal about high-speed barriers, first the sound barrier and now the heat barrier. But among aeronautical scientists and engineers there is a growing concern, and possibly more sleep being lost, over a less publicized barrier at the other end of the scale: what might be called the low-speed "barrier." As faster aircraft are built, it is becoming increasingly difficult to make their minimum flying speed slow enough to land them safely.

In World War I the fastest military planes landed at 40 to 60 miles per hour. During the 1920s the minimum landing speed of the fastest planes rose to 75 m.p.h. By the end of World War II it was 120. Today, for the latest aircraft, it is between 175 and 200 m.p.h. The problem of bringing a heavy airplane to earth at such a speed is appalling. The strain is terrific both on the pilot and the machine.

The Air Force is beginning to find that



LANDING SPEED of airplanes has risen sharply since 1935. Each airplane shown in silhouette at the top of this diagram is directly above its landing speed on the curve. The airplanes are as follows: S.P.A.D. (1), Thomas Morse MB-3 (2), Curtiss pursuit (3), Curtiss R-2C-1 Navy racer (4), Charles A. Lindbergh's *Spirit of St. Louis* (5), Gee Bee Senior Sportster (6), Boeing P-26 (7), Curtiss Hawk Type IV (8), Seversky 2 PA-L (9), Grumman Hellcat (10), Focke-Wulf 190 (11), F-86 (12), F-102 (13) and Douglas X-3 (14).

runways several miles long are barely adequate, and the Navy faces practically insuperable problems in designing arresting gear and catapults capable of stopping or launching such planes on carrier decks. The military services are not alone in these difficulties. Few present civil airfields can handle the fast new jet airliners that are already flying or projected.

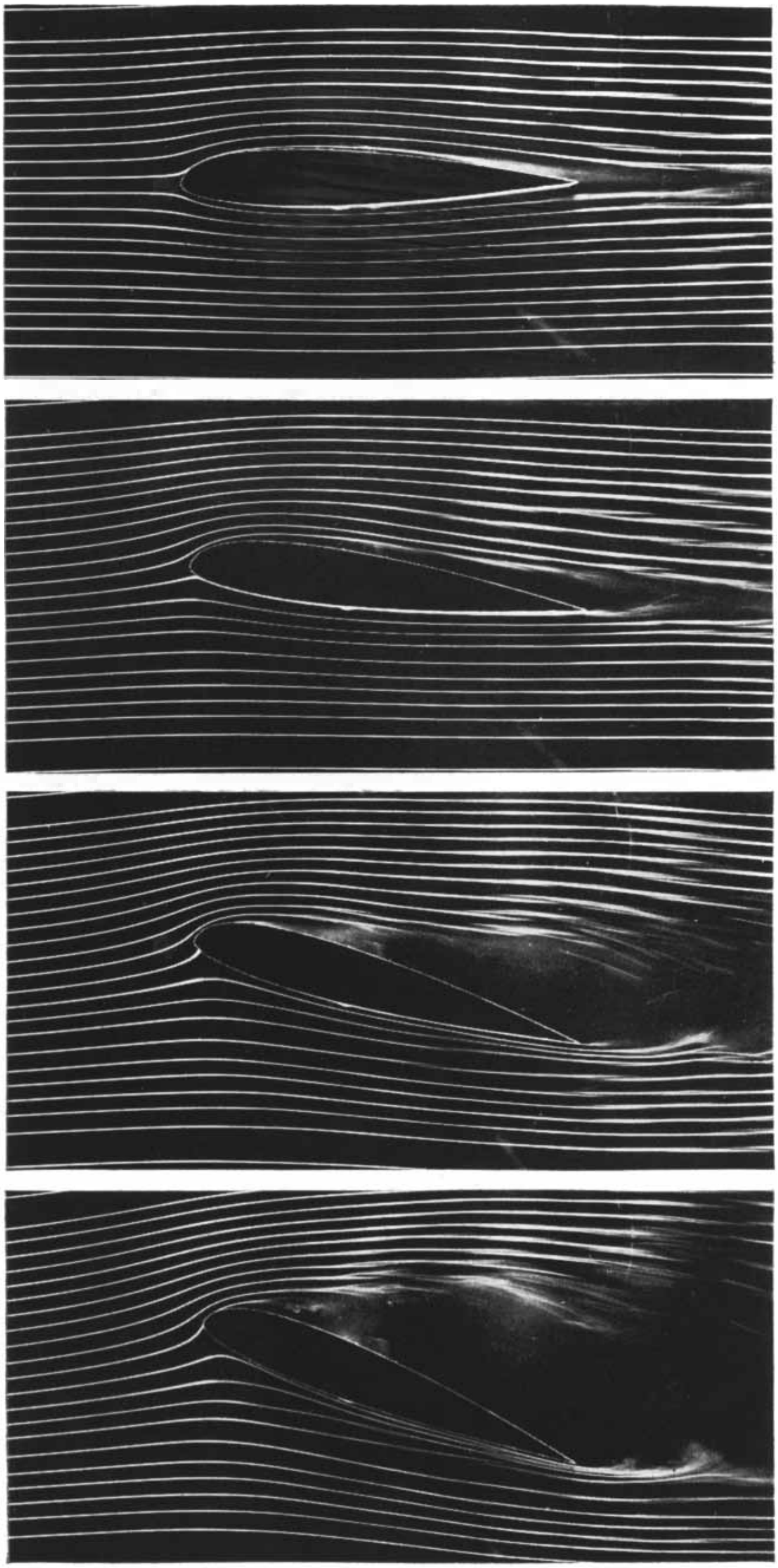
U. S. governmental agencies, particularly the very active Air Branch of the Office of Naval Research, are therefore sponsoring research to see what can be done about the low-speed, or stalling, "barrier." In this article we shall report wind-tunnel studies that have been made in the James Forrestal Research Center at Princeton University.

The speed at which an airplane must travel to maintain lift depends on three factors (aside from air density, or altitude): (1) the plane's weight, (2) its wing area and (3) the angle of attack. In modern jet aircraft all three of these factors conspire to increase the minimum speed necessary to avoid stalling. First, to fly very far the jet plane must carry a tremendous fuel load. Second, to reduce drag for high-speed flight its wing area must be cut to a minimum. Third, to avoid creating shock waves at high speed it must have extremely thin wings, and as a result the lifting force at a given angle of attack is limited.

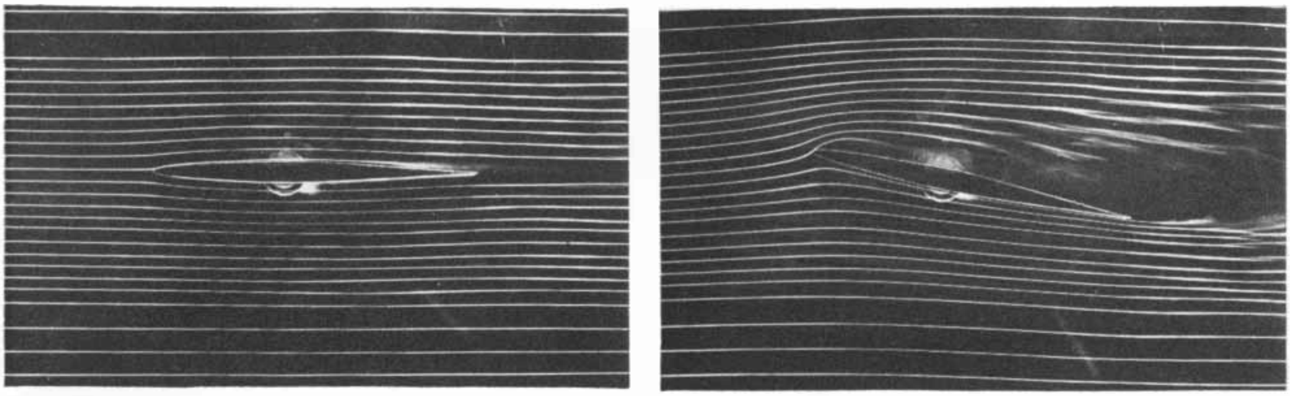
This last point can be illustrated by experiments in a special wind tunnel at Princeton where the streamlines of air flow around a wing model are made visible by means of smoke filaments. If we station a blunt-nosed wing horizontally (at zero angle of attack), the air stream flows smoothly around the whole wing [*see top photograph at right*]. But as the angle of attack is increased, by tilting the wing, the flow begins to become turbulent and to separate from the wing surface; with increasing angle the point of separation moves farther and farther forward on the wing until finally no flow adheres to the top of the wing, which is then said to be stalled.

Now if we apply the same test to a thin, sharp-nosed wing, we see that the stalling situation develops at a considerably lower angle of attack [*photographs at top of next page*]. A bubble-like diversion of flow starts at the nose and soon grows to a complete separation from the wingtop. This illustrates why a thin wing has considerably less lift potential than the blunt-nosed one.

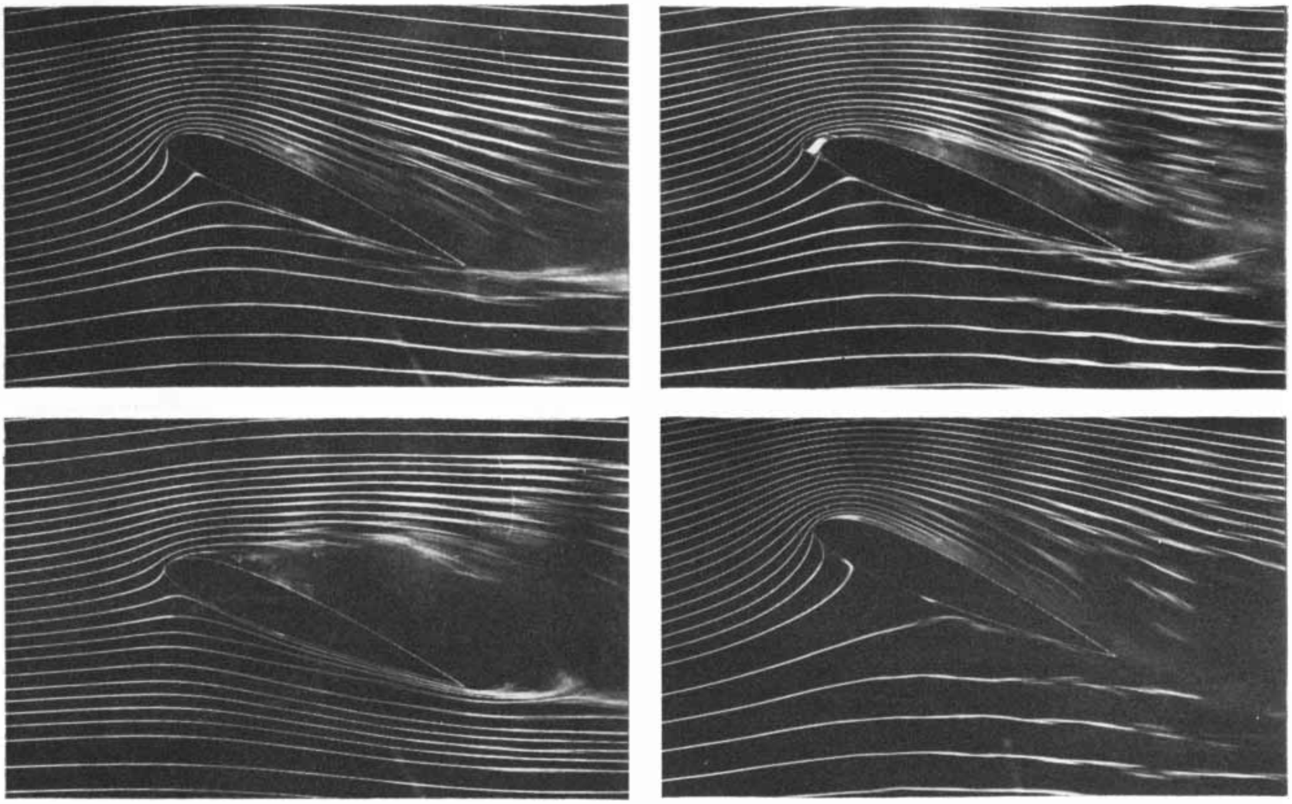
The reason the flow adheres better to the thick wing is that it accelerates



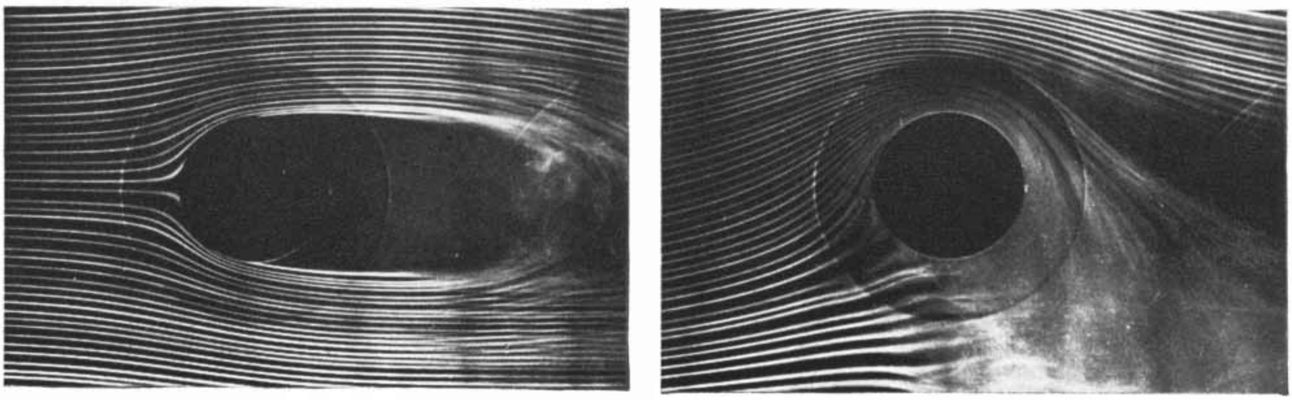
SMOKE-TUNNEL PHOTOGRAPHS **show a wing of thick cross section at four angles of attack: 0 degrees (*top*), 8 degrees (*second from top*), 16 degrees (*third*) and 20 degrees (*fourth*). At 16 degrees the wing is in a partial stall. At 20 degrees it is in a complete stall.**



THIN WING is shown at two angles of attack. In the photograph at left the angle of attack of the wing is 0 degrees. In the photograph at right the angle of attack of the wing is 12 degrees. Thin airfoils stall at a smaller angle of attack than thick wings.



THICK WING aerodynamics are altered by various devices. At upper left the wing is in a stall. At upper right it is fitted with a slat on its leading edge; at lower left, with blowing jets in its upper surface; at lower right, with suction slots in its upper surface.



CYLINDER is examined in the smoke tunnel. In the photograph at left the cylinder is stationary; the smoke filaments flow past it smoothly. In the photograph at right the cylinder is rotating in a clockwise direction; the filaments are pulled downward in its wake.

gradually over the blunt leading edge, with the result that the flow remains laminar (smooth) to a point well back on the wing even when the wing is tilted somewhat [*see photograph at right*]. On the other hand, when the thin wing is tilted from the horizontal there is a sharp acceleration of flow over its leading edge and a very quick drop in speed behind this point, resulting in increased pressure on the wing there and a consequent increase in friction, which in turn produces turbulence.

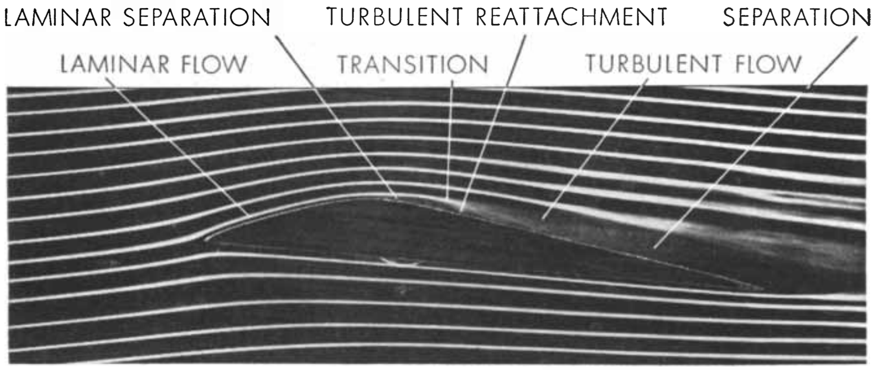
All this is well explained by the concept of the boundary layer, the thin envelope of air that sheathes a wing during flight [see "The Boundary Layer," by Joseph J. Cornish III; SCIENTIFIC AMERICAN, August, 1954]. Within this envelope there is a gradual drop in velocity of the air molecules from the outer part, where the molecules move over the wing at about the same speed as the surrounding air stream, to the wing surface itself, where the air molecules cling to the surface and have zero velocity with respect to the wing. Friction between the sublayers of different speeds within the boundary layer of course results in loss of energy of the air, the loss being greatest in the sublayers closest to the wing surface. This friction is minimized when the pressure on the wing is reduced by acceleration of the air stream over the wing. But when the air flow begins to decelerate, as it does when it reaches the downslope of the wing curve toward the trailing edge, pressure on the wing increases, frictional loss of energy in the boundary layer becomes more severe and the air flow becomes turbulent and separates from the wing. The result is that the wing loses lift, *i.e.*, stalls.

The boundary layer, then, is the crux of our problem. If it can be controlled in some way to prevent turbulence and separation of the air flow from the wing, the wing's lifting power will be enhanced and the minimum flying speed of the plane can be reduced.

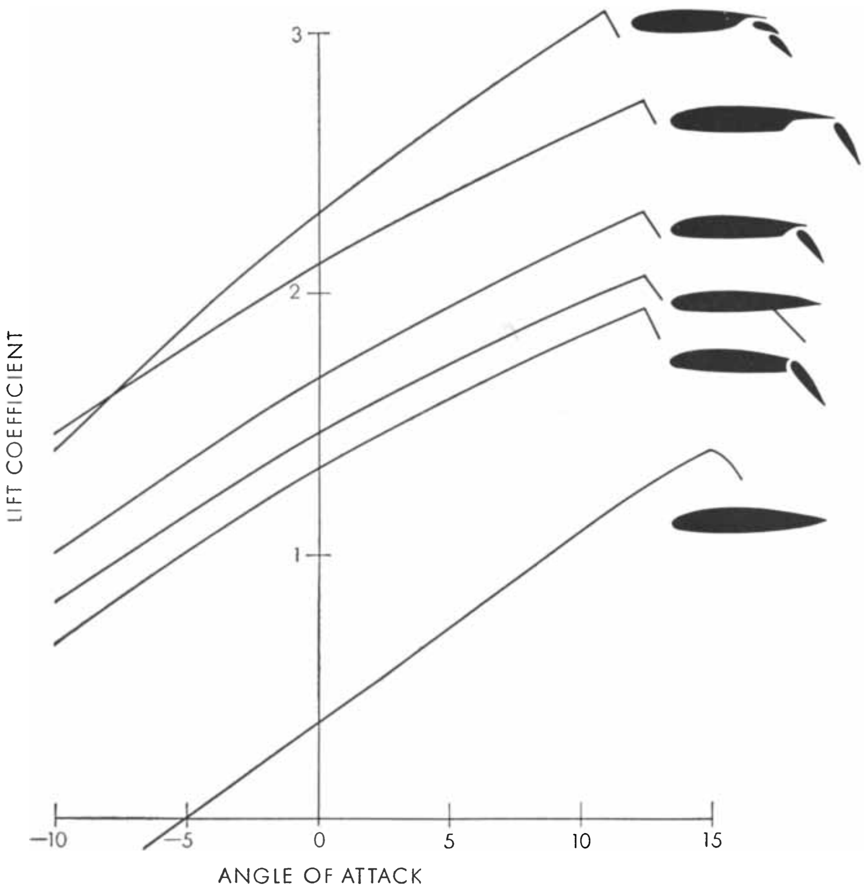
The most obvious and direct approach is to inject more energy into the boundary layer to replace frictional losses. This can be done in one of two ways. First, we can blow high-energy air into the boundary layer, either by placing a slat at the wing's leading edge to scoop in air from the air stream or by pumping jets of air into the layer from within the wing itself. Secondly, we may suck the low-energy air immediately next to the wing surface into the wing, through holes or slots in its surface, and thereby draw high-energy air from the air stream into the boundary layer. The effects of these devices are pictured in the series of photographs in the middle of the opposite page.

Such systems, particularly the suction method, look promising. However, for reducing the landing and take-off speed of a plane they have an important limitation. They serve this function by permitting a higher angle of attack for the wing, but this means the plane will be tilted so steeply that the pilot will have difficulty seeing the runway and the passengers will be tipped at an uncomfortable angle.

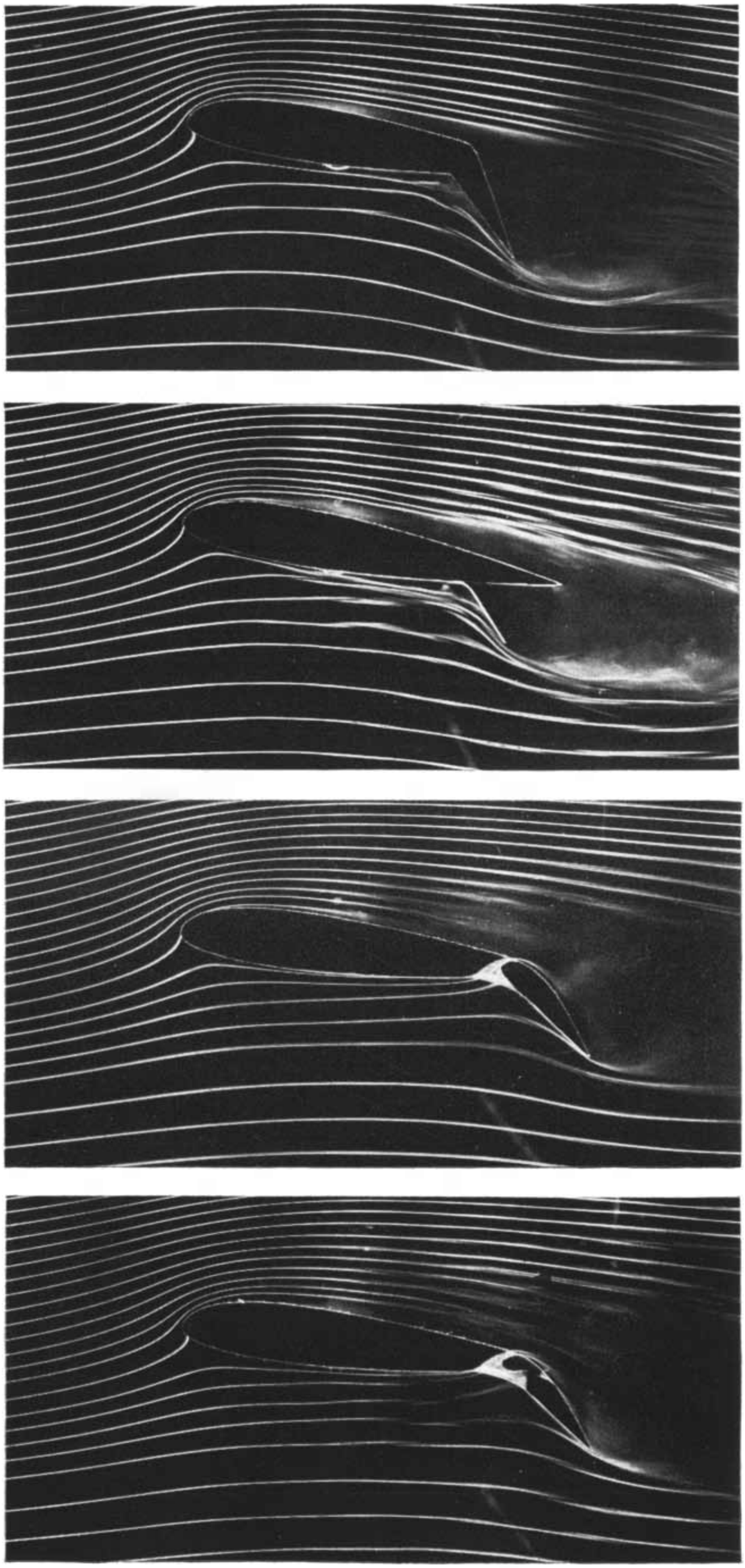
Fortunately there is a different approach which makes it possible to maintain lift without tilting the wing at a steep angle. It is known as "circulation control." The underlying principle, or at least its effect, is familiar to any pitcher who has ever thrown a curve or a golfer who has ever sliced a drive. Consider



BOUNDARY LAYER is analyzed in this smoke-tunnel photograph. The tunnel in which photographs were made is 36 inches high and 2 inches thick. It is at Princeton University.



LIFT of various wings is plotted against angle of attack. The cross sections at right are, from the top, double-slotted flap, Fowler flap, slotted flap, split flap, plain flap and plain airfoil.



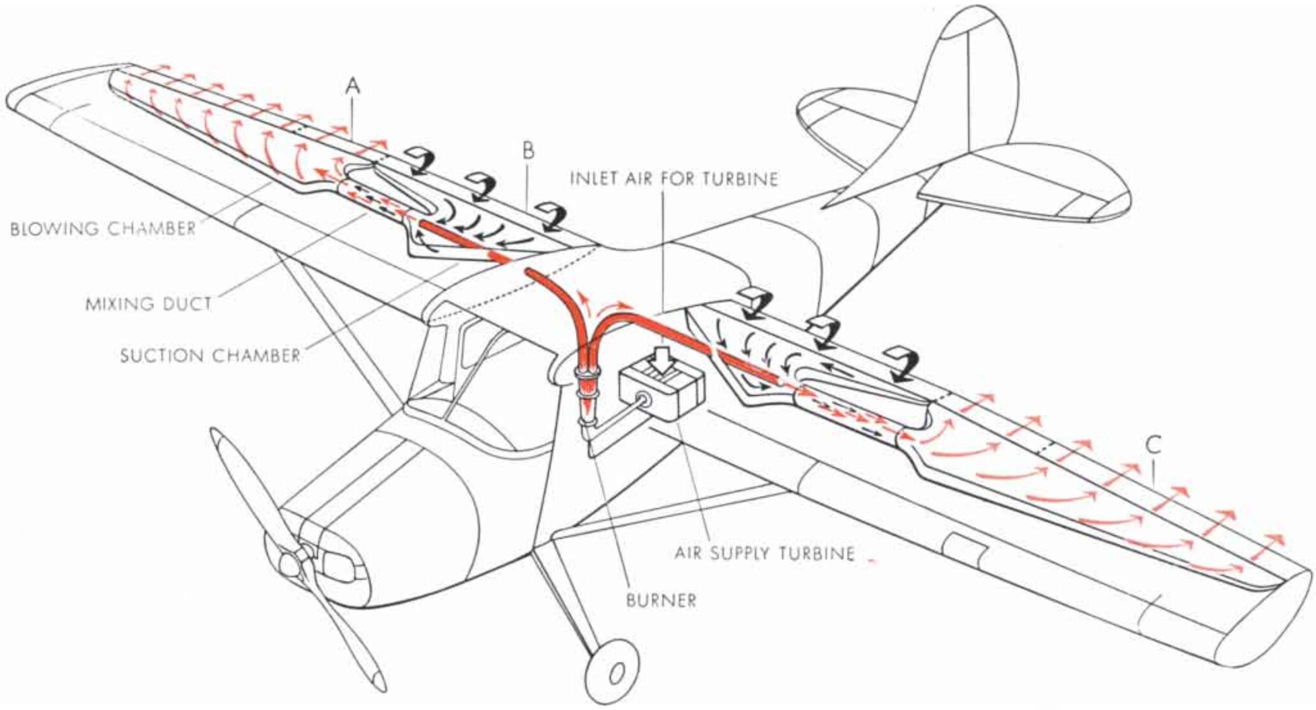
VARIOUS FLAPS are shown in the smoke tunnel. At the top is a plain flap; second from the top, a split flap; third from the top, a slotted flap; fourth, a double-slotted flap.

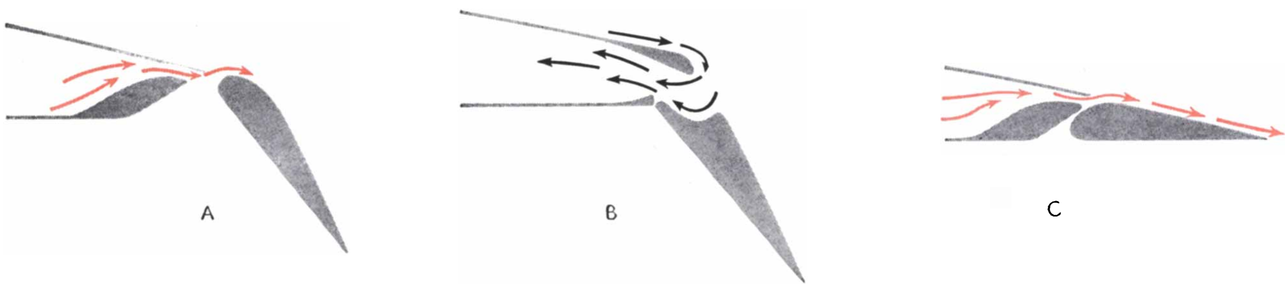
the flow of air around a cylinder placed across an air stream [*see photographs at the bottom of page 48*]. If the cylinder is stationary, the streamlines flow symmetrically around the circle and meet considerably behind it. There is no lifting force on the cylinder. But if the cylinder is rotated clockwise, the frictional drag of the upper side of its surface accelerates the air flow over the top, while the lower side opposes the flow. The result is a reduction of pressure on top and an increase of pressure on the bottom—*i.e.*, lift. The lifting force increases with the speed of rotation.

An airplane wing does not, of course, spin like a cylinder, but the concept of air "circulation" around the wing has been enormously helpful and may truly be called the seed of modern aerodynamic theory. Consider how it applies to the aircraft wing. At the leading edge of the wing there is a "stagnation point" where a streamline of air meets the wing "head on," so to speak, and stops. All the air above this point flows over the wing, and all that below flows under. When the wing is tilted so that the stagnation point is on its underside, the upper path to the trailing edge is longer than that beneath. Consequently in laminar flow the air must travel faster over the upper side if the streamlines are to meet at the trailing edge. Increasing the angle of the wing's attack shifts the stagnation point back on the underside of the wing and lengthens the upper path further, thus increasing the acceleration of flow over the wing. There is another way, however, to lengthen the upper path: namely, by bending down the trailing edge. The rear flaps of the conventional aircraft wing are, of course, a familiar application of this idea; what interests us now is the possibility of modifying them to achieve a circulation control which will increase lift without changing the angle of the wing's attack.

On the flaps, as on the unflapped wing, blowing and suction devices help to prevent separation of air flow and keep the air stream adhering to the flap. Various forms of flaps and boundary-layer-control methods have been tried [*see photographs at left*].

A new photography technique developed at Princeton has enabled us to see the effects of the various systems in clear and vivid fashion. Double exposures in different colors show the streamlines before and after a given method is applied. One of these photographs is reproduced on the cover of this issue of SCIENTIFIC AMERICAN. The red streamlines show the air flow in the "before" exposure, made through a red filter. The air is





CIRCULATION-CONTROL SYSTEM installed in a Cessna 170 enables it to fly more slowly without stalling. Air is sucked in by a small turbine and heated by using it to burn fuel. The air (*dark red arrows*) is then mixed with cool air (*black arrows*) sucked in through a slot in the trailing edge of the inner half of each wing. The warm air (*light red arrows*) is finally expelled through a slot in the trailing edge of the outer half of each wing. The small drawings at the bottom show sections through the wing.

flowing past a slightly tilted wing with a bent-down flap. The green streamlines show how the flow pattern changed when air was blown over the flap from a blower inside the wing. The number of streamlines flowing over the wing increased greatly (indicating increased lift), and the streamlines bent down and washed over the flap instead of streaming straight out behind.

As the picture indicates, when the blower is operating the streamlines tend to sweep sharply upward from the nose of the wing and separate from its upper side. This upwash can be corrected, however, by a design in which the leading edge is bent slightly downward. Other effective systems have been tested and photographed by an improved photographic method, developed by Sylvester Hight at Princeton; it reduces the exposure time and avoids the overlapping of colors which produced the confusing yellow lines.

It may seem odd that the simple blowing and suction systems described in this article were not adopted and perfected long ago, but there are several good reasons. The most important is that until the arrival of the jet engine, airplane engines did not have any substantial surplus of power that could be diverted to operating blower or suction systems. Now the jet engine has presented aeronautical engineers with a high-power package from which they can bleed all the power they need for the auxiliary devices.

During World War II the Germans built several experimental aircraft with circulation control systems. Notable among them was an Arado troop transport with a jet pump. Most of the new systems now being developed in this country are still in the laboratory state, but the number being installed and tested in experimental planes is increasing daily. Two airplanes built and flown here since the war give some indication of what can be expected in the near future. One, a Cessna 170 equipped with a system essentially similar to that of the Arado plane, early demonstrated that circulation control was feasible and has sparked a considerable number of investigations of such applications to reciprocating engine airplanes. The other, a Grumman F9F4, utilizes the jet engine as its power source. It is undergoing intensive tests by the military services.

Aviation stands on a threshold. The advent of the utilization of power to influence the lift directly is the first step toward aircraft which will be vastly more flexible and easier to handle than those we have today.

CORE OF THE LARGE CLOUD OF MAGELLAN appears in this photograph made with the 30-inch reflecting telescope of the Commonwealth Observatory on Mount Stromlo near Canberra in Australia. The photograph shows faint stars mingled with dark clouds of dust, clusters of stars and bright nebulae. The field of the telescope is too small to show the structure of the Cloud.

THE CLOUDS OF MAGELLAN

These two ornaments of the skies visible from the Southern Hemisphere are the galaxies nearest our own. Long believed to be formless, they now appear to have a spiral structure

by Gérard de Vaucouleurs

In January, 1521, as the ships of Magellan pushed slowly through the unknown solitudes of the South Pacific, the chief chronicler of the voyage, Marco Antonio Pigafetta, recorded observantly in his log: "The antarctic pole has not the same stars as the arctic pole; but one sees there two clusters of small nebulous stars, which look like small clouds (*nubeculae*), at a short distance from each other."

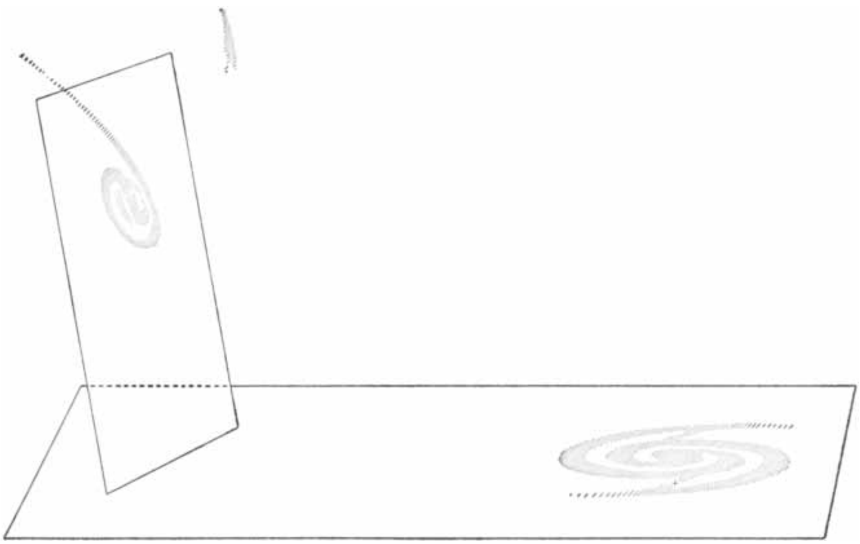
Not until three centuries later did astronomers, preoccupied in the Northern Hemisphere, turn their attention to Pigafetta's "nubeculae," which were to become known as the Clouds of Magellan. In the years 1834 to 1838 the English astronomer Sir John Herschel went to the Cape of Good Hope and studied the Clouds in minute detail. He decided that they were unique systems "which have no analogues in our hemisphere."

Herschel was both right and wrong. It is true that the great Magellanic Clouds appear larger than any other star system seen in either hemisphere, aside from the Milky Way. But as early as 1867 the U. S. scientist Cleveland Abbe, in an article, "The Nature of the Nebulae," suggested that the Clouds of Magellan are simply galaxies—the closest to us outside our own. Abbe's guess was little noticed at the time, but studies in this century have proved it correct. The two Clouds have been found to possess a form and structure which identify them as spiral galaxies. While external to our galaxy, they are comparatively close neighbors.

Because nearly all the world's observatories are located in the Northern Hemisphere, the galaxy that has received most attention as our "closest" neighbor is the great spiral nebula in Andromeda. But this northern neighbor, estimated to be nearly two million light-years from us, is more than 10 times farther away than the Clouds of Magellan. They are only about 150,000 light-years away—just across the street as distances between galaxies go. As a result we can get an unparalleled "close-up" view of the two Magellanic galaxies. Even the comparatively small telescopes in the Southern Hemisphere—the largest of which are the 74-inch reflectors at Pretoria in South Africa and at Canberra in Australia—can easily resolve details of the galaxies' structure: they can in fact pick out millions of individual stars outside the concentrated nuclear regions.

The nearness of the Clouds more than compensates for the advantages that the 200-inch telescope on Palomar Mountain gives to northern astronomers in observing galaxies. Since the Clouds are less than a tenth as far away as the Andromeda Nebula, we see their formations on a scale more than 10 times larger, and stars with the same intrinsic luminosity appear more than 100 times brighter in the Clouds than in the Andromeda galaxy. Observing the Magellanic Clouds with a good 74-inch telescope is in effect equivalent to studying the Andromeda Nebula with an 800-inch telescope! No wonder the West Coast astronomers are sometimes a bit unhappy that the Clouds are so far south.

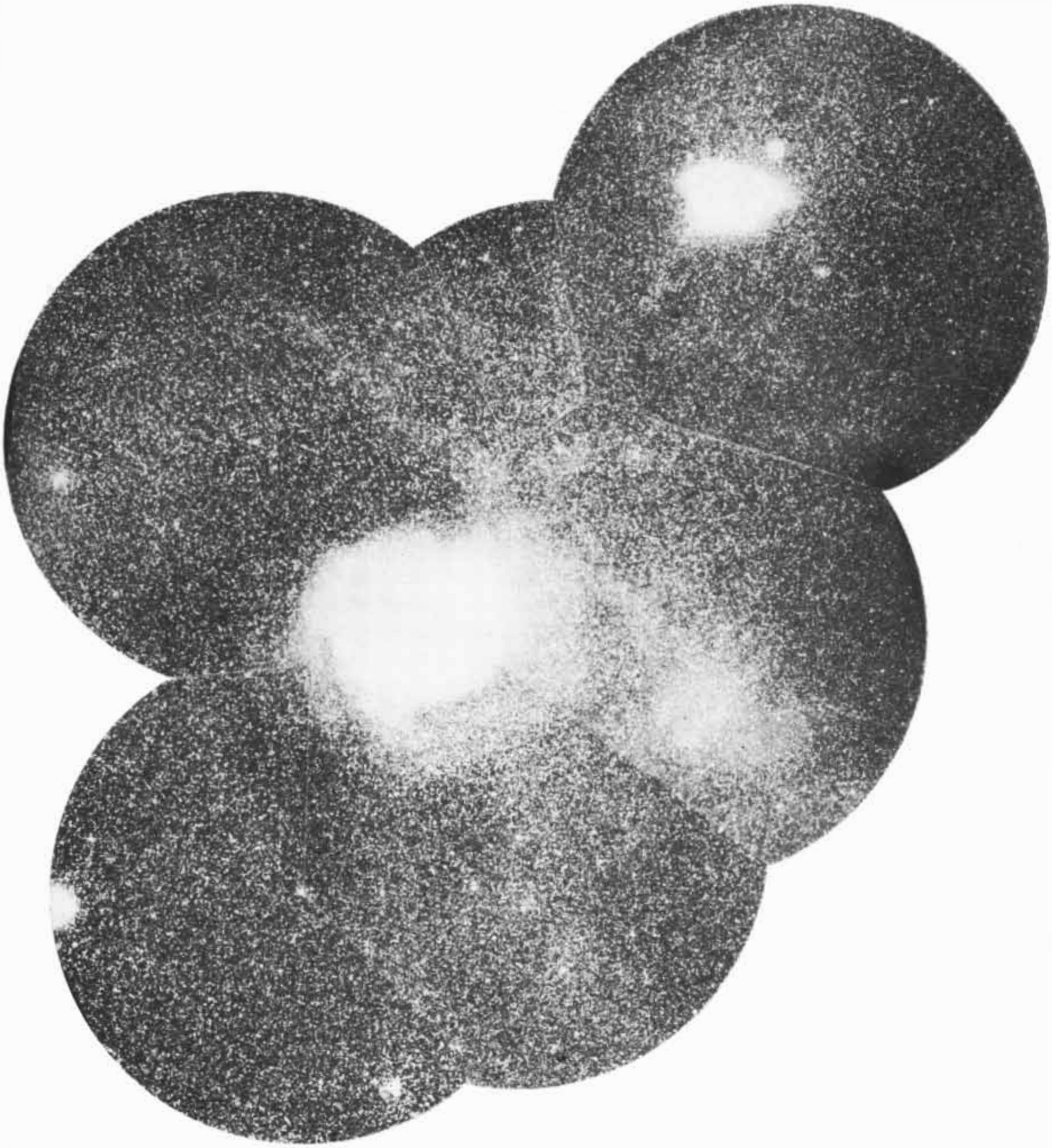
As a matter of fact, we can make highly useful pictures of the Clouds with an ordinary small camera. A camera with



LARGE AND SMALL CLOUDS OF MAGELLAN (*left*) are oriented with respect to our galaxy (*right*). The rectangle drawn in perspective at the left projects the plane of the Large Cloud on that of the Milky Way. The Small Cloud is seen nearly edge on. The distance to the two Clouds is 150,000 light-years. The cross marks the position of the Sun.

an aperture of an inch or two and a focal length of a few inches is in many respects as powerful a tool for studying the Clouds as a fair-sized telescope is for examining the more distant spiral in Andromeda. During the last three years we have been photographing the Clouds of Magellan from Mount Stromlo in Australia with standard miniature cameras using 35-millimeter film, and with other small cameras equipped with war-surplus Aero-Ektar Kodak lenses of seven-inch focal length and an aperture of less than two inches when stopped to *f*/4.

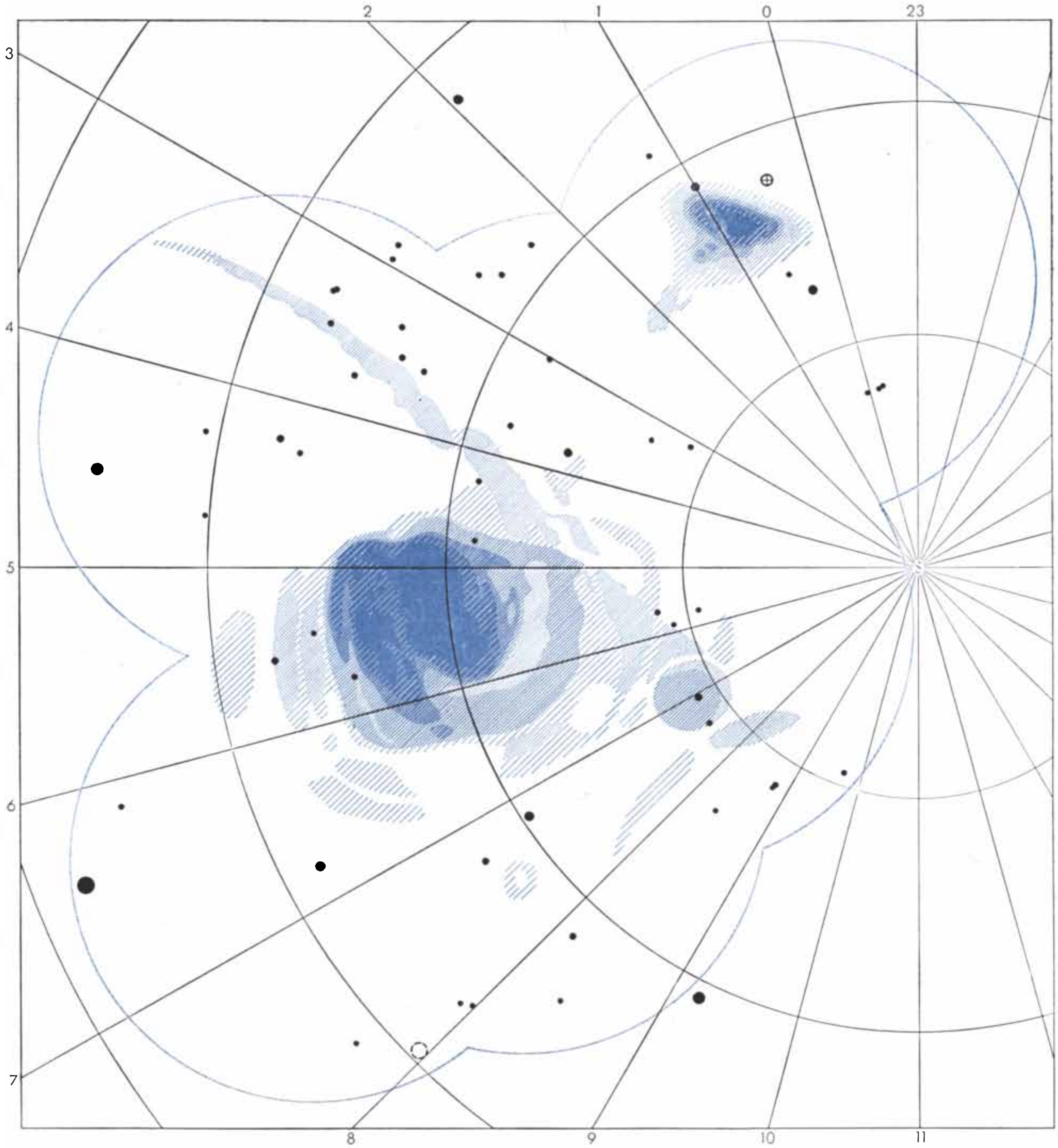
This program, which might be disparagingly referred to as "observing the galaxies with a Kodak," has in fact yielded information of great interest about the two Magellanic galaxies. The small camera has given us a new and broader view of these systems. A large telescope, with its narrow field of view, shows only a small section of the Clouds—a "microscopic view," as it were, of its details. With the small camera, covering a field 20 degrees wide with good definition,



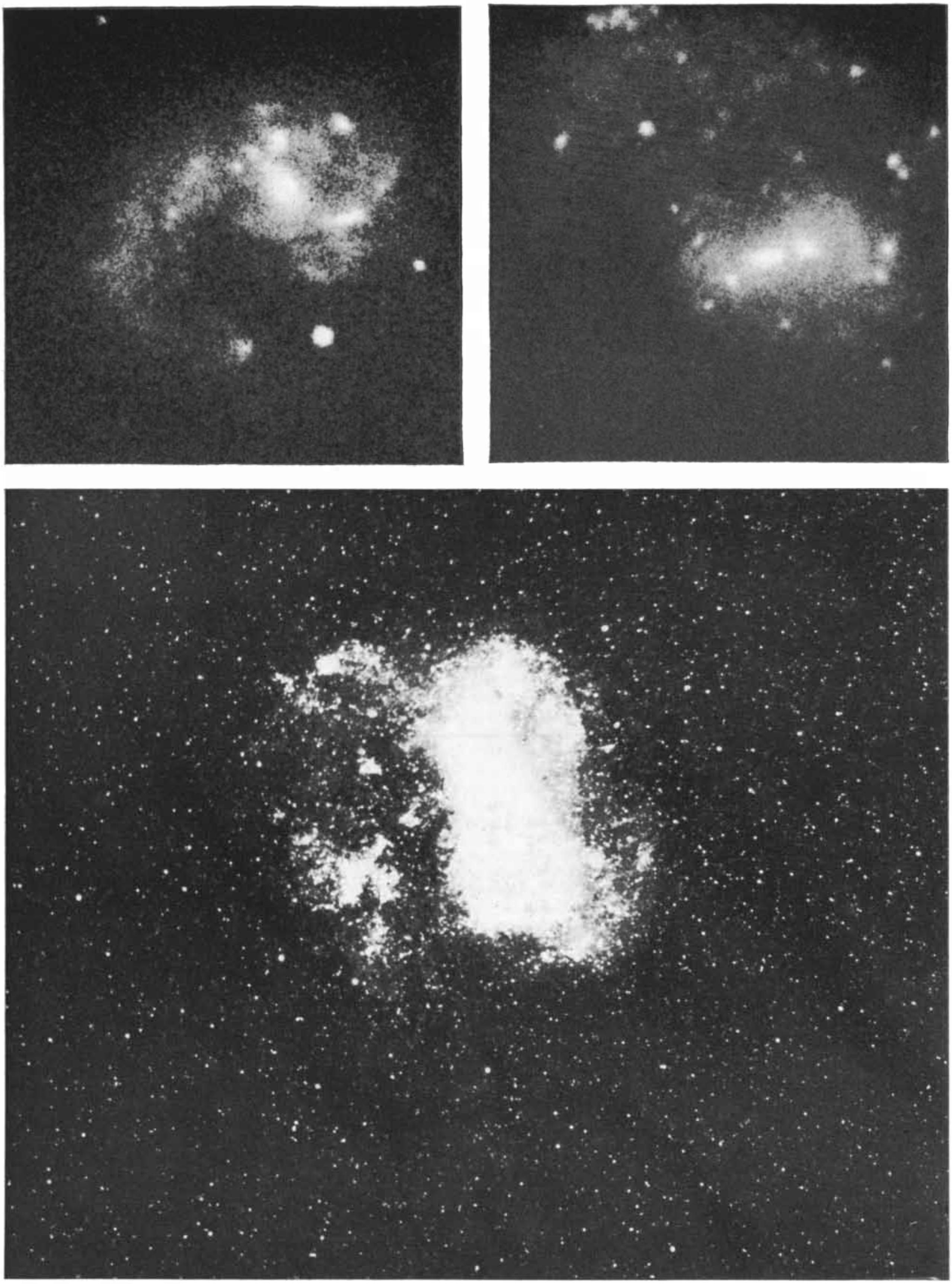
MOSAIC PHOTOGRAPH of both Clouds shows the faint spiral structure of the Large Cloud. The individual exposures were made with an Aero-Ektar lens of two inches aperture and seven inches focal length. At the lower left edge is the bright star Canopus.

we can photograph these galaxies as a whole, and this "macroscopic" view clearly shows features of their over-all structure and large-scale patterns which had not previously been observed. The small inner details largely disappear, and the outlines of the system become better defined.

One interesting finding is that both the Large Cloud and the Small Cloud are bigger than had been supposed. To the naked eye the Large Cloud looks about seven degrees in diameter, and the Small Cloud about three degrees. When Harvard University astronomers measured the extent of the Clouds, some 20 years ago, by studies of long-exposure telescopic photographs, they put the dimensions at 12 degrees and eight degrees, respectively. Now our similar studies of small-camera photographs show that the main part of the Large Cloud covers about 17 by 15 degrees, and it has long outer extensions which make its total dimensions nearly 30 by 20 degrees; the over-all dimensions of the Small Cloud are nine



SPIRAL STRUCTURE is emphasized by this map of the brightness of the areas in the photograph on the opposite page. The lines radiating from the South Celestial Pole (S) give the right ascension in hours. Each concentric circle is 10 degrees of declination.



TWO GALAXIES of the irregular "barred spiral" type (*top*) are compared with the Large Cloud of Magellan (*bottom*). At upper left is N.G.C. 4027; at upper right, N.G.C. 4618. Both the latter were photographed with the 36-inch reflector of Lick Observatory.

by eight degrees. This means that the Large Cloud is more than 50,000 light-years across, and the Small Cloud's diameter is more than 20,000 light-years. The 20-degree field of the small camera does not take in all of the Large Cloud, and to show its full extent we must piece together separate photographs of different sections [*see composite photograph on page 54*].

Thus it now appears that the Clouds of Magellan are not merely midget companions but full-fledged partners of our own galaxy. The Large Cloud, with its long appendages, is not a great deal smaller than the diameter of the Milky Way, and its total spread in space is about half as great as the distance between us and the Clouds. It looks as if the Milky Way and the two Clouds are comparable members of a triple system of galaxies.

Concerning the Clouds' structure, the new photographs tell another interesting story. The "microscopic" examination of the Clouds' internal structure with telescopes had indicated that they were unorganized and chaotic, and they have long been considered galaxies of the "irregular" type. However, our new general view shows that they have a definite large-scale structure [*see diagram on page 55*]. The Large Cloud has a long loop or whorl encircling its bright central region. That is, it appears to be a one-armed spiral system. Most spiral galaxies have two arms, but systems with one arm, like this one, have been seen before. In fact, the Clouds of Magellan can now be identified as members of a class of galaxies known as "barred spirals." They probably represent an early stage in the evolution of this type of spiral galaxy [see "Why Do Galaxies Have a Spiral Form?" by Cecilia H. Payne-Gaposchkin; SCIENTIFIC AMERICAN, September, 1953].

The spiral structure of the Small Cloud is more difficult to detect, because it is tilted toward our line of sight and we see it partly edge on; the tilt angle appears to be about 30 degrees. Nevertheless it has been possible to determine that the Small Cloud has basically the same spiral pattern as the Large Cloud.

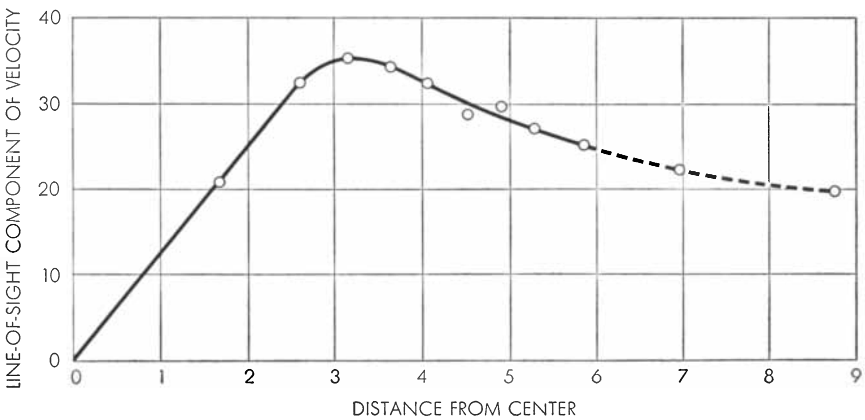
The finding of spiral structure in the Clouds indicated, of course, that they must be rotating and must have a disk shape, like our own galaxy. Various observations soon confirmed that this was indeed the case. They included explorations by radio astronomy, which verified the rotation of the Clouds.

Let us consider first the evidence that the Clouds have a flattened form. As I have just mentioned, the Small Cloud gives a plain indication of such flattening in its elongated shape, showing that we see it partly edge on. But there are also other indications which apply to both Clouds. For one thing, both the Large and Small Clouds proved to be remarkably similar in certain respects to the great southern nebula called N.G.C. 55, which we know to be flattened because we see it edgewise. For example, B. Y. Mills of the Radiophysics Laboratory in Sydney, Australia, found that the Clouds and N.G.C. 55 emit exactly the same ratio of radio energy to light, which is taken to identify them as the same type because the ratio is different for other classes of spiral galaxies. Another kind of evidence of the Clouds' disk shape is provided by the velocities of gaseous nebulosities in the Large Cloud. According to measurements made many years ago by astronomers of the Lick Observatory in an expedition to the Southern Hemisphere, the velocities of these objects do not differ by more than about five kilometers per second. This small spread is a strong indication that the objects are all in nearly the same plane—*i.e.*, the equatorial plane of the Cloud's assumed rotation. Thus the system would have a flattened shape like that of the Milky Way.

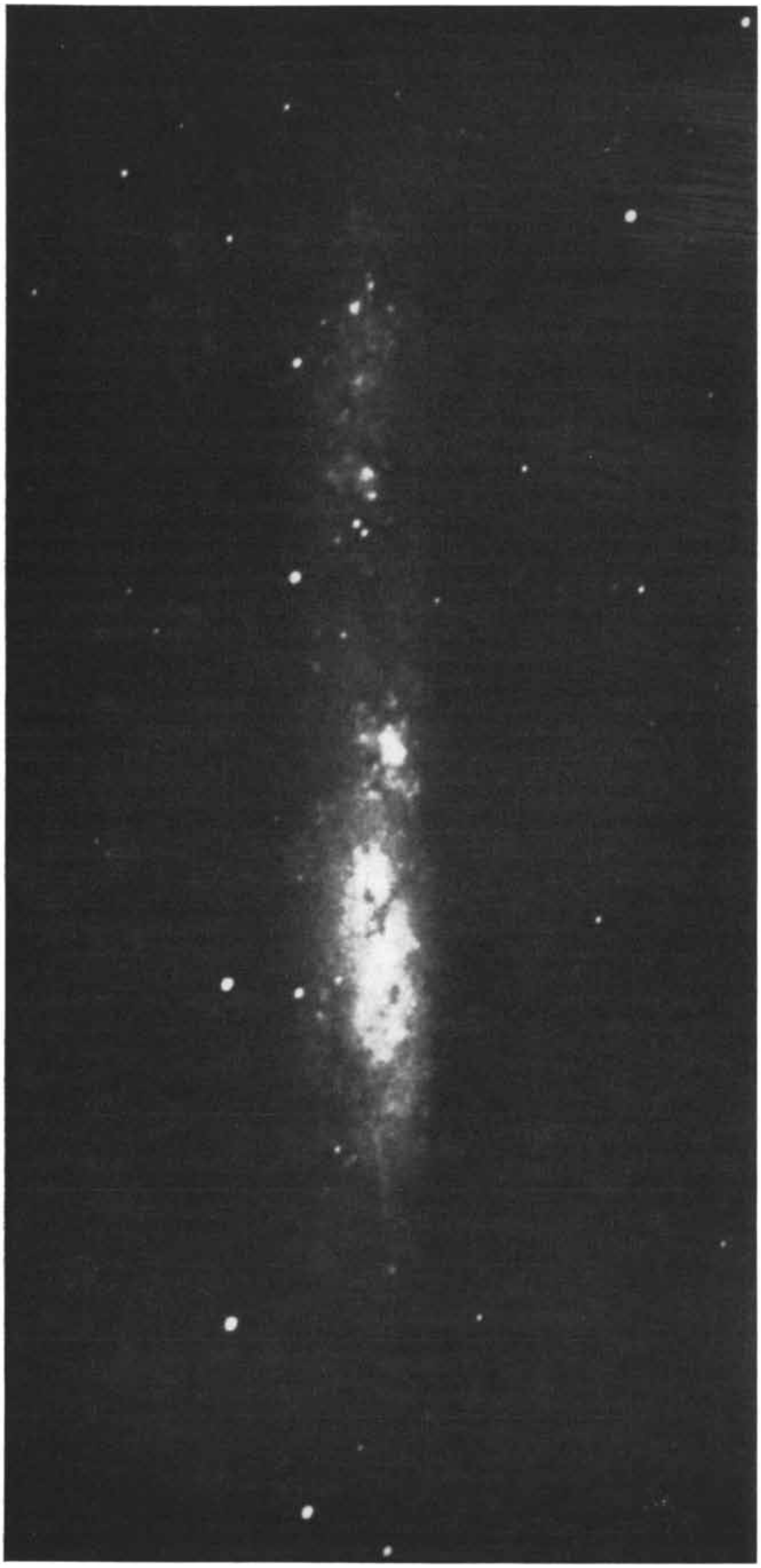
The investigations of the Clouds' rotation supported the structural studies. The Australian radio astronomers F. J. Kerr and J. V. Hindman had picked up "the song of hydrogen"—the 21-centimeter radio emission by hydrogen in space—from the Magellanic Clouds. This opened up the possibility of a detailed study of the Clouds' motions, for, thanks to the Doppler effect, the motions can be measured by shifts in the radio frequency [see "Radio Waves from Interstellar Hydrogen," by H. I. Ewen; SCIENTIFIC AMERICAN, December, 1953].

Because the Magellanic Clouds are so close to our galaxy, they should not be moving very rapidly away from the galaxy as a whole. However, our galaxy is rotating at high speed, and as a consequence the Sun and Earth are traveling rapidly away from the Clouds. The radio studies showed that the Earth is moving away from the Large Cloud at a speed of about 175 miles per second, and from the Small Cloud, at about 100 miles per second. These figures agree very well with measurements arrived at by studies of the red shift of light—and the agreement constitutes the first confirmation from beyond our own galaxy that light and radio waves travel at the same speed.

Late in 1953 radio and optical astronomers who had been making separate investigations of the Clouds' structure and rotations were invited by the Australian National University to a conference in Canberra to compare their results. The radio observations beautifully confirmed the Clouds' rotational motions [*see diagram below*]. From the data on the Clouds' rotations it became possible to calculate the mass of each Cloud. The Large Cloud was estimated to have five billion times the mass of our Sun; the Small Cloud, 1.5 billion times. Thus the



ROTATION of the Large Cloud is indicated by this curve based on observations of a shift in the frequency of radio waves from neutral hydrogen between the stars of the Cloud. The velocity with which the hydrogen is advancing or receding, corrected for the rotation of our own galaxy, is given in kilometers per second. The distance from the center of the Cloud is given in degrees. The curve resembles those plotted for other rotating galaxies.



GALACTIC TYPE of the Large Cloud is probably represented by N.G.C. 55, a large galaxy of the Southern Hemisphere. Seen from the edge, it is flattened and thus appears to be rotating. The photograph was made with the 30-inch Commonwealth Observatory reflector.

mass of the Large Cloud is much less than that of our galaxy (100 billion Suns), although it is not much smaller in diameter. The Large Cloud seems to have about the same mass and brightness as the well-known spiral galaxy in the constellation Triangulum.

What sort of effects may our galaxy exert on the Clouds of Magellan, or the Clouds on us? That neighboring galaxies interact is strongly indicated by recent photographs made with the 200-inch telescope by Fritz Zwicky of the California Institute of Technology. His pictures show spectacular filaments and "bridges" of gas and stars between galaxies. In our own triple system our massive galaxy clearly must dominate the two Clouds, and in all likelihood it causes strong perturbations in the outer parts of the Clouds. This may account for the single long, spiral arm that streams from the central body of the Large Cloud in a direction away from the center of our galaxy. This amazing formation is more than 50,000 light-years long —one third as long as the distance between the Earth and the Clouds. A similar effect of the Large Cloud may be responsible for an extensive prominence that projects from the Small Cloud toward the Large.

There is as yet no theory as to how our galaxy may exercise such effects. Gravitational force alone does not appear sufficient to explain them. Perhaps magnetic or magneto-hydrodynamic processes also are at work. There seem to be reasons to believe that our galaxy and the Clouds are surrounded by weak magnetic fields. J. Heidmann, a French physicist, recently suggested that at the boundary between these fields there may be a turbulent zone where matter which is being dragged through space by the field of our galaxy "blows like a wind" on the Large Cloud and is accelerated by a "betatron effect" to produce high-energy cosmic rays. Heidmann proposed this process as the basis of a new theory on the origin of these rays. Needless to say, there is plenty of room for controversy here.

It was in the Clouds of Magellan that astronomers found their first reliable yardsticks (the Cepheid variable stars and so forth) for measuring distances between the galaxies of our universe. Now they are telling us a great deal about the galaxies themselves. In the next few years optical and radio astronomers, joining forces with cosmic ray physicists, may well extract some great surprises from the Magellanic Clouds.

Kodak reports to laboratories on:

a palm-sized movie maker in a thin-skinned box . . . a real heavy ion with a triple charge . . . what the color-film processing fee buys

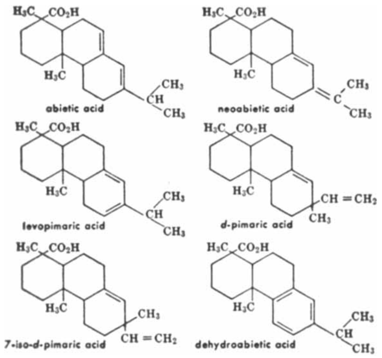
A glossing over

Go down to your Kodak dealer and look at the new *Cine-Kodak Medallion 8 Camera*. If the salesman is having such an unlucky day that he fails to persuade you to part with $144.50 for this palm-sized movie maker that you can load with a magazine in three seconds and be ready to shoot—at least look at the carton the camera comes in. Possibly of more interest to you is the substance (just as dearly beloved a product of ours as the exquisite little machine within) that constitutes the outer skin over the printing on the box. This *Half-Second Butyrate* has been known to retain its effectiveness in films as thin as .0001 inch. "Ordinary" lacquers give little appreciable gloss when applied that thin.

Persons whose minds dwell more on putting the glossiest, toughest gloss on a surface with the least coating material than they dwell on recording the coming summer's pleasant moments are urged to apply for information about Half-Second Butyrate *to Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company).*

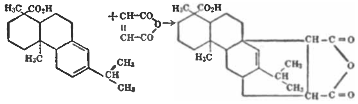
In early spring sap

When the bark of a longleaf pine is scraped down into the sapwood, the wound exudes an item of commerce called gum oleoresin. This consists of a mixture of α- and β-pinenes, sold as gum turpentine, plus a mixture of the following resin acids:

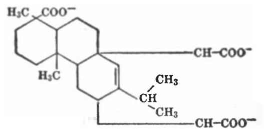


Dancing to the tune of temperature and pH, the loose protons and the double-bond electron configurations can twinkle around in these isomers like so many animated electric signs. If you do your work in the cold, you'll find that levopimaric acid is the largest single component of these resin acids; it is particularly dominant in early spring sap.

The levopimaric acid—and only the levopimaric acid—reacts exothermically with maleic anhydride, Diels-Alder-wise, to yield our new *Maleo-pimaric Acid* (Eastman 7151):



With the aid of a little sodium hydroxide, this can pick itself up a solvating charge at three places and go floating off to new adventures with all that molecular weight, water-soluble as you please.



Think, particularly, of the interesting esters it would make.

You take it from here. 100 grams of Maleo-pimaric Acid *(Eastman 7151) costs $3.00. It and roughly 3500 other Eastman Organic Chemicals come from Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Colorful tale

Arranging for the processing of *Kodachrome* or *Kodacolor Film* is now a separate transaction from the purchase of the film. In the dicker with the dealer you can, if you wish, ask that he have us do the processing, for we are still in the processing business. On the other hand, if you don't specify and he sends it to someone else who can process competently, that's all right, too. As long as the pictures turn out well, we'll be happy.

In the case of *Kodacolor*, we were able to do a little simplifying while changing over from the old processing-paid-in-advance film to the new processing-not-paid-in-advance product. The new *Kodacolor Film* comes in just one type, good for both natural and artificial light. Balancing for one or the other is deferred until the negative is printed.

With *Kodachrome Film*, where you get no negative, the color balance has to be set in manufacture. The dyes you see in the resultant transparency are formed by the reaction of the oxidation products of three different developers with three different coupler compounds introduced during processing. These couplers themselves have no color.

Kodacolor Film comes with its couplers already present in the emulsion layers. It is processed to a negative with the familiar over-all orange hue.

(Why it's orange instead of just complementary to the original scene is quite simple. The orange comes from the fact that the unreacted coupler in one of the emulsion layers is itself yellow, and the unreacted coupler in another layer has a reddish cast of its own. The couplers should form dyes complementary to the colors recorded by their respective layers. However, the best of magenta dyes for the green-sensitive layer still absorbs some blue light, and this would upset the scheme. Therefore we use as our coupler for this layer a compound that in unreacted form absorbs just as much blue light as the unwanted blue absorption of the dye it forms. Then the difference in absorption between image and no-image in this layer will be right. Similarly, the unreacted coupler in the red-sensitive layer has a little blue- and green-absorption equivalent to the unwanted blue- and green-absorption of the cyan dye it forms.)

If several re-readings of that last paragraph leave it still tightly locked, get the Kodak Data Book "Color As Seen and Photographed," which is part of the Kodak Color Handbook, *on sale by your Kodak dealer. It explains better, with diagrams. If all you want are nice color photographs, he can load you up right then and there with all the* Kodacolor *and* Kodachrome Film *you want to pay for.*

Prices include Federal Tax where applicable and are subject to change without notice.

This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

Kodak
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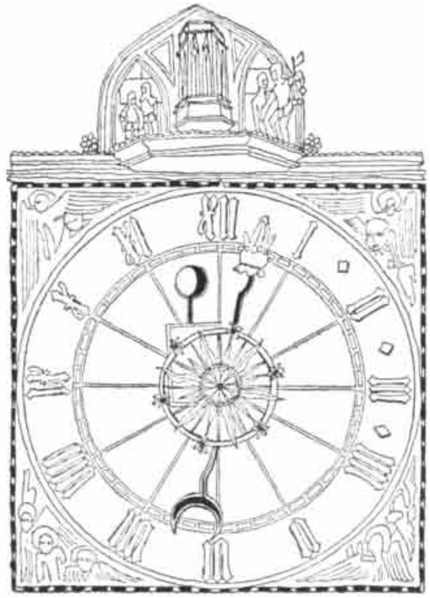


Big Atom Smasher

A cooperative organization of midwestern universities, incorporated as the Midwestern Universities Research Association, was authorized by the Atomic Energy Commission last month to design and build a new particle accelerator. The AEC wants the machine to be the "finest and most powerful in the world at the time of its completion." No one can yet say what form the monster will take, but it will almost certainly incorporate some new ideas developed by a Midwestern study group during the past three years.

One possibility under serious consideration is to build two accelerators side by side, with the particle beams directed against each other. Such an arrangement would enormously magnify the effective energy of the beams. When the speeding particles from an accelerator hit the nuclei in a stationary target, a large part of their energy is spent in recoil motion. But in a head-on collision between two high-speed particles there would be much less recoil and more energy available for disintegrating the colliding particles and creating new ones. It is estimated that two opposing accelerators of 10 billion electron volts each would give an energy equivalent to that of a 250-Bev accelerator operating against a stationary target. Two 22-Bev machines would yield the equivalent of a trillion electron volts.

The opposed-beams idea has been thought of before, but has seemed impractical. Present accelerators produce so few particles that collisions would be far too rare. The Midwestern designers are reconsidering the possibility because they have hit on a way of greatly intensifying an accelerator's particle beam. This development, now being tested in a small-scale model, is called Fixed Field Alternating Gradient, or FFAG. It uses a constant magnetic field. The particles will travel through a circular track a yard or two wide, spiraling from the inner to the outer edge as they speed up. The fixed magnetic field grows stronger from the inner edge outward. The advantage of the fixed field is that particles can be started on their way continuously, instead of having to be synchronized with the pulsations of the guiding field. Thus more and more particles can be "stacked up" in the outermost part of the beam. There they can circulate almost indefinitely, being strongly focused into a narrow stream by the "alternating gradient" arrangement of the magnetic field. The designers believe they can hold the beam on the track while the particles make hundreds of millions of trips around the accelerator. Particles in two opposed beams would make a huge number of passes at one another and would have a high probability of colliding eventually.

The physicists estimate that their machine will take at least seven years to build. It may cost as much as $100 million.

Members of the association are the University of Chicago, University of Illinois, Indiana University, University of Iowa, Iowa State College, University of Michigan, Michigan State University, University of Minnesota, Northwestern University, University of Notre Dame, Ohio State University, Purdue University, Washington University of St. Louis and University of Wisconsin.

Big Radio Telescope

Work is beginning at Ohio State University on what is to be the largest reflecting radio telescope in the world. Its antenna will consist of a fixed, parabolic metal screen 700 feet long and 75 feet high facing a flat, tiltable screen of about the same size. Radio waves from space will be reflected from the flat screen into the parabola, which will feed the collected energy into a sensitive receiver. The instrument was described by its designer, John D. Kraus, director of the Ohio State radio observatory, in his article on radio telescopes in SCIENTIFIC AMERICAN for March, 1955. He expects it to locate "thousands of new radio stars." The National Science Foundation has provided $48,000 for the first half of the construction.

Uranium Unlimited

The U. S. will release 88,000 pounds of fissionable uranium 235 for research and development and for fueling nuclear power reactors, President Eisenhower announced last month. Half of the uranium will be sold or leased to approved groups in the U. S.; the rest will be available to foreign nations. The U.S.S.R. and its satellites are excluded from the plan; so are Britain and Canada, which already make nuclear fuel.

The 88,000 pounds of U-235 represent $1 billion worth, or the product of two million tons of ore mined on the Colorado Plateau, or enough fuel to generate four million kilowatts of electric power, or the combined explosive charge of some 3,000 atomic bombs.

Another effect of the announcement was to set off speculation as to how much fissionable material exists, particularly in the form of weapons. The *Manchester Guardian* published an estimate of atomic bomb stockpiles, based on a public speech by a British official, a "Congressional indiscretion" in Washington and available public information. The publication guessed that the U. S. has 32,500 bombs, about three times as many as the U.S.S.R. But even Britain, in third place, "now has enough nuclear explosive in its possession to destroy every large city in the world and probably most of the large towns as well."

10-Million-Year-Old Jaw

In 1872 a French paleontologist found in a coal seam in Northern Italy a beautifully preserved jawbone and other fossil bones of an apelike creature. The fossils were in a stratum dated as some 10 million years old. When first discovered, they were thought to be the bones of an extinct monkey and were given the name Oreopithecus—"mountain ape."

Last month these fossils became a subject of considerable excitement. A

special meeting of anthropologists was convened in New York by the Wenner-Gren Foundation for Anthropological Research to hear some new startling conclusions about the fossils by Johannes Hurzeler, curator of vertebrate paleontology at the Basel Natural History Museum in Switzerland. After 20 years of study of the remains, Hurzeler has become convinced that the 10-million-year-old creature was closer to a man than to an ape.

Its teeth, he said, were nearly straight instead of forward-jutting; it had no simian gap between the canines and the adjacent teeth; its canines were smaller than an ape's and its molars were human; its chin was rounded instead of pointed; its jawbone had a hole for a nerve passage which is characteristic of a human jaw; and there were other humanoid features.

Hurzeler and some anthropologists thought the finding must drastically revise the theoretical timetable and line of human evolution. It indicates, he believes, that a manlike creature was in existence long before the "man-apes" of South Africa, long before the earliest men previously identified and at least as long ago as the supposed common ancestors of man and the apes such as the fossil known as Proconsul.

Micro Machine Tool

Grooves scarcely wider than a wavelength of light can be cut in metal with a new machine developed at the Bell Telephone Laboratories. The instrument can drill holes one fiftieth of a millimeter in diameter and affix plated dots and circles of comparable size, according to its inventor, Arthur Uhlir, Jr.

The bit of this micro machine tool is a glass tube drawn down to an extremely sharp tip, as small as one 5,000th of a millimeter. When current flows through an electrolytic solution in the tube, it is focused through the tiny opening and etches away only the area of metal next to the tip.

When the current is reversed, the machine tool, instead of etching, plates metal from the electrolytic solution. The tip can then be held stationary to plate dots or moved around to "write" whatever pattern is desired.

Uhlir developed the technique while working on germanium transistors. He got the idea from physiologists who use similar fine-pointed tubes to make contact with individual nerve fibers. His micro machining is applicable to most,

if not all, metals, semiconductors and such near-metals as tungsten carbide.

Soldering the Unsolderable

Joseph C. McGuire ruined a grinding wheel, but at the same time he discovered a way of soldering materials which had been impossible to solder. While cleaning up some unsuccessful solder joints at the Los Alamos Scientific Laboratory, McGuire found that although the residue of solder gummed up his abrasive, it left a shiny coating firmly adhering to the base metal.

The method he developed from this accidental observation is described in *Chemical and Engineering News*. First he applies a preheated grinding wheel to a piece of soft solder, until it melts and flows onto the surface of the wheel. Then he presses the solder-loaded wheel against the material he wants to solder. Again the heat of friction melts the solder, which flows onto the freshly abraded surface and adheres to the surface strongly.

With McGuire's simple technique it is possible to solder glass, ceramics and a great variety of metals, including cobalt, titanium, niobium and tantalum.

In Defense of Cholesterol

Cholesterol in the blood has been blamed for many human ills, particularly hypertension and disease of the heart and circulatory system. Now evidence to the contrary is reported by Harold D. Chope, director of the Department of Public Health and Welfare at San Mateo, Calif., and Lester Breslow, chief of the California health department's Bureau of Chronic Diseases.

In the *American Journal of Public Health* they describe a survey begun in 1948 on 577 persons between the ages of 50 and 90. They found no correlation between the level of blood cholesterol and hypertension or deaths from cardiovascular or kidney disease. In fact, their analysis shows that among persons over 70 "the higher the cholesterol, the lower was the mortality."

Polio Reservoir?

Cows and a few other domestic animals may harbor the poliomyelitis virus. Pasquale Bartell and Morton Klein of Temple University Medical School have found polio antibodies in the blood sera of cows, horses and hogs, they reported recently in the *Proceedings of the Society for Experimental Biology and Medicine*. Chicken blood also may con-

tain the antibodies in weak concentration.

Bartell and Klein believe that the substances found are true polio antibodies, rather than non-specific virus-killing substances. Some individual animals have antibodies against Type 1 virus, some against Type 2, some against Type 3 and others against various combinations of polio viruses. This would indicate that the antibodies were built up as a reaction to infection. Additional support for this view comes from the fact that young steers generally have less antibody than mature cows, and calves have little or no antibody.

The authors have been unable to isolate the actual viruses from cow blood. If the antigens are not polio viruses but kindred benign microbes, they "may be important as immunizing agents against polio virus in humans." They would then parallel the role cowpox virus plays in immunizing people against smallpox.

Versatile Hormones

The queen bee safeguards her sexual hegemony by secreting a hormone which prevents the development of ovaries in worker bees capable of becoming females. Female prawns store in their eyestalks a similar hormone, which keeps their ovaries from becoming active until spawning time.

The two hormones prove in fact to be very alike, according to a new study by two British biologists—David B. Carlisle of the Marine Biological Laboratory in Plymouth and Colin G. Butler of the Rothamsted Experimental Station's Bee Department. They report in *Nature* that when the queen-bee hormone is administered to prawns, it acts to prevent the prawns' sexual development, and *vice versa.*

Carlisle and Butler note further that the queen-bee hormone keeps worker ants from maturing into queen ants, and that crustaceans other than the prawn secrete the prawn hormone.

Heritage of Chromosomes

New information on the mechanism of heredity was reported recently by Walter S. Plaut and Daniel Mazia of the University of California in the *Biological Bulletin.*

When a cell divides, the nucleic acid in its chromosomes doubles and is divided between the two daughter cells. How is the apportionment carried out? Does the parent chromosome retain its identity in one daughter cell and make

a replica of itself out of new material for the other? Or does it break up, distributing its material equally to its daughter chromosomes?

According to one current theory, it does the latter. The nucleic acid DNA is thought to be made up of two identical, intertwined molecular chains which separate when the cell divides, one chain going to each new chromosome [see "The Structure of the Hereditary Material," by F. H. C. Crick; Scientific American, October, 1954]. Now Plaut and Mazia have found evidence that the DNA is not equally divided in multiplying plant cells. They studied seedling roots of a plant, labeling the cells' DNA with carbon 14 and then measuring the radioactivity in daughter cells produced by division. In many cases sister cells had greatly different amounts of radioactivity, showing that they had not shared their parent's DNA equally.

Roast Elephant, 27,000 B.C.

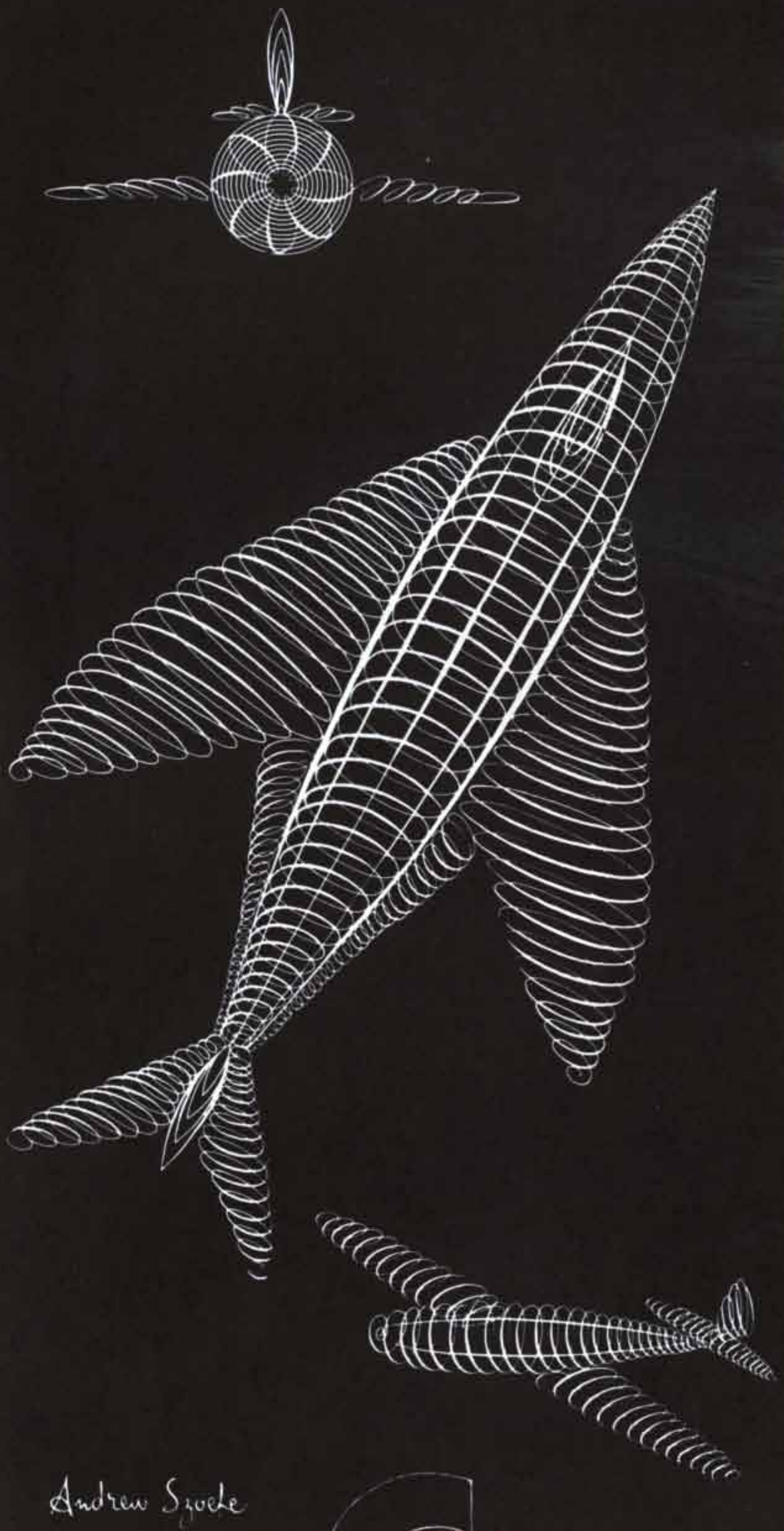
More than 29,000 years ago men were broiling dwarf mammoths on a little island off the California coast, according to George F. Carter, a geographer at The Johns Hopkins University. If true, this would place man in the area some 20,000 years earlier than archaeologists had previously estimated.

Carter has long argued for an early arrival of man in America. (His penchant for seeing hand-chipped stones where others see only naturally broken fragments, he says, has led his colleagues to name the doubtful items "Carti-facts.") He knew that during the last ice age dwarf mammoths roamed the island of Santa Rosa, which was then part of the mainland. If there were also men there at the time, he reasoned, they would have cooked and eaten these animals, which are the "original large economy-size package of protein." On an expedition to Santa Rosa last summer he found charred mammoth bones in several ancient fire sites. Radiocarbon dating put the age of the bones at 29,650 years.

Negroes on the Move

A detailed geographic study of the Negro population in the U. S., documenting its migrations in recent years, is reported in *The Geographical Review* by Wesley C. Calef of the University of Chicago and Howard J. Nelson of the University of California at Los Angeles.

About 60 per cent of the nation's 15 million Negroes are still concentrated in the Southeast, but they no longer make



Avco Crosley helps bring a new anatomy of flight to life

Today, new breeds of planes are filling America's skies! In a brief decade of bold experimentation inspired by the military, the aircraft industry has created swept-winged, smooth-skinned new speedsters of almost unrecognizable sleekness.

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Beads by the cubic foot

Sitting here for their portrait are beads representative of several AMBERLITE® ion exchange resins. They and the paper on which they are posed have been magnified 24 times—to the detriment of the paper, perhaps, but not to the uniformity of the beads.

Actually, Rohm & Haas Company produces over 20 ion exchange resins, a variety large enough to serve such diverse uses as water conditioning, metals recovery, pharmaceutical production, sugar refining, chemical processing, and decontamination of radioactive wastes. Some AMBERLITE ion exchange resins even act as medicinals.

Gem-like in appearance, the AMBERLITE resins are nonetheless rugged and durable, serve efficiently for many years. They are manufactured in bulk and are sold by the cubic foot.

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ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA up more than half the population of any State. Only one city—Greenville, Miss.—has more Negroes than whites. Calef and Nelson take issue with the assertion that the northward migration of Negroes will mitigate the South's racial friction. They point out that despite the migration the ratio of Negroes to whites remains unchanged in nearly half the South.

Population Pressure Contest

A $5,000 prize for the best essay on how to solve the world's population problems has been offered by the International Catholic Institute for Social Research, whose headquarters are in Geneva, Switzerland.

Entrants are asked to devote at least 50,000 words to answering two questions: (1) What social, economic and cultural measures should be taken in underdeveloped areas? (2) How can population growth be limited where necessary? The rules require that solutions be both scientifically effective and in conformity with Roman Catholic principles.

As a starting point G. H. L. Zeegers, director general of the Institute, has chosen the population projections prepared by the United Nations in connection with the Population Conference held two years ago in Rome [see "World Population," by Julian Huxley, Scientific American, March]. Zeegers says: "Catholic ethics in the situation under discussion are not opposed to the state in the pursuance of a population policy. In pursuing a population policy, however, the state must not propose a system [of birth control] which prescribes for individual application but must confine itself to collective and indirect measures."

Wasted Words

Scientists who wish their research to become part of the "common pool of world scientific knowledge" must learn to write English or German, for publications in any other language stand an "overwhelming" chance of passing unnoticed. So concludes Knut Faegri, a Norwegian biologist, after an informal survey of international literature in botany.

Faegri checked the references at the end of technical papers in botanical journals from England, France, Germany, the Scandinavian countries, Switzerland, the U. S. and the U. S. S. R. English publications were overwhelmingly the most frequently cited. English and German publications accounted for more than 80 per cent of the citations in all except the French and Soviet journals. The French references were 56 per cent English and German; the Soviet references, 26 per cent.

American and British authors showed the narrowest linguistic spread; their references were, respectively, 84 and 78 per cent in the home tongue. Soviet scientists also lean heavily on their own language—73 per cent of their references were in Russian. But the Soviet lists were 27 per cent Western, while only two Western lists contained any Soviet references: the German (one-half per cent) and the Scandinavian (one per cent). The disparity, remarks Faegri, "is nothing new, but it is deplorable."

Faegri, who writes papers in two languages other than Norwegian (his report appeared in Britain's *Nature*), is "convinced that a brain that has the capacity for scientific work has also the capacity to learn so much of at least one foreign language as to be able adequately to express scientific ideas in it."

Touring Teachers

A new idea for training high-school teachers in science will be tried by the National Science Foundation and the Atomic Energy Commission in the coming year.

At the Oak Ridge Institute of Nuclear Studies this summer eight or 10 selected teachers will take two months of training in basic physical science, radioisotope techniques, science teaching methods, laboratory experiments and demonstrations. Then these teachers will spend the ensuing academic year touring high schools throughout the country, giving lectures and demonstrations to sophomore and junior classes. Each teacher will be provided with a station wagon outfitted with the necessary material.

The touring lecturers, who will be on leave of absence from their own schools, will receive from the National Science Foundation an amount at least equal to their regular salaries plus travel expenses. Each teacher will be assigned an area around his home town. The group is expected to visit about 250 high schools.

A somewhat similar plan is also to be tried at Harvard University. The Medical School and the Graduate School of Education will offer an eight-week course in radioactive measurements, with applications to biology. At the conclusion of the course the 20 graduates will receive a complete set of counting equipment for demonstrations.

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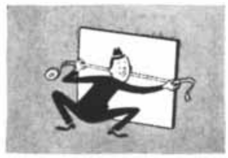

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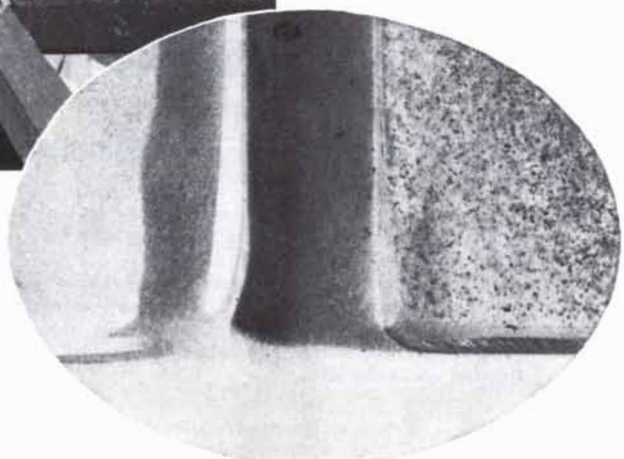
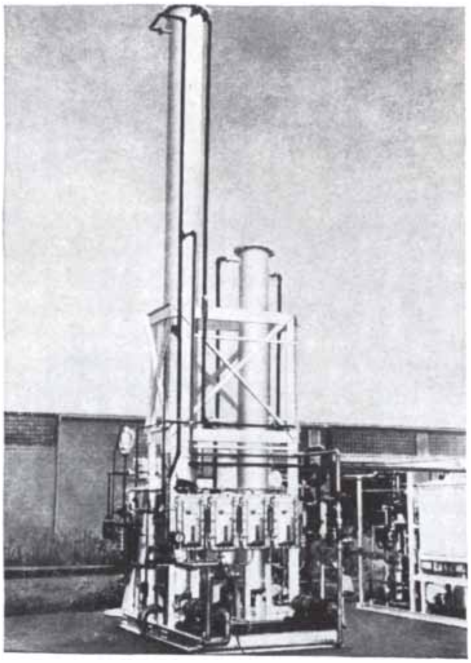
A BETTER AMERICA THROUGH CHEMICAL PROGRESS



MOLTEN METAL SPECKS BOUNCE OFF NEW PLASTIC, HT-CR-39 polymer *(left)*, made exceptionally heat and abrasion resistant by Cyanamid's triallyl cyanurate. The sparks leave the plastic surface unmarred *(inset, left)* but fuse to glass *(inset, right)*. Developed by Cast Optics Corp., Hackensack, N. J., HT-CR-39 rivals optical glass in clarity. It remains flat and rigid even at 230° F, where acrylics become fluid. By the Taber test, it is 35 to 45 times as abrasion resistant as the acrylics. Triallyl cyanurate, a new chemical combining three allyl groups with the exceptionally stable triazine nucleus, confers to a wide variety of resins a high heat distortion point, high temperature stability, stable electrical properties and high resistance to solvents, chemicals and fire. **(New Product Development Department, Section A)**

LOADING COSTS HAVE BEEN CUT as much as 50%, and unloading costs as much as 75% by the use of ACCOPAK® Paper Pallets over a year-long test period in Cyanamid and customer plants. In handling a flaked chemical in multiwall bags, loading cost was reduced from $27.80 per car to $17.77. The receiving plant reported that unloading costs fell from $22.86 to $4.06. Labor savings are dramatic: in another case, loading time was cut from 12 to 6.8 man-hours, unloading time from 8 to 1.2 man-hours. With this pallet, a kraft paper sling between two spiral-wound paper tubes, unitized loads can be tiered without use of space-wasting platforms. Crush-resistant tubes allow easy re-entry of lift truck bayonet forks without damage to adjacent bags. Today, ACCOPAK Pallets are available to plants handling bagged materials. **(Industrial Chemicals Division)**

NEW COSMETICS AND PHARMACEUTICALS based on AERO* Glycolonitrile are joining other fine products in medicine cabinet and vanity. Of particular interest are N-substituted sarcosinates, surfactants which provide antienzyme action, make an excellent shampoo base, provide dispersion and wetting in aerosol formulations, shaving creams and synthetic bar soaps. Glycolonitrile also is a valuable intermediate in making calcium and iron sequestrants. N-methylglycine, another derivative of glycolonitrile, is used as a stabilizer for diazo compounds, which are intermediates in dye manufacture. A new bulletin on properties and applications of glycolonitrile will be sent on request. **(Industrial Chemicals Div., Dept. A)**



NOW HYDROGEN GENERATORS COME "PACKAGED"! This generator was designed, fabricated, pretested and shipped as a unit within four months after the contract was awarded to Chemical Construction Corporation, a subsidiary of Cyanamid. Two weeks after start-up, the generator exceeded performance guarantees—55,000 SCFD of gas with a purity of over 98% hydrogen. CHEMICO produces "packaged" hydrogen generators of this type in various capacities to produce hydrogen as needed by the chemical, metallurgical and petrochemical processing industries. **(Chemical Construction Corp.)**

BIGGEST REINFORCED PLASTIC BOAT TAKES SHAPE. A revolutionary new method was used to construct the 42-foot ketch *Arpege*, destined for a two-year scientific voyage in the South Pacific. Biggest sailboat ever made with reinforced plastic hull, it was built without permanent mold or expensive tooling. A thin inner shell of mahogany veneer, shaped over conventional hull forms, was covered with Fiberglas cloth and a specially compounded mixture of LAMINAC® Polyester Resins. A minimum of 19 layers was applied, with 30 layers in the keel sections. Several final coats of pigmented resin completed the job. Stronger than steel, pound for pound, the hull is impervious to marine borers, rot and warping, and is relatively unaffected by the elements. **(Plastics and Resins Division)**

NOW SOIL GETS A "SHOT IN THE ARM"! To meet growing demands for liquid fertilizers that can be injected directly into the soil, Cyanamid has introduced its new AMANOL* Nitrogen Solutions. Applied when plowing, discing or cultivating (eliminating an extra step), solutions are injected 4 inches below the surface to prevent escape of ammonia into the air. This ammonia becomes fixed on soil particles and is released slowly for long feeding, right in the feeding zone. These solutions may also be metered into irrigation water for use in flood-type irrigation systems. **(Agricultural Chemicals Division)**

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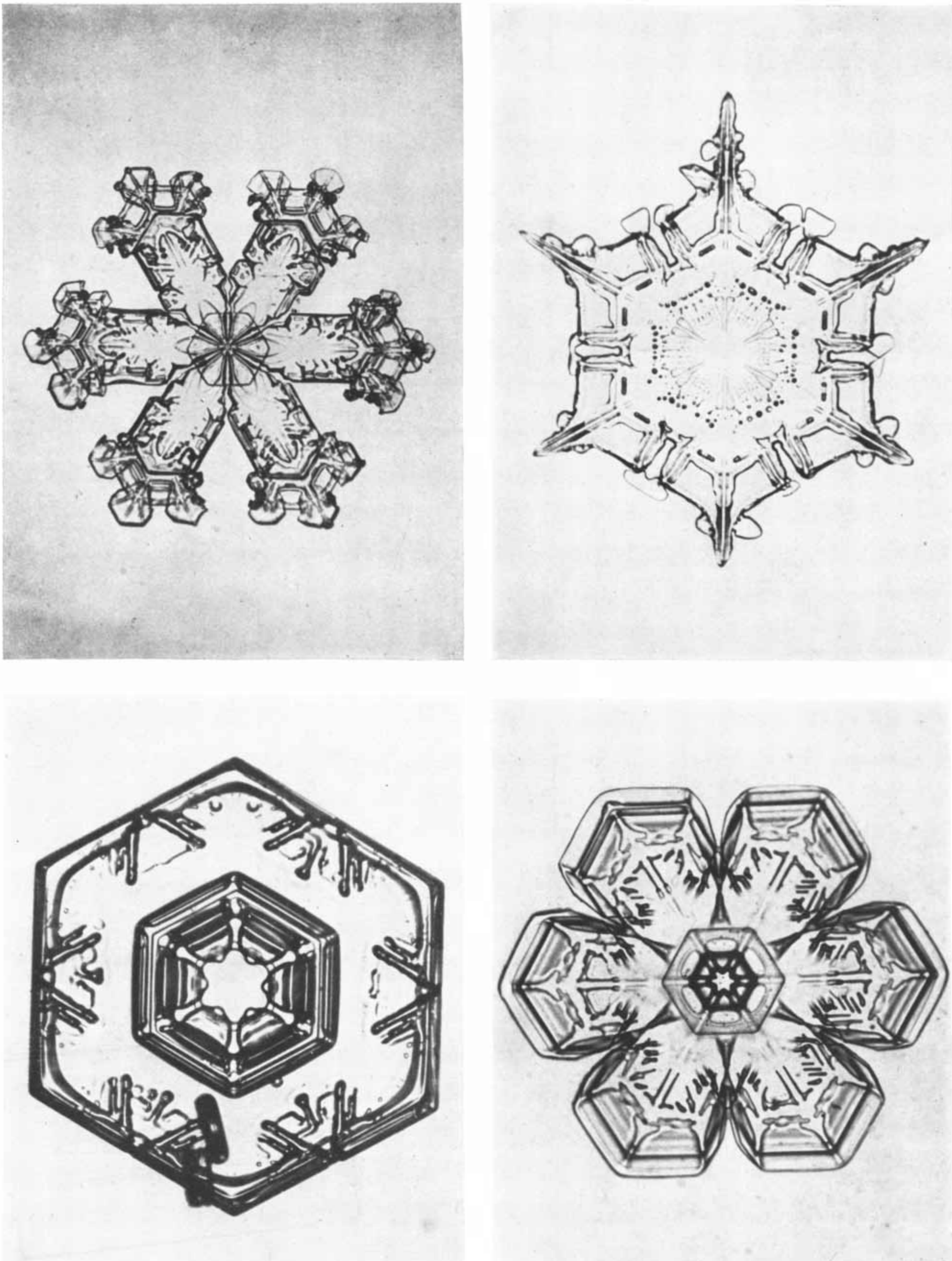


SNOW CRYSTALS are enlarged about 50 diameters in these photomicrographs by Vincent J. Schaefer of the Munitalp Foundation in Schenectady, N. Y. The hexagonal symmetry of the crystals is due to their molecular structure *(see diagram on page 80)*.

WATER

Although we take its properties for granted, they are most unusual. As an example, it has the rare property of being lighter as a solid than a liquid. If it were not, lakes would freeze from the bottom up!

by Arthur M. Buswell and Worth H. Rodebush

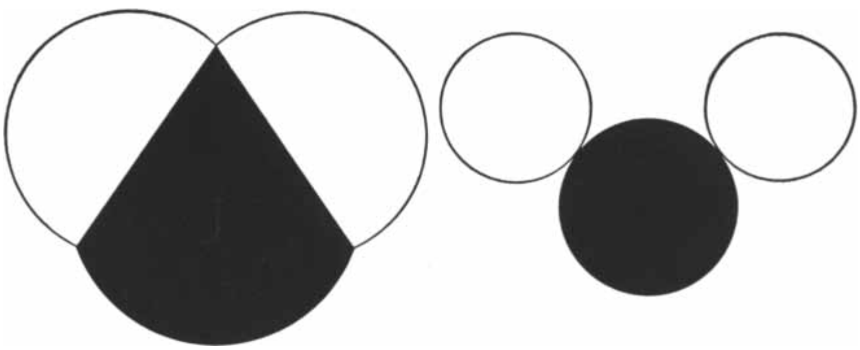
Water is the only common liquid on our planet. Next to air it is the substance with which we are most intimately acquainted. Because it is so familiar, we are apt to overlook the fact that water is an altogether peculiar substance. Its properties and behavior are quite unlike those of any other liquid. To take just one example, water has the rare property of being denser as a liquid than as a solid, and it is probably the only substance that attains its greatest density at a few degrees above the freezing point (four degrees centigrade). The consequences of this behavior are of great importance to life on our planet. When ice forms on a lake, for example, its lower density (only nine tenths that of liquid water) keeps it on top and it acts as an insulating blanket to retard cooling of the underlying water. As a result lakes in the temperate zones do not freeze solid to the bottom but leave a zone for the winter survival of aquatic life. On the other hand, the same peculiar property of water has fatal consequences for living cells. When water in the cells freezes and becomes less dense, its expansion damages or breaks up the cells.

Even the elements of which water is composed—oxygen and hydrogen—are chemically exceptional. Both are unusually reactive. Oxygen is our chief source of energy, being responsible for the respiration of living organisms and the combustion of fuels. Hydrogen, unique in the fact that it has no enclosing shell but only a single electron, is able to attach itself to other atoms not only by means of its electron (a valence bond) but also by virtue of the attraction of its unoccupied, positively charged side for an electron in a second atom. This attachment is known as the hydrogen bond. In water the two hydrogen atoms attached to each oxygen atom can become linked to other atoms as well by means of these so-called hydrogen bonds. As a consequence the H_2O molecules are joined together, so that water should be considered not a collection of separate molecules but a united association. In effect the whole mass of water in a vessel is a single molecule.

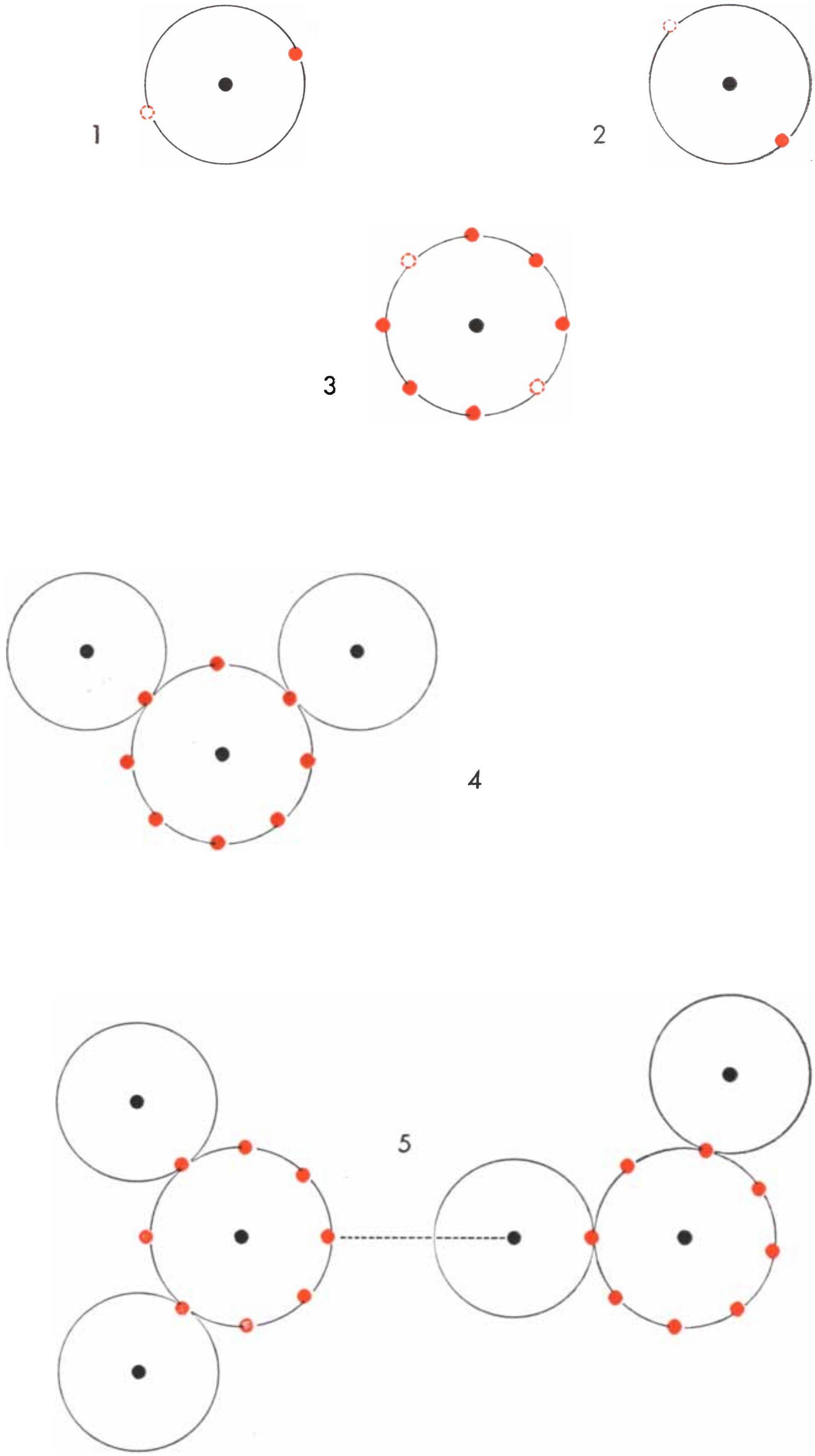
The best method of detecting hydrogen bonds is to study water with the infrared spectrograph. We have found that the hydrogen bond absorbs radiation most strongly at a wavelength of about three microns, which is in the near infrared region of heat radiation—*i.e.*, close to the visible light spectrum. Liquid water absorbs this radiation so powerfully that if our eyes were sensitive to the infrared, water would appear jet black. There is some absorption even in the visible spectrum at the red end. The fact that water absorbs red light accounts for its characteristic blue-green color.

Water's 33 Components

One of the shocks to our familiar notions about water is that its formula is not simply H_2O. Nor is it a single substance. The beginning of this disillusionment came in 1934 when Harold Urey discovered "heavy water." Urey found that the purest water contained besides hydrogen and oxygen another substance like hydrogen but with an atomic weight of two, or twice that of hydrogen. This substance, which is now called deuterium, combines with oxygen to form the compound D_2O. By now, we know, of course, that there is a third isotope of hydrogen, called tritium, and three isotopes of oxygen: 0-16, 0-17 and 0-18. Thus the purest water that can be prepared in the laboratory is made up



MOLECULE of water consists of one oxygen atom (*black*) and two hydrogen atoms (*white*). The distance between the center of the oxygen atoms and the center of each of the hydrogen atoms is .9 Angstrom unit (one Angstrom unit: .00000001 centimeter). The angle formed by the two hydrogen atoms is 105 degrees. These dimensions are fitted together in the drawing at left. In the more schematic drawing at right the size of the atoms has been reduced. This representation of the molecule is used in the following drawings.



ELECTRONS AND PROTONS of the water molecule account for most of its physical and chemical properties. The hydrogen atom (1 *and* 2 *in this highly schematic picture*) consists of one positively charged proton (*black dot*) and one negatively charged electron (*red dot*). The oxygen atom (3) has eight electrons, six of which are arranged in an outer shell. Because the shell of hydrogen has room for one more electron (*broken red circle*), and the outer shell of oxygen has room for two more electrons, the atoms have an affinity for each other. In the water molecule (4) the electrons of the hydrogen atoms are shared by the oxygen atom. Because the positively charged proton of the hydrogen atom now sticks out from the water molecule, it has an attraction for the negatively charged electrons of a neighboring water molecule (5). This relatively weak force (*broken line*) is called a hydrogen bond.

of six different isotopes, which may be combined in 18 different ways. If we add the various kinds of ions into which the addition or removal of an electron may transform water's atoms, we find that pure water contains no fewer than 33 substances [*see top of page* 82].

Of course the amounts of the isotopes other than common hydrogen and common oxygen (0-16) are tiny. Tritium and oxygen 17 appear only in the minutest traces, and deuterium is present to the extent of about 200 parts per million and oxygen 18 about 1,000 parts per million. However, the properties of heavy water, particularly the D_2O variety, have attracted wide interest and have been extensively studied.

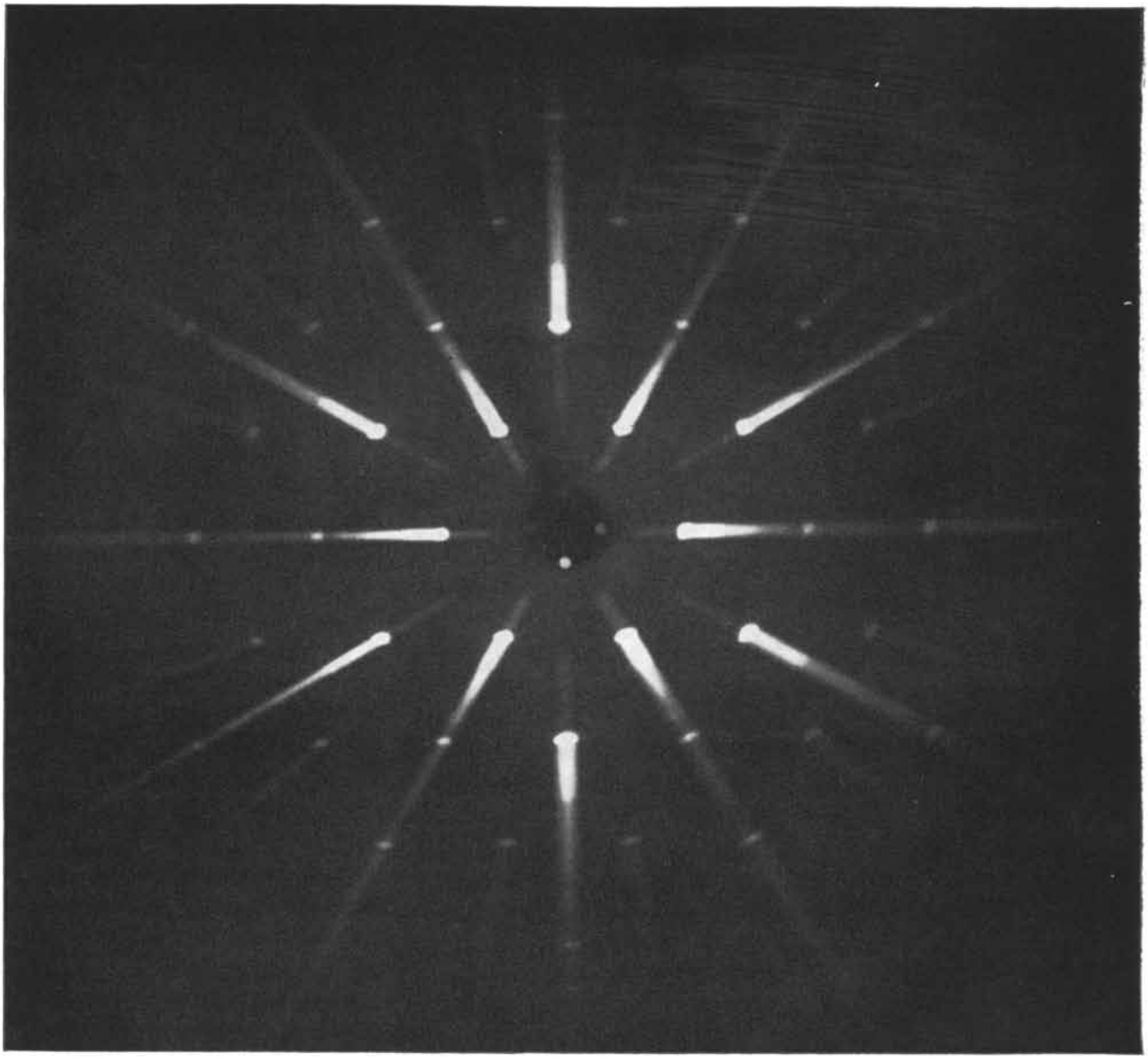
D_2O has a slightly higher boiling point than H_2O (101.4 degrees C.), freezes at a substantially higher temperature (3.8 degrees C.), and is somewhat more viscous than ordinary water. Its physiological properties are surprising. In animals and plants it appears to be entirely inert and useless. Seeds will not sprout in D_2O, and rats given only D_2O to drink will die of thirst.

The largest use of heavy water is as a moderator in nuclear reactors, but it is also widely employed in theoretical research, especially in organic and biological chemistry. If compounds containing active hydrogen are treated with D_2O, deuterium will replace the hydrogen and the compound will show changes in chemical properties resulting from the lesser reactivity of deuterium.

It is interesting to find that the amount of D_2O in natural water appears to be the same whether the water comes from an alpine glacier or the bottom of the ocean, from willow wood or mahogany.

Tritium is more ephemeral and more variably distributed. It is formed in the highest layers of the atmosphere by the bombardment of cosmic rays, and falls in rain and snow [see "Tritium in Nature," by Willard F. Libby; SCIENTIFIC AMERICAN, April, 1954]. Since tritium is radioactive, with a half-life of 12.5 years, it disappears after a time from water which has been out of contact with the atmosphere. Wines, and water in wells, can be dated by their tritium content. An interesting well in the Urbana-Champaign area was found to be devoid of detectable tritium, which means that at least 50 years have elapsed since the water fell as rain.

The functions of water in nature are innumerable. It is the solvent par excellence. It is the medium in which life originated and in which all organisms still exist. The living cell consists largely



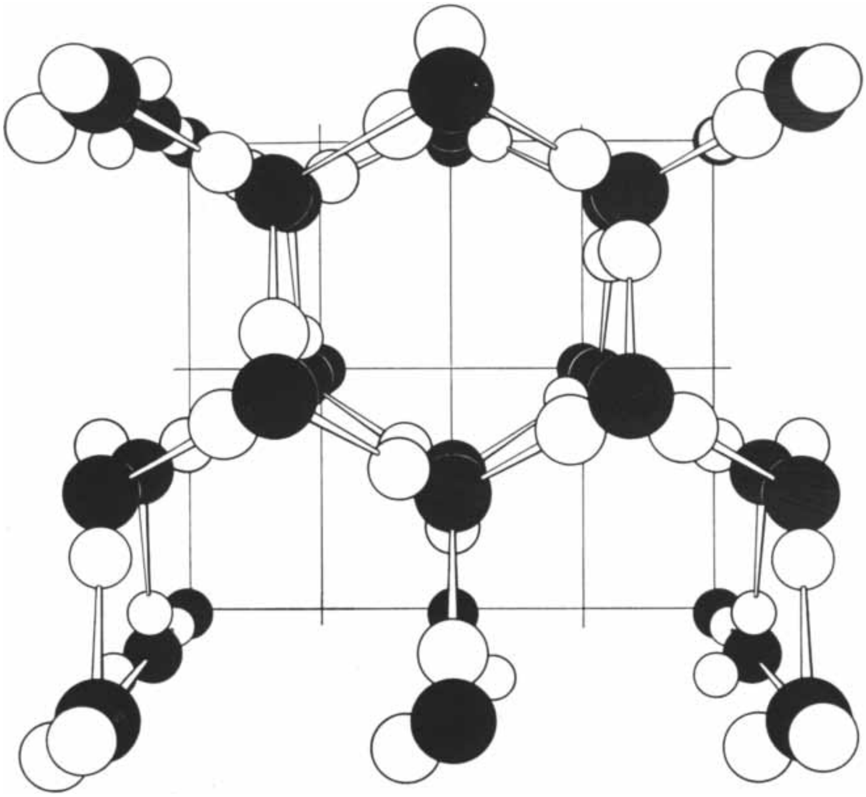
X-RAY DIFFRACTION photograph of ice was made with a precession camera by I. Fankuchen and his colleagues at the Polytechnic Institute of Brooklyn. The position of the spots in the photograph is related to the symmetry of the crystal (*see diagrams on next page*).

of water and literally floats in water. Considering how predominantly living matter is made up of this fluid, the extent to which it takes on a solid shape is surprising indeed.

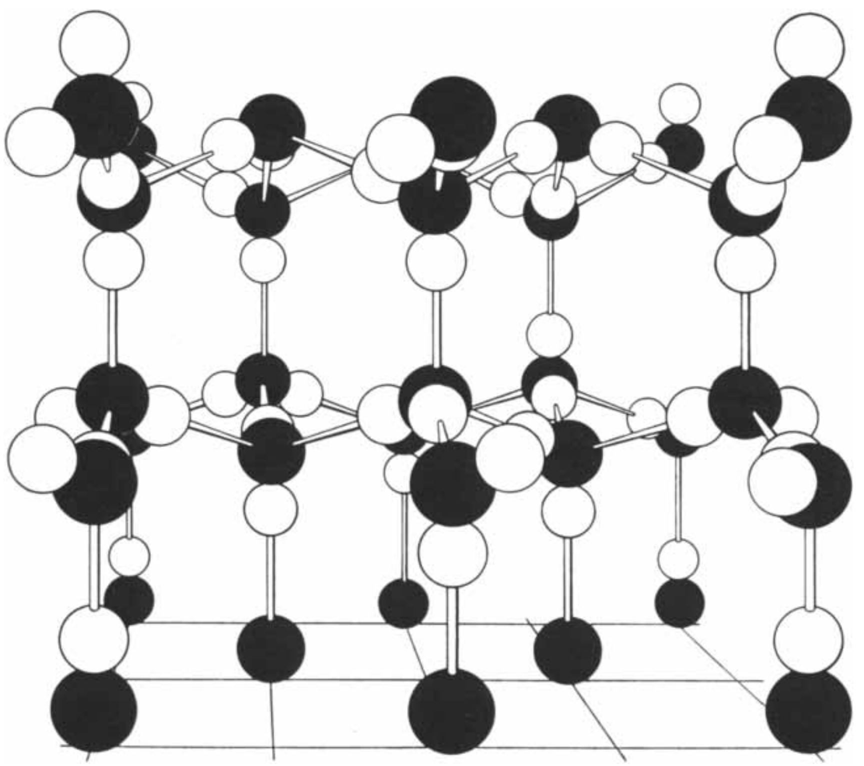
Water plays a fundamental role in the protein molecule, the basic material of living matter. Proteins have a structure which places them in the class of substances known to chemists as plastics. In order that a plastic may possess flexibility and other desirable physical properties, it must contain a fluid called a plasticizer. Water is a "plasticizer" for proteins. In the chainlike protein molecule the hydrogen bonds of water provide secondary links which fix the pattern of the molecule. Removal of water alters the pattern and "denatures" the protein. Fortunately the process is reversible, so that water in the cells can restore the pattern. On the other hand, the hydrogen bonds of hydrides other than water, such as ammonia or hydrogen cyanide, form a stable denatured configuration which freezes the protein in a dead pattern. This is why all the hydrides except water are extremely toxic. Their action is somewhat like that of a virus, which corrupts the true protein structure into a strange distorted pattern.

Water's Structure

To understand the behavior of water we must understand its structure. It is far from simple. The best approach is a study of the structure of ice. The arrangement of the oxygen and hydrogen atoms in the ice crystal has been determined by X-rays and other means. The two hydrogens are bonded to the oxygen approximately at right angles to each other, more exactly, at an angle of 105 degrees [*see illustrations on page* 77]. If the angle were 109 degrees, the frozen water molecules would form a cubic lattice, as in the diamond crystal. But in this case such a structure would be unstable because of the strain on the distorted bonds. The exact arrangement of the molecules in the ice crystal is not known with certainty; we know that they form a hexagonal structure, which



ICE consists of water molecules in this arrangement. The top drawing shows a model of ice seen from one direction. The bottom drawing shows the same model seen as if the reader had turned the top drawing forward on a horizontal axis in the plane of the page. Some hydrogens have been omitted from the molecules which touch the grid. Each hydrogen in each molecule is joined to an oxygen in a neighboring molecule by a hydrogen bond (*rods*). In actuality the molecules of ice are packed more closely together; here they have been pulled apart to show the structure. In a similar model of liquid water the molecules would be much more loosely organized, farther apart and joined by more hydrogen bonds.

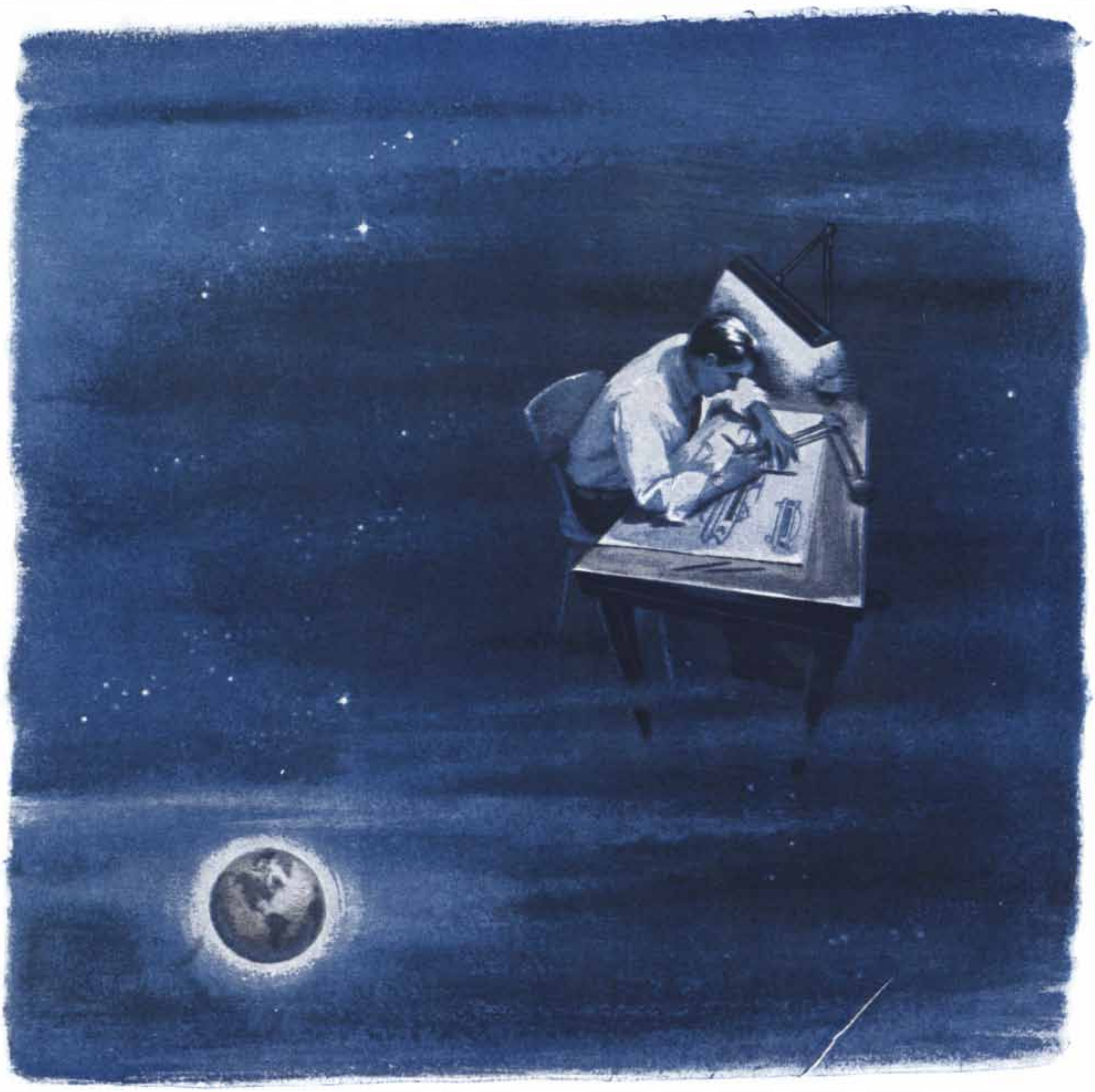


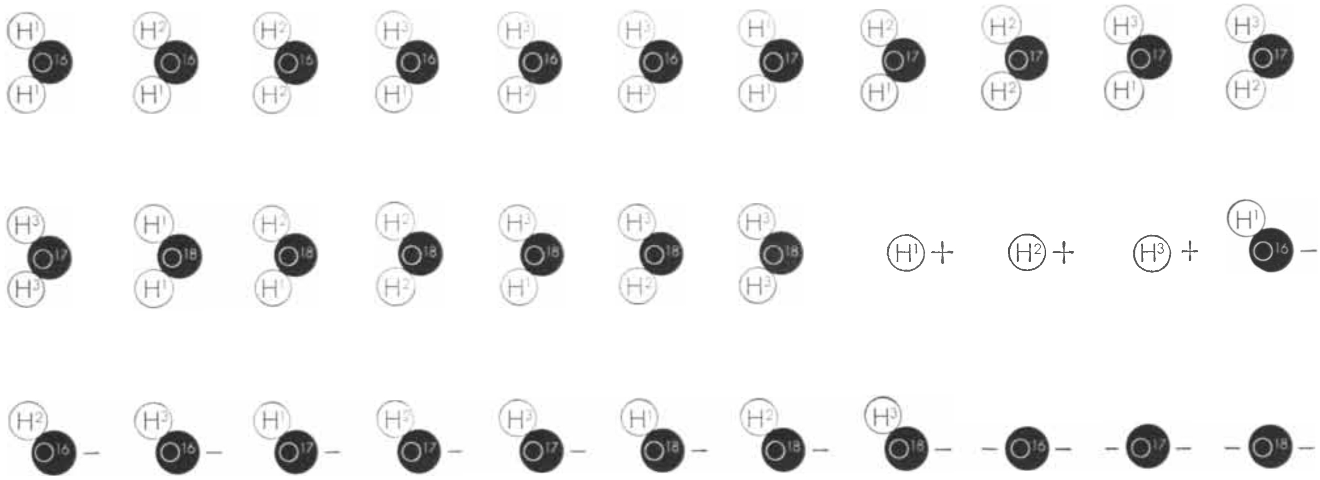
is exhibited on the macroscopic scale in the form of snowflakes. Each molecule is surrounded by four nearest neighbors, so that the group has one molecule at the center and the other four at the corners of a tetrahedron. The molecules and groups of molecules are joined together by hydrogen bonds.

The forces of attraction between the molecules in ice or water produce a strong inward pressure. As we shall see, this accounts for some of water's peculiar properties. In the form of ice, its open structure resembles a bridge arch under heavy downward stress. When the temperature of the ice rises to zero centigrade, the thermal agitation of the molecules is sufficient to cause the ice structure to collapse, and the water becomes fluid. It is well known that the application of pressure from outside will make ice melt at a lower temperature; evidently this reinforces the internal pressure within the ice and assists its collapse. Contrariwise, we can assume that if the internal pressure is reduced in some way, the melting point of ice will rise. Calculations indicate that if this pressure were entirely eliminated, ice would not melt until its temperature reached 15 degrees or more centigrade (59 degrees Fahrenheit).

According to X-ray determinations, the average distance between the center of one oxygen atom and the center of the next in the ice crystal is 2.72 Angstrom units (an Angstrom being one hundred-millionth of a centimeter). When ice melts to liquid water, the hydrogen bonds are stretched and the molecules move farther apart: the distance between oxygens is increased to about 2.9 Angstroms on the average. This stretching would open the structure further and make water less dense were it not for the fact that in the fluid the molecules crowd together in more compact groups. Each molecule is now surrounded by five or more neighbors instead of only four.

The chaotic disorder in which water molecules exist in the liquid state is difficult to picture. Their arrangement shifts continually. The angle between the two hydrogen atoms in the water molecule no longer remains fixed near a right angle but becomes variable, so that the molecule is flexible. Each oxygen atom now attracts by electrical forces not two extra hydrogen atoms as in ice, but three or more. Thus we may find an oxygen atom surrounded by five or six hydrogens and a hydrogen atom surrounded by as many as three oxygens. In the closely knit, flexible structure the hydrogens constantly shift their posi-





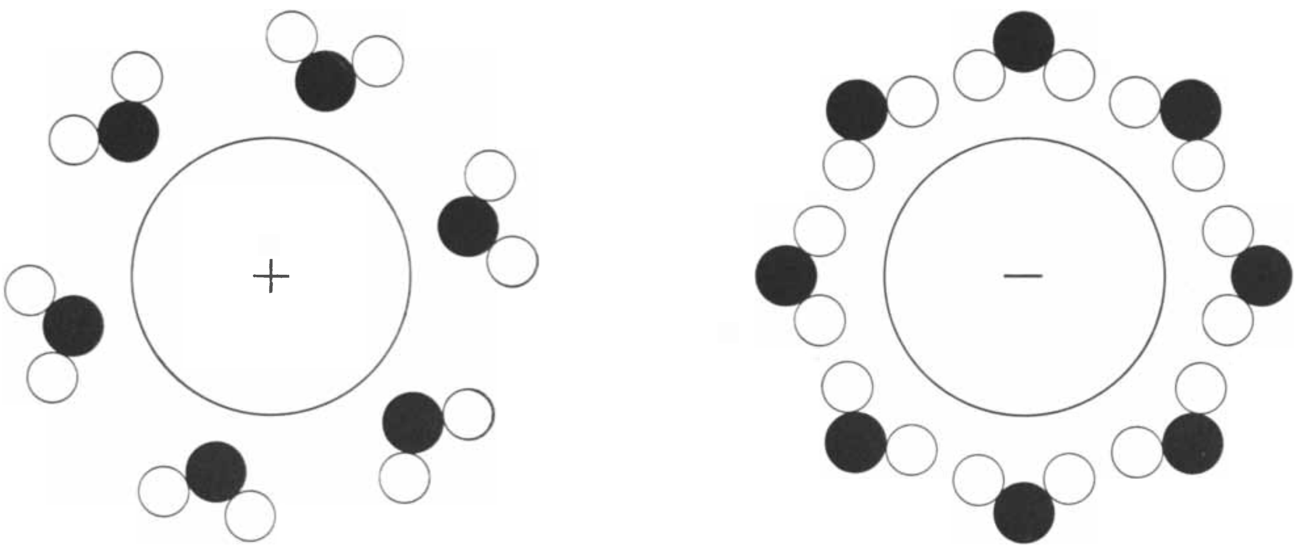
WATER IS NOT H_2O but a mixture of 33 different substances. Eighteen of these are combinations of three isotopes of hydrogen and three of oxygen. The three hydrogen isotopes are ordinary hydrogen (H^1), deuterium (H^2) and tritium (H^3). The three oxygen isotopes are ordinary oxygen (O^{16}), oxygen 17 and oxygen 18. The remaining substances are various ions (*plus or minus signs*).

tions and displace one another. Each such displacement is propagated in a chain or zipper fashion throughout the liquid. This has consequences which affect the viscosity, dielectric constant and electrical conductivity of water.

Water's Properties

In an ordinary unassociated liquid such as benzene the molecules flow by sliding around one another. In water the motion is rolling rather than sliding. Since the molecules are connected by hydrogen bonds, at least one bond must be broken before any flow can occur. From the fact that the molecules are bonded together, it might be expected theoretically that the viscosity of water should be comparatively high. However, each hydrogen bond in water is shared on the average between two other molecules, and one of these weakened bonds is easily broken. The greater viscosity of ice is due to the fact that each hydrogen is bonded to only a single oxygen atom from another molecule, and this firmer bond must be broken before any movement can occur.

The dielectric constant of a liquid is a measure of its capacity to neutralize the attraction between electrical charges. For example, when sodium chloride dissolves in water, the positively charged sodium and negatively charged chlorine ions are separated. They are kept apart because water has a high dielectric constant—the highest of any known liquid. It reduces the force of attraction between the oppositely charged ions in solution to not much more than 1 per cent of the original value. The reason for water's strong neutralizing action lies in the arrangement of its molecules. In an aggregation of water molecules a hydrogen atom does not share its electron equally with the oxygen atom to which it is attached: the electron is closer to the oxygen atom than to the hydrogen. As a result the hydrogen atoms are positively charged and the oxygen negatively charged. Now when a substance is dissolved, separating into ions, the oxygen atoms are attracted to the positive ions and the hydrogens to the negative ones. Consequently water molecules surrounding a positive



IONS (*circles labeled with plus and minus signs*) in water are kept apart because they polarize the water molecules around them. Because the oxygen atom of the water molecule has more negative charge than the hydrogen atoms, it is attracted to a positive ion (*left*). Because the hydrogen atoms have more positive charge than the oxygen atom, they are attracted to a negative ion (*right*).

Rare Earth Chloride

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a report by LINDSAY

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The rare earths are trivalent metals, and rare earth chloride is an excellent source, and an economical source, of these heavy metals. It is a water-soluble salt showing relatively little hydrolysis. Like most other rare earth salts, its basicity is generally like that of calcium salts.

° ° ° °

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It's a versatile material, this rare earth chloride – it is used in paint and ink driers, as an anti-corrosive treatment for filter cloths, and in many other applications.

This unique material (there is nothing else quite like it) is challenging the imagination of research people in a wide variety of industries. Some see it as a possible replacement for other, higher cost materials. Others are exploring it with a view to improving production processes, enhancing product quality, and developing by-products.

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You may have research projects or production processes in which rare earth chloride could be of help. To satisfy a researcher's insatiable curiosity, or to appraise its potentials in your operations, it will reward you to talk with us about rare earth chlorides. We'll be happy to send you technical data and a typical analysis.

Photos show latest addition to Lindsay monazite processing plant at West Chicago and a car being loaded with rare earth chloride for shipment to a Lindsay customer.

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ion are oriented with their oxygens next to the ion, and molecules around a negative ion turn their hydrogens toward the ion. Thus the water molecules act as cages which separate and neutralize the ions. This explains why water is so effective a solvent for electrolytes (substances which dissociate into ions) such as sodium chloride.

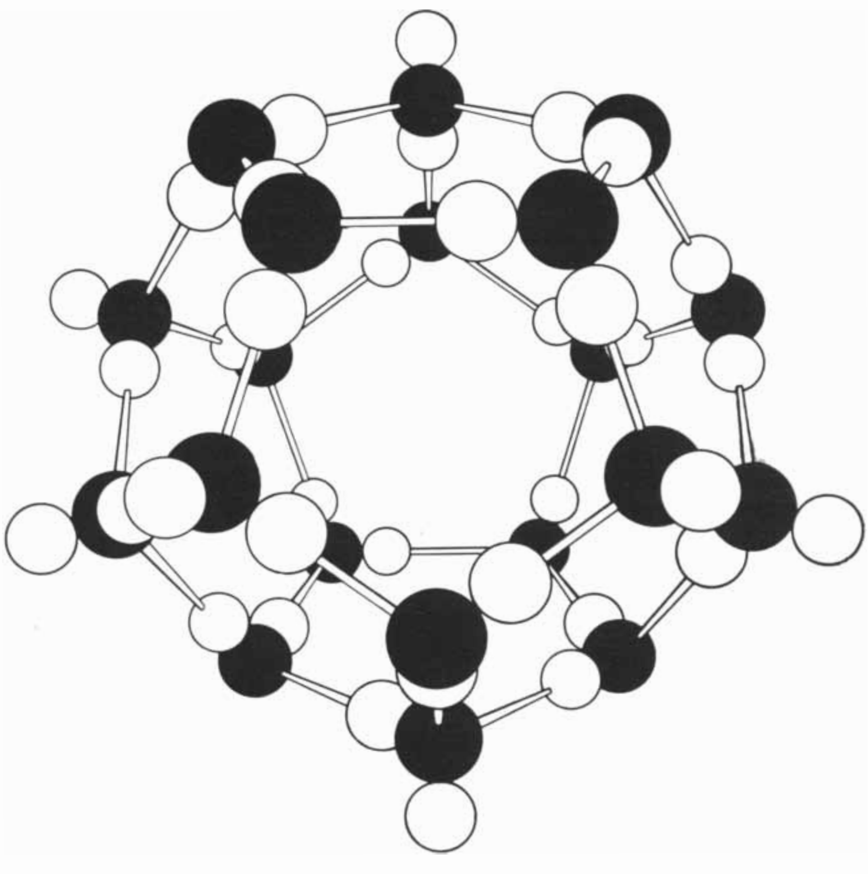
Water is generally supposed to be a good conductor of electricity. Every lineman knows the danger of handling high-voltage electrical lines when standing on a moist surface. Actually the conductivity is due to impurities dissolved in the water. Water is such a good solvent for electrolytes, including carbon dioxide from the atmosphere, that any moist surface may be assumed to be a good conductor. But pure water (which is difficult to keep pure—it must be kept out of contact with air and in a vessel of an inert material such as quartz) is a very good insulator indeed. The reason is that while the hydrogen and oxygen atoms in a water molecule are in a sense charged, or ionized, they cannot move about separately because they are attached to each other, and hence cannot carry an electric current.

One of the anomalous properties of liquid water is its high specific heat, or heat-holding capacity. The specific heat of a substance is the quantity of heat required to raise the temperature of one gram one degree centigrade. The specific heat of liquid water is more than twice as great as that of ice. The explanation is that the liquid's ionized oxygen and hydrogen atoms, though held together, behave like free ions in their capacity to vibrate in response to heat. Thus they can absorb as much energy as if the ions were really free.

The strong bonding of water molecules accounts for the fact that water has unusually high melting and boiling points. It also explains why it is so difficult to vaporize ice. To do this we must break all the hydrogen bonds holding the molecules together. Calculations indicate that the total energy of the hydrogen bonds in one mole of water (18 grams) is equivalent to 6,000 calories.

Hydrates

For more than 60 years physical chemists have studied water largely in terms of solutions of electrolytes. This



HYDRATE is formed when a foreign molecule in water is electrically neutral and just the right size for the water molecules to collect around it in crystalline cage. This cage can then grow to a much larger crystal. It is part of a repeating unit of 136 molecules.

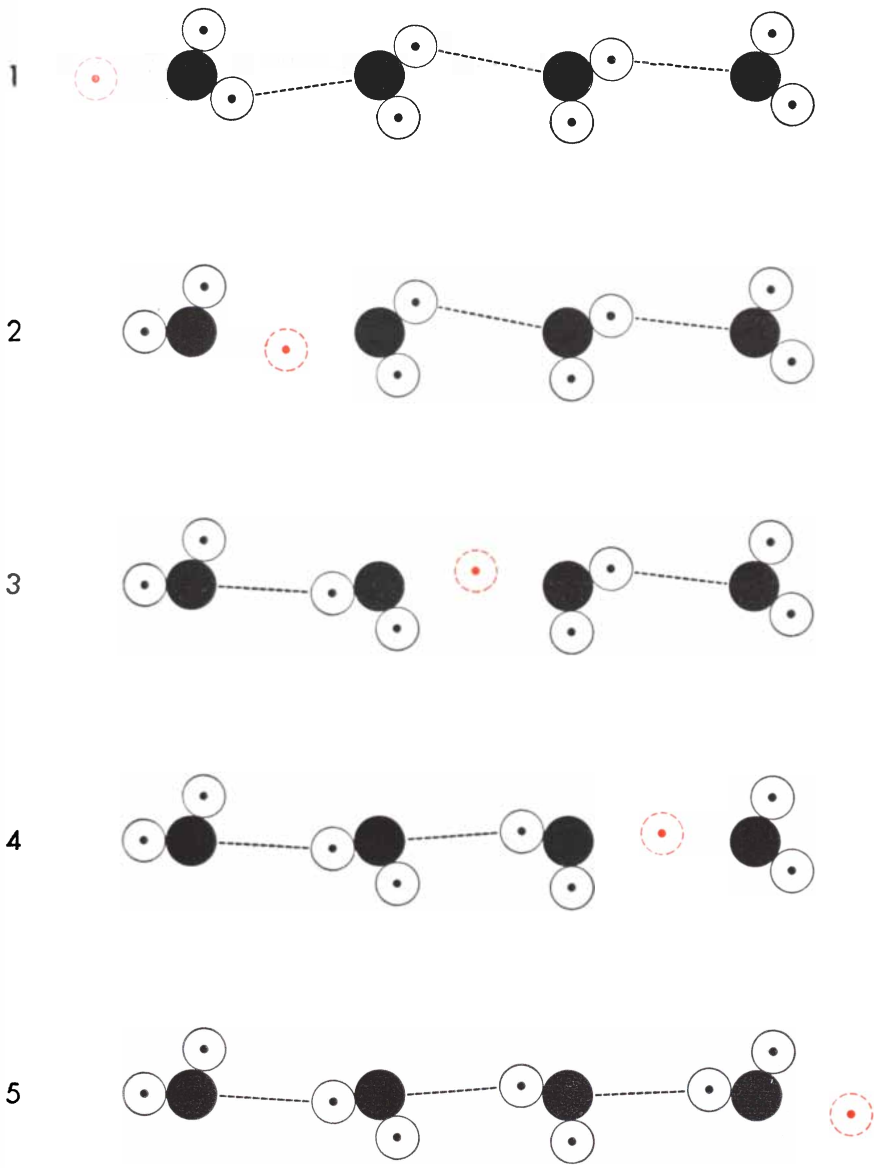
study has produced considerable information about electrolytes and ions, but not a great deal about the properties of water itself. Strangely enough, in recent years we have learned much more about water by examining its behavior with substances which for all practical purposes are insoluble in water!

This behavior was called to the attention of chemists in a dramatic fashion by certain surprising natural phenomena. One was the fact that corn sometimes showed frost effects when the temperature was 40 degrees F., well above freezing. Another was the discovery that pipelines carrying natural gas often became clogged with a slushy "snow," containing water, at temperatures as high as 68 degrees F. The plain indication was that these freeze-ups were due to the water. But this raised some startling and interesting questions. What made water freeze at these high temperatures? How could water combine, or become "bound," with substances which were all but insoluble in it? The mystery was not lessened when it was discovered that even the noble gases such as argon and krypton, which refuse all chemical reactions, could join with water to form a quasi compound.

Let us look at these questions in the light of what we have learned about water's structure and properties. Ten years ago in Illinois we began a study of the water-solubility of certain hydrocarbons. Methane gas will serve as an example. The methane molecule does not form ions in water, nor does it accept the hydrogen bonds. There is very little attraction between it and the water molecule. It is, however, slightly soluble in water, and the dissolving methane molecules form compounds with water—"hydrates"—in which several water molecules are joined to one of methane.

The reaction liberates 10 times as much heat as when methane dissolves in hexane, although it is much more soluble in hexane than in water. This fact becomes even more surprising on close examination. The methane molecule occupies more than twice the volume of a water molecule. To form this relatively large cavity for itself on dissolving, a great deal of energy would be required: it should be somewhat greater than the heat of vaporization of water—say 10,000 calories per mole. How could so much energy be provided? The forces of attraction between methane and water are apparently too slight to supply any appreciable part of such an amount.

There is an alternative possibility. The presence of the methane may drastically change the water structure itself.



RAPID MIGRATION OF HYDROGEN IONS through water is explained by the assumption that the ions do not actually travel through the water but are passed from one molecule to the next by a process of exchange. Here the hydrogen ion is represented by a red dot surrounded by a broken circle. In the first horizontal row the hydrogen ion approaches a water molecule. In the second row the ion has taken the place of one hydrogen atom of the molecule, expelling the atom as a new ion. In the third row the new ion repeats this process.

Let us suppose that the dissolved methane molecule is surrounded by an envelope of 10 or 20 water molecules. The formation of such a structure would account for the heat liberated. In the space occupied by the methane molecule the attractive force on the water molecules, and hence the inward pressure, would disappear. Under these conditions, as we have seen, water will freeze at a higher temperature. Thus the molecules at the interface between the methane and water molecules may crystallize into "ice." The frozen hydrates may accumulate and separate out of the solution.

This hypothesis is known as the "iceberg" theory. It is supported by the fact that practically all the nonelectrolytic substances tested have been found to form solid crystalline hydrates. In contrast, electrolytes show little tendency to form them.

All this leads to an entirely new concept of solubility. Chemists have long supposed that solubility always involves attractive forces. But it now appears that the dissolution of a nonelectrolyte is due not to an attraction between the substance and water but to a lack of attraction. The nonionic substances combine with water because they remove internal pressure and thereby permit formation of a crystalline compound.

In order to understand the formation

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of these hydrates, it is necessary to consider their molecular structure in detail. They tend to fall into groups according to the number of water molecules they contain.

The ground work for the study of the hydrates structure was laid by M. von Stackelberg in Germany 10 years ago. He showed by X-ray studies that this structure was cubic, in contrast to the hexagonal structure of ice. W. F. Claussen of our laboratory recently attacked the problem of building such cubic structures, each containing a gas molecule, into a repeating lattice. It turns out that there are two possible cubic lattices, one of which was proposed and worked out by Linus Pauling of the California Institute of Technology. This has a spacing of 12 Angstroms between molecules while the other has 17 Angstroms. The smaller lattice contains 46 water molecules and the larger one 136. The holes for gas molecules in the smaller lattice have 12 or 14 walls, while those in the larger one have 12 or 16 sides. These holes are of different sizes and make possible a bewildering array of hydrates. The different sized holes can be filled only with different sized molecules, and not all the holes in a lattice need be filled. The model explains the actual composition of hydrates with remarkable precision.

The importance of this type of hydrate to the processes of life cannot be overemphasized. These processes occur mainly at the interfaces between water and protein molecules. Water has a very strong tendency to crystallize there, for the protein molecule contains large nonionic, or nonpolar groups. Any hydrate so formed has a lower density than ice; consequently its formation can cause a large, destructive expansion.

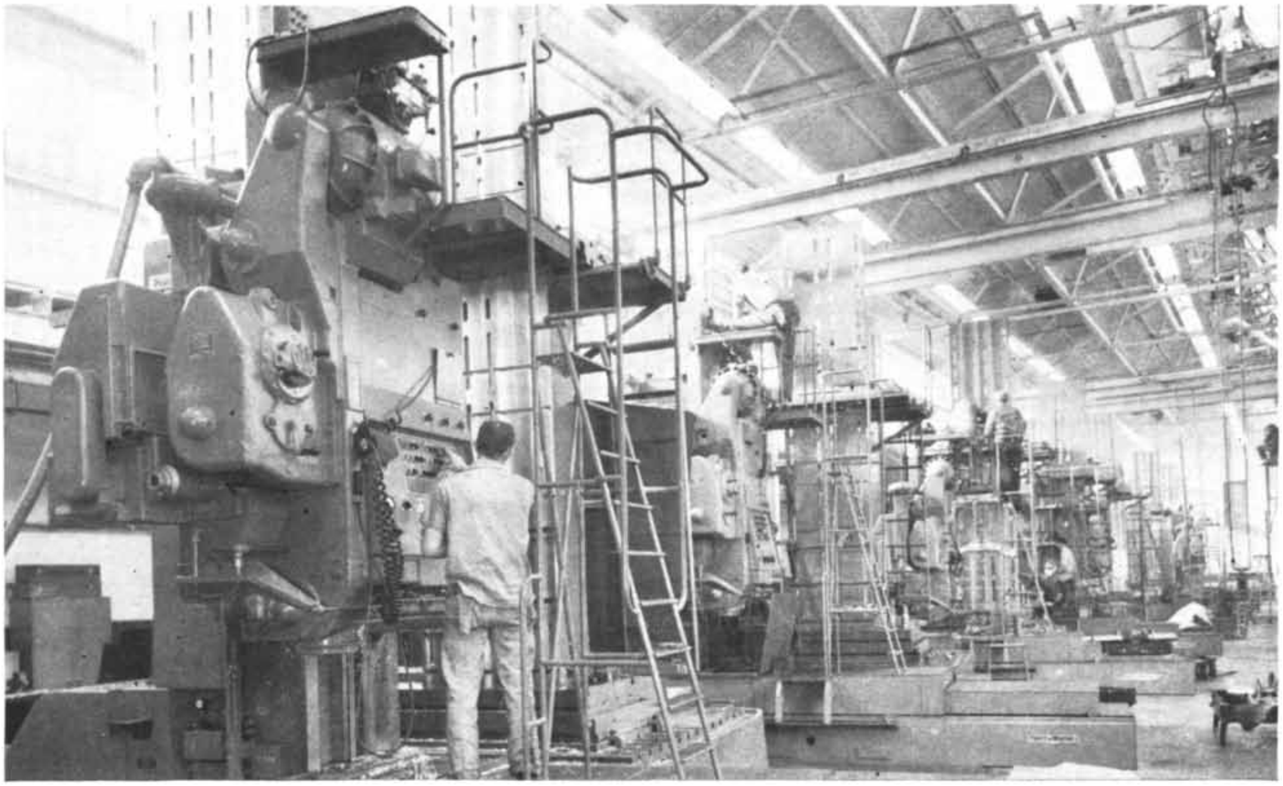
The freezing of corn at a temperature of 40 degrees F. becomes understandable in terms of the formation of a hydrate. Winter wheat, on the other hand, forms hydrates slowly as temperatures drop through the fall, and under these conditions the hydrate acts as an effective antifreeze protecting the cells from damage.

The frozen food industry uses rapid freezing to avoid the formation of large crystals which would damage the plant cells. But it might be well to explore the possibility of the opposite approach. Very slow cooling of living plant foods might form hydrates which would prevent damage from ice crystals when the plant was frozen.

Let us return now to see how the structure of water may be modified when an electrolyte, say a salt, goes into solution. The only direct physical clue we have lies in the behavior of the salt ions in conducting an electric current. The rate of motion of the ions will depend in part on the resistance they encounter in the liquid, and this in turn will depend on the size of the moving particles. If water molecules are attached to an ion firmly enough to move along with it, they will of course increase the apparent size of the ion. Studies of the mobilities of various ions show that positive ions smaller than potassium carry such a cage of water molecules with them. The positively charged ion attracts the oxygens of two water molecules quite strongly, and if the volume of the ion plus its two water molecules is not greater than that of a methane molecule, a cage of hydrogen-bonded water molecules will form around this group as a nucleus. Positive ions larger than potassium fail to pick up such a cage. The same is true of most, but not all, negative ions.

The positively charged hydrogen ion and the negatively charged hydroxyl ion (OH) are surrounded by cages, and yet they show the highest mobility in carrying a current. We must conclude that they manage in some way to escape from the cage. Actually the mechanism is not hard to picture: they continually form new cages as they travel by a process called proton transfer. Under the influence of an electric field a hydrogen ion may jump from one water molecule to the next. When this has occurred, the hydrogen on the farther side of the water molecule takes up its part in the race like a relay runner and jumps to the next water molecule. Thus a succession of protons, each doing its bit, carries the current. The motion is rapid, because each proton moves only a short step. Transfer of the proton also explains the conduction of electricity by hydroxyl ions. When a proton jumps toward the right, say, and joins a hydroxyl ion, it leaves a hydroxyl ion on its left. The effect is the same as if a hydroxyl itself moved to the left.

Water, then, is not simple H_2O but a unique and complicated material with distinct and varied chemical properties. It has a definite though changing physical structure which depends on the orientation of its molecules with respect to one another and to the molecules of dissolved substances. Since the behavior of all living nature and much of the inanimate world is inseparably linked to the peculiar characteristics of this liquid, the study of water substance can tell us a great deal about fundamental aspects of the world in which we live.



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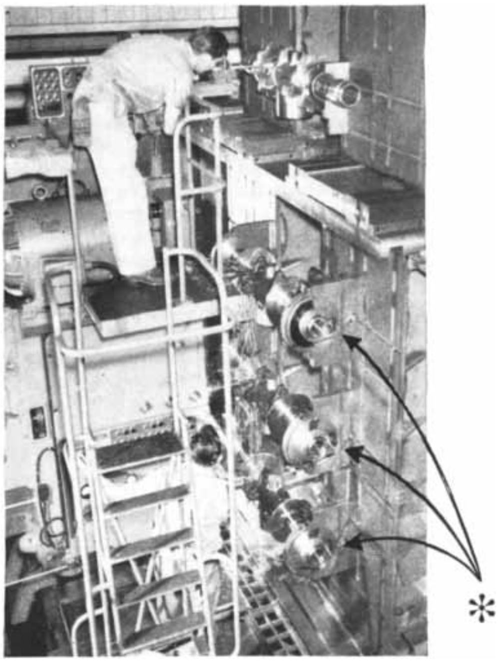

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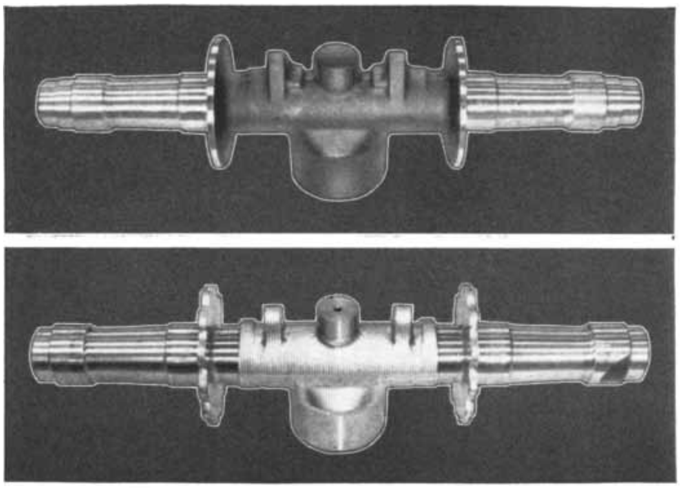

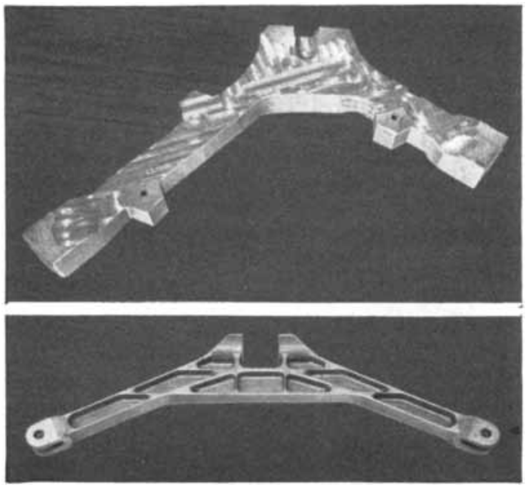

General view of the Kellering Department at CPT, showing the 8 new 3-spindle Kellers.

Top photo shows an aircraft axle before it was Kellered. Bottom photo shows it after Kellering.

This aircraft structural part has been Kellered from a rough forging similar to the one shown at top.

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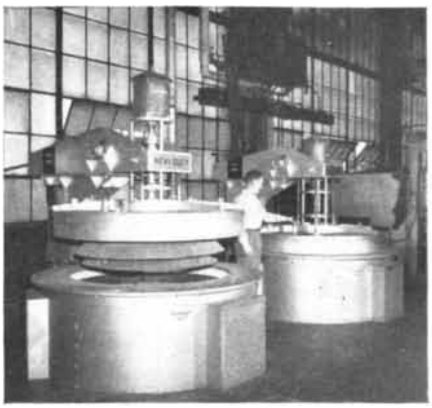
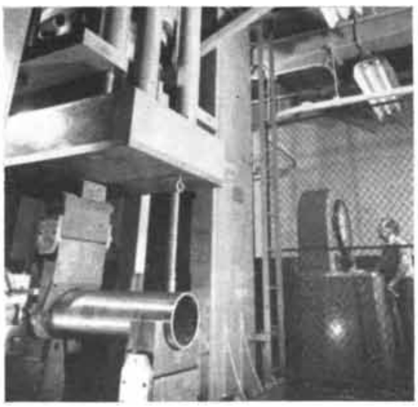
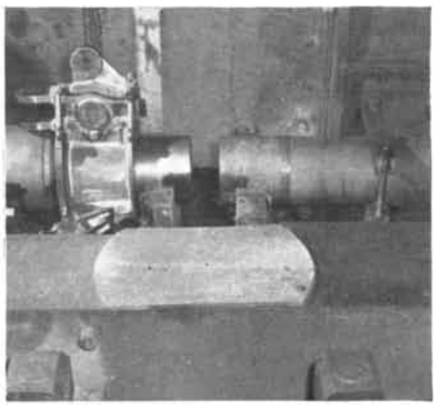


Part of the battery of electric heat-treating furnaces at CPT. Pieces up to 13 feet long can be handled in these furnaces and quench tanks.



CPT's Baldwin-Southwark one-million-pound-capacity tensile testing machine can exert this pressure either in tension or compression.



Kellered head section about to be joined to cylinder tube by resistance welding on CPT's giant flash-butt welder.

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Animal Sounds in the Sea

During World War II underwater-sound men were puzzled to hear weird noises that were not made by ships. Now it is known that many marine species emit, among other sounds, chirps, whistles, grunts and groans

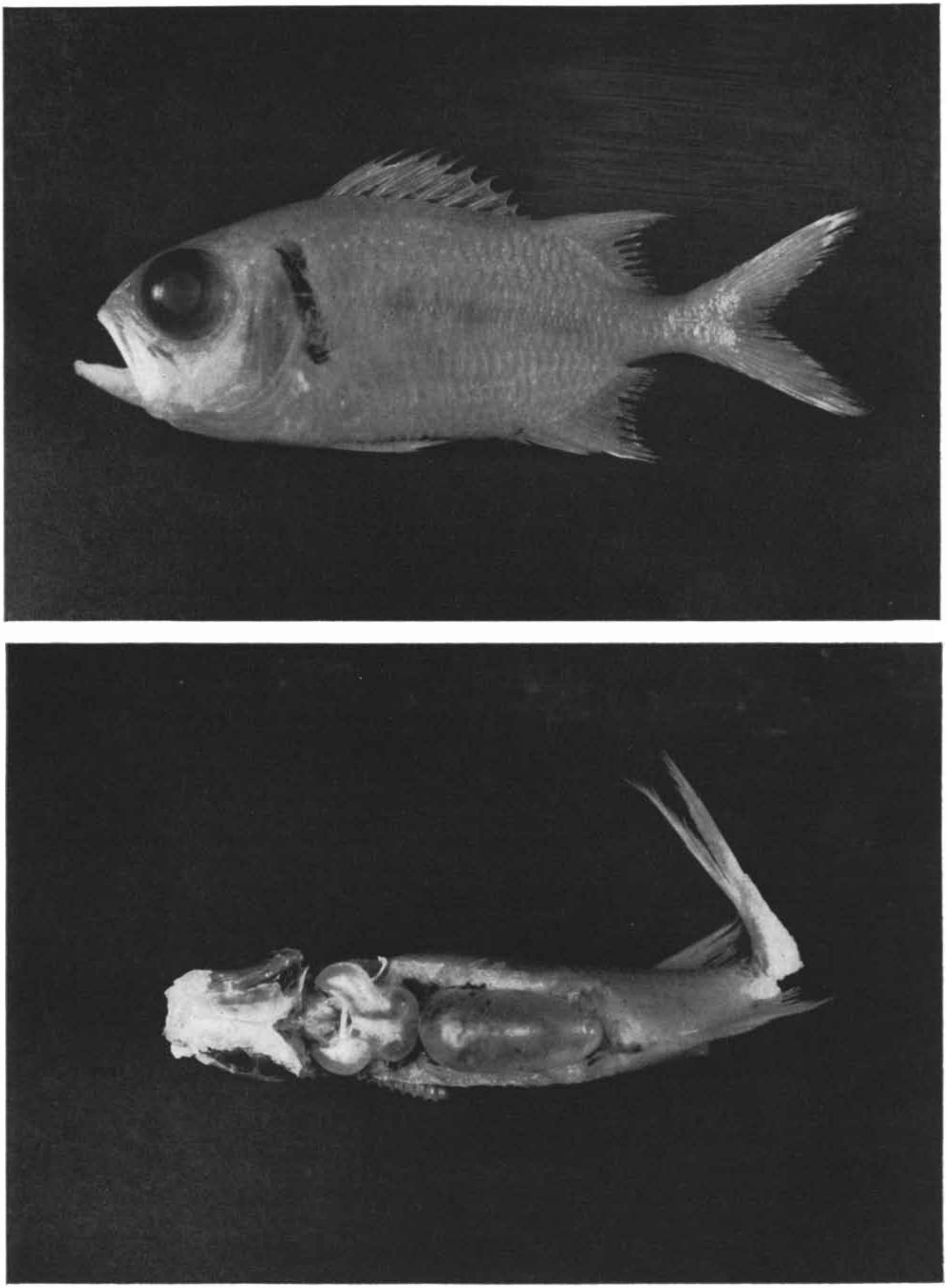
by Marie Poland Fish

Traditionally the sea is synonymous with silence. Novelists have ever loved to brood upon its vast quiet, and mariners voyaging over the soundless oceans have stood their long silent watches from time immemorial without suspecting that the sea deeps held anything but the stillness of the grave. And yet if they had pondered a fact which they might have remembered from their physics lessons, they should have been more suspicious. The ocean surface is an insulating wall that almost totally bars the passage of sound from the water into the air or from the air into the water. To fishes, the cackling, brawling world of the air inhabitants is soundless. We are just as deaf to their world. Is it possible that it is as noisy as ours?

During World War II the ocean waters were explored widely for the first time with sensitive listening devices. The submarine eavesdroppers had a startling and ghostly experience. They heard sounds which they took to be from ships where there were no ships. A bedlam of mysterious "beeps," "groans," "croaks," "crackles," "whistles" and "moans" came to their earphones. Gradually the Navy began to suspect that these noises were the chatter of underwater animals. After the war the Office of Naval Research launched a comprehensive study of sea-animal sounds.

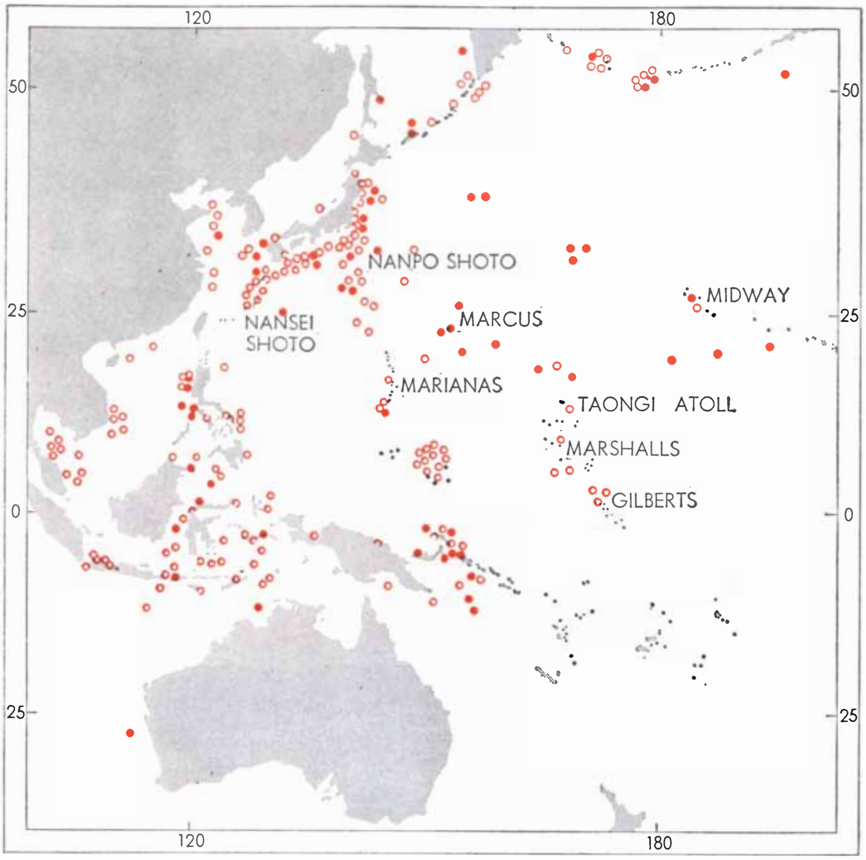
Our laboratory at the University of

AUTHOR RECORDS SOUND made by a fish in an aquarium at the Narragansett Marine Laboratory of the University of Rhode Island. Suspended at the right side of the aquarium is a cylindrical hydrophone. In the center foreground is a tape-recording machine.



SQUIRRELFISH makes a rasping grunt by amplifying with an air bladder the sound made by grinding two toothed areas in the back of its mouth. At the bottom the fish is shown from below after dissection. The constricted, translucent object is the air bladder.

Rhode Island, with O.N.R. support, has been investigating the subject for seven years and has learned something about the noises and languages of the sea inhabitants. We have listened with hydrophones and recorded on tape the sounds of hundreds of species of animals, from shrimps to porpoises. The articulate denizens of the sea "speak" a confusing variety of dialects, but each is distinctive, and with experience one can learn to identify the kind of animal by its sounds, as one recognizes a familiar voice on the telephone. Listening to tropical fishes in the waters of the Caribbean, we have often been able to recognize them on approach even before they came into view.



DISTRIBUTION OF ANIMAL SOUNDS in the western Pacific was plotted on submarine reports. The open circles are unidentified animal sounds; the dots, marine mammal sounds.

Fishes and other sea animals have no vocal organs: they make sounds in diverse and intriguing ways which sometimes involve a large part of the anatomy. A convenient way to describe and classify them is by their sound-making method.

One group produces sound by vibrating the walls of their balloon-like air bladder, the bladder acting like a soundbox or drum. The toadfish, for example, sets up vibrations of its bladder by means of muscle contractions, and the sound emitted ranges from a grunt to a "foghorn" boom. We demonstrated that the sound originates in the air bladder by experiments. When the bladder was removed, the fish could produce no sound. But the air bladder alone, placed in a jar of sea water and stimulated by electricity, emitted grunts which were typically "toadfish" to the ear.

The sea robin has a similar mechanism. Its air bladder is vibrated by contraction of border muscles, but it also has in the left lobe of the bladder a thin partition perforated by a tiny hole; when gas is forced through the hole, the partition vibrates and presumably strengthens the sound waves. The larger the fish, the lower the pitch of its grunt. Sea robins with small bladders may emit sounds with frequencies 200 cycles per second higher than those with large sacs.

The triggerfish carries the drum principle to its logical conclusion. A taut membrane—a kind of outer window of the air bladder—lies just below each pectoral fin, and the rays of the fin beat on the membrane like drumsticks.

The croaker and certain other fishes use the bladder for sound-making in a somewhat different manner. Their bladder is set in motion by straplike muscles attached to the backbone or skull, which vibrate like violin strings. The result is a rhythmic roll of rapid grunts or croaks.

A second class of sound-makers produce noises by scraping one body part against another. Particularly common are the teeth-grinders. The squirrelfish, for example, grinds together toothed areas in the back of its mouth, called gill teeth, and thus generates a sound which is amplified by the adjacent air bladder and becomes a rasping grunt. The parrot fish, rubbing together sets of gill teeth, emits a scratchy crackle. The filefish has front incisors with fine ridges which when scraped generate a loud, metallic rasp. The porcupine fish simply rubs together its toothless jaws and generates a raspy whine which sounds like a saw or the creaking of a rusty hinge. This noise may be as frightening to the fish's enemies as its sharp spines.

One of the most puzzling sounds we encountered was that of the sculpins, a family of spiny sea fishes like the freshwater bullhead. These fishes issue a dull, low-pitched drone which suggests the hum of an electric generator. The sculpin has no air bladder, and it was difficult to imagine how the fish produced its sound. Examination of its anatomy and recent experiments suggest that the noise is made by rapid vibration of muscles attached to certain bones in its skeleton [*see illustration on page 98*].

Of all the fishes to which we have listened, by far the most garrulous is the sea robin. Most fishes try to make a silent escape when something strange approaches. Not the sea robins. They keep up a barrage of grunting and cackling—disturbed or undisturbed. Our hydrophones have even caught solitary ones occasionally "talking to themselves." When trawls are hauled in the sea robin grounds in Narragansett Bay, the fish often set up a pandemonium of squawking. A tame sea robin in an aquarium clucks softly when stroked, like a purring cat, but if it is handled too much, it will break away in seeming annoyance and emit a burst of noise.

Other fishes appear to be noisy only when noise is called for, in which they are not different from land animals: dogs do not bark continuously, nor do horses neigh without reason. With the approach of a ship, fishes usually cease

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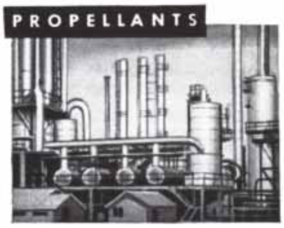

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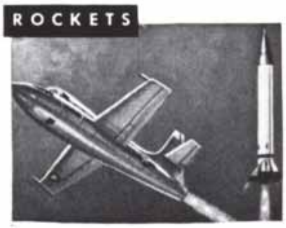

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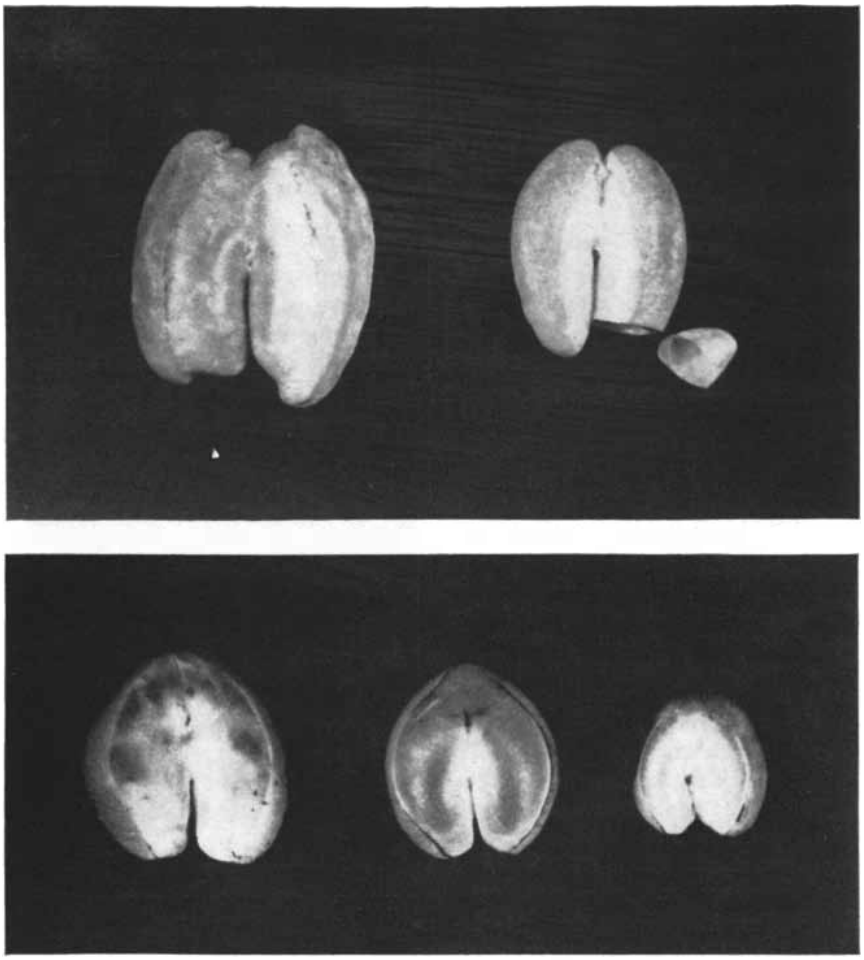


AIR BLADDERS are dissected out of two sea robins (*top*) and three toadfish (*bottom*). Both species produce a grunting noise. The larger the air bladder, the deeper the grunt.

their chatter instantly. In the waters of the West Indies we often noticed that a noisy school of fish became silent as it swam by our boat. When we lowered a hydrophone into a fenced enclosure of fish, complete silence would fall and we could see the fish dart noiselessly into corners or rock crevices.

Fish apparently make noises for a great variety of reasons. It should be no surprise that they use sound to communicate. Squirrelfishes, which are inclined to be nocturnal; eels and catfishes, which live in muddy, murky waters; croakers, which become most active after sunset—these and similar species must find sound useful for aggregating. Many fish become most loquacious during the spawning season. Indeed, around the Malay States they are so noisy that commercial fishermen send divers down to locate schools by ear.

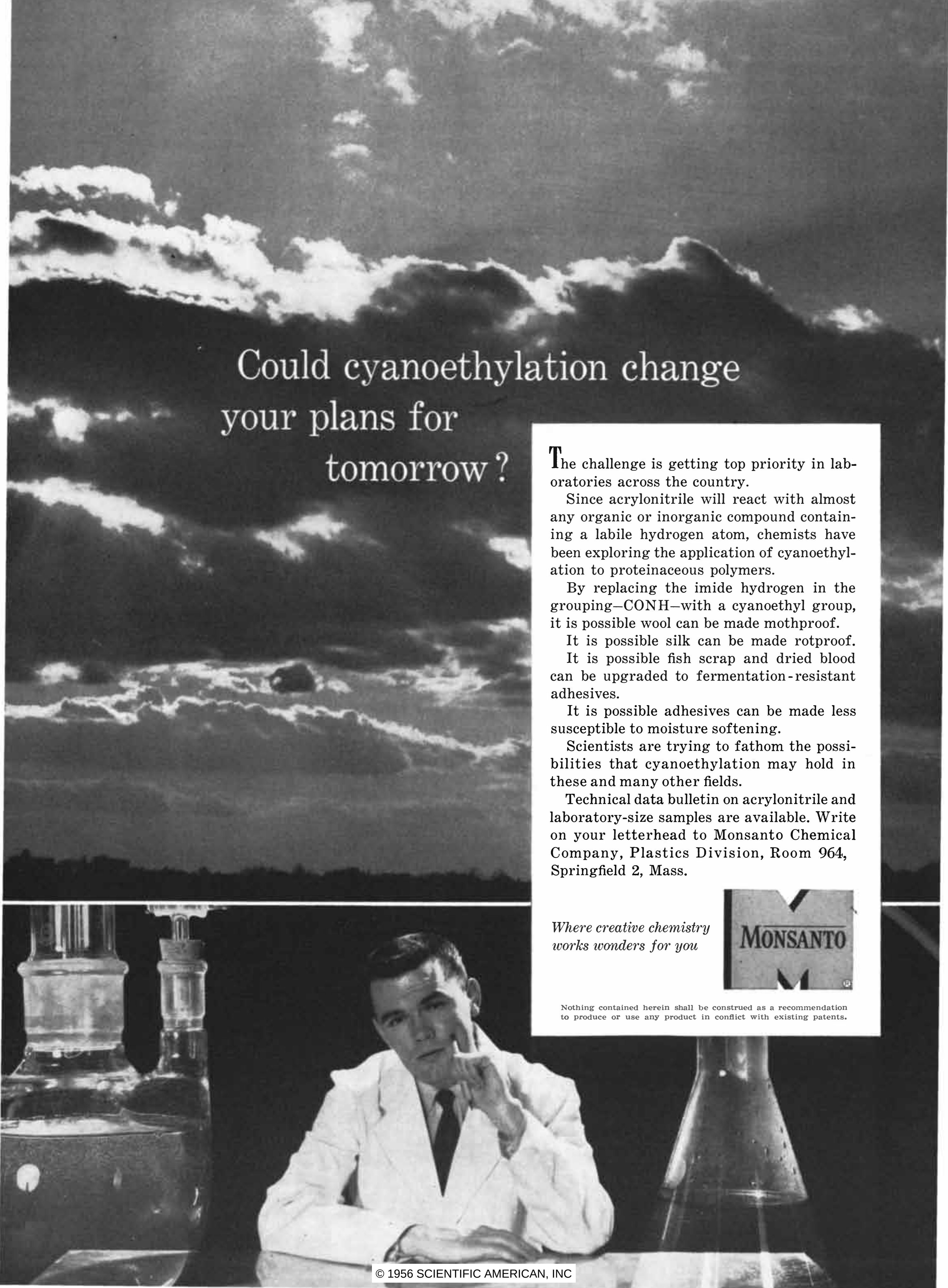
We were able to distinguish the toadfish's "mating call," which is quite different from its other sounds. Just before its spawning period our hydrophones picked up a medley of "foghorn" or "boat whistle" sounds arising from deeper water off the coast. The calls of individual fish were repeated at regular intervals of about 30 seconds, and sometimes we heard what seemed to be an "answer" from some fish at a distance. When the females had deposited their eggs in the shallow inlets, these clear, loud calls ended, and afterward the only sound that could be evoked was the low, coarse growl of the pugnacious males guarding the nests.

Competition seems to be a common stimulus to sound. Sprinkling of food in a tank of sonic fishes incites a general noisy commotion. A large-voiced fish that arrives late often can disband a whole group of competitors with a bellow. The arrival of a natural enemy may move fish to cries of alarm, and if a real fight occurs, the sound level rises abruptly. The frenzied chorus sometimes sounds like a mob reaction.

Experiments have indicated that sea horses may use sound for orientation. During the first few days of captivity they make vigorous snapping noises, apparently associated with the strangeness of the new environment. This sound stops when they have become accustomed to the aquarium, but if they are moved to a new one or if the water temperature is changed, it breaks out again.

Of the more primitive forms of sea life below the fishes, the animals that have given us the best records so far are the shrimps. In shallow, warm waters along the southern coasts our hydrophones pick up an almost continuous din, which sounds like "fat frying in a pan" or the burning of dry twigs. The so-called snapping shrimp has a plunger socket in the larger claw from which issues a popping sound, like a tight cork coming out of a full bottle. The combined popping of thousands of shrimps in their unseen beds makes a crackling chorus day and night. Experiments indicate that this noise accompanies the ejection of jets of water which the shrimps use for offense and defense.

SCULPIN (*top*) is the noisiest winter resident of Narragansett Bay. The needles (*bottom*) point to ridged areas where rapidly vibrating muscles produce a sustained droning noise.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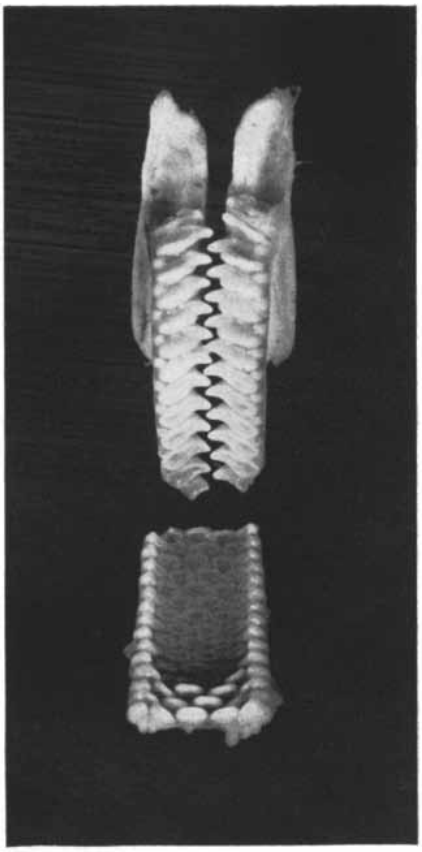


PHARYNGEAL TEETH are dissected out of the parrot fish. When they are rubbed together, they make a scratchy crackling sound.

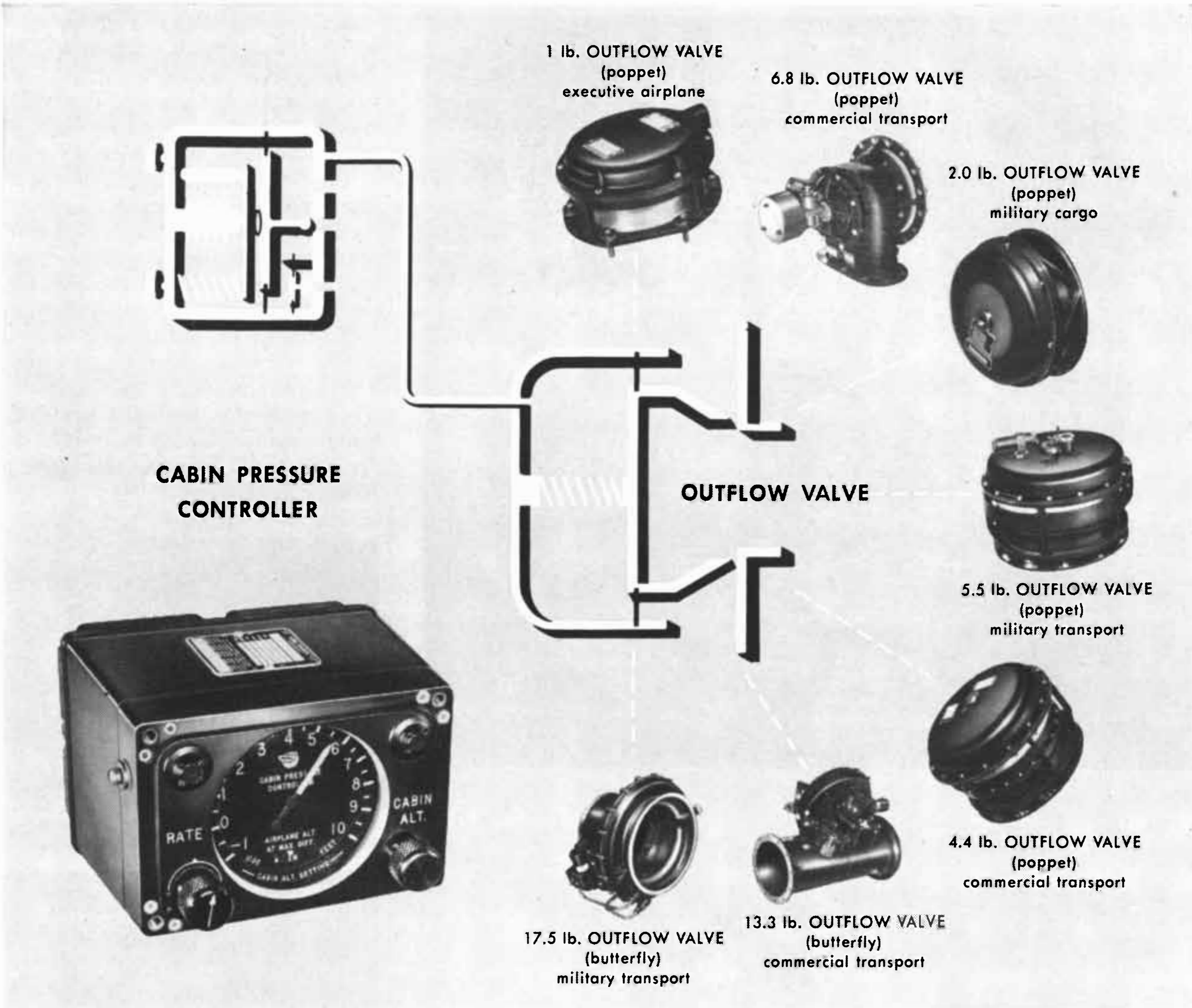
Virgil Harris of the Fish and Wildlife Service found that the commercial pink shrimp crackles when eating.

Spiny lobsters have given us good recordings. When startled or annoyed they noisily grind their antennae against their shells. Some crabs, squid and even barnacles are reportedly sonic.

As for the marine mammals, the noises of whales and porpoises may be heard all over the oceans. Submariners have described several types of these sounds. There are rhythmic "propeller or screw noises," clucking and squealing sounds covering the whole sound band, and pings suggestive of echo-ranging.

It seems safe to conclude that the din of animal life pervades the underwater world as it does our forests, countryside and cities on land. It is noisiest in the warm inshore waters, but even the deeps of the sea are not silent.

Learning the sea sounds and languages obviously has certain practical uses. Already the Navy has found the research helpful for predicting underwater sound conditions in strategic areas, for developing underwater acoustic gear and for training sonar operators. Commercial fishermen are using acoustic finders pat-



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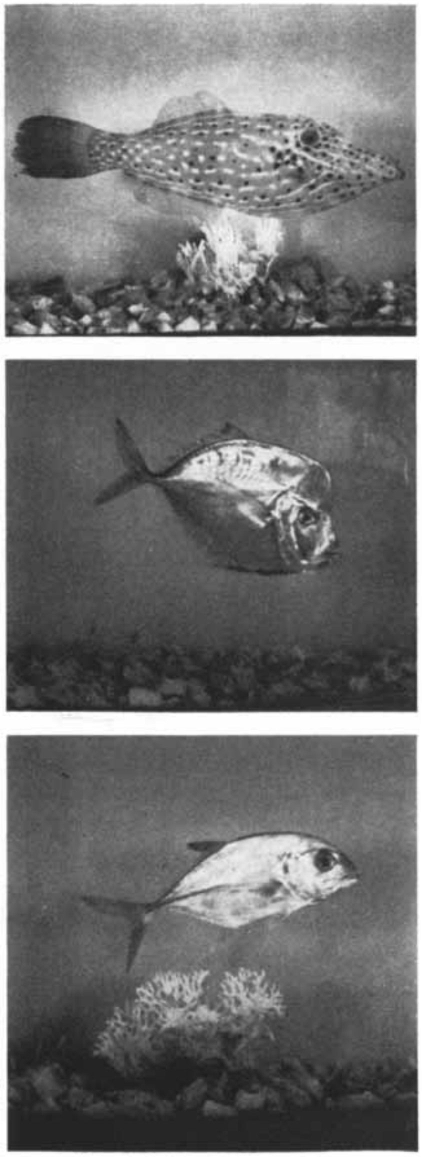
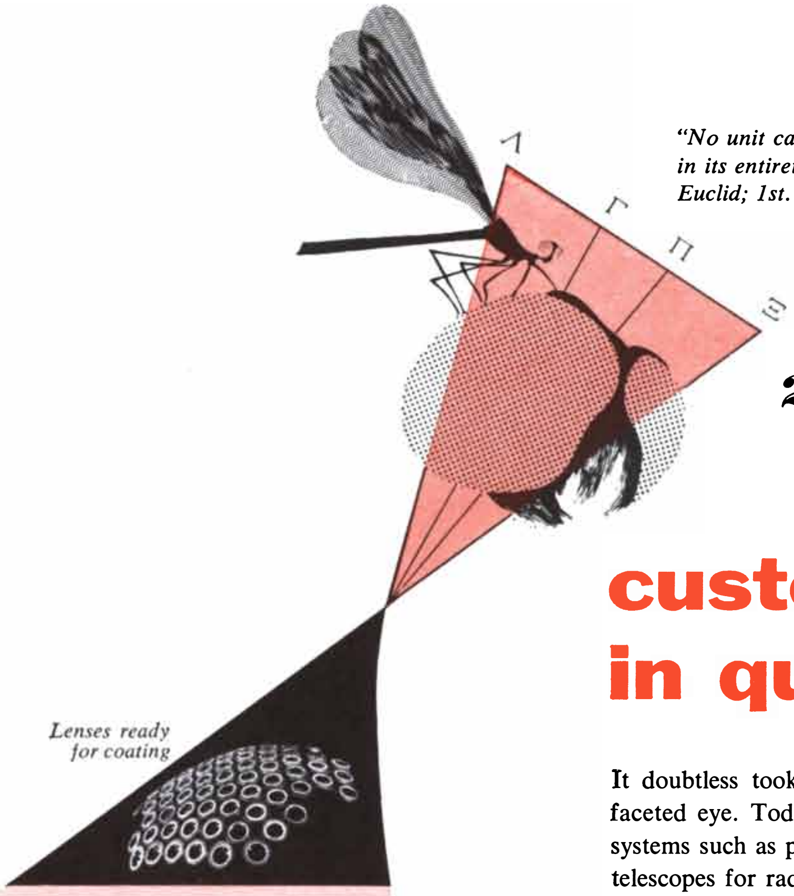
For biologists the research has opened a new world—the once silent world covering three quarters of the earth's surface. There is a lot of eavesdropping to be done down there.



THREE NOISEMAKERS are the filefish (*top*), which grinds its front teeth, the moonfish (*middle*), which grunts, and the horse-eyed jack (*bottom*), which croaks.



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THE HUMAN CROP

All animals are ultimately nourished by plants. Therefore the abundance of plants regulates the quantity of animals. How many acres of vegetation does it take to raise a man?

by Edward S. Deevey, Jr.

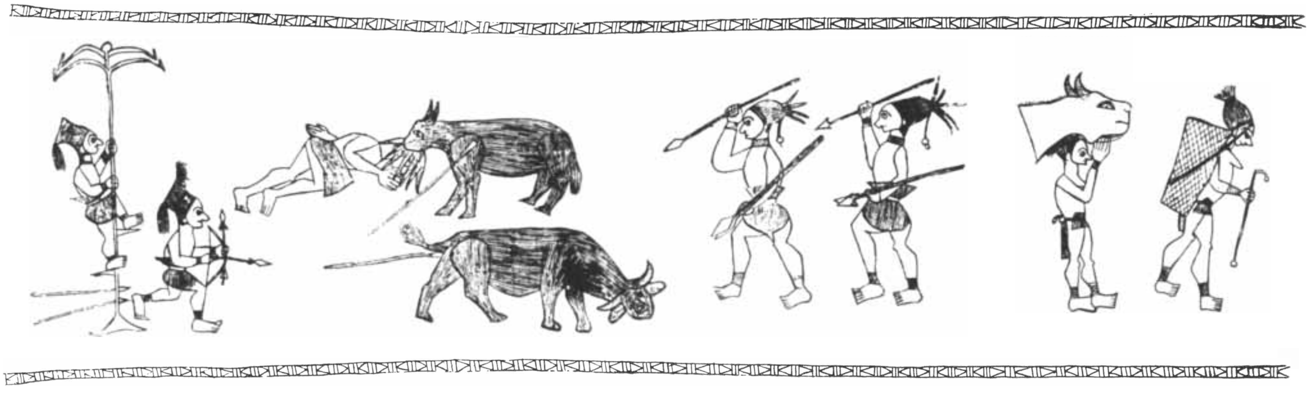
History's only recorded crop of human beings is the one reaped from dragon's teeth by Cadmus, but it may not be farfetched to regard the human race literally as a crop derived from the land. Some students of population believe that the ever-increasing harvest of human substance threatens to overflow the earth, like the porridge secreted by the magic pot in the Scottish folktale. In discussing this problem it is helpful to look at the production of human beings in the context of what ecologists say about productivity in general.

The fundamental idea is a good deal older than ecology and its jargon. All life on the earth receives its energy from the sun, but animals cannot use this energy directly; they must get their energy secondhand from the green plants. Since the plants spend some of their energy for their own vegetable purposes, and since animals which feed on them spend an even larger proportion of their energy in activities other than body-building, it follows that no area can produce as much animal as plant substance. Moreover, carnivores spend still more energy in chasing other animals than herbivores spend in grazing, so even if pursuit of food were the only means of dissipating energy, a carnivore would be an uneconomical beast. It is no accident that all of the animals man has domesticated for food (with the sole exception of the Aztecs' edible dog) are herbivores.

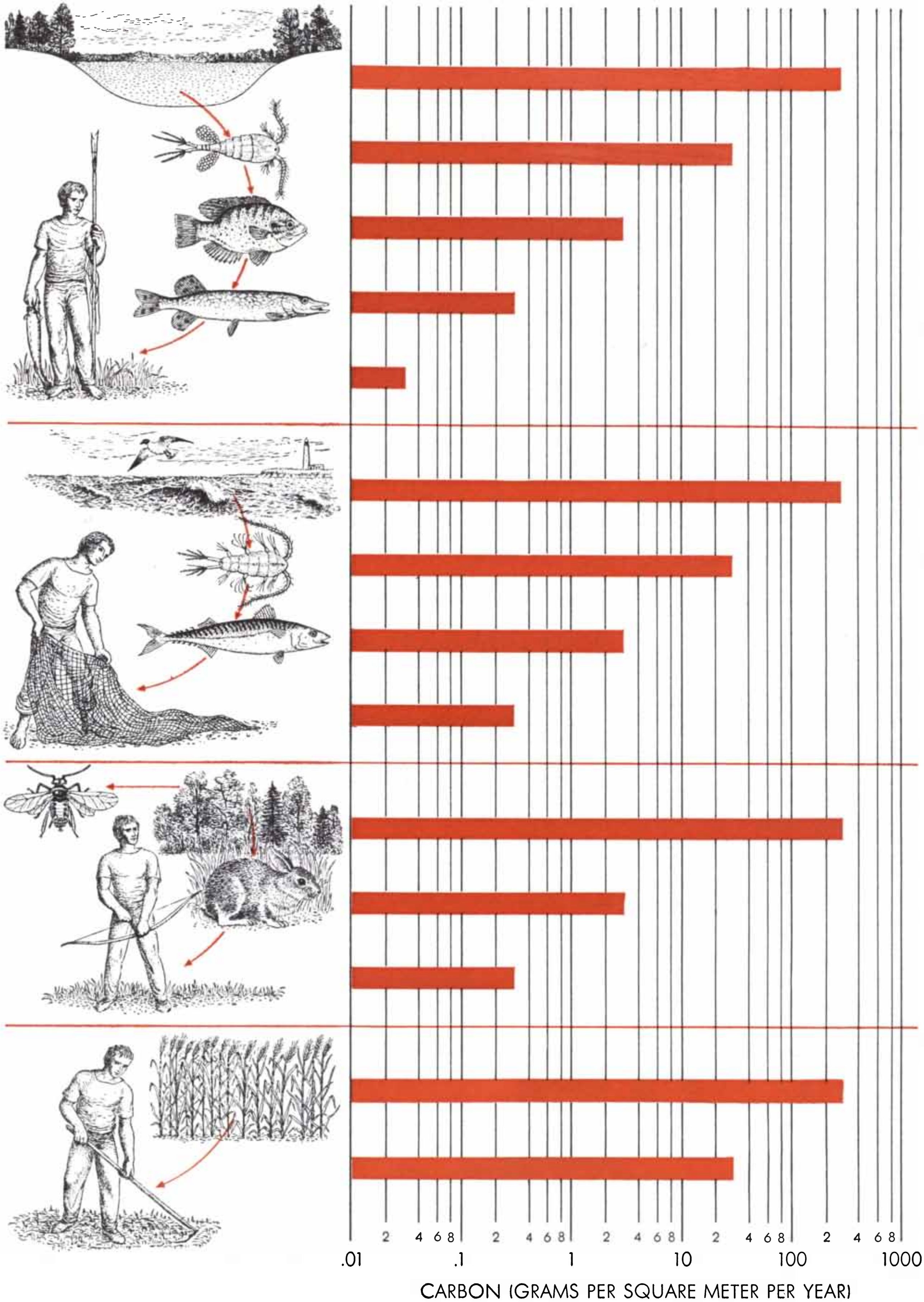
The late Raymond Lindeman, of the University of Minnesota, made a notable attempt to compute the energy balance sheet of a whole community. His working model was a small lake near Minneapolis. He studied the rates of production and turnover of algae, pondweeds, copepods, fish and other plant and animal life in the lake, and estimated the chemical energy stored in their bodies. Lindeman found that the plants converted solar energy to organic matter with an efficiency of about one tenth of 1 per cent; the herbivorous animals utilized the available plant energy with about 10 per cent efficiency, and the carnivores were at least 10 per cent efficient in utilizing herbivores. Applied to a community consisting of man, domestic animals and plants, these figures are helpful as well as easy to remember. If the people eat nothing but meat, and keep out all inedible herbivores (such as beetles) and all competing carnivores (such as wolves and botflies), an area that would support 10 vegetarians will support just one meat eater.

The dependence of the human crop on plants as the ultimate source of bodily fuel can be compared to the life of a crowd of squatters along a railroad track whose only source of warming fuel is coal dropped by passing trains. Clearly, if the situation is to last indefinitely, the squatters must adjust their rate of coal consumption to the rate at which coal is lost from the tenders. The efficiency of squatting could be expressed in various ways, but none is quite so fundamental as the ratio of these two rates.

Eugene Rabinowitch, the eminent student of photosynthesis at the University of Illinois, has calculated the



IVORY CARVING from the Belgian Congo depicts the activities of a primitive culture which lived largely by hunting and fishing. The members of such a culture, by eating herbivorous and carnivorous animals, receive most of their plant nourishment indirectly.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CARBON (GRAMS PER SQUARE METER PER YEAR)

efficiency of the human population's consumption of living matter as 1 per cent. He arrived at this figure by multiplying the world population (2.2×10^9 persons) by its total annual output of energy (at the average rate of 2,100 large calories per person per day) and dividing by the production of plant carbon on land in terms of its potential energy (1.9×10^{17} large calories per year).

The figure of 1 per cent for mankind's efficiency in utilizing the plant production of the earth is impressive. However, it is open to the objection that it is not actually a measure of the human crop's efficiency in producing human substance. It amounts to comparing the rate of loss of coal to the size of the squatters' fires.

A better way of stating the facts is to consider the net production of human

EFFICIENCY of four basic human economies is schematically presented in the chart on the opposite page. The logarithmic scale at the bottom of the page indicates the production of living matter by its carbon content. At the top of the chart is a primitive lake-fishing culture. The lake itself produces about 300 grams of plant carbon per square meter per year (*top horizontal bar*). Tiny animals such as copepods utilize about 10 per cent of the plant carbon, *i.e.*, 30 grams (*second bar*). Larger animals such as sunfish utilize 10 per cent of the carbon in the smaller ones, *i.e.*, 3 grams (*third bar*). Larger fishes such as pickerel utilize 10 per cent of the carbon in the smaller ones, *i.e.*, .3 grams (*fourth bar*). Fishermen utilize 10 per cent of the carbon in the larger fishes, *i.e.*, .03 grams (*fifth bar*). Second from the top in the chart is a more advanced oceanic fishing culture. The supply of plant carbon is the same, but because the chain of predation is more efficient, the fishermen represent .3 grams of carbon per square meter per year. Third from the top is a hunting culture. Here again the supply of plant carbon is the same, but it is eaten by insects as well as other animals. The supply of catchable animals such as rabbits therefore utilizes only about 1 per cent of the plant carbon, *i.e.*, 3 grams. Thus the over-all efficiency of the hunting culture is about the same as that of the advanced fishing culture. At the bottom of the chart is an agricultural society. Here the plant production (including stems and leaves) is about the same as before, *i.e.*, 300 grams of carbon per square meter per year. Because the plants are directly utilized by the society, its human crop can amount to about 10 per cent of this, or 30 grams per square meter per year. Thus the agricultural society comprises 1,000 times more living matter than the primitive lake-fishing culture.

substance and the total metabolic cost of maintaining that net. Since human beings are warm-blooded, active and expensive to keep, only about one sixth of the energy they spend appears in the form of net production of bodily substance (which to maintain the size of the crop must be replaced at the rate of one 25th per year—taking 25 years as the generation interval). That is, the human race spends 5.18×10^{13} large calories per year in stoking itself (respiration) and only 1.09×10^{13} calories in creating the replacement crop. The two figures, added together, give the gross productivity of the human population—*i.e.*, 6.27×10^{13} calories. The gross productivity of the plant world comes to $19{,}000 \times 10^{13}$ calories. On this basis, dividing the former by the latter, we get only .03 per cent as the efficiency of human production.

There are theoretical objections to this figure, too, and it seems to be too small, as Rabinowitch's is too large. In the calculation of the gross total productivity of the land plants it was assumed, for averaging purposes, that all the carbon produced is in the form of glucose, whereas actually it is mainly cellulose—a compound which most animals can digest only after bacteria have broken it down. To be fair to human efficiency we should allow for the fact that a large fraction of the world's vegetation is inedible. What that fraction may be is hard to say. If it is larger than our assumption implies, the efficiency of human production must be reckoned higher than .03 per cent. A second objection is that the calculation of the efficiency is based on plant growth on all land areas of the earth, but it may not be fair to include such regions as the Arctic, where there is a fair amount of plant production but the people live on walrus, supplemented by canned goods shipped from Moscow and New York.

Allowing for such objections, it seems reasonable to raise the estimate of .03 per cent efficiency to about one tenth of 1 per cent. If this guess is correct, it is a startling figure. It would mean, supposing that man were exclusively carnivorous, that he would account for one tenth of all the meat eaten by all the carnivores of the earth. Even allowing for the fact that the diet of most human beings is at least partly vegetable, the future looks ominous. Granting that the men of the future will consume less meat (though they certainly will want more), when the world's population grows to 10 times its present size (which it will do in 230 years at the present rate) it

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City ________ *Zone* ____ *State* ________ will be consuming about a tenth of all the *plant* food that is produced. In such a community no competing carnivores, even as inoffensive as a robin or a perch, will be tolerable, and the existence of a single pickerel (a second-degree carnivore) will threaten the whole balance of nature.

Fortunately the future is not so black as this implies. Farms will replace the forest primeval, and when agriculture has done all it can on land, we may be able to farm the sea in earnest. Besides, we may expect other utilizations of energy (solar and atomic) to emancipate us all some day from our bondage to chlorophyll.

Still, the thought of 10 times as many mouths to feed is rather appalling, and romantics may prefer to look back nostalgically at the productivity of past ages. Through most of human history man lived off land in the "wild" state—either forests or steppes. His tribal groups were small. How many people can an acre of wilderness support? Anthropologists dislike to attempt a general answer to such questions, because human efficiency depends so heavily on skills, *i.e.*, on culture. We know that the aboriginal American Indians averaged about four persons per 100 square kilometers, and the aboriginal Australians about three per 100 square kilometers. Most authorities would guess that the size of hunting-and-gathering populations was related to the size of the catchable food supply. Certain rough calculations show, however, that food supply cannot have been the whole story, for the population did not approach the numbers that the wilderness might have supported.

R. G. Green and C. A. Evans carefully studied the population of snowshoe hares, certainly an eligible Indian food, in Minnesota. The average density of these animals was 255 per square mile. On the basis of an average lifetime of just under one year and an average weight per animal of 1.9 kilograms, of which 35 per cent is protein with an energy content of 5,650 small calories per gram, we calculate that the net productivity of the hares was about 410 calories per square meter. By the same kind of arithmetic the productivity of wood mice (as studied in Michigan) is estimated at 271 calories per square meter. Deer, according to a census in Wisconsin, yield 24.5 calories per square meter. If we add forest birds, we get another 31.6 calories. So we have 737 calories per square meter as the total net production of catchable animals. Several

kinds of checks show that this figure is conservative, and that the best forest can produce many times that amount of animal food, particularly if insects are counted. Grassland is no less productive than forest, so it is safe to consider prairie and woodland Indians together.

To calculate how many Indians could live on the catchable animals, we assume they could utilize these animals with 10 per cent efficiency: say 700 calories of animal food would support 70 calories of Indian per square meter. The mean Indian longevity would have been about 25 years, so the potential standing crop of hunters was 1,750 calories or 310 milligrams of protein or 885 milligrams of wet weight or 1.45×10^{-5} persons per square meter, *i.e.*, 1,450 Indians per 100 square kilometers. This is about 400 times the estimate of the actual population. Not even in James Fenimore Cooper's novels were the woods so full of Indians.

A possible flaw in the calculations is that they are based on averages. Indians cannot eat statistics: they require living rabbits. The size of the rabbit population fluctuates by twenty- or fiftyfold from year to year, and it may be objected that the human population would be adjusted to the poorest rabbit crop rather than to the average. However, we may answer that other animals would not be likely to fluctuate exactly in phase with the rabbits. In years when rabbits were scarce, the people could lean more heavily on wood mice.

Assuming there is nothing seriously wrong with the arithmetic on food supply, the trouble must be with the Indians. If food did not limit their numbers, what did? The answer, probably, is "social forces"—vague as that may sound. No doubt there was a lot of no-man's-land, bordering the ranges of all the tribes, where the Indians did not dare hunt regularly for fear their enemies, or perhaps an evil spirit, would catch them at it. Fear of evil spirits is a social force, and taboos on certain kinds of food would have the same effect. Whatever the reason, it seems that the primitive crop of men was adjusted to its means of subsistence with a wide margin of safety. Populations had ample room to fluctuate without danger of destroying the whole economy.

It would be comforting, but decidedly naive, to think that the same conditions hold today. The margin of safety is rapidly narrowing, and at its present rate the expansion of the human crop may soon force mankind to face up to the logic of the ecologist's arithmetic.

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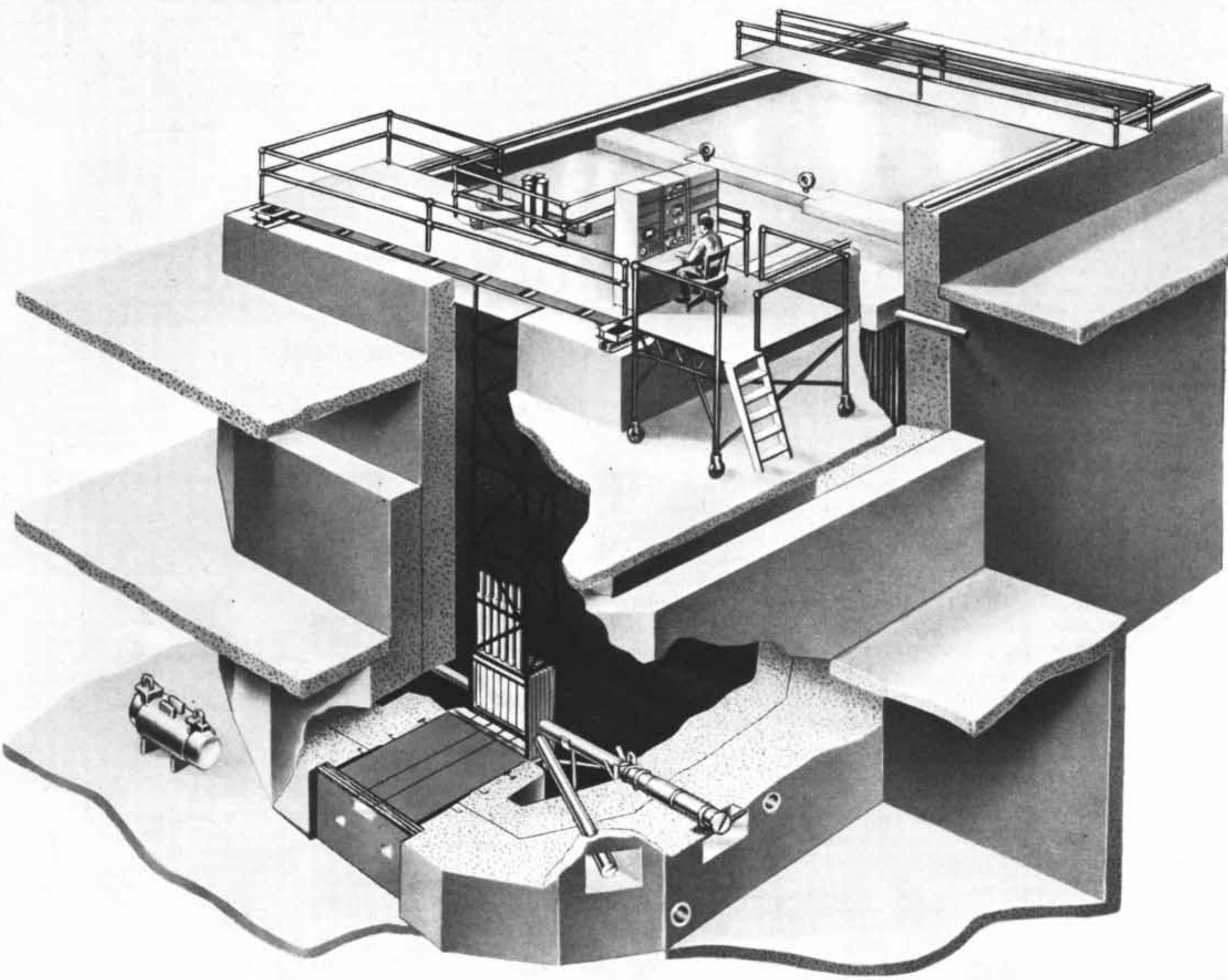

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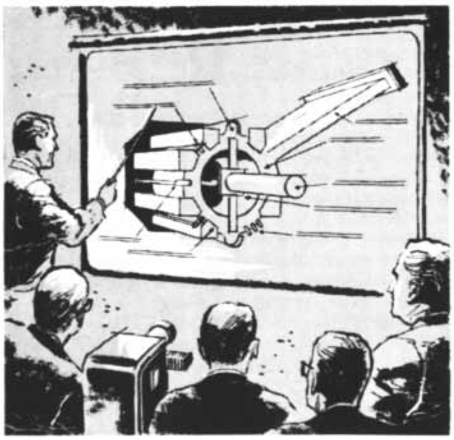

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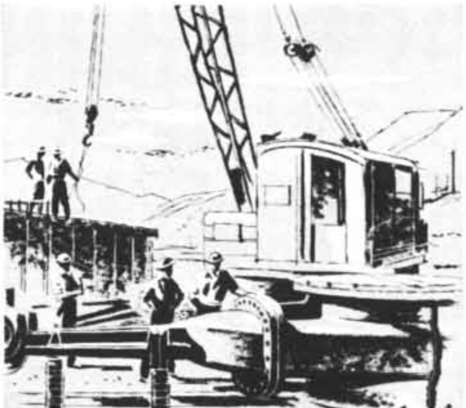

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Lewis Carroll: Mathematician

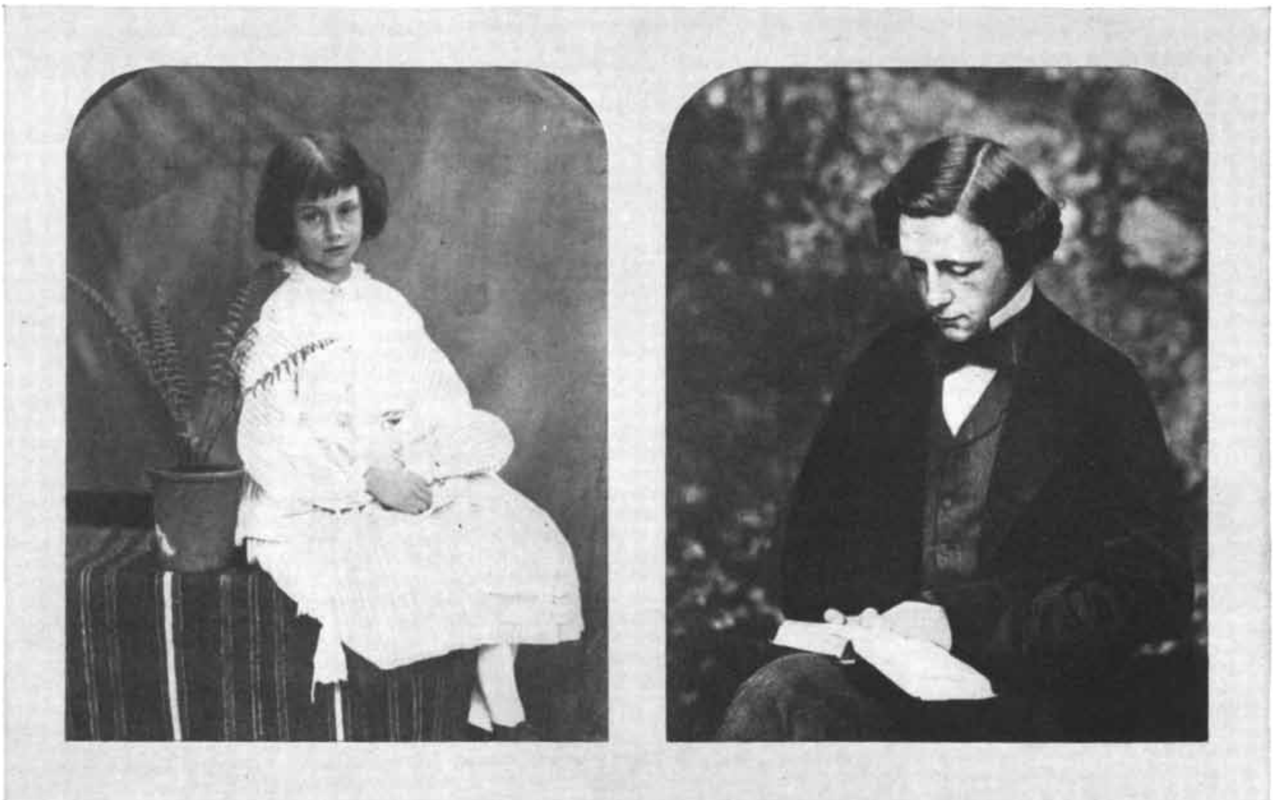
Many people who have read "Alice's Adventures in Wonderland" and "Through the Looking-Glass" are aware that the author was a mathematician. Exactly what was his work in mathematics?

by Warren Weaver

"Lewis Carroll—wasn't he a first-class mathematician too?" This is a typical remark when the name of the author of *Alice in Wonderland* comes up. That Carroll's real name was Charles Lutwidge Dodgson and that his main lifelong interest was mathematics is fairly common knowledge. In fact, among his literary admirers there has long been current a completely false but unstoppable story that Queen Victoria read *Alice*, liked it, asked for another book by the same author and was sent Dodgson's very special and dry little book on algebraic determinants.

Lewis Carroll was so great a literary genius that we are naturally curious to know the caliber of his work in mathematics. There is a common tendency to consider mathematics so strange, subtle, rigorous, difficult and deep a subject that if a person is a mathematician he is of course a "great mathematician"—there being, so to speak, no small giants. This is very complimentary, but unfortunately not necessarily true. Carroll produced a considerable volume of writing on many mathematical subjects, from which we may judge the quality of his contributions. What sort of a mathematician, in fact, was he?

The story of his academic career is quickly told. C. L. Dodgson was born in



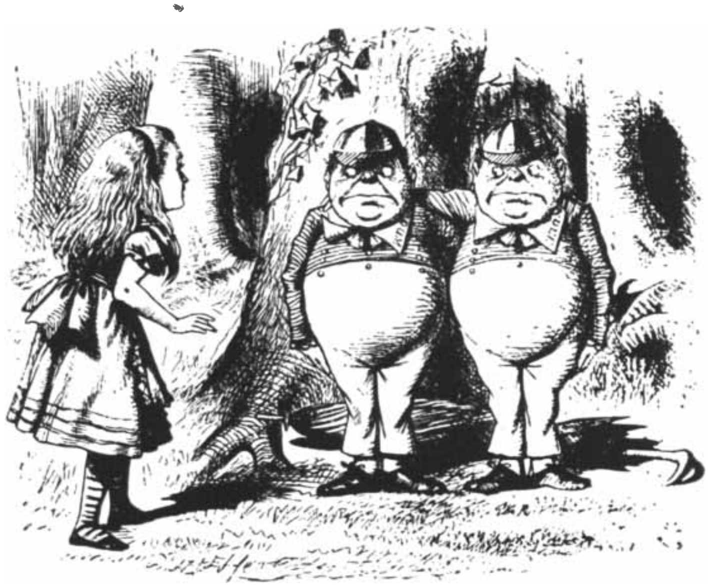
CARROLL AND ALICE appear in these photographs from the Morris L. Parrish Collection in the Princeton University Library. Alice was Alice Liddell, whom Carroll had in mind when he wrote *Alice's Adventures in Wonderland.* Later she became Mrs. Reginald Hargreaves. Alice was photographed by Carroll himself in 1859, when she was seven years old. Carroll was photographed, probably by Reginald Southey, in 1856, when he was 24. In 1855 he had been made a don and a lecturer in mathematics at Oxford.

1832 near Daresbury in Cheshire. His father was a clergyman, as had been his grandfather, great-grandfather and great-great-grandfather. He went up to Oxford in 1850 after six unhappy years in English "public" schools. At the end of 1852 he was given first class honors in mathematics and was appointed to a "studentship" (what we would call a fellowship) on condition that he remain celibate and proceed to holy orders. He took his B.A. with first class honors in the final mathematical school in 1854 and his M. A. in 1857. In 1855, at the age of 23, he was given a scholarship that paid the princely sum of 20 pounds a year, and was appointed senior student, or don, at Christ Church, and mathematical lecturer in the University. He lived, a bachelor, in college quarters in Tom Quad from 1868 until he died, 66 years old, in 1898. His academic life was enlivened, if you will pardon the expression, by the very Victorian activities of being made a sublibrarian in 1855; being ordained a deacon in 1861, and as a climax, when he was 50, being made curator of the Common Room—a sort of club steward.

The even tenor of this secluded life gave him ample time for writing, both as Charles Lutwidge Dodgson and as Lewis Carroll. There must be few authors who wrote so much and are remembered for so little. The standard bibliography of his work lists 256 items printed during his lifetime, and nearly 900 items in all. Of these 16 are books—about six written for children and about 10 devoted to mathematics and logic. One has to say "about" because it is hard to tell whether some were intended for children or adults, whether others are mathematics or fantasy. In addition Carroll wrote nearly 200 pamphlets. About 50 related to minor academic quarrels at Christ Church, about 30 to word games, ciphers and the like, and more than 50 to wildly miscellaneous subjects: how to memorize dates, how to bowdlerize Shakespeare for young girls, how to score tennis tournaments, common errors in spelling, rules for reckoning postage, and so on.

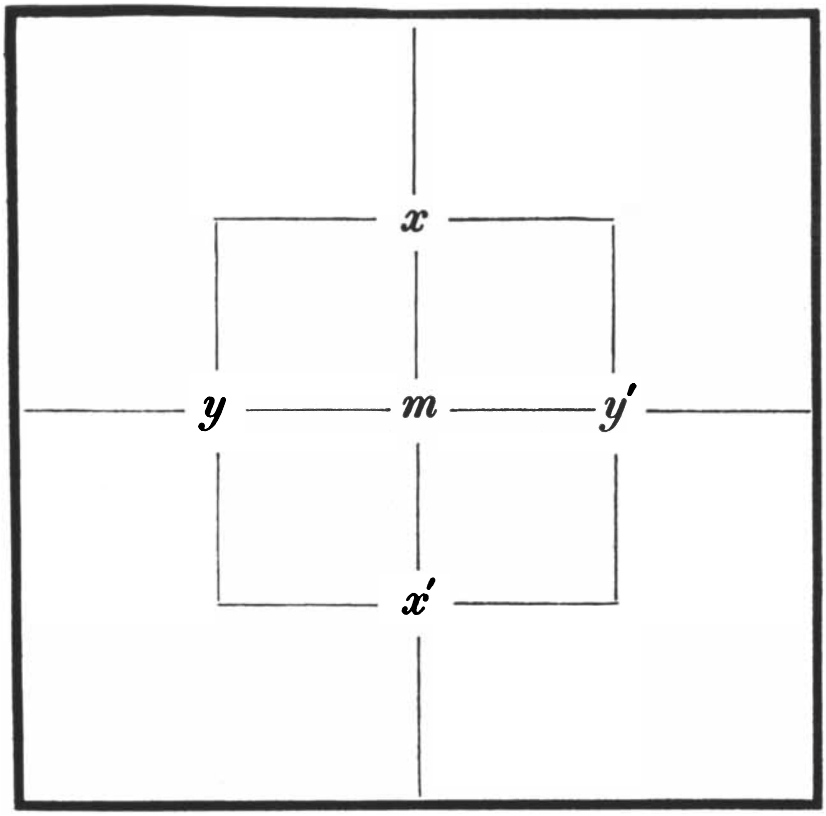
Of the 256 items printed during his lifetime, 58 were devoted to mathematics and logic. If we consult these works for an estimate of Carroll's—or perhaps we should now say Dodgson's—stature as a mathematician, we discover that he was first of all a teacher, earnestly concerned with methods of instruction in elementary subjects. He wrote nearly two dozen texts for students in

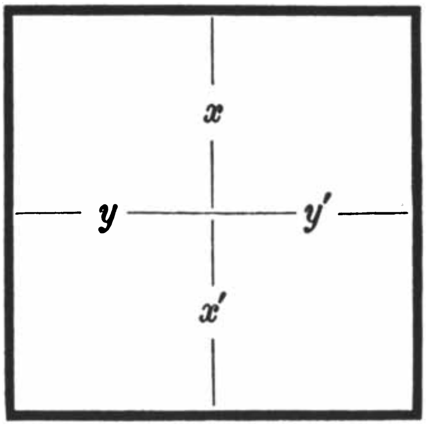
A LESSON IN RELATIVITY: The White Queen cries, "Faster, faster," and explains to Alice, "Now, *here,* you see, it takes all the running *you* can do, to keep in the same place."



A LESSON IN LOGIC: "Contrariwise," explained the one with his collar labeled DEE, "if it was so, it might be; and if it were so, it would be; but as it isn't, it ain't. That's logic.

A LESSON IN ARITHMETIC: "Can you do division?" asked the White Queen. "Divide a loaf by a knife." "Try another subtraction sum," said the Red, "Take a bone from a dog."





LOGICAL DIAGRAM, printed on separate card, accompanied copies of Carroll's *Game of Logic*. Readers of the book were also furnished nine cardboard counters, four of them red (meaning "yes") and five gray (meaning "no"), and invited to play the game. Readers of this magazine, using pennies ("yes") and dimes ("no") for counters, may play out the conclusion from the following two premises: "All dragons are uncanny" and "All Scotchmen are canny." The top diagram is used to state the premises; the lower one to state the conclusion. In accord with Carroll's directions, let everything in the four central boxes of the top diagram be "canny" (m); everything outside the boxes "uncanny" (m′). Correspondingly, animals that are dragons (x) will be found in the upper two boxes; not-dragons (x′) in the lower two boxes. Finally, animals that are Scotchmen (y) will be found in the left-hand boxes; not-Scotchmen (y′) in the right-hand boxes. In laying out premises on the diagram, it should be recalled that each of them implies its negative; *e.g.:* "No dragons are canny" and "No Scotchmen are uncanny." On Carroll's advice, it is best to stake out negative statements first. Hence a dime should be placed in each of the two upper boxes in the central diagram ("No dragons are canny"). Readers who proceed correctly from here will end up with a dime in the upper left box in the conclusion diagram ("All dragons are not Scotchmen") and a penny in the lower left box ("All Scotchmen are not dragons").

arithmetic, algebra, plane geometry, trigonometry and analytical geometry.

Dodgson's largest and most serious work on geometry, *Euclid and His Modern Rivals*, gives us an insight into his approach to mathematics. It shows him as a militant conservative, dedicated to defending Euclid against any modern move to improve or change him in any way. Dodgson sought to prove in this book that Euclid's axioms, definitions, proofs and style simply could not be changed for the better. He even insisted that the order and numbering of Euclid's theorems be preserved. Dodgson skillfully ridiculed contemporary geometers who tried to restate Euclid's parallel axiom, and threw out all their attempts as "simply monstrous." (It is, however, worth noting that in a later book entitled *A New Theory of Parallels* Dodgson himself sought to replace the classical axiom by one of his own devising.)

Euclid and His Modern Rivals must be classed as amusing, ridiculously opinionated and scientifically unimportant. It reflects nothing of the growing realization among contemporary mathematicians that the axiom of parallels was not a self-evident fact of nature but an arbitrarily adopted and unprovable postulate. Non-Euclidean geometry, with its revolutionary consequences for mathematics and science, was not dreamt of in Dodgson's philosophy.

The bleak impression of the Reverend Dodgson created by his pedagogical works is pleasantly relieved when we turn to his other mathematical writings. He comes closer to the man we know as Lewis Carroll in, for example, a strange little book called *Pillow Problems*. Here Dodgson presents 72 problems—chiefly in algebra, plane geometry and trigonometry—all of which he had worked out in bed at night without pencil or paper. Dodgson suffered from insomnia, and while he was careful to point out that mathematics would put no one to sleep, he argued that it would occupy the mind pleasantly and prevent worry. It is characteristic of his severely pious attitude that he offered mathematical thinking, during wakeful hours, as a remedy for "skeptical thoughts, which seem for the moment to uproot the firmest faith . . . blasphemous thoughts, which dart unbidden into the most reverent souls . . . unholy thoughts which torture with their hateful presence the fancy that would fain be pure."

The problems in this book, while elementary, are nevertheless complicated enough to require real skill in concentration and visualization, if one is to solve them in his head. A geometrical problem, reproduced from his manuscript, is shown on page 124. Here is another example:

"On July 1, at 8 a.m. by my watch it was 8 h. 4 m. by my clock. I took the watch to Greenwich, and when it said *noon*, the true time was 12 h. 5 m. That evening, when the watch said 6 h. the clock said 5 h. 59 m. On July 30, at 9 a.m. by my watch, it was 8 h. 57 m. by my clock. At Greenwich, when the watch said 12 h. 10 m. the true time was 12 h. 5 m. That evening, when the watch said 7 h., the clock said 6 h. 58 m. My watch is only wound up for each journey, and goes uniformly during any one day: the clock is always going, and goes uniformly. How am I to know when it is true noon on July 31?"

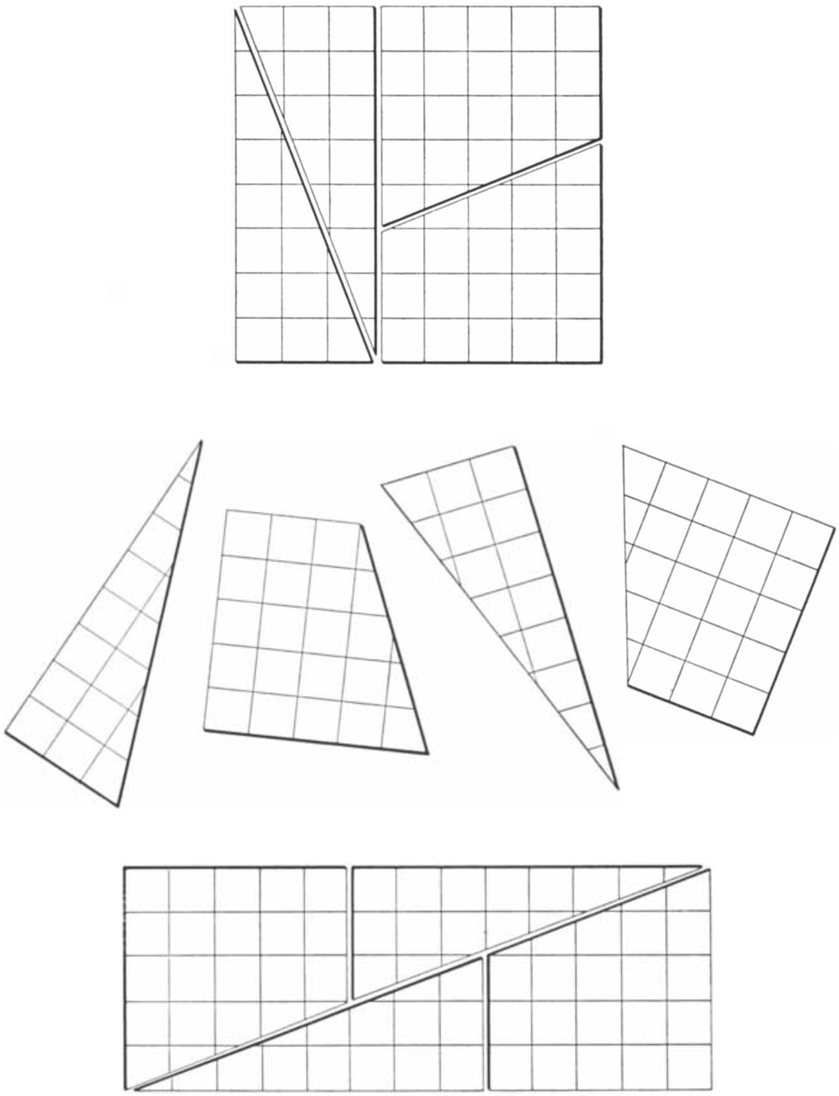
Dodgson's solutions of the problems in this collection are generally clever and accurate, but one of them ludicrously exposes the limitations in his mathematical thinking. The problem is: "A bag contains 2 counters, as to which nothing is known except that each is either black (B) or white (W). Ascertain their colors without taking them out of the bag." In his attack on this problem (which as stated cannot actually be solved) he makes two dreadful mistakes. First he assumes, incorrectly, that the statement implies the probabilities of BB, BW and WW (the three possible constitutions of the bag) are 1/4, 1/2, and 1/4 respectively. Then he adds a black ball to the bag, calculates that the probability of now drawing a black ball is 2/3 and makes his second fatal error in concluding that the bag now must contain BBW. His line of reasoning thus leads him to the conclusion that the two original balls were one B and one W! This is good Wonderland, but very amateurish mathematics. It has been pointed out that if one applies Dodgson's argument to a bag containing three unknown balls (black or white), he can come out with the conclusion that it was impossible for there to have been three balls at all.

Dodgson's zest for mathematical puzzles produced a second little book which he called *A Tangled Tale*. The problems are named "Knots," and Knot I, for example, presents this tangle: Two travelers spend from 3 o'clock until 9 o'clock in walking along a level road, up a hill, back down the hill, along the same road, and home. Their pace on the level is 4 miles per hour, uphill it is 3, and downhill 6 miles per hour. Find the distance walked and, within a half-hour, when they were on the summit.

My collection of Dodgson's manuscripts includes his two favorite puzzles, which he did not publish. One, called "Where Does the Day Begin?", considers the paradox that a man who travels westward around the earth at the same speed as the sun will find that though he started on a Tuesday, when he returns to his starting point the day is now called Wednesday. Where and when did the date change? Dodgson troubled many officials in government offices and telegraph companies with correspondence on this question, which he first posed in 1860. No one could answer it, of course, until the arbitrary International Date Line was established in 1884.

Dodgson's other favorite puzzle, named "The Monkey and Weight," was equally baffling to his contemporaries. A weightless, perfectly flexible rope is hung over a weightless, frictionless pulley. At one end is a monkey, at the other a weight which exactly counterbalances the monkey. The monkey starts to climb. What does the weight do? One of the difficulties in this tricky problem is that it is not well defined. For example, does the monkey jerk the rope? Or does he begin pulling on it very gently, and if so, how does he maintain the pull?

In all of Dodgson's mathematical writing it is evident that he was not an important mathematician. As we have seen, in geometry his ideas were old-fashioned even for his time; in the probability problem cited he failed to grasp the principle of insufficient reason; in algebra he once wrote in his notes: "that $2(x^2+y^2)$ is always the sum of two squares seems true but unprovable." It took him some time to recall the fact, familiar to any high-school student of elementary algebra, that $(2x^2+y^2)=(x+y)^2+(x-y)^2$. In calculus his concept of infinitesimals was the wholly confused one that these were queer shadowy quantities which were non-infinite, non-finite and also non-zero! His notes record such logical monstrosities as "infinitesimal unit," "infinity unit," "minimum finite fraction." He did not understand the basic concept of the limiting process in the calculus, as is indicated by the remark in his notes: "The notion that because a variable magnitude can be proved *as nearly equal* to a fixed one as we please, it is therefore equal, is to my mind unsatisfactory, as we only *reduce* the difference, and never annihilate it."



TRIANGLE PARADOX leads to the impossible conclusion that 64 equals 65. The square at top, composed of 8 × 8 square units, is cut into the four parts shown. These may then be fitted together to form the rectangle of apparent area 5 × 13 square units, shown at bottom. Close inspection of the rectangle, however, shows that the angle of inclination of the hypotenuse of each triangle is not quite the same as that of the slanting side of the tetragon next to its shortest side. The extra "square" unit is actually spread out in the resulting open space between the upper and lower parts of the rectangle. Carroll generalized this paradox in an algebraic equation that yields the dimensions of all the possible squares that can be cut in the same paradoxical fashion; for example, squares with sides 21 and 55.

But before we write Dodgson off as a mathematician we must consider his contributions to formal logic. Nearly half of his mathematical writings were in this field.

The most important were *The Game of Logic*, published in 1886, and an expansion of it 10 years later into a longer and somewhat more serious book called *Symbolic Logic: Part I, Elementary*. In these works Carroll developed the use of a scheme which had first been introduced by the Swiss mathematician Leonhard Euler in 1761. It involves the representation of sets of similar propositions by spatial diagrams [*see page 118*], together with a symbolic language for translating the diagrams back into verbal statements. The examples he invented for the use of the method were characteristically clever and amusing.

For instance, from the premises:

All dragons are uncanny,
All Scotchmen are canny;

he derived the comforting conclusions:

All dragons are not-Scotchmen,
All Scotchmen are not-dragons.

Another example of the fun he had with simple logic is the following (de-

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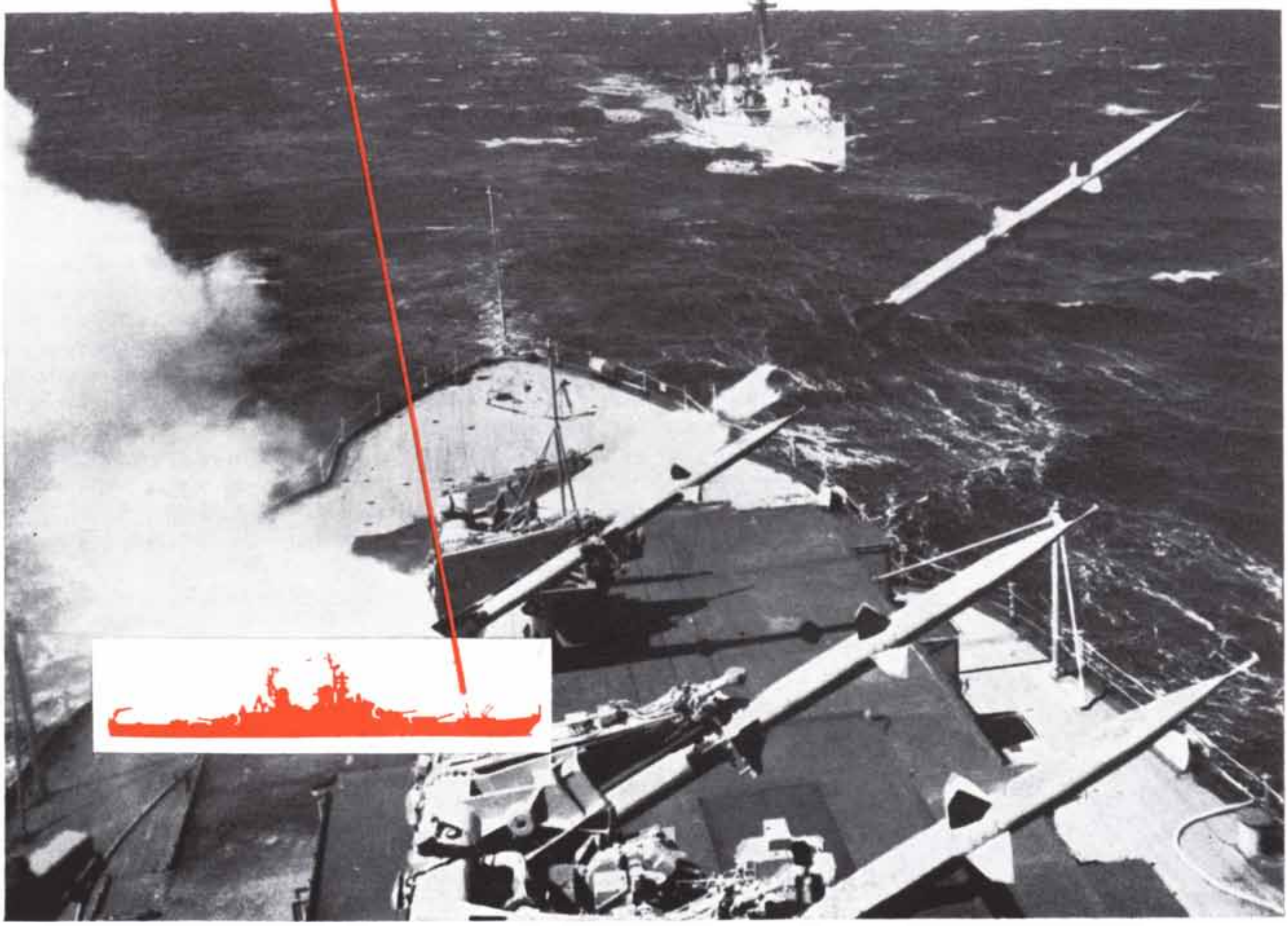

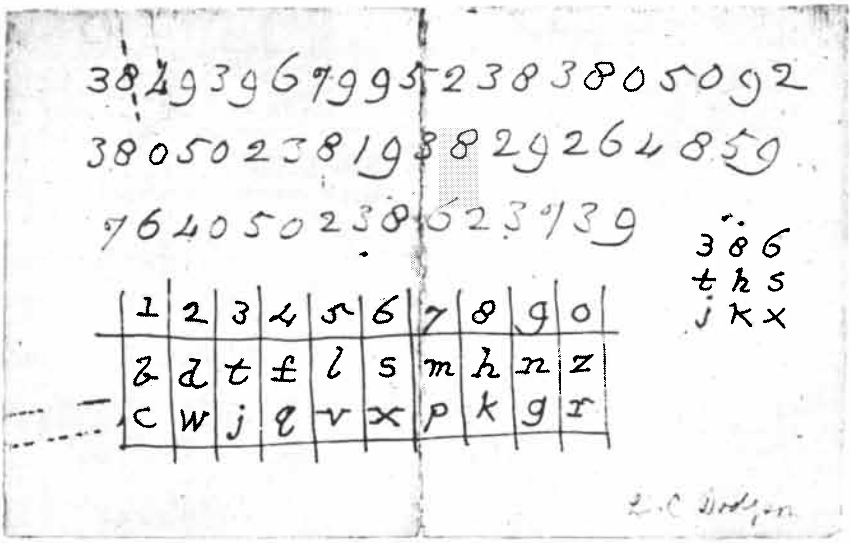

MNEMONIC AID was worked out by Carroll to facilitate his recollection of numbers. First he associated certain consonants with the digits. In his table, it is apparent that "b" and "c", the first consonants, go with 1; "q" (for "quarto") and "f" go with 4, etc. Given a number, he would incorporate its consonants in an appropriate word or phrase; thus 545 could be "voice of glee." He would fix the phrase in his mind by incorporating it in a rhyming verse of two or four lines. Then, if he remembered the verse, he could recall the number.

duce a conclusion from the given premises):

"It was most absurd of you to offer it! You might have known, if you had any sense, that no old sailors ever like gruel!"

"But I thought, as he was an uncle of yours. . . ."

"An uncle of mine indeed! Stuff!"

"You may call it stuff if you like. All I know is, *my* uncles are all old men: and they like gruel like anything!"

"Well then, *your* uncles are—" [not sailors].

Amusing as Carroll's games of logic were, they were neither technically original nor profound. In his formal works on logic, as in geometry, he remained a resolute conservative. The British logician R. B. Braithwaite has pointed out that Carroll "did not accept the doctrine that has done so much to simplify traditional formal logic—the interpretation of a universal proposition as not involving the existence of its subject-term." Thus to Carroll the statement "All frogs that jump more than 20 feet croak loudly" necessarily implied the existence of frogs that jump more than 20 feet.

Near the end of his life, however, Carroll did make one formal contribution to logic that has intrigued serious mathematicians. It was a problem containing a paradox which no one has conclusively resolved. A barber shop has three barbers, A, B and C. (1) A is infirm, so if he leaves the shop B has to go with him. (2) All three cannot leave together, since then their shop would be empty. Now with these two premises, let us make an assumption and test its consequences. Let us assume that C goes out. Then it follows that if A goes out, B stays in (by premise 2). But (by premise 1) if A goes out, B goes out too. Thus our assumption that C goes out has led to a conclusion we know to be false. Hence the assumption is false, and hence C can't go out. But this is nonsense, for C obviously can go out without disobeying either of these restrictions. C can in fact go out whenever A stays in. Thus strict reasoning from apparently consistent premises leads to two mutually contradictory conclusions.

Bertrand Russell tried to get around the difficulty by saying that the statement "If A goes out then B must go out" is not contradictory to the statement that "If A goes out then B must stay in." He argues they can both be jointly true on the condition that "A stays in." But this is the same as arguing that there is no disagreement between the statement by one politician that "If the Republicans win, things will improve," and the statement by another politician that "If the Republicans win, things won't improve." Neither politician would be satisfied by a logician's assurance that a Socialist victory would make both their statements true. The paradox has recently been answered in a more complicated

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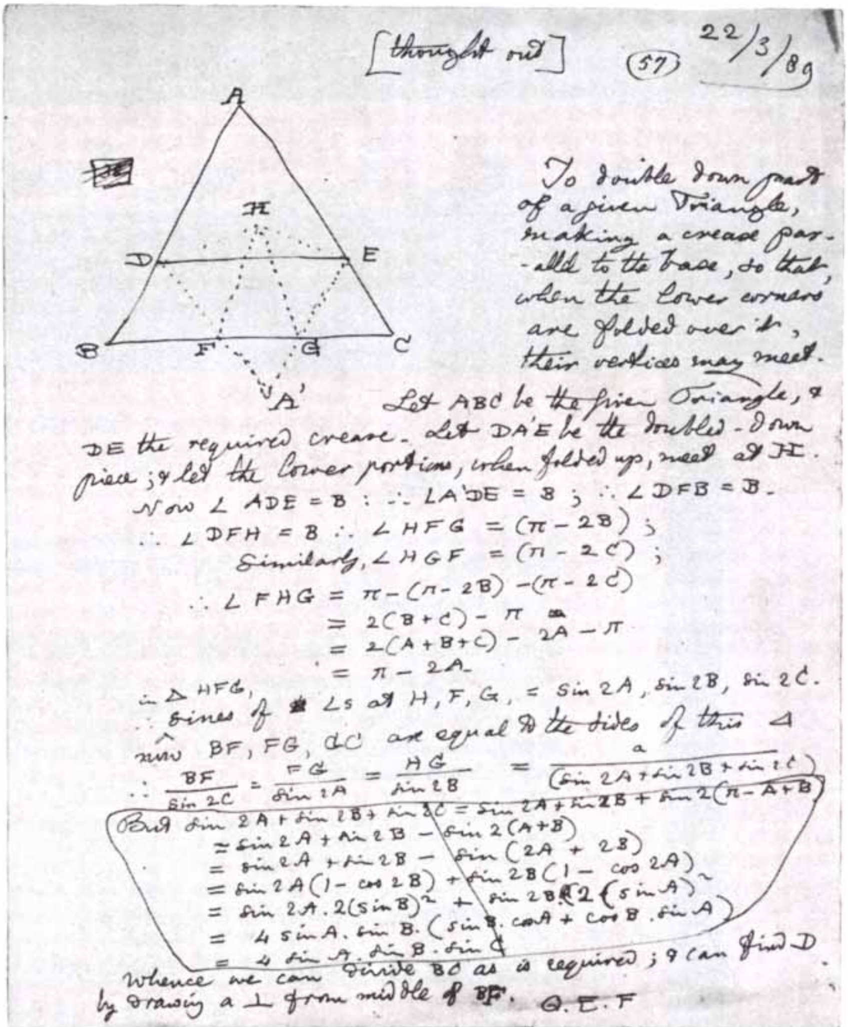
and interesting way by two logicians in a paper published in the British Journal *Mind*. The continuing discussion is evidence of the interest which still attaches to this logical puzzle. As Braithwaite observes, "Carroll was ploughing deeper than he knew. His mind was permeated by an admirable logic which he was unable to bring to full consciousness and explicit criticism. It is this that makes his *Symbolic Logic* so superficial . . . and his casual puzzles so profound."

It would be hard to state better than Braithwaite does in these words the conclusion of the matter. The Reverend Dodgson was a dull, conscientious and capable teacher of elementary mathematics. Lewis Carroll was, in a tantalizingly elusive way, an excellent and unconsciously deep logician. But when he tried to approach logic head on, in a proper professional way, he was only moderately successful. It was when he let logic run loose that he demonstrated his true subtlety and depth. In fact, for a full measure of his stature as a logician we must look into Wonderland.

Alice and her companions have often been quoted in books on logic and philosophy. P. E. B. Jourdain, in his delightful book, *The Philosophy of Mr. B*rtr*nd R*ss*ll*, relies heavily on Carroll to demonstrate the key notions of logic. The sampling of Carroll's virtuosity which follows is taken from that book.

Logicians have for ages struggled with "theories of identity." Just when is one justified in saying "X is identical


[thought out] (57) 22/3/89

To double down part of a given Triangle, making a crease parallel to the base, so that, when the lower corners are folded over it, their vertices may meet.

Let ABC be the given Triangle, & DE the required crease. Let DA'E be the doubled-down piece; & let the lower portions, when folded up, meet at H.

Now ∠ ADE = B ∴ ∠ A'DE = B ; ∴ ∠ DFB = B.
∴ ∠ DFH = B ∴ ∠ HFG = (π − 2B) ;
Similarly, ∠ HGF = (π − 2C) ;
∴ ∠ FHG = π − (π − 2B) − (π − 2C)
= 2(B + C) − π
= 2(A + B + C) − 2A − π
= π − 2A

∴ Δ HFG, sines of ∠s at H, F, G, = sin 2A, sin 2B, sin 2C.
now BF, FG, GC are equal to the sides of this Δ
∴ BF / sin 2C = FG / sin 2A = HG / sin 2B = a / (sin 2A + sin 2B + sin 2C)

But sin 2A + sin 2B + sin 2C = sin 2A + sin 2B + sin 2(π − A + B)
= sin 2A + sin 2B − sin 2(A + B)
= sin 2A + sin 2B − sin (2A + 2B)
= sin 2A (1 − cos 2B) + sin 2B (1 − cos 2A)
= sin 2A . 2(sin B)² + sin 2B . 2(sin A)²
= 4 sin A . sin B . (sin B . cos A + cos B . sin A)
= 4 sin A . sin B . sin C

Whence we can derive BG as is required; & can find D by drawing a ⊥ from middle of BF. Q.E.F.

PILLOW PROBLEM helped Carroll endure insomnia through a night in 1889. He would set himself the task of framing and solving such problems without putting a mark on paper until morning. Then he would write it up in the form shown here, with the notation "thought out" and the date, determined by whether he solved it before or after midnight. Carroll published some of these problems in a book for other insomniacs. The manuscript reproduced here is one of a number of "pillow problems" in the author's collection.

A BOLD APPROACH TO MISSILE ELECTRONICS

a statement by DR. L. N. RIDENOUR, *Director of Research, Lockheed Missile Systems Division*

Electronics is central to the technology of guided missiles. Dramatic improvements in missile performance require faster, more accurate perceptions and reactions of electronic missile guidance and control systems.

Here at the Missile Systems Division of Lockheed, we are aware of this requirement. We also know that electronics is experiencing the greatest revolution in its history; the vacuum tube, hitherto the cornerstone of electronic design, is being replaced by new solid-state devices which have superior performance and reliability.

Thus the times favor a bold approach to missile electronics. Past techniques will not meet requirements of the future. Experience in old-fashioned electronics is no great qualification for the present challenge. By giving the broadest responsibility to scientists and engineers, we are trying to lay proper emphasis on the new electronics.

Lockheed MISSILE SYSTEMS DIVISION *research and engineering staff*

LOCKHEED AIRCRAFT CORPORATION • VAN NUYS, CALIFORNIA with Y," or "X is the same as Y," or "X is Y"? This matter was entirely clear to Carroll's little friends:

> "The day is the same length as anything that is the same length as *it*." (*Sylvie and Bruno*)

> "Bruno observed that when the Other Professor lost himself, he should shout. 'He'd be sure to hear hisself, 'cause he couldn't be far off.' " (*Sylvie and Bruno*)

Most logicians—and most of the rest of us for that matter—have to be very careful about precision in definitions and about the confusing overlap between what words denote and what they connote. But this was not a matter of confusion on the other side of the Looking-Glass:

> "Tweedledum and Tweedledee were, in many respects, indistinguishable, and Alice, walking along the road, noticed that 'whenever the road divided there were sure to be two finger-posts pointing the same way, one marked "TO TWEEDLEDUM'S HOUSE" and the other "TO THE HOUSE OF TWEEDLEDEE." '
> " 'I do believe,' said Alice at last, 'that they live in the same house! . . .' "

> " 'When *I* use a word,' Humpty Dumpty said in rather a scornful tone, 'it means just what I choose it to mean—neither more nor less.'
> " 'The question is,' said Alice, 'whether you *can* make words mean different things.'
> " 'The question is,' said Humpty Dumpty, 'which is to be master—that's all.' "

Extremely subtle and intricate problems in modern mathematical logic hinge on the question whether there exists any such thing as a universal class of all possible things. But even the Gnat had that one figured out. The Gnat had told Alice that the Bread-and-Butter-Fly lives on weak tea with cream in it:

> " 'Supposing it couldn't find any?' she suggested.
> " 'Then it would die, of course!'
> " 'But that must happen very often,' Alice remarked thoughtfully.
> " 'It always happens,' said the Gnat." (*Through the Looking-Glass*)

If existence is difficult to analyze, then

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CORNING GLASS WORKS, 49-4 Crystal Street, Corning, New York
Please send the material checked below:
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☐ Bulletin B-83: "Properties of Selected Commercial Glassware."
☐ Bulletin B-84: "Manufacture and Design of Commercial Glassware."
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How to make a point—painlessly

In the syringe behind the needle, which your dentist wields so deftly, is a neatly prepackaged dose of anesthetic. These containers are glass tubes stoppered at both ends.

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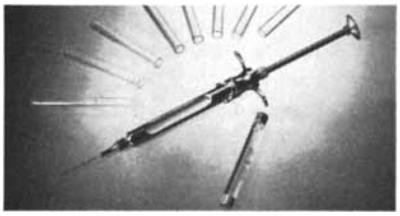

While the title may be lacking in imaginative quality, the glass is not. Consider, for a start, the fact that the glass cartridges must be made to close inside-outside tolerances because (a) rubber stoppers must fit snugly inside and (b) the cartridge itself needs nestle neatly in the dentist's hypo or syringe.

These close fits demand fire polishing the ends (so they won't chip) without impairing dimensional tolerances—quite a delicate operation for mass production.

The glass tube must be capable of being sterilized without undue strain or breakage; it must be chemically inert so it neither adds to nor detracts from the quality of its contents. And the cartridges must be economical as, in the interests of sterility, they are used once and discarded.

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And certainly of importance, the fact that countless customer-conceived projects have *proved* its profit worth.

We recommend for your reading a copy of Bulletin B-83, "Properties of Selected Commercial Glassware." Within the 14 pages of this unpretentious volume you'll find detailed, for a number of our glasses (No. 7740 included), data on mechanical properties, thermal stresses, heat transmission, and electrical and chemical characteristics. Free. Much easier with the coupon.

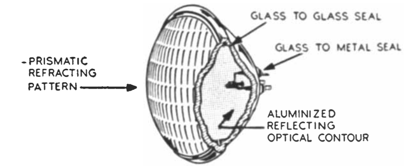
Stray rays . . . the care and handling thereof

Selective maneuvering of rays in the visible spectrum has traditionally been one of the roles that glass plays with considerable success.

Now comes another improvement in this field—one that adds comfort and safety to your motoring and, conceivably, some valuable facts to your files on glass utility. It's the new sealed-beam headlight which reduces the hazards of driving at night and in the fog.

The glass lens and reflector of the new headlight, sealed together hermetically, are designed to reduce stray rays, to concentrate more light—further ahead on the high beam and to the right of the road on the low beam.

Sounds like a simple achievement, but it took several years to accomplish and involved significant contributions of automotive, lighting, and Corning glass engineers working together on lens design, reflector design, and filament design. Corning now makes these prismatic lenses and the reflectors for several headlight manufacturers, one of whom even includes three aligning knobs on his lens, which contribute to easier and more positive focusing.



The new sealed-beam headlight illustrates how you can engineer glass to maneuver light into places where it does the most good. It also illustrates high perfection in hermetic sealing—glass-to-glass and glass-to-metal. The sealed-beam headlight is as airtight as a lamp bulb.

You can glean more about the nature and extent of engineered glass accomplishments, in *many* fields, from an attractive little primer called "Glass and You." We'll gladly send you a copy—free.

Or, Bulletin B-84: "Manufacture and Design of Commercial Glassware." Contents follow the title, offering suggestions for matching design to known advantages (as well as limitations) of various processes. The coupon will bring them to your drawing board or desk.

The big payoff?

Here's a quiz that may get you prizes galore in the form of money made (or saved). This is a matching game, aimed at showing you how one just-right Corning glass handles a difficult problem.

Write the number of the appropriate glass in the box following each description.

Protects light-sensitive substances from wayward and annoying angstroms. ☐

Conducts electricity and provides uniform heating surface. ☐

Protects against radiation effects as effectively as concrete; is nonbrowning; has density of 3.3. ☐

Can be used with intermittent temperatures to 1200° C.; has thermal coefficient of expansion of 8×10^{-7} per °C. ☐

Absorbs visible light from tungsten filament (2700° K.) but transmits infrared. ☐

1. VYCOR brand Glass No. 7910
2. Low Actinic Glass
3. Corning Code No. 8362 Glass
4. Corning E-C Glass
5. VYCOR brand Glass No. 7950

Correct answers: 2, 4, 3, 1, 5.

And that's just a start. There's also ribbon glass that outperforms mica; glass that's brick-wall thick or eggshell thin; glass that handles metal-eating acids without ill effects; glass that copes with almost any form of radiant energy—glass that improves performance of and often adds beauty to many, many, many products.

Jot down your most vexing problem and we'll let you know if one of our glasses can help you solve it.

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Corning means research in Glass

nonexistence is perhaps even more elusive, but not to Alice:

> " 'I see nobody on the road,' said Alice.
> " 'I only wish *I* had such eyes,' the [White] King remarked in a fretful tone. 'To be able to see Nobody! And at that distance, too! Why, it's as much as *I* can do to see real people by this light!' " (*Through the Looking-Glass*)

> ". . . The Dormouse went on, . . . : 'and they drew all manner of things—everything that begins with an M.'
> " 'Why with an M?' said Alice.
> " 'Why not?' said the March Hare.
> "Alice was silent.
> ". . . [The Dormouse] went on: '—that begins with an M, such as mouse-traps, and the moon, and memory, and muchness, you know you say things are "much of a muchness"—did you ever see such a thing as a drawing of a muchness?'
> " 'Really, now you ask me,' said Alice, very much confused, 'I don't think . . .'
> " 'Then you shouldn't talk,' said the Hatter." (*Alice's Adventures in Wonderland*)

Those interested in the logic of modern science are by no means agreed as to the significance and validity of imaginary experiments, particularly if they involve unrealizable conditions. This is a matter which did not worry the White Queen:

> "Alice laughed. 'There's no use trying,' she said; 'one *can't* believe impossible things.'
> " 'I daresay you haven't had much practice,' said the White Queen. 'When I was your age, I always did it for half-an-hour a day. Why, sometimes I've believed as many as six impossible things before breakfast.' " (*Through the Looking-Glass*)

So rare and so great were Carroll's true talents that we need not be condescending about the shortcomings of his formal mathematical writings. Carroll himself had no pretensions about them, and pronounced his own modest verdict in his diary. The very first entry in this two-volume record, which he wrote down on January 1, 1855, at the age of 23, says: "tried a little mathematics unsuccessfully."

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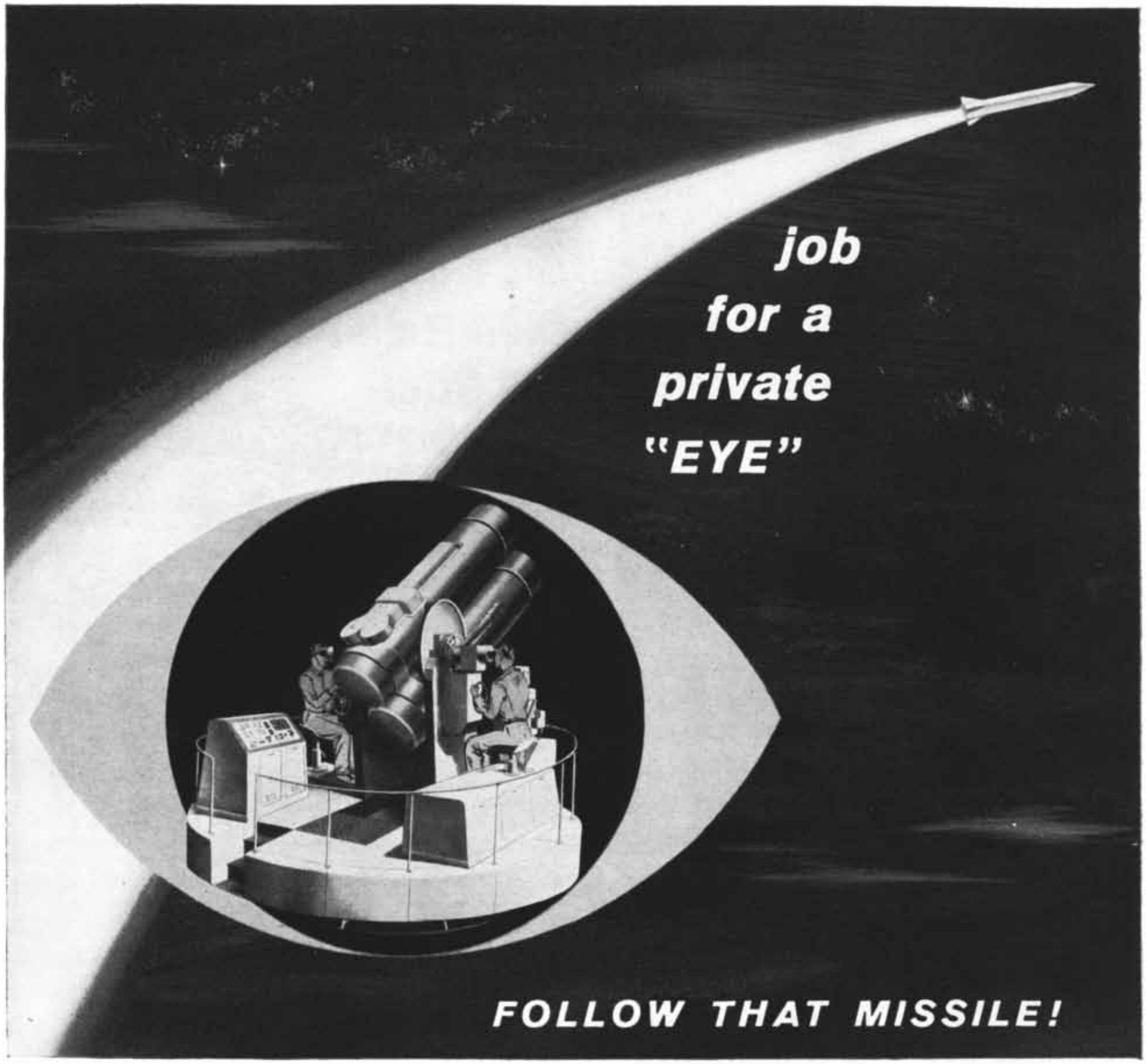

Tailing an experimental missile in flight takes a special kind of "eye." Seconds after takeoff the missile has kicked through the sound barrier and receded to a fast-moving speck that registers no larger than a few thousandths of an inch in a telescopic field.

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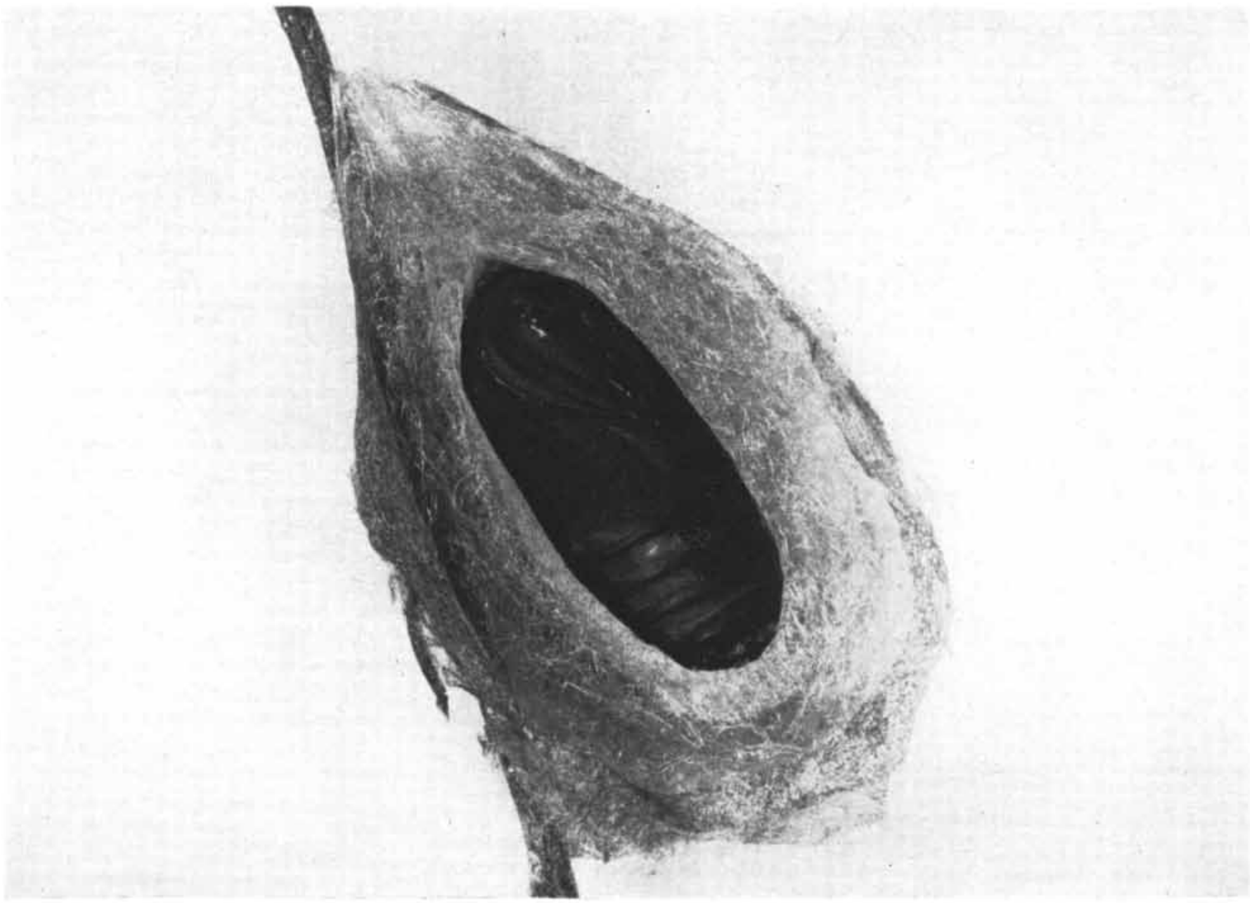
Brains and Cocoons

The fluffy shroud of the silkworm represents a map of its spinning movements. This pattern may be altered by brain surgery, shedding light on the relationship between the nervous system and behavior

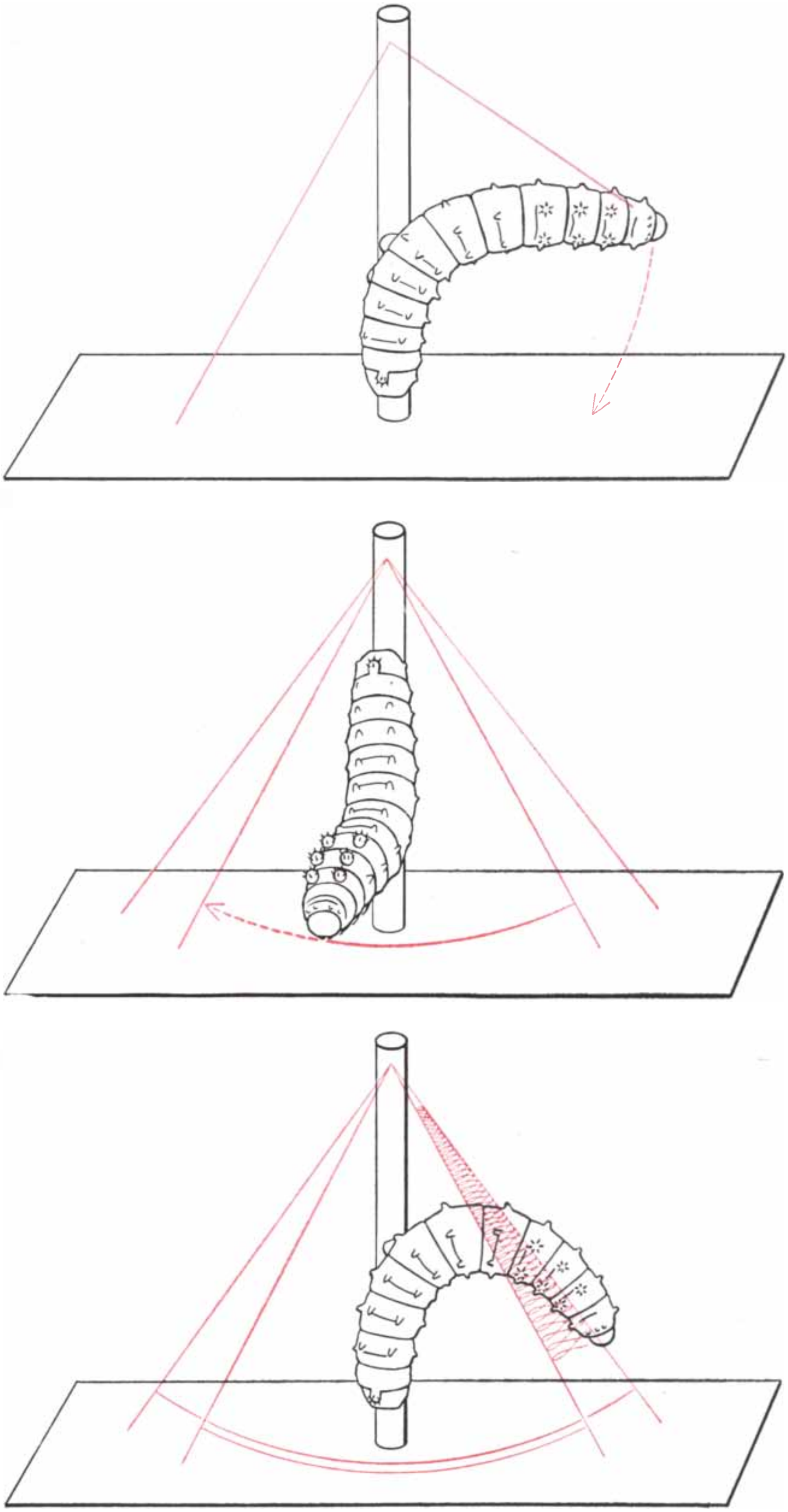
by William G. Van der Kloot

Every silkworm that is to become a moth must first spin itself a cocoon. This is an intricate process. Just how intricate can be seen by looking at the cross-sectioned cocoon in the photograph below. The caterpillar first spun a thin, tough, densely woven outer envelope. Then it laid down a loose cushion of silk. Inside this it enclosed itself in a second thin, tough envelope. There the caterpillar rests, metamorphosed to the pupal stage. In building the cocoon the caterpillar extruded more than a mile of silk.

The intricately woven cocoon gives us a three-dimensional map of the caterpillar's behavior. It thereby presents a visible record of the operations of the insect's nervous system. As such it serves as a convenient and relatively simple model for analyzing nervous systems in general. Beavers build dams, and men may build cathedrals. Silkworm cocoons, beaver dams and cathedrals all arise basically from the action of units which are much the same in each case—the nerve cells. We know that all nerve cells function on the same elementary "all or nothing" principle. A nerve cell either fires an impulse or it remains dormant; the impulse either excites or inhibits a neighboring cell. It is the patterned firing of thousands and millions of nerve



COCOON of the *Cecropia* silkworm is cut in half to show its inner construction. In the middle of the cocoon is the pupa of Cecropia. The cocoon consists of three layers: a thin outer envelope, a thin inner envelope and a thick, loose cushion of silk between them.



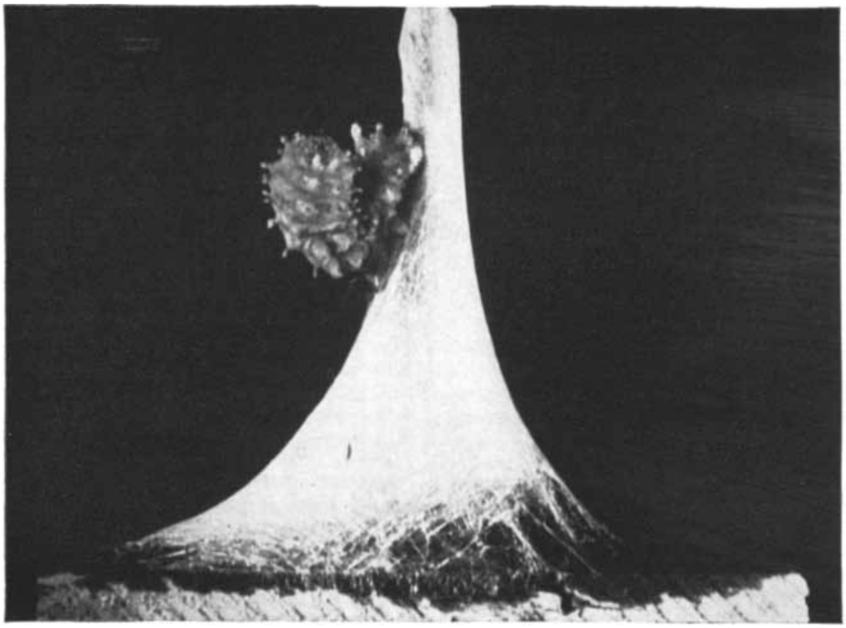
MOVEMENTS OF A SILKWORM spinning its cocoon are shown in these drawings. The movements are executed on a dowel mounted on a board in the laboratory. At first the silkworm climbs the dowel, fastens a thread to it and bends downward to attach the thread to the board (*top drawing*). Then the silkworm faces downward and spins the floor of the cocoon (*middle drawing*). When the floor and the framework of the cone are complete, the silkworm weaves a fabric between the threads of the framework with figure 8 movements (*bottom*). The silkworm is unable to make these movements near the apex of the cone.

cells that determines specific behavior. To understand how behavior is directed and controlled we must look into the circuitry by which a creature's nerve cells are hooked up in its central nervous system.

The building of cocoons provides an excellent approach to the investigation of nervous system circuitry. Although the silkworm's circuitry is sufficiently baffling, it is far simpler than the humblest vertebrate brain. Cocoon building is an inborn behavior pattern, dependably repeated by each individual without prior learning. The *Cecropia* silkworm invariably builds the same kind of cocoon; other caterpillars build other kinds. And the ways in which the silkworm's behavior may be modified by experiments are recorded visibly in its spinning patterns. These conveniences led Carroll M. Williams and me to select cocoon construction for study in the Biological Laboratories at Harvard.

We provide our silkworms with a spinning platform which consists of a dowel mounted perpendicularly in the center of a board. In this controlled situation they give us a uniform performance. Two patterns of movement shape the cocoon. The silkworm climbs up the dowel until its hind end is just above the board. In this position it stretches the forepart of its body upward and fastens the beginning of its silk thread to a point near the top of the dowel. Then it bends its forebody downward and to the side, paying out the line of silk as it moves, until its head touches the board. The caterpillar fastens the silk thread there, stretches upward again, glues the thread again to the dowel, and bends down to a different point on the board. The sequence of movements is repeated again and again. The silkworm gradually shrouds itself with a cone of silk.

Periodically during spinning its behavior changes. The silkworm reverses its position on the dowel so that its hind end is up and its head toward the board. It now swings the forebody first to one side and then to the other, spinning a relatively flat sheet of silk on the board. This will be the bottom of the cocoon. In nature the caterpillar rarely finds a flat surface beneath it, and the bottom is usually rounded. The shape of its cocoon, in short, is influenced by the environment: the silkworm must find points on a surface (or the webbing of its own silk) to attach the thread. If it does not make contact with some surface at the end of a movement, the silkworm will sway about until a contact is made. Where points of silk attachment are limi-



EXPERIMENT with one silkworm consisted in tying its tail to the dowel so that it could only face downward. The silkworm was able to spin the cocoon, but remained outside it.

ted, the caterpillar goes through much wasted swaying motion.

When the silkworm has built the skeleton of its cocoon, it weaves the fabric of the envelopes with a third movement. Rocking its head back and forth in a figure 8 pattern, it connects the silk threads already laid down—adding, so to speak, the woof to the warp. At the apex of the cone, however, the space between the silk threads is too confined for figure 8 movements, and the top of the cocoon is therefore only loosely woven—so loosely that a pencil can be slipped through the fabric. This feature, though not the result of conscious foresight, is important in the life of the silkworm. It provides an escape hatch through which the mature moth will make its exit to the world outside.

Now these three movements, which normally produce a cocoon, will produce strange and distorted variants when the silkworm is restricted in some way in the laboratory. For example, we tried the experiment of tying the caterpillar to the dowel with its head toward the board, so that it could not reverse its body and face upward. The animal began by stretching its forebody to the farthest point on the board it could reach and fastening the thread there. Then it bent the forebody toward the dowel, but since it could not reach upward, it had to fasten the thread at a point below or alongside its body. The result was that, though the silkworm succeeded in spinning a cone, it was left outside its cocoon [*photograph above*].

The structure had the usual two layers, corresponding to the outer and inner envelopes of the normal cocoon. The question arises: What sort of stimulus causes the spinning of the second layer? Evidently it is not contact with the completed first layer, because the insect was not enclosed in it.

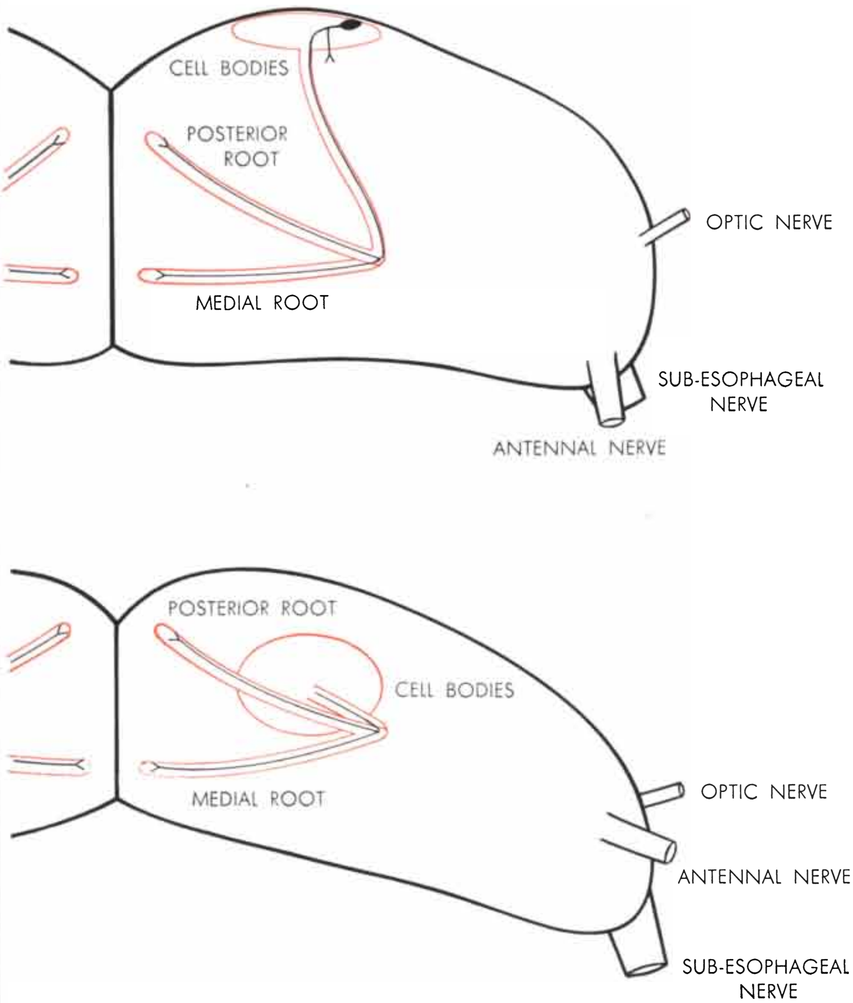
Normally the silkworm invests 60 per cent of its silk in the construction of the outer envelope. We wondered what a silkworm would construct if we could make it spend the initial 60 per cent of its silk in making a sheet instead of an envelope. To do this we had to provide the silkworm with a two-dimensional environment. Accordingly we inserted it in a large inflated balloon. In this endless two-dimensional world the insect could find no points in the third dimension for attachment of its silk. It had to spin the silk as a sheet spread out on the inner surface of the balloon. When a caterpillar had spun 60 per cent of its silk in this fashion, we restored it to the three-dimensional world. It proceeded as if it had made an outer envelope and built what corresponded to an inner one.

We concluded that the starting of the second layer must be controlled by sensory messages from the silk-forming gland, signaling when 60 per cent of the material has been spent. Further experiments showed that the silkworms actually measure the length of silk spun, "record" this information and finally act on the accumulated data.

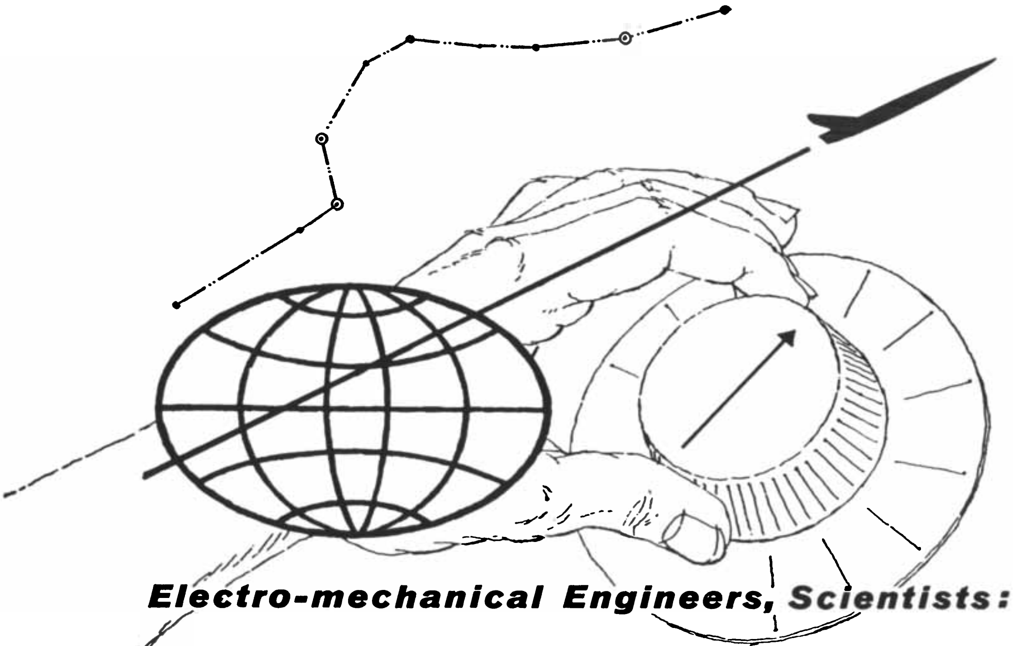
Sensory messages from the spinning apparatus are important in other ways. By means of a simple device in our laboratory we are able to record the gross spinning movements of a silkworm even when it is not actually building a cocoon. When we plug the insect's silk outlet with paraffin, it performs the usual ordered pattern of movements—it "spins an imaginary cocoon." But when we remove the silk glands surgically, the movements become disorderly. Apparently control of the movements to build a cocoon depends on a constant background of messages from the silk gland to the central nervous system.

Our task now was to get inside the silkworm to see if we could find out how its central nervous system translates the inflowing sensory barrage into an outflow of coordinated motor signals. We conceived this to be essentially a geographical question: What areas of the central nervous system perform this sensory-to-motor translation?

A first look inside the head of a silkworm raises doubt whether its brain is capable of conducting such a sophisticated operation. One is reminded of the thesis of the 18th-century naturalist and classifier Carolus Linnaeus, who held that insects have no brains at all: "Organs of sense: tongue, eyes, antennae on the head, brain lacking, ears lacking, nostrils lacking." The silkworm does have a brain, but it is not much more than a millimeter across and weighs but one or two milligrams. The structure gets something of the appearance of a brain from a constriction down the middle which divides it into right and left hemispheres [*see diagram below*]. Two nerves, one from each hemisphere, connect the brain to the rest of the central nervous system. They run downward around the esophagus and to a mass of nerve cells called the sub-esophageal ganglion. From here a pair of nerves extends down the length of the animal's abdomen. This is the ventral nerve cord, the insect's equivalent of the vertebrate spinal cord. Periodically the ventral



BRAIN of the silkworm is depicted in these schematic drawings. At the top the left hemisphere of the brain is seen from above. Its front faces down. At the bottom the hemisphere is seen from the front. The corpus pedunculatum, the message center of the brain, is in color.



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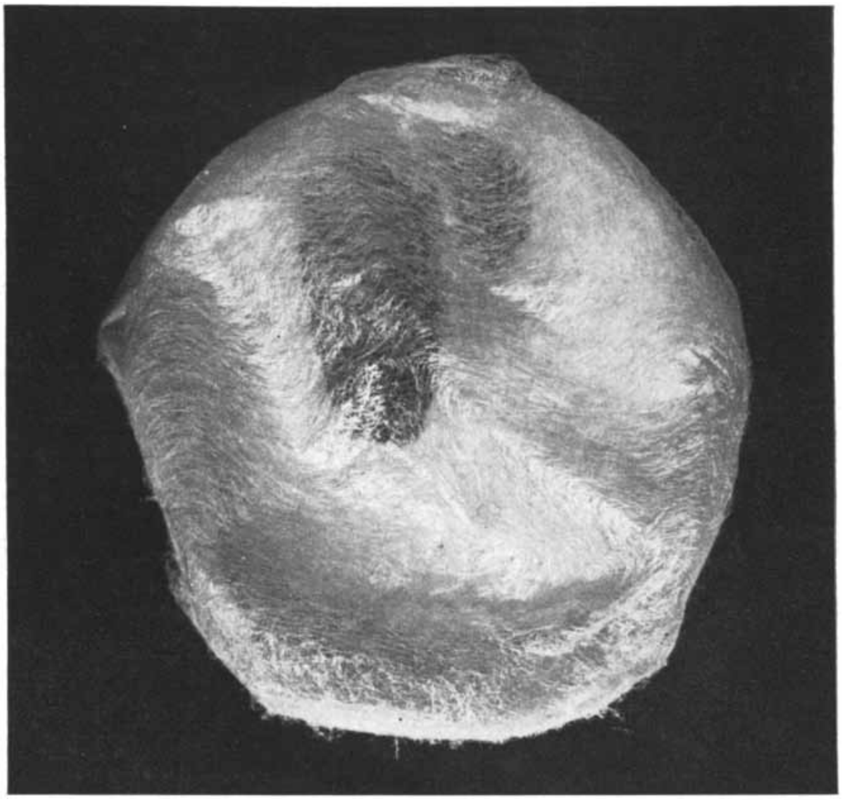

DAMAGED BRAIN caused another silkworm to spin its cocoon in this pattern. Placed in a cylindrical cardboard container, the silkworm covered the floor of the container with silk. Visible inside the silk sheet of the cocoon is the pupa and the shed skin of the silkworm.

nerve cord branches off small packets of nerve cells. These ganglia send nerves to the body muscles and receive nerves from sense organs nearby.

Does the brain coordinate the spinning movements or can this function be performed by the ventral cord alone? To answer this question we cut the cord. We found that even when the cut is made close to the head, the muscles at the front end of the silkworm that are still commanded by the brain drag the rest of the body through the movements of spinning. As long as a small fraction of the body is directed by the brain, the silkworm tries gamely to shape a normal cocoon.

We get a very different result when we remove the brain. The caterpillar retains coordination; it can crawl or climb. But it does not attempt to spin a cocoon. This experiment showed that the brain must be the control center for cocoon construction.

In the next experiment we disconnected one of the hemispheres of the brain from the central nervous system by cutting the sub-esophageal nerve. The silkworms spun, but in a disorganized way. They crawled about laying down silk as a sheet over every surface they encountered [*see photograph above*]. A similar derangement resulted when a hemisphere itself was cut through. Again the silkworms lined the inner surface of the container with a sheet of silk.

We went on to a more precise exploration of the brain. When a hemisphere was cut along a line close to the midline, the silkworms retained part of their normal behavior: they spun two layers of silk, one above the other, corresponding to the outer and inner envelopes of the normal cocoon. When we cut the brain through right on the midline, the animals spun perfect cocoons. Thus it was clear that nerve tracts which pass across the midline from hemisphere to hemisphere were not an essential part of the neural apparatus for spinning.

These results hinted that the control center could be located precisely somewhere in the hemispheres of the minute brain. To pinpoint that center, cuts through the brain, even with microscissors, were unavailing. We turned to burning tiny parts of the brain with high-frequency electric currents, which permitted us to destroy pieces of brain less than one twentieth of a millimeter in diameter.

We learned with this technique that more than half of the brain tissue was

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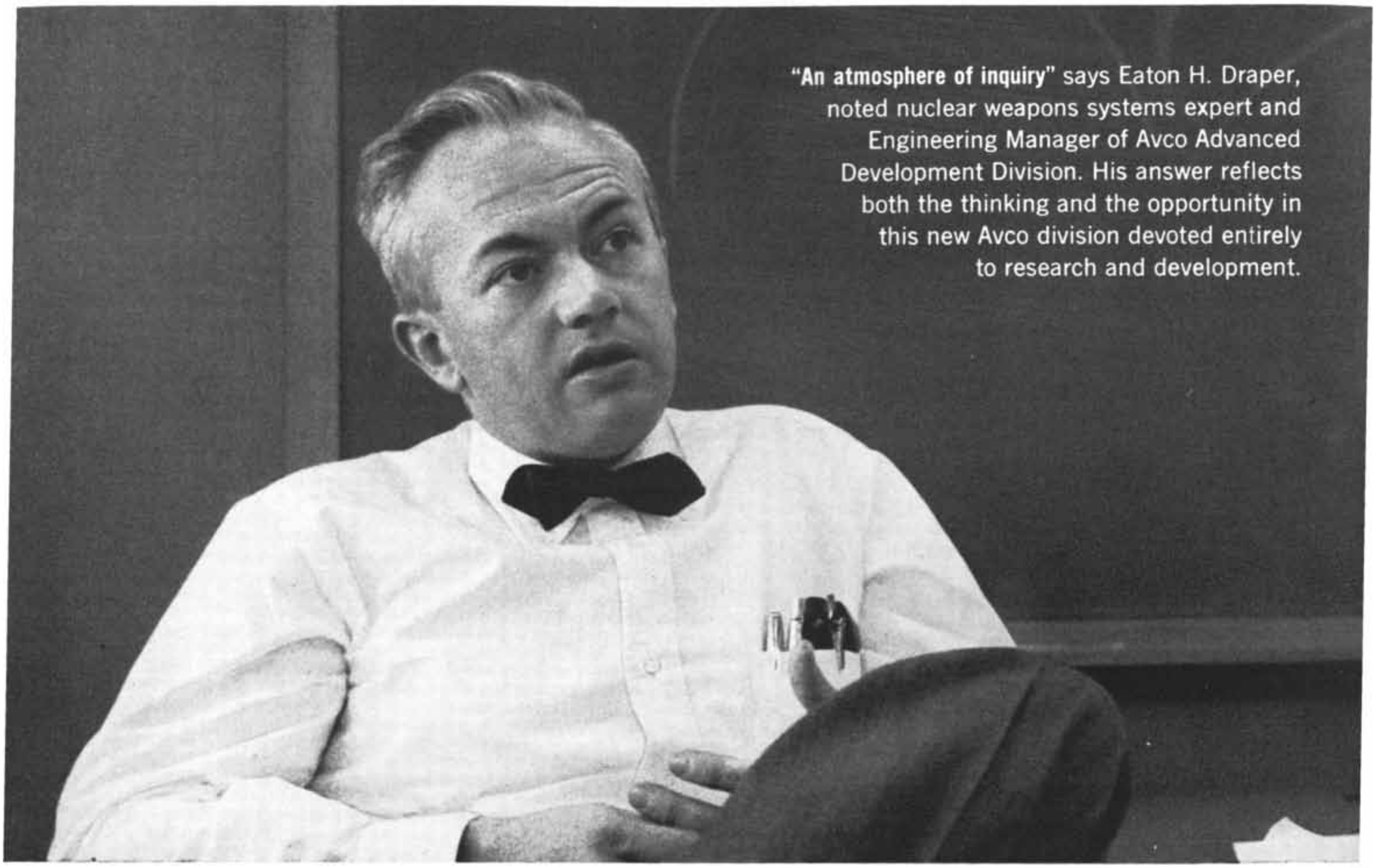

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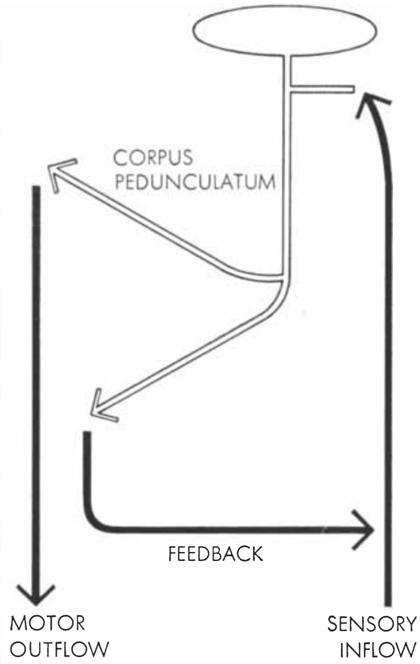

RELATIONSHIP between the corpus pedunculatum (*open lines*) and functions of the silkworm nervous system are outlined.

not involved in cocoon construction. The silkworm's spinning behavior was not affected by destruction of the receiving areas for nerves from the eyes and antennae or of regions containing tangles of association fibers. Eventually we located the critical areas around a pair of structures known as the corpora pedunculata. Even slight damage to these brain regions produced profound aberrations of spinning behavior.

The corpora pedunculata have long been familiar to insect neurologists. Félix Dujardin, a French zoologist, discovered these structures over a century ago in the course of an investigation which upset Linnaeus' contention that insects have no brains. He found that the structures attain maximum development in the social insects (bees and ants) and he called them "the seat of intellectual faculties."

There is a corpus pedunculatum ("body with stem") in each hemisphere of an insect brain; it can be seen even on external inspection. The "body" is a clump of nerve cells, and the "stem" is a cable which carries the cells' long filamentary axons to other centers in the brain. In the silkworm the structures are so small that it must be admitted the insect is an intellectual pauper. The stems follow a peculiar course. From the cell body, located at the rear near the top of the brain, each stem extends forward and downward into the hemisphere and later forks in a complex manner. Near

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the cell body each axon in the stem gives off one or more short branches, which make contact with axons coming from the sensory centers of the brain. A little further along, the stem forks into two roots, one running to the midline of the brain, the other running upward and back toward the cell body. At the end of the latter root, the axons carried by the stem make contact with motor pathways in the brain.

This circuitry suggests that the corpora pedunculata function as central message centers in the insect brain. Experiments strongly sustain the deduction. When the cell bodies of either corpus pedunculatum are destroyed, the caterpillar spins only one flat sheet. The same result in behavior occurs when we burn away the two roots running to the midline of the brain. If we leave these intact, however, and destroy only the roots going to the rear of the brain, caterpillars spin two layers. Thus it appears that the midline roots control the division of the silk into layers. The silkworms whose circuits were destroyed only at some points could perform all the motions of spinning, but they were unable to coordinate the individual motions into the building of a cocoon.

Anatomical studies suggest that the cells of the corpora pedunculata may be fired by sensory stimuli originating both inside and outside the body, and that the messages may interact, so that each pattern of stimulation causes a particular pattern of firing in the circuit. The resulting impulses pass down the stem and roots to excite the motor pathways and induce a patterned series of movements.

There is another possible circuit. Some of the axons that go to the roots do not connect with motor centers but instead return to the sensory centers. In the sensory center they may fire nerve fibers going to the input axons on the stem. This would provide a pathway by which some of the output of the circuit would be returned as input. We may deduce, in short, a feedback loop [*see diagram on page 138*]. It will be recalled that feedback circuits of similar design are the essence of mechanical and electronic control mechanisms.

The circuitry of the silkworm brain appears to be an ideally simple testing ground for investigating animal coordination. In most nervous systems integration occurs in incredibly tangled masses of nerve cells. The corpus pedunculatum presents the experimenter with an accessible bundle of oriented fibers, now known to be essential for complex behavior.

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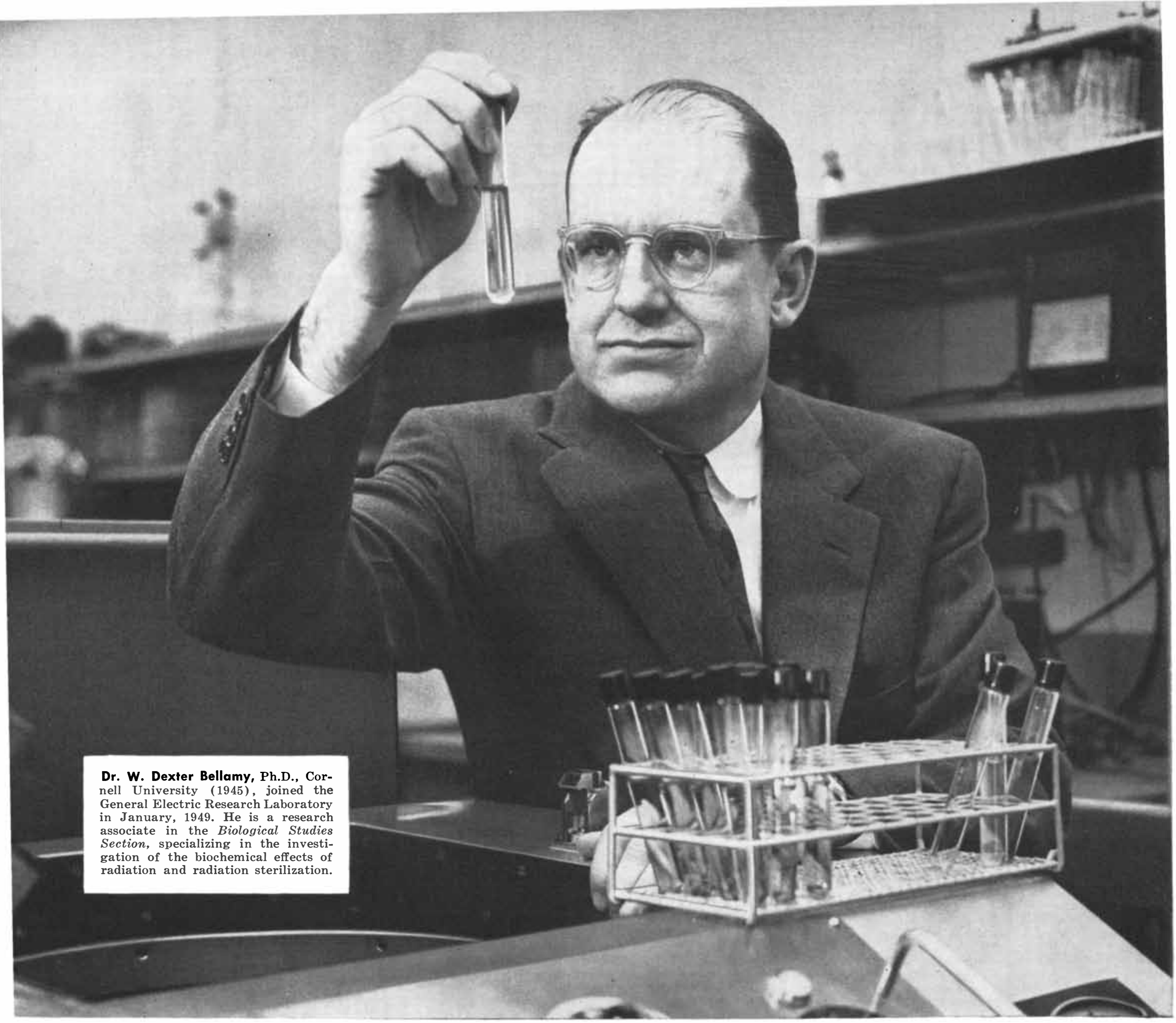

Dr. W. Dexter Bellamy, Ph.D., Cornell University (1945), joined the General Electric Research Laboratory in January, 1949. He is a research associate in the *Biological Studies Section,* specializing in the investigation of the biochemical effects of radiation and radiation sterilization.

Biological effects of electron bombardment

G. E.'s Dr. W. Dexter Bellamy finds new facts about irradiation

Since 1925, when Dr. William D. Coolidge first began bombarding materials with *high-voltage electrons,* the effects of electron-beam irradiation have been studied by researchers in many branches of science. Dr. W. Dexter Bellamy's work at the General Electric Research Laboratory is aimed at finding new fundamental facts about the *biological* and *chemical* effects of this radiation. A popular prophecy stemming from work in this area is the possibility of radiation-sterilized food that will keep indefinitely without refrigeration. Several problems — for instance, the changes of color and taste of irradiated foods — must be solved before the prophecy is fulfilled. While working on these problems, Dr. Bellamy and his associates are finding that knowledge already gained has other important implications. Their experiments have included the effects of irradiating bacteria, the chemical effects of irradiation on amino acids and protein, and the modification of dextran to produce a blood extender for emergency treatment of shock. As often happens in research, unexpected results have come from a program whose initial goal was simply "to learn more" in a new scientific field.

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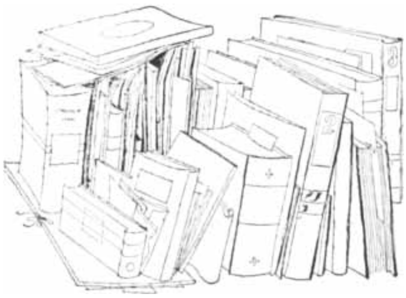

BOOKS

A new survey of psychoanalysis and related schools of thought

by Robert P. Knight

SCHOOLS OF PSYCHOANALYTIC THOUGHT, by Ruth L. Munroe. The Dryden Press, Inc. ($7.50).

There is a great deal of confusion and misinformation in the public mind regarding psychoanalysis. In the attempt to understand it each of us is influenced by his own life experiences, by what he needs or wishes to believe and by a need to protect himself somehow against unwelcome and disturbing self-knowledge. These prejudices unfortunately are reinforced by a steady barrage of distorted accounts or interpretations of psychoanalysis: popular books of a pseudoscientific, partisan or polemic nature; newspaper editorials hailing the new "tranquilizing" drugs as definitely outmoding psychoanalysis and all other non-pharmaceutical treatments of mental illness; plays, movies and novels which misportray psychoanalytic treatment for purposes of comedy or melodrama; or the arrant nonsense about Freud's theories in a syndicated medical column, written by a doctor who should know better—to mention but a few of the dubious sources for public opinion forming which I have noted in the past few months. Under the circumstances it is remarkable to find so many people with reasonably objective opinions and continuing open-mindedness on this subject.

Speaking both for informed laymen in general and for this reviewer's fellow psychoanalysts in particular, it is a pleasure to encounter Ruth Munroe's book. Her work, a survey of the various schools of psychoanalytic theory, is the most comprehensive and most reliable general book on the subject available at the present time. Dr. Munroe identifies herself as "a layman writing for laymen." She is not herself a psychoanalyst, but she is a clinical psychologist of high repute, a college teacher of rich experience, a master of clear exposition and the wife of a Freudian psychoanalyst. In the latter role, as well as in her own right as a professional, she is widely acquainted and respected in psychoanalytic circles, and she has had many opportunities to listen in on psychoanalytic shoptalk and to seek statements of views and criticisms of her manuscript from representatives of the various "schools" of thought she describes. She has enriched her exposition with personal experiences —as the mother of two children, as a once distressed human being who sought therapeutic help from psychoanalysis and found it, and as a psychologist. Her accounts of these personal and professional experiences, and the book itself, show her to be a highly intelligent, sensitive, capable and likable person.

As Dr. Munroe has identified herself for the readers of her book, this reviewer should also identify himself and his point of view in discussing the book. I am a Freudian psychoanalyst and psychiatrist who has been active in the American Psychoanalytic Association for two decades. I have taught psychoanalysis to students in training, have tried to apply it to the wider psychiatric field and have attempted to explain it to all levels of the associated professions and to all sorts of lay groups. I would not myself have attempted the task Dr. Munroe set for herself in writing this book, nor shall I attempt in this essay a detailed critique of the various schools. I shall content myself with describing and briefly discussing the psychoanalytic "arena" to which Dr. Munroe addresses herself.

The term "psychoanalysis" was first used by Sigmund Freud for his gradually evolving investigative and therapeutic method in 1896, so that psychoanalysis is now 60 years old. The term has come to have three connotations: (1) a research method for studying human psychology and psychopathology; (2) a growing body of empirical data and a collection of scientific hypotheses; and (3) a special technique of therapy. Until 1902, when he was 46 years old, Freud pioneered in depth psychology entirely alone, sharing his observations and hypotheses only in correspondence with his physician and friend Wilhelm Fliess. In 1902 he began to form a small group of interested colleagues, which included first Alfred Adler; then Otto Rank, a non-physician; Carl Jung, a Swiss physician, and others who were later to become well known. The Vienna Psychoanalytic Society was formed in 1908, and in the same year a group which became the International Psycho-Analytical Association held a meeting in Salzburg. The first American to be associated with Freud was A. A. Brill, a New York psychiatrist, in 1908. Three years later the New York Psychoanalytic Society and the American Psychoanalytic Association were organized.

The mainstream of the science of psychoanalysis and of organized psychoanalysis is definitely, and quite logically, "Freudian." Few if any of the 620 current members of the American Psychoanalytic Association would have any hesitation in replying in the affirmative if asked whether or not they are Freudians, although almost none would profess absolute agreement with every hypothesis Freud advanced in his writings. Nor, for that matter, would Freud himself. To the year of his death (1939) he was constantly observing and re-examining his hypotheses—discarding some, revising others and elaborating still others. Also, throughout his life he respected and accepted into the body of psychoanalysis the contributions of other analysts, so that while the main structure of theory is the product of his genius, significant developments have come from many others. Freudian psychoanalysis is taught today in 17 training centers in the U. S., all under the aegis of the American Psychoanalytic Association, and in a number of other institutes in Europe and South America.

How, then, could various "schools" of psychoanalytic thought develop in such a way as to make necessary the present exposition by Dr. Munroe? If Freud and psychoanalysis are practically synonymous, as they are, how can there be non-Freudian psychoanalysis? The answer is that there is no such thing as non-Freudian psychoanalysis: several of the so-called "schools of psychoanalytic thought" in Dr. Munroe's book are so designated incorrectly.

Having given the name psychoanalysis to the system he was developing, Freud quite understandably felt entitled to declare which hypotheses of others were or were not consistent with psychoanalysis. In a polemic article called "The History of the Psycho-Analytic Movement," written in 1914 shortly after the defections of Adler and Jung, Freud stated that his former disciples were free to follow their own theories, but these theories should not bear the name of psychoanalysis. Adler, who had organized a "Society for Free Psychoanalysis," thereafter labeled his theories "Individual Psychology." Jung took the label "Analytical Psychology" for his. Both schools of psychology survive today as minor groups, but, by their founders' own insistence, they were not and are not schools of psychoanalysis. Nevertheless in popular parlance the shortened term "analysis" still clings to their names, and people speak not only of a Freudian analysis, but of an Adlerian analysis, a Jungian analysis or a Rankian analysis.

The word "psychoanalysis" has never been copyrighted by the Freudians, and remains in the public domain. Those who claim to practice psychoanalysis are legion. They range from the well-trained Freudians through practitioners of various non-Freudian schools down to palm readers and crystal-ball gazers, who include "psychoanalysis" on their window signs. Any present-day analyst who feels impelled to lead a secession movement from Freudian psychoanalysis can do so by resigning from his psychoanalytic society, gathering a few faithful students together and founding a new "school" which is still called psychoanalysis. Karen Horney, one of the leaders of a school discussed in Dr. Munroe's book, did just what has been described, forming an "Association for the *Advancement* of Psychoanalysis" (italics mine), reminiscent of Adler's "Society for *Free* Psychoanalysis," and an "American Institute for Psychoanalysis." Furthermore, any psychiatrist can represent himself as a psychoanalyst, whether or not he has had proper training for the use of that technique of treatment, and there is no law or official group to challenge his claim. In the 1955 official membership roster of the American Psychiatric Association 1,063 of the 8,534 members list themselves as practicing psychoanalysts, but only 378 of these are members of the American Psychoanalytic Association. Of the remaining 685, some are young psychiatrists in psychoanalytic training, some were trained in non-Freudian institutes, and some, one fears, have had no special training in psychoanalysis. The prestige value of the designation "psychoanalyst" is fairly high, and it has been several decades since any analyst discarded this title when he formed a new school. I believe that Otto Rank was the last to do so when, in the late 1920s, he ceased calling himself a psychoanalyst and thereafter referred to himself as a psychotherapist.

To a layman the concern about the use of the label "psychoanalysis" may sound like quibbling, or something worse. It may suggest that psychoanalysis is like a religious dogma, and that the faithful cast out as heretics any who dissent from the founder's accepted doctrines. It must be admitted that there has been at least some of this flavor in psychoanalysis, and to the extent that this has been true the young specialty of psychoanalysis has not lived up to the dignity of the science. But the differences between psychoanalysis and the rival "schools" are not merely a question of labels. Each has a different approach, and the real question is how each measures up to the applicable criteria of science—that is, to what extent it can be regarded as a scientific system.

There are difficulties in studying human depth psychology which are not present in anything like the same degree in the natural sciences. No one has made exact quantitative measurements of such forces as fear, love, hate, motivation, volition or instinct. Nor can one set up rigidly controlled psychological experiments with human beings, except to a very limited extent. Furthermore, in psychology the investigator himself is practically always a significant factor in the investigation in a much more important way than is the investigator in natural science studies. And, perhaps most important of all for this discussion, an investigator of human nature inevitably has some degree of resistance to some parts of the field he is investigating. He has some blind spots, some needs to see and believe certain half-truths, and some needs not to see and not to believe whatever would threaten his own equanimity. To reduce these blind spots and biases to a minimum, a trainee in psychoanalysis is required to investigate his own inner psychology thoroughly in a training analysis as the very first step of

his studies. Such self-knowledge is exceedingly hard-won, proceeding as it does against resistances. And unfortunately it is not always retained throughout the analyst's professional life. A few may, under certain life stresses to which they are individually vulnerable, revert to preanalytic attitudes, usually rationalizing this shift as an *advance* in insight and theory. They may even attack (verbally, that is) their own analysts, or perhaps more often the man responsible for all the trouble in the first place, Freud. For being analyzed involves a reawakening of the powerful feelings of love and hate that he felt in his earliest years toward his parents, brothers, sisters and others, and the analysis of these transference feelings is one of the chief tasks of the therapy. If the analysis is successful, these feelings are resolved with new understanding and release of energy for harmonious living and working. But here again the resolution may, in some analysts, be undone by later life stresses. Psychoanalysts are not supermen, nor have their lives been rendered immune to stress by their own analyses. Mostly they do exceedingly well, considering the highly sensitive personality make-up they must have to be able to perceive the subtleties of the emotional troubles in their patients. But the few defectors make quite a commotion.

It is not surprising that the part of Freudian theory most often repudiated by those who found new schools is the libido theory—the hypothesis that each individual's personality is rooted in his early psychosexual development and experiences. For it was in just this area that Freud was the greatest disturber of the psychological peace. Dr. Munroe in fact designates the non-Freudian schools as the "non-libido" schools. Most of them have turned to the environment (the culture) and at least partly away from the individual unconscious for explanations of human behavior.

Freud once remarked that he could not study every part of the human psyche at once. He first tackled the unconscious—the hidden inner forces and impulses which he was convinced were rooted in biology. Of the inner impulses he perceived and studied sexuality first, and aggression only much later. Indeed, he was impatient with Adler for his early emphasis on aggression. Although Freud studied the individual psyche much more than he studied the environment, it would be ridiculous to call him anticulturist. Throughout his scientific work he aimed at a unified, all-inclusive theory of personality, but he died at 83 before it was achieved. Freudian psychoanalysis continues to work toward the unified theory.

Each of the "non-libido" school leaders mentioned in Dr. Munroe's book has made definite contributions to the total theory, but none of them has attempted to develop an all-inclusive science of personality. Each has focused on certain areas of the problem, remaining silent on others. Dr. Munroe attempts to compare the various schools and to check each school critically against broad scientific criteria. For the purposes of such a cross-comparison one must grant her the right to call them all "schools of psychoanalytic thought." She examines each school's theories according to how it deals with: (1) biological inheritance, constitution and instincts; (2) man's relation to his fellows and to his environment or culture; (3) the process by which personality develops; (4) the dynamics of the functioning personality; (5) pathology and treatment. In admirably clear fashion she explains and comments on Freudian psychoanalysis and the schools of Adler, Horney, Erich Fromm, Harry Stack Sullivan, Jung and Rank.

The Freudian school comes off as considerably the most scientific in Dr. Munroe's critical examination, though she finds gaps in its theories too, particularly with reference to its incomplete concept of the self and to its insufficient attention to nonsexual factors. Of the other schools, she feels that the Sullivan school is most likely to survive. Adler, Rank and Horney are especially criticized for being "reductionist", *i.e.*, for erecting their theories on certain partial aspects of the personality.

Dr. Munroe has read prodigiously and worked prodigiously in preparing the manuscript, and the publisher has performed an impeccable and attractive job of book-making. It is a real labor of love on the author's part, for she has succeeded in providing a sympathetic, nonpartisan exposition of each school's views. For the most part the volume is easy reading. Where it is hard going the fault lies not with the author but in the confusing terminology of the school she is describing. There is a bibliography at the end of each chapter, and an index which looks adequate. However, when this reviewer tried to look up "nonsexual systems," among which "motility" had been emphasized, he could not find "nonsexual" nor "systems" nor "motility" in the index.

If Dr. Munroe falls somewhat short of providing a definitive reference book, it is not at all to her discredit. She did not aim so high in the first place, and, in the

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second place, such a task would be so formidable as to cause dismay to even our most scholarly colleagues. Dr. Munroe, I am told, labored five years on the book as it is. A colleague who is exceptionally erudite in psychoanalytic theory remarked to me that he might be able to bring off the final reference book on the subject in 20 years of work. I think he might do it in 10.

Short Reviews

FRONTIERS OF ASTRONOMY, by Fred Hoyle. Harper & Brothers ($5.00). Astronomy and cosmology are among the oldest sciences, but they are not sedate in proportion to their years. The modern ferment in these branches of knowledge may be attributed not only to advances in observational techniques but to the very character of astronomical thought, which both permits and requires more extensive speculative flights than any other of the physical sciences. Cosmology, in short, is a paradise for the imaginative thinker. This fact is well brought out in Hoyle's new book, which is a successor to his popular *The Nature of the Universe* but differs considerably from it in scope and in the demands made on the reader. *Frontiers* is a comprehensive account of major astronomical discoveries and cosmological theories in recent years. The author considers in detail the formation and structure of the Earth, the cause of the ice ages, the origin of the planets, the beginnings of life (primitive forms, he suggests, came into being before the Earth was born), the evolution of the Sun, the natural history of the galaxies. A chapter is devoted to the physics of the "ultra-small"—atoms and related particles—since the knowledge of matter at this end of the scale is believed fundamental to an understanding of the ultra-large aspects of the universe. Other subjects include the measurement of astronomical distances, radio astronomy, the features of the moon and the use of isotopic dating methods. Hoyle's book abounds in theories which make Sherlock Holmes's ratiocinative high jinks look as unexciting as an old calabash pipe. One of them has to do with the formation of the Earth by a cold process of agglutination: colliding chunks of ice, rock and iron were held together by some "sticking agent"—perhaps a hydrocarbon—and gradually snowballed into larger bodies. Another theory attempts to link the ice ages to periods of heavy rainfall which are supposed to follow within 30 days after intense meteor showers. Hoyle argues that the breakup of comets in the solar system in the last million years produced the necessary meteoric dust. Still another theory purports to explain the coupling of the rotation of the Sun to a disk which once surrounded it and from which the planets were formed. This disk, as another theory suggests, had been torn loose from the Sun, of which it was originally a bulge. But in that case how could the Sun continue to transfer its momentum to the disk, as the theory requires, and how could the disk have decreased the speed of the Sun's rotation to a rate which conforms with observation? A very pretty saving hypothesis was introduced some years ago by the Swedish physicist Hannes Alfvén. He proposed that the rotational momentum was carried by a magnetic field, and that the lines of magnetic force, acting like elastic strings, connected the disk with the Sun. If one now imagines these strings to be the spokes of a wheel whose rim is the disk, and whose hub is the Sun, the rim could lag behind the hub and the spokes would thereby be stretched; this in turn would slow down the hub. It is easy to see that the invention of theories of this kind is limited only by the cleverness of theorizers—which is to say that a great many models will satisfy a single set of data, especially when the data are meager. Hoyle is altogether at home in this fascinating field of conjecture, and while he lacks the expository virtuosity of a Jeans or an Eddington, he is capable of arguing so persuasively that the reader is at times hard put to distinguish between the frontiers of astronomy and the frontiers of Fred Hoyle. All the same this is an absorbing and valuable survey. Illustrated with excellent photographs.

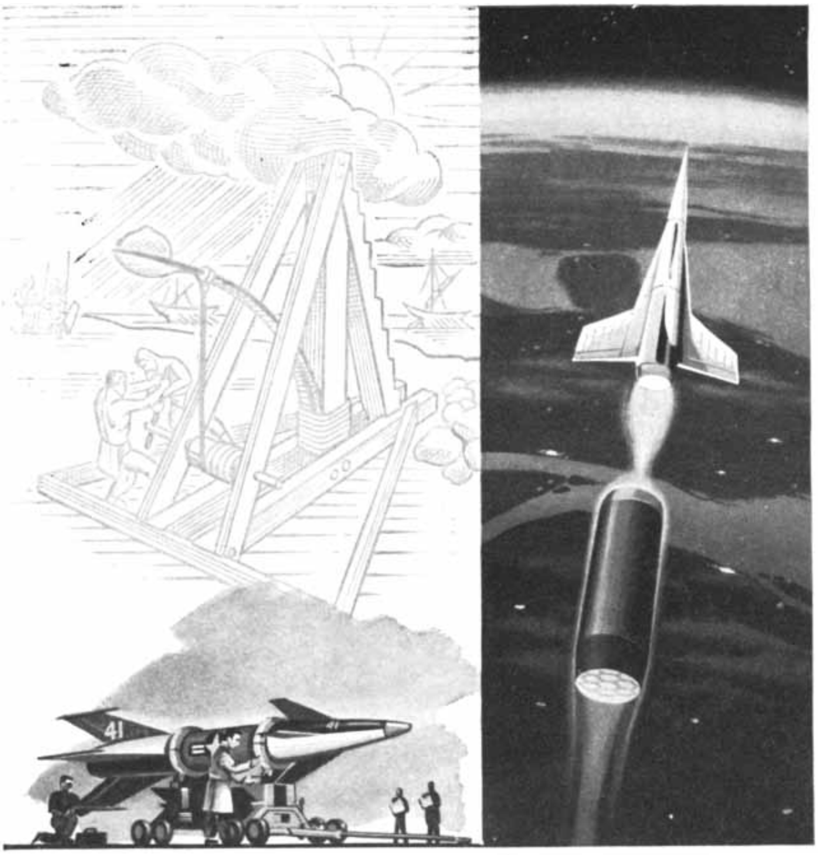
2000 FATHOMS DOWN, by Commander Georges S. Houot and Lieutenant Pierre Henri Willm. E. P. Dutton & Company, Inc. ($4.00). On February 15, 1954, these two French naval officers descended to a record ocean depth of more than 13,000 feet off the African coast at Dakar in the French "bathyscaphe" F.N.R.S.3. They give an account of the building of the craft, the preparations and the descent. The adventure makes a lively story, but by far the most interesting aspect of the undertaking is the structure of the bathyscaphe, which looks like a midget submarine with a spherical cabin hanging from its keel and operates like an underwater balloon. The cabin has steel walls three and a half inches thick and can withstand a pressure of nine and a half tons per square inch. The submarine-shaped superstructure is nothing but thin sheet-metal, yet it also resists the enormous pressure by means of an ingenious arrangement which lets sea water into the hull to compensate for compression of gasoline in tanks in the hull by the outside pressure.

THE DEVELOPMENT OF ACADEMIC FREEDOM IN THE UNITED STATES, by Richard Hofstadter and Walter P. Metzger. Columbia University Press ($5.50); ACADEMIC FREEDOM IN OUR TIME, by Robert M. MacIver, Columbia University Press ($4.00). Academic freedom is like the household gods: its position is determined by the household more than by heaven. With the other freedoms—of religion, of speech, of the press, of assembly—it does not stand outside society but is an intimate part of it. Men have created the concept, put it into practice, cherished and strengthened it, quarreled over it and attacked it; at different times and places they have come close to destroying it. In our country today it has dangerous enemies as well as stubborn protectors. These two books, fruits of a Columbia University project initiated and supported by the Louis M. Rabinowitz Foundation, constitute an invaluable contribution to an understanding of the history and present status of academic freedom in the U. S. Hofstadter and Metzger trace its evolution from colonial times through the sectarian struggles and politics of the 19th century to the intellectual conflicts and the conflicts of interest in which it is enmeshed in the 20th century. Their book is the first comprehensive history of its kind—a just, sober and most interesting work. MacIver reports on the vicissitudes of academic freedom in U. S. universities today. He discusses the structure of public opinion in the U. S., academic government and political controls, the religious and economic attacks on academic freedom, the freedom the student needs as well as the teachers. Many of his case studies involve events as ludicrous as they are shameful. They include the burning of books by the vigilant ladies of Sapulpa, Okla., the discovery of the subversiveness of Robin Hood by an eminent member of the Indiana Textbook Commission, the forced resignation of the president of the University of Illinois under a list of counts which included the serious charge that he had taken an important part in the development of UNESCO. MacIver is a long-winded, didactic writer, but his sermons do not diminish the importance of his balanced appraisal. Academic freedom, as these volumes clearly show, *defines* the true university, and while this ideal has long been incorporated in our rhetoric, the vigor of its application has always depended on individual leadership by the heads of universities, on the determination of faculty and students to fight for the maintenance of their liberties, and above all, on a society which respects men and learning.

INTERNATIONAL ENCYCLOPEDIA OF UNIFIED SCIENCE, edited by Otto Neurath, Rudolf Carnap and Charles W. Morris. The University of Chicago Press ($11.00). This notable encyclopedia, begun in 1938 under the editorship of the late Otto Neurath, has thus far appeared in 20 paper-bound monographs. The first 10 of them are now issued together in two hard-cover volumes. Among the authors and topics represented are Charles W. Morris on the theory of signs; Rudolf Carnap on the foundations of logic and mathematics; Ernest Nagel on the theory of probability; Philipp Frank on the foundations of physics; Egon Brunswik on the conceptual framework of psychology; and John Dewey, Niels Bohr, Bertrand Russell and Otto Neurath on other aspects of "encyclopedia and unified science."

EARLY VICTORIAN ARCHITECTURE IN BRITAIN, by Henry-Russell Hitchcock. Yale University Press ($20.00). In two handsomely designed volumes, one of which is entirely given to illustrations, a leading American historian of architecture tells the story of the buildings of England from the early 1830s to the middle 1850s. He discusses the church architecture of Augustus Pugin, the "palace" architecture of Sir Charles Barry, the manorial and castellated country houses, commercial buildings, housing developments, the great railroad stations and other iron constructions, and, of course, that incomparable "ferro-vitreous" triumph, the Crystal Palace, dreamed up by the Duke of Devonshire's quondam head gardener at Chatsworth, Joseph Paxton. Hitchcock's monumental book is in a sense a social as well as a technological history: he illuminates the curious mixture "of romantic archaeology," "naked industrial progress" and religiosity which found expression in the structures of the Victorian age, and whose influence was felt in the U. S. and the Dominions. A thoroughly enjoyable work of scholarship.

THEORETICAL GENETICS, by Richard B. Goldschmidt. University of California Press ($8.50). Genetics, says



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Goldschmidt, has not reached the level at which a full-scale theory of the subject can be established. Nevertheless the attempt at least to sketch an outline of a "future theoretical genetics" is "not outside the trend of the times." In this volume, based on 45 years of research, the author tries to achieve a synthesis of all the basic features. Three major problems are considered: the "nature of the genetic material," the mechanism whereby it controls specific development, and how evolution is to be explained in terms of the material and its action. A stimulating monograph for advanced students.

Experimental Design and Its Statistical Basis, by D. J. Finney. The University of Chicago Press ($4.50). The emphasis of this introductory volume is on the design of experiments in biological research. It discusses such topics as counts and measurements, randomization, Latin squares, factorial and sequential experiments. The author addresses himself to persons with no previous knowledge of statistical analysis, and even the simplest mathematical sequences are carefully explained.

Amateur Astronomer's Handbook, by J. B. Sidgwick. The Macmillan Company ($12.50). Background on the theory and making of instruments for astronomical observation. The topics include the functioning of a telescope, aberrations, optical materials, metal-on-glass films, eyepieces, compound optical instruments, mountings, spectroscopes, photography, measurements, time and clocks. A companion volume just issued, *Observational Astronomy for Amateurs*, deals with the techniques of observation.

The Moon, by H. Percy Wilkins and Patrick Moore. The Macmillan Company ($12.00). A Baedeker of the moon. All the aspects of the moon are treated: the fascinating names, discoverers, historical details and physical features of the mountains, craters, rings, "seas," "capes," ridges, clefts, plains, polar regions. Dr. Wilkins' standard map of the moon's surface, divided into 29 sections, is presented in this revised edition, together with many additional drawings and plates.

Water: The Yearbook of Agriculture, 1955, edited by Alfred Stefferud. U. S. Government Printing Office ($2.00). The yearbooks of the U. S. Department of Agriculture have for two decades or more set a high standard. They are authoritative, readable, attractively made and marvelously inexpensive. In recent years the practice has been to devote the annual to a comprehensive treatment of a single subject. Water in its various aspects is dealt with here in some 100 articles running to 750 pages. Many charts and illustrations.

JANE'S FIGHTING SHIPS: 1955-56, edited by Raymond V. B. Blackman. The McGraw-Hill Book Company, Inc. ($25.00). Revised and updated with 450 fresh illustrations. Fighting ships can still float, but there the resemblance to ships ends. This is demonstrated, as the editor points out, by the anachronistic character of the traditional nomenclature. There are battleships, but there is no longer a line of battle. Cruisers don't cruise—whatever that might once have meant. Escort vessels don't escort nor do patrol vessels patrol. Frigates are any kind of ship under 2,000 tons which doesn't fit into one of the other ill-designated categories.

JANE'S ALL THE WORLD'S AIRCRAFT: 1955-56, edited by Leonard Bridgman. The McGraw-Hill Book Company, Inc. ($25.00). Hundreds of new illustrations and an article on guided missiles are among the features of this edition.

Notes

SCIENCE IN PROGRESS, edited by George A. Baitsell. Yale University Press ($6.50). The ninth volume in the series of National Sigma Xi Lectures includes reports on heredity (Laurence H. Snyder), the bristles of Drosophila (Curt Stern), the molecular basis of visual excitation (George Wald), nuclear magnetism (Felix Bloch), suspension bridges (D. B. Steinman), transistor physics (William Shockley).

FUNCTIONAL ANALYSIS, by Frigyes Riesz and Bela Sz.-Nagy. Frederick Ungar Publishing Company ($10.00). This monograph by two leading Hungarian mathematicians deals with modern theories of differentiation and integration, integral equations, linear functionals and transformations.

THE ATOMIC NUCLEUS, by Robley D. Evans. McGraw-Hill Book Company, Inc. ($5.50). An exhaustive monograph representing the content of a two-semester course by the author at M.I.T.

THE APPRECIATION OF ANCIENT AND MEDIEVAL SCIENCE DURING THE RENAISSANCE (1450-1600), by George Sarton. University of Pennsylvania Press

($5.00). Professor Sarton takes the reader on a learned, discursive, agreeably unmethodical journey through the incunabula and scientific classics of the 15th and 16th centuries.

CLINICAL PAPERS AND ESSAYS ON PSYCHO-ANALYSIS, by Karl Abraham, edited by Hilda Abraham. Basic Books, Inc. ($6.00). Second volume of the writings of one of Freud's most devoted followers.

THE ORIGIN OF THE EARTH, by W. M. Smart. Penguin Books (65 cents). This is a reissue of a readable, unencumbered account of the contributions of various sciences—from astronomy to biology—to our knowledge of how the earth and other planets came to be.

THE EXPRESSION OF THE EMOTIONS IN MAN AND ANIMALS, by Charles Darwin. Philosophical Library ($6.00). A reprint of a classic inquiry. It is illustrated with some modern photographs and drawings of expressive behavior.

RAND MCNALLY COSMOPOLITAN WORLD ATLAS. Rand McNally & Company ($13.95). The Centennial Edition of this standard work has some new features: full-color relief maps of all continents and the U. S. and Canada; a 12-page illustrated section on "places of interest" in the U. S.; new population figures and other new statistical data.

THE COMMON SENSE OF THE EXACT SCIENCES, by William Kingdon Clifford. Dover Publications, Inc. ($3.00). A new edition of a classic of popularization by one of the great thinkers of the 19th century. Clifford's famous work deals with number, space, quantity, position and motion. The edition has a biographical essay by James R. Newman, its editor, and a preface by Bertrand Russell.

A HISTORY OF ASTRONOMY FROM THALES TO KEPLER, by J. L. E. Dreyer, revised with a foreword by W. H. Stahl. Dover Publications, Inc. ($3.95). The re-publication of this standard work, long out of print, by a leading Danish astronomer and historian of science who died in 1926 will gratify many readers.

PLOUGH AND PASTURE—THE EARLY HISTORY OF FARMING, by E. Cecil Curwen and Gudmond Hatt. Abelard-Schuman ($5.00). The authors first examine the subjects of agriculture and animal husbandry in light of the archaeological facts and then review "the economic culture of non-European peoples of modern and late historic times."

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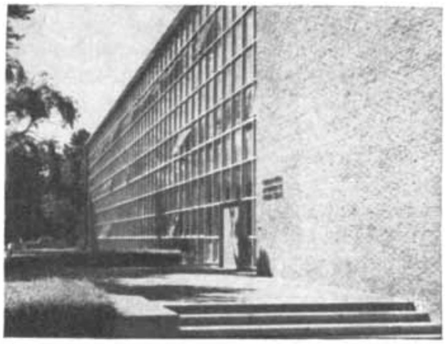

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Mostly about making a cloud chamber to reveal the paths of nuclear particles

If you fasten a disk of alcohol-soaked blotting paper in the bottom of a jar, screw on the lid and up-end the jar on a cake of dry ice, you will occasionally see the concluding phase of an event which may have had its origin millions of years ago in an exploding star. The apparatus comprises a cloud chamber of the diffusion type. Every few seconds a sharp, momentary vapor trail will appear near the bottom of the jar. Most of the trails represent particles from radioactive material in the earth, or fragments of atoms smashed in the atmosphere by cosmic rays. But once in a great while the trail will mark the passage through the jar of a primary cosmic particle from space.

Whatever their origin, nuclear particles make wonderful playthings and can become the central objects of a fascinating hobby. Some 6,000 U. S. amateurs have taken up nuclear experiments and built diffusion cloud chambers of the type described in this department in September, 1952. Our incoming mail continues (after three and a half years) to bring daily requests for the speck of radium mentioned in that article and for information about other nuclear experiments. Most of these amateurs turn out to be engineers or scientists of one branch or another. But one of the nation's better-known ballerinas has taken up the study of pi mesons, and hundreds of other nonscientists, ranging from business executives to craftsmen, have learned that the atom can be relaxing as well as awesome—depending on how you look at it.

Each of the known nuclear particles leaves its characteristic trail in the cloud chamber, and photographs of them are available in reference texts. A number were illustrated by diagrams in "The Ultimate Particles," by George W. Gray, in SCIENTIFIC AMERICAN of June, 1948. With the help of published photographs of tracks you can identify the particles as you would birds or butterflies. You may find the behavior of the particles just as fascinating.

The vapor trails of particles are like the swath that a cannon ball might cut through a young forest. If you were to view a series of such events from an airplane, you could judge the relative size, speed and energy of the balls by the length and width of the swaths. From the zigzag paths of ricocheting missiles you might learn something about the structure of the forest. Occasionally a swath unlike any previously recorded might signal a new type of cannon ball or gun. That is how the list of nuclear particles has been compiled and how the cloud chamber tips off physicists to the presence of unexplained forces in the universe.

Because dry ice is often difficult to procure, a number of our correspondents have asked for the design of an iceless chamber. A simple one can be built on principles used by C. T. R. Wilson, the inventor of the cloud chamber, in his first version. While at the Ben Nevis Observatory in Scotland in 1894, Wilson became fascinated by the play of sunlight on clouds surrounding the mountain, particularly by circular rainbows around the sun. On returning to the University of Cambridge, where he was senior demonstrator in the Cavendish Laboratory, Wilson attempted to imitate the phenomenon in miniature. His apparatus consisted of three bottles, some tubing and an air pump. He put some water in a large bottle and inside this up-ended a small bottle, also partly filled with water. It was held in place about half way down in the larger bottle. Now the large bottle was stoppered and connected by tubing to an evacuated third bottle. When a petcock was opened, air rushed out of the big bottle into the vacuum chamber. As a result the moist air in the small inverted bottle expanded suddenly, and the air was suddenly cooled. At the reduced temperature, the air contained an excessive amount of water vapor and was in a state of supersaturation. If dust particles or other nuclei were present, the excess vapor would condense on them and form a cloud.

Out of two 12-ounce peanut-butter jars, a coffee can, some tubing and a toy balloon you can make a version of Wilson's apparatus in an hour or less [*see illustration on the opposite page*]. Cut the jars' tops so as to leave the screw-rims, then butt and solder the two rims together with a disk of fly screening sandwiched between. Next drill a hole, large enough to take a No. 6 machine screw, through the bottom of one of the jars, and drill a larger hole, about 3/8 inch in diameter, in the side of the same jar. Drilling glass is not difficult. Cut several notches in the end of a piece of brass tubing, chuck the piece in an electric drill and rotate the notched end against the glass while applying a slurry of No. 120 Carborundum grains in water. Avoid wobbling the drill and go easy on the pressure when the drill cuts through the inner wall.

This first jar will be the expansion chamber. In the wall of the second jar cut a hole 9/16 inch in diameter, and fit it with a short pipe nipple screwed to a "street" elbow—a fitting with a male thread on one end and a female on the other. This piping and the fittings should be of the size known in the trade as 1/4 inch: its outside diameter is 35/64 of an inch and the inside diameter, 3/8 of an inch. Fasten the nipple in place with a mixture of litharge and glycerin or any of the commercially available rubberized cements. When the cement has set, fit the balloon over the end of the street elbow and tie it in place as shown in the diagram.

A circle of 14-gauge bare copper wire is then fastened to the inside bottom of the expansion chamber and secured by a machine screw. The remaining hole in the chamber is fitted with a rubber stopper. Now make a solution consisting of equal parts by volume of water and alcohol with ink added (to color the fluid black) and a half teaspoon of salt. Fill the second jar with the fluid and partly fill the expansion chamber. Then screw both jars into the cap assembly. The filling job is simplified if you make up a large crock of solution and assemble the apparatus while it is partly immersed in the fluid.

Connect the outer end of the pipe nipple with a source of compressed air. The easiest source is a pumped-up automobile inner tube, but you can make a convenient pressure tank of a coffee can of the one-pound size. The valve assembly from an old inner tube will serve as an inlet. Solder a pipe nipple into the tank for an outlet and fit it with a shut-off cock ("A" in the drawing) for admitting air to the expansion chamber. A drain cock ("B") is also provided for bleeding the chamber during the expansion stroke.

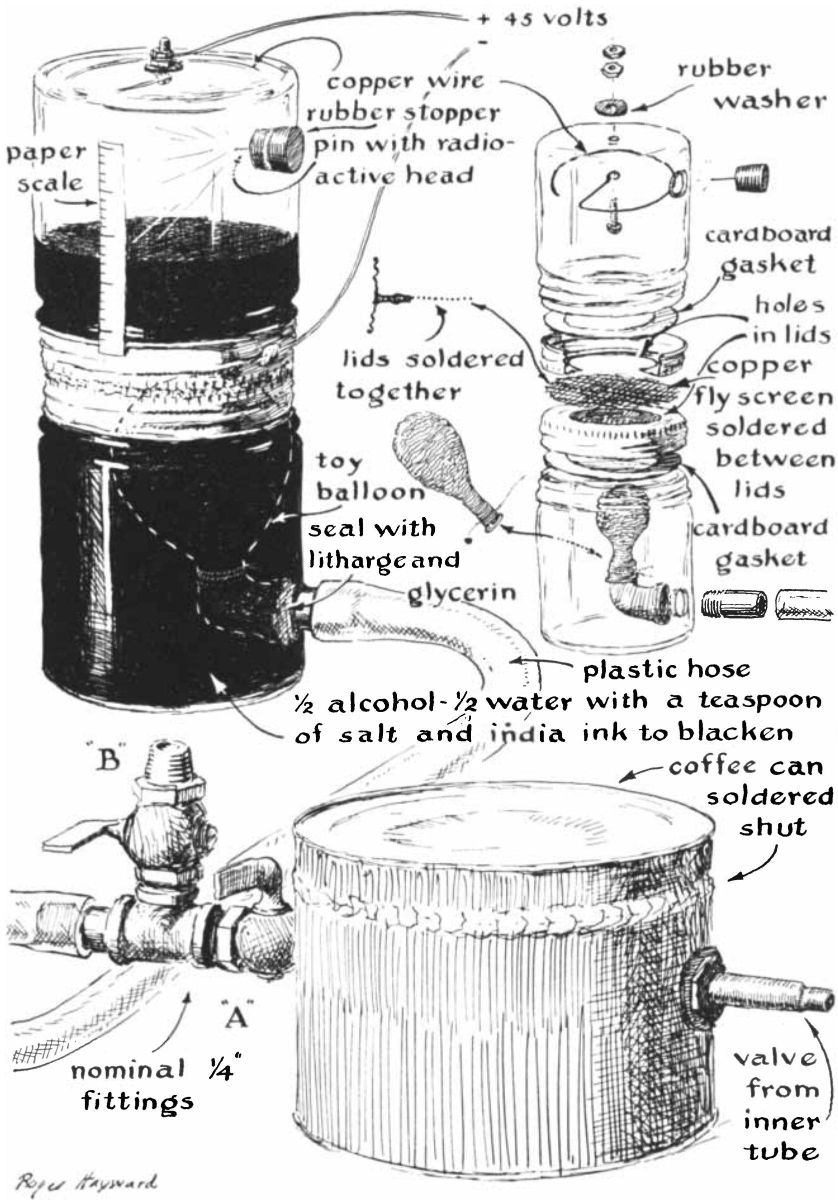
In preparing the apparatus for operation, first close both cocks and pump the tank to a pressure of about 10 or 12 pounds. Opening the shut-off cock "A" admits air to the balloon and forces the fluid from the lower jar through the screen (which minimizes turbulence) into the chamber above. This compresses the air trapped above the fluid, and its temperature increases. The warmed air quickly takes up additional moisture from the fluid. Close the shut-off cock and open the bleeder. This relieves the pressure inside the chamber, and air escapes from the balloon through the bleeder valve. Both the fluid and the temperature drop abruptly, creating a state of supersaturation in the expansion chamber. The action differs from that of Wilson's chamber in that the expansion stroke ends with air at substantially atmospheric pressure, whereas expansion in the Wilson chamber is completed at lowered pressure. The higher working pressure gives the "peanut butter" chamber an advantage because the increased density of the gas betters the chance that a nuclear particle will collide with the nucleus of an atom and thereby produce an interesting event.

Beginners sometimes attempt to simplify Wilson's apparatus by exhausting air directly from the chamber, thus avoiding the complication of a piston, either liquid or mechanical. Such schemes invariably fail because the turbulence created by the escaping air destroys the tracks. Piston devices confine the motion of the air to the vertical direction. Small eddies are created near the lower walls of the chamber, but they are not serious.

Wilson took special pains to avoid turbulence when constructing his second instrument. This one had a more accessible chamber, consisting of a glass cylinder and piston. The moving parts were fitted with almost optical precision to prevent air from leaking past the piston into the chamber. Lord Rutherford recalled in later years how, during the early stage of construction, he observed Wilson in his laboratory painstakingly grinding the piston into the cylinder. Rutherford, called away from Cambridge, returned some months later to find Wilson still sitting in precisely the same place, patiently grinding away!

Wilson's third and final design featured a clever solution of the problem of access to the interior of the chamber. Essentially this apparatus consists of a cylinder equipped with a glass top and a close-fitting, free-floating piston. The assembly stands in a shallow pan of water which acts as a seal. The expansion stroke is made by exhausting air beneath the piston through a vent in the center of the pan extending slightly above the level of the water. The length of the expansion stroke is limited by a rubber stop beneath the piston. To reach the interior of the chamber, you simply lift the assembly from the pan and pull out the piston.

This is the chamber Wilson described in the celebrated paper he presented before the Royal Society in 1912. A tribute to the excellence of the design is the fact that during the remainder of Wilson's long career all his nuclear researches were made with this chamber. It is now



Details of a Wilson cloud chamber made from two peanut-butter jars preserved in the Cavendish Museum. A few years ago Sir Lawrence Bragg asked Wilson whether the apparatus could properly be labeled "the original." "I never used or made but one," Wilson replied.

Certain requirements must be observed when operating an expansion chamber. The volume and speed of expansion must be maintained, and stray ions must be swept from the chamber. The expansion stroke of the apparatus diagrammed here is completed in about a twentieth of a second, well within the limit required. It can be speeded by increasing the diameter of the tubing.

Early in his experiments Wilson learned that the supersaturation required for showing tracks of negatively charged particles is reached when the ratio of the chamber's volume before expansion to its volume after expansion is 1.25. At this ratio a few drops form in a dust-free atmosphere. Positive ions will not act as condensation nuclei for water vapor until the expansion ratio reaches a value of 1.31. This requirement can be lowered somewhat by adding alcohol to the water. When the expansion ratio exceeds 1.38, a dense cloudy condensation is produced in the chamber even when no nuclei are present. Wilson usually adjusted his apparatus for a ratio between 1.33 and 1.36. The expansion ratio of the peanut-butter chamber is established by the amount of air admitted to the balloon and, hence, by the level reached by the fluid in the expansion chamber during the compression stroke. This level is measured by the paper scale cemented to the upper jar.

The chamber is cleared of spurious ions (and unwanted clouds) by connecting a voltage between the copper electrode in the expansion chamber and the salt solution. It is good practice to sweep the field after each expansion and to maintain the voltage across the chamber until the moment of expansion.

The peanut-butter chamber is suggested as a starting point for those amateurs who find dry ice in short supply. Its disadvantage, compared to the diffusion chamber, is that its surveillance of particles is not continuous.

Beginners will discover that the tracks show up best when viewed obliquely in an intense beam of collimated light. The irregular end of a peanut-butter jar has thus far won no laurels in the optical goods industry, and the walls are not much better. Professional chambers are equipped with windows of plate glass. If you want to make good photographs of nuclear tracks, you must of course synchronize the camera shutter with the

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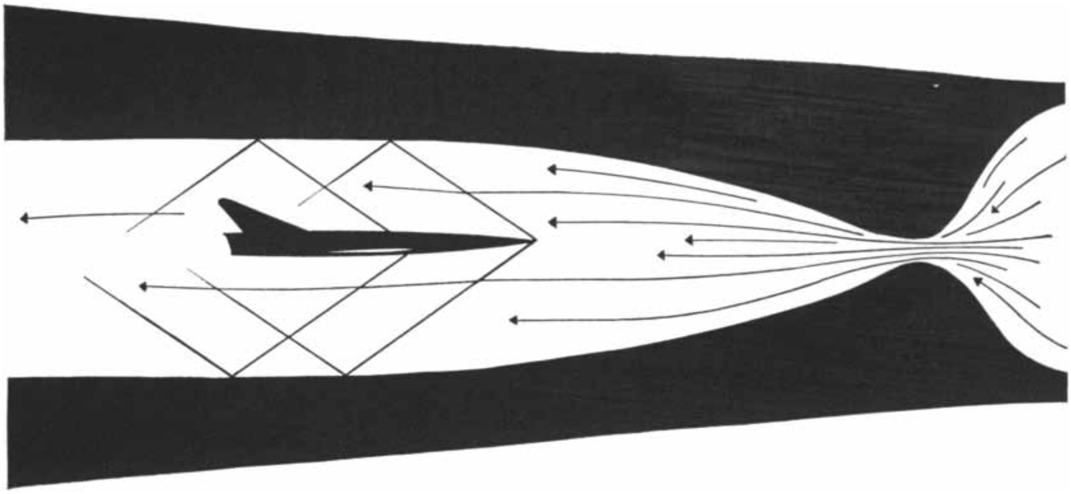

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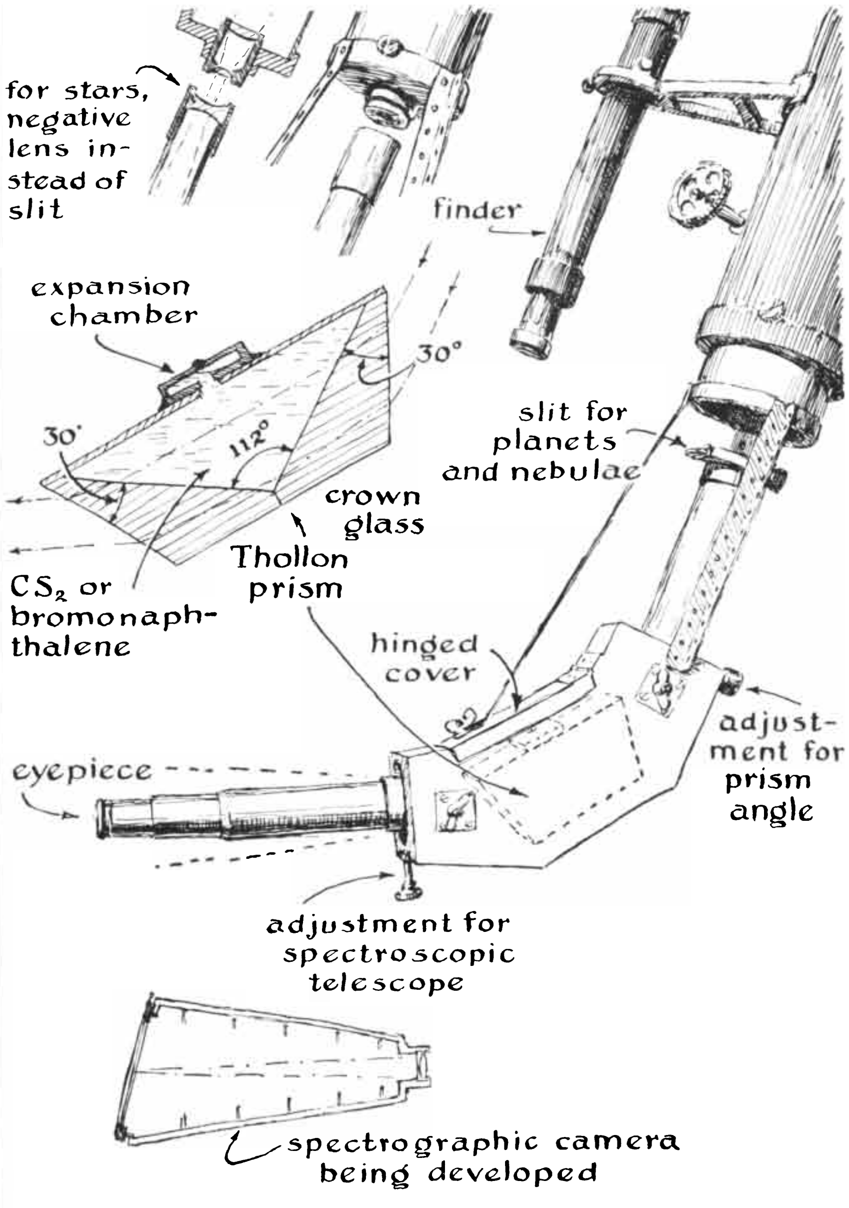


A stellar spectroscope employing a liquid prism

completion of the expansion stroke. Wilson's exposures were made by discharging two gallon-sized Leyden jars through a mercury spark gap. The exposure time was about a thousandth of a second. If you own one of the electronic-flash outfits now popular with photographers, you will be spared the labor of duplicating Wilson's gap.

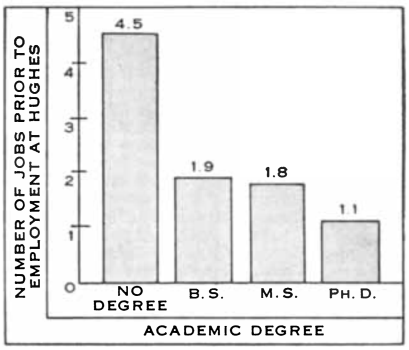
A self-addressed, stamped envelope sent to this department will bring you a speck of radium suitably mounted for actuating cloud chambers, Geiger counters and other devices.

Last June this department carried a description of Robert Bunsen's original spectroscope, which employed a triangular glass box filled with carbon disulfide as the prism. Amateurs generally experience some difficulty in making liquid prisms. A Portuguese correspondent, Commander Eugenio C. Silva (whose observatory and 20-inch Cassegrainian telescope were described in this department in September, 1952) writes that he has found simple solutions for some of the problems mentioned in the Bunsen article.

"For some time," he writes, "I have been experimenting with liquid prisms and have uncovered some information which may be helpful to those who find themselves up against the characteristic difficulties of these devices. The main problem was finding an effective cement to hold the glasses together. It has to be some stuff which sets by cooling, does

Some of the young fellows on our staff have been analyzing our files of personal data regarding scientists and engineers here at Hughes. What group characteristics would be found?

With additional facts cheerfully contributed by their colleagues they have come up with a score of relationships—some amusing, some quite surprising. We shall chart the most interesting results for you in this series.



The above chart represents the number of positions held prior to employment at Hughes—by academic degrees (and by lack of a degree). The Ph. D. has changed jobs the least. Data obtained from a 20% random sample of the 2400 professional engineers and scientists of Hughes Research and Development Laboratories.

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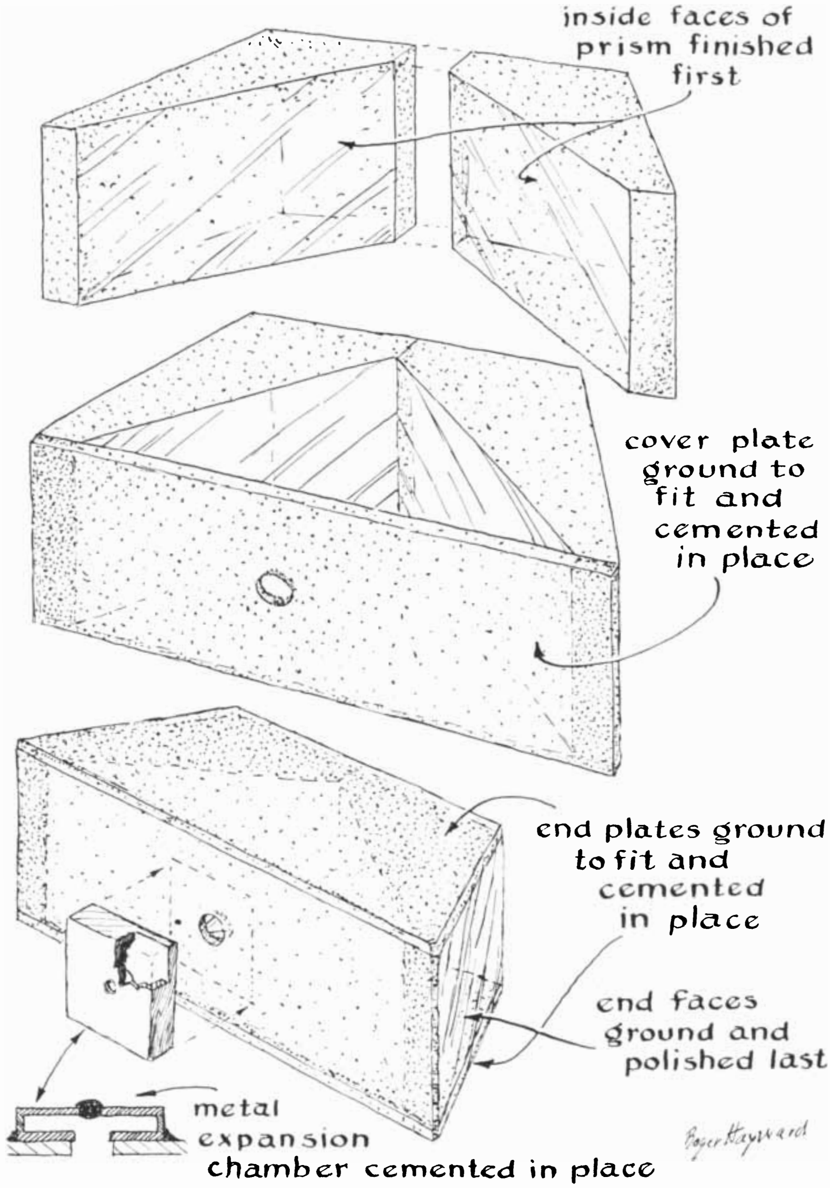
not require a volatile solvent and is quite insoluble in the liquid with which the prism is filled. For prisms filled with carbon disulfide or bromonaphthalene I have, after many trials, found a very good cement—shellac.

"In making the prisms I first heat the pieces of glass on an electric hot plate. The shellac is then applied to the edges to be joined and, as it begins to melt, is spread evenly with a needle. The hot plate must be regulated for the melting temperature of shellac and controlled so the shellac is neither burned nor comes to a boil. The work must then be cooled slowly to avoid cracking the glass. The joint is very strong, and after cooling the glass will break before the cement if you try to pull the elements apart.

"I have made two types of prisms. For medium dispersion I use the simpler ones of plate glass described by R. B. Nevin in "The Amateur Scientist" last June. For high dispersion I use the type developed by the French astronomer, Louis Thollon [*see drawing in the illustration on page 160*]. Though more difficult to make, the dispersion of Thollon prisms is four times greater than that of a conventional 60-degree prism of the same size. The single Thollon prism now in my telescope (filled with bromonaphthalene) easily resolves the 'D' doublet of sodium and a few faint lines can be seen between D_1 and D_2.

"The two crown-glass prisms of the Thollon design were cut from a glass slab about 30 millimeters thick and hand



Details of a liquid prism

A stereoscopic view of the moon that can be viewed with a mirror

ground [*see lower drawings in the illustration on page 162*]. The inside faces were fine ground and polished. Then the two prisms were cemented together with the plate glass top cover. The side faces (held together at the top) were then fine ground and the side plates cemented to the assembly. The rim around the base was fine ground and the base cover cemented in place. Finally outside faces were fine ground and polished in a plaster cradle. (These operations are much easier to perform than to describe.)

"The faces of the assembled prism were cleaned with a cotton swab dipped in alcohol, a good solvent for shellac.

"All liquid prisms must be fitted with a small expansion chamber to relieve the inner pressure when the fluid expands and contracts with changes in temperature. My prisms are equipped with the small metal chamber shown in cross-section. The chamber is left empty when the prism is filled. I did not provide for expansion in my first Thollon prism, which was filled with carbon disulfide. When I picked it up, the slight heat from my hand expanded the fluid and cracked the side plates! My prisms measure 30 millimeters in width and 40 millimeters in height. The glass covers measure two millimeters in thickness.

"As a stopper for the filler hole I use a small sheet of glass. The prisms cannot be heated on the hot plate after filling, so the glass cover is placed over the hole and cemented to the expansion chamber by means of a soldering iron.

"My prisms are now more than three years old and they have developed no leaks. It seems probable that they are as permanent as solid glass ones."

George W. Ginn of Hilo, Hawaii, submits some stereo photographs of the moon. Two sets of his pictures are shown on this page. One is a pair of views which gives the illusion of three dimensions when viewed with the aid of a thin mirror. Stand the mirror vertically with respect to the plane of the page and

A stereoscopic view of the moon to be viewed by the "cross-eyed" method

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NORTH AMERICAN HAS BUILT MORE AIRPLANES THAN ANY OTHER COMPANY IN THE WORLD align the edge with the boundary separating the right and left views. If the glass is a foot high, let the tip of your nose touch the upper edge and look toward the view behind the mirror.

The lower picture is printed for viewing either "cross-eyed" or, in case you are not blessed with this talent, by means of a conventional stereoscope. With a bit of practice, most persons can perfect the art of cross-eyed viewing. Hold the page in your left hand about a foot from your eyes. Now place the tip of your right index finger between the views, focus both eyes on the fingertip and slowly move the finger toward you. When your finger reaches a certain distance, you will become conscious of four indistinct moon images in the background. Move your finger until the inner images merge. Then shift your focus to this center picture. The moon will appear clear, sharp and in three dimensions.

In commenting on his lunar stereos, Ginn writes: "The views were taken with a three-and-a-half-inch objective of 42 inches focal length. My telescope has provision for placing an Exakta camera at the prime focus in place of the eyepiece. The pentaprism finder of the camera makes a fair eyepiece. The image of the moon on the film is three eighths of an inch in diameter and has been enlarged about six diameters.

"The two halves were taken seven hours apart, allowing the earth's rotation to provide the base line. For true perspective they would have to be viewed at a distance of about 20 feet."

Dr. John H. Schaefer, a Los Angeles physician, writes us the following letter:

"I suspect that whoever prepared the captions for the illustration on construction details of an acoustic lens of the gas type on page 122 of SCIENTIFIC AMERICAN for January had his mind elsewhere. At the bottom of the cut the gas generator is shown with these words–'dry ice for CO_2, marble chips and HCl for hydrogen.' When I went to school, marble chips (calcium carbonate) and hydrochloric acid reacted to liberate carbon dioxide. Zinc and hydrochloric acid liberate hydrogen."

Dr. Schaefer's observation confirms this department's sad experience that editors as well as laboratory workers are subject to Murphy's Laws, to wit:

I. If something can go wrong, it will.

II. When left to themselves, things always go from bad to worse.

III. Nature always sides with the hidden flaw.

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APRIL, 1956

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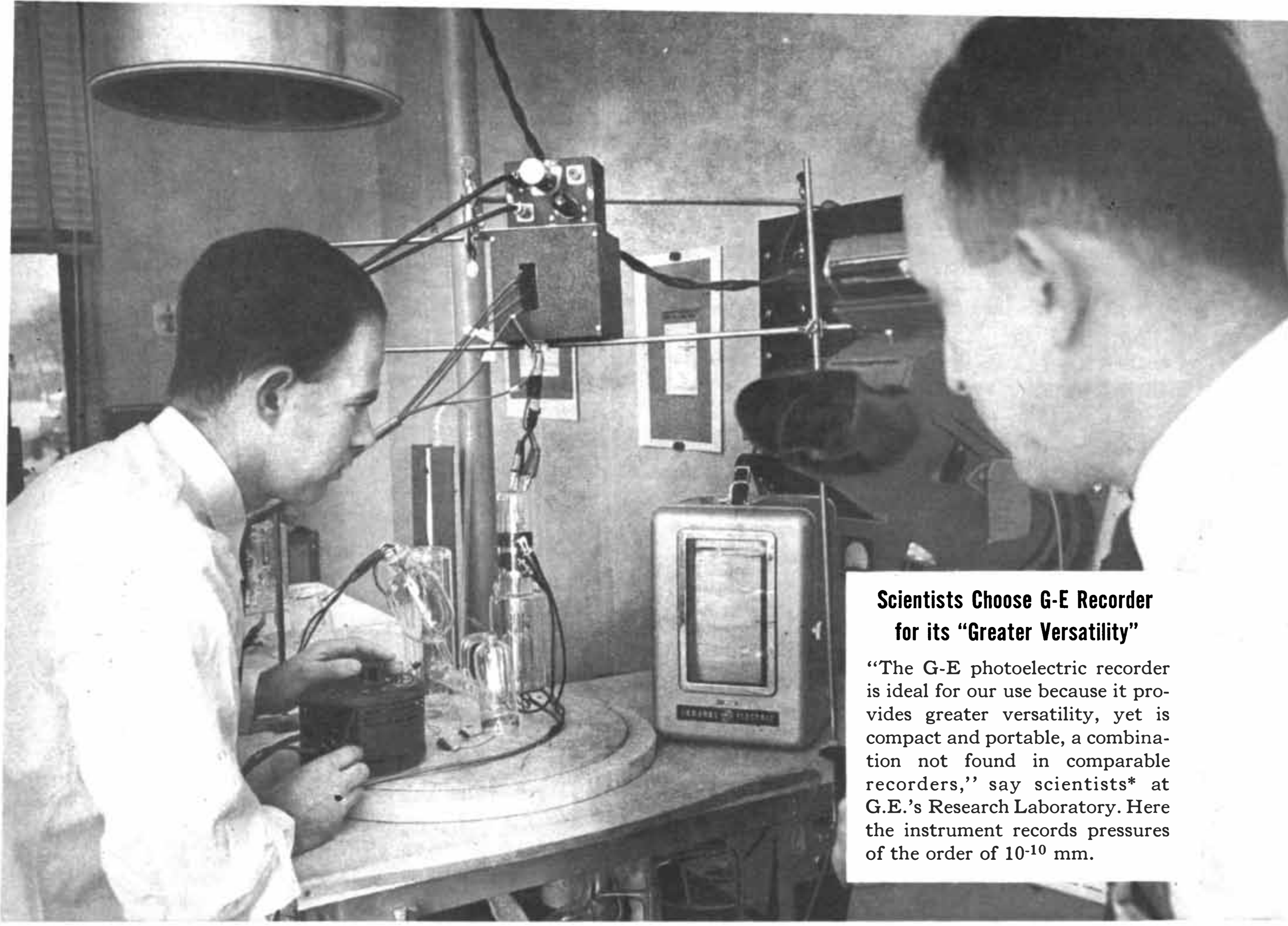

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*Dr. N. R. Whetten (left) and Dr. A. B. Laponsky (right), Research Associates at the General Electric Research Laboratory.

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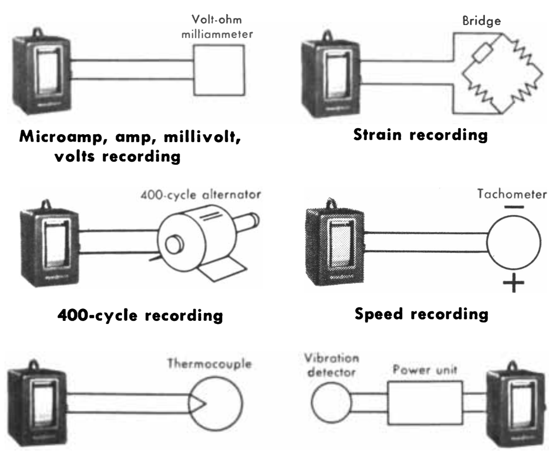

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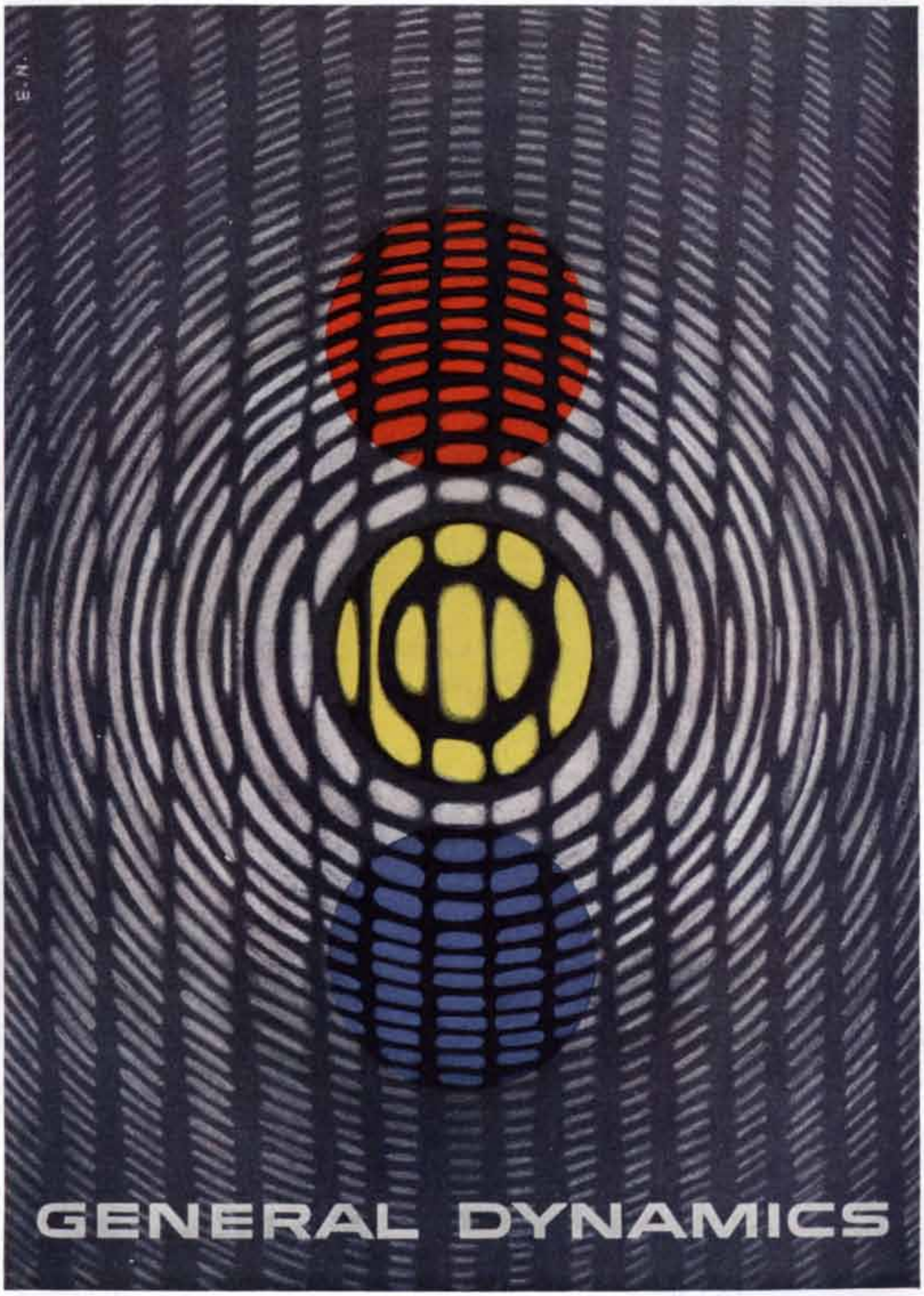

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