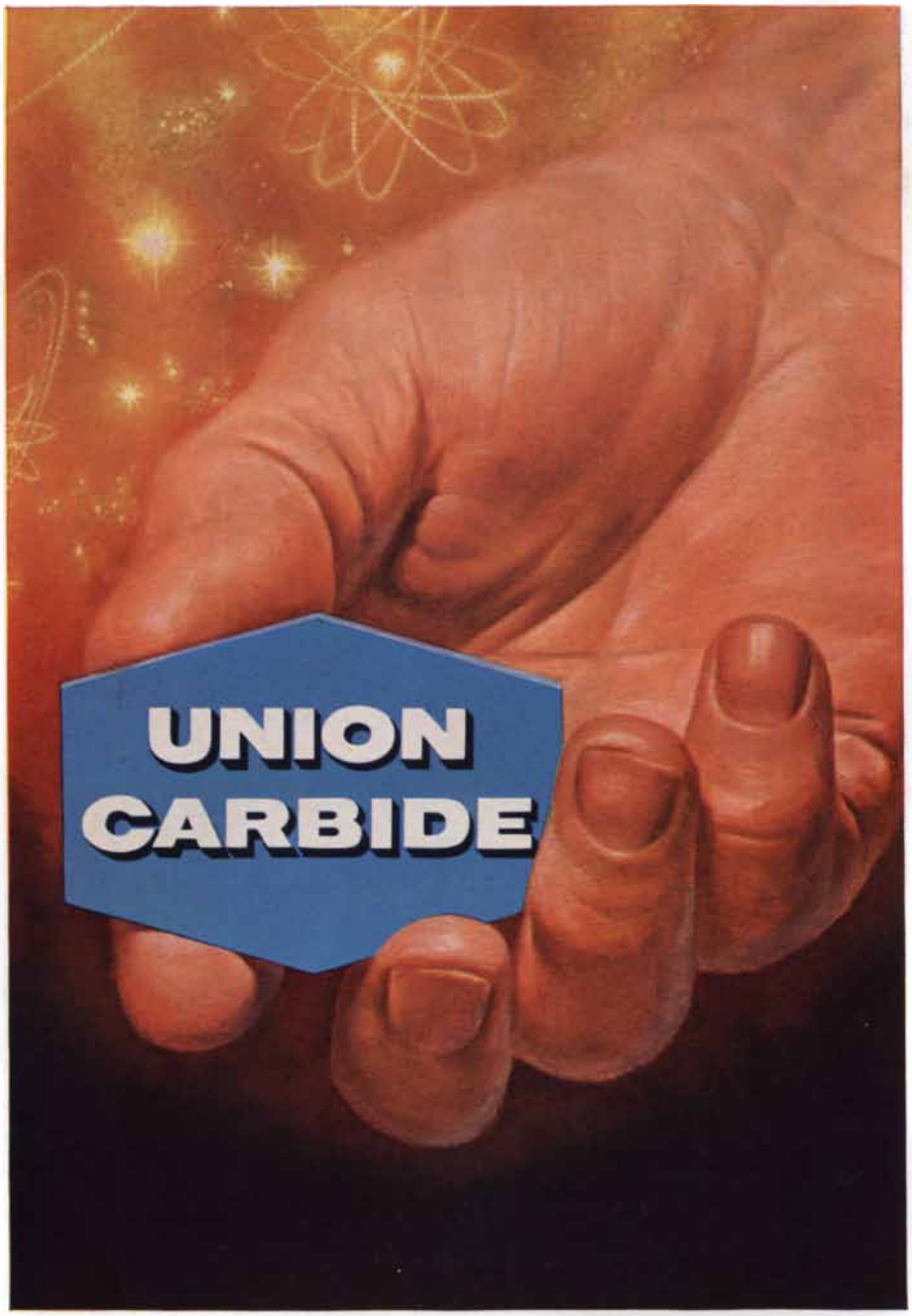
SCIENTIFIC AMERICAN

BIRDS IN THE MUSEUM

FIFTY CENTS

May 1957



For Forty Years our name has been Union Carbide and Carbon Corporation . . . more generally called "Union Carbide."

Now our company name will be Union Carbide Corporation. The change is in name only. The people of Union Carbide will continue to pioneer in developing and producing carbons and gases, chemicals, plastics, alloys and nuclear energy.

UCC's principal divisions and subsidiaries include

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- Electro Metallurgical Company
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- Union Carbide Nuclear Company
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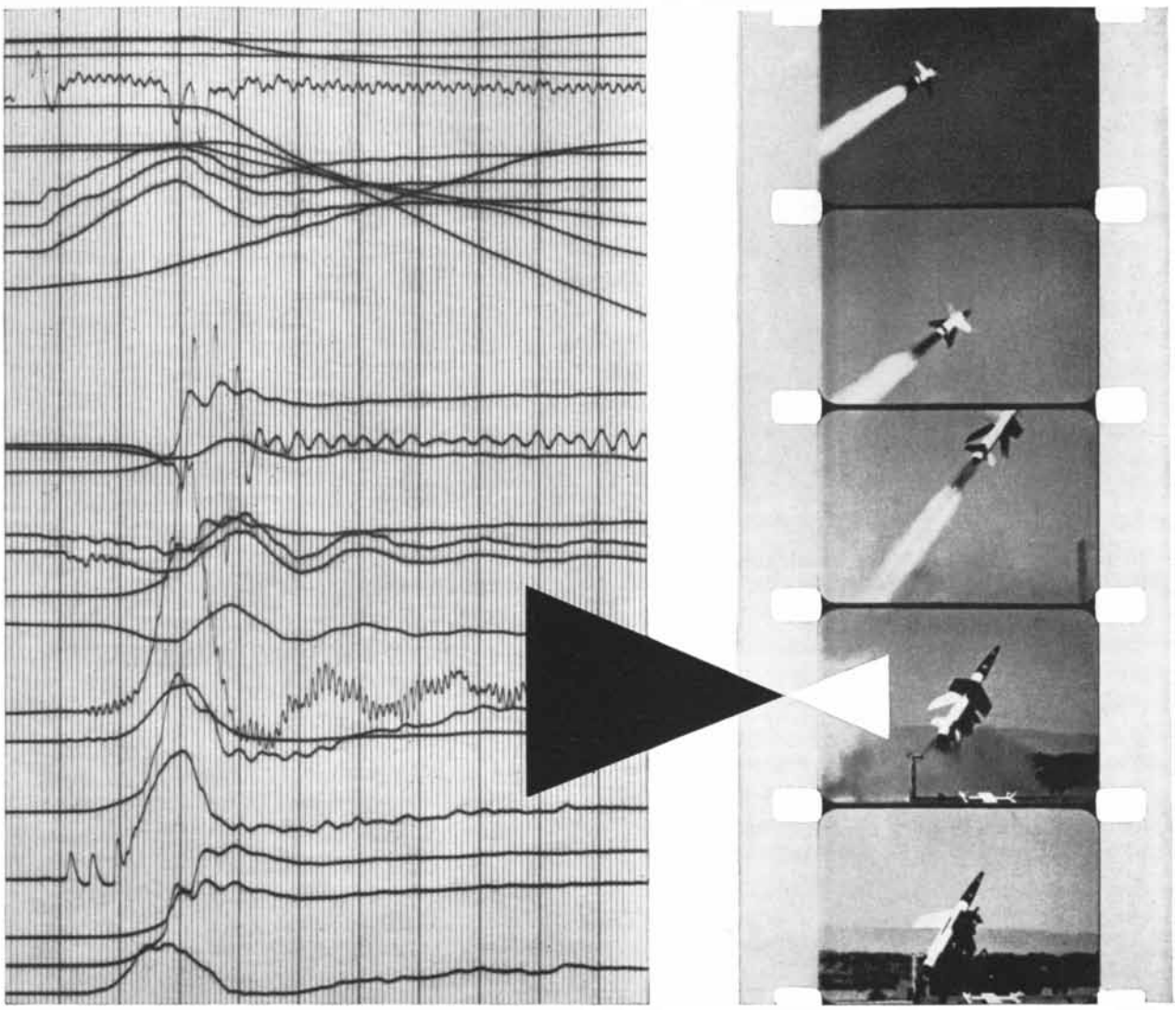
Write for free booklet and learn how UCC research can help you. Ask for "Products and Processes." Union Carbide Corporation, Dept. E, 30 East 42nd Street, New York 17, N. Y.

UNION CARBIDE



Trace: courtesy Reaction Motors, Denville, N. J. *Film:* U.S. Army's new guided missile, LACROSSE.

Two ways to look at a missile

Here are two photographs you might make on Du Pont Film and Paper.

The photograph to the left is a trace made on Du Pont "Linowrit" oscillographic paper. It records the performance of a rocket power plant by capturing on photographic paper the path of a beam of light.

The photograph to the right takes a film like Du Pont Type 931 High Speed Rapid Reversal motion picture film. Its contrast range makes it ideal for use in the tracking cameras that follow a missile into the sky.

Both photographs have this in common. This is photography with a purpose. Photography that is not an end in itself but a means to an end. This is Functional Photography. And it is this field that the Du Pont Photo Products Department very specially serves.

Among our products are x-ray films for medical and industrial radiography . . . photo copy paper . . . specialized films used in printing by offset, lithography and gravure —engineering reproduction films.

If you use Functional Photography in your business—and you should—you should get to know our products and the many ways in which they can serve you. E. I. du Pont de Nemours & Co. (Inc.), Photo Products Department, Wilmington 98, Delaware.

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. . . THROUGH CHEMISTRY

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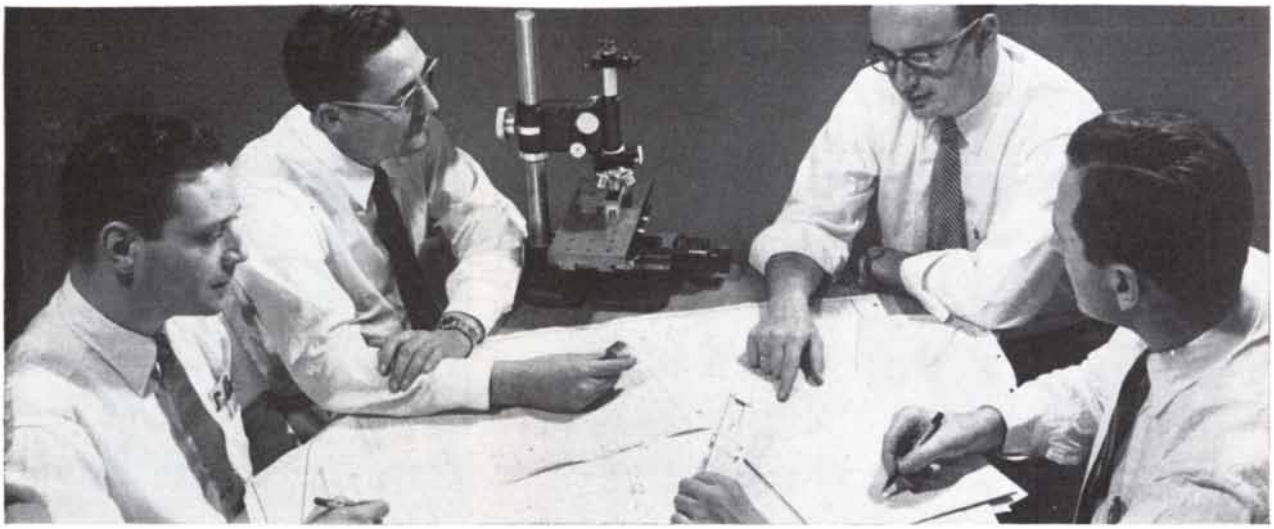
FUNCTIONAL PHOTOGRAPHY



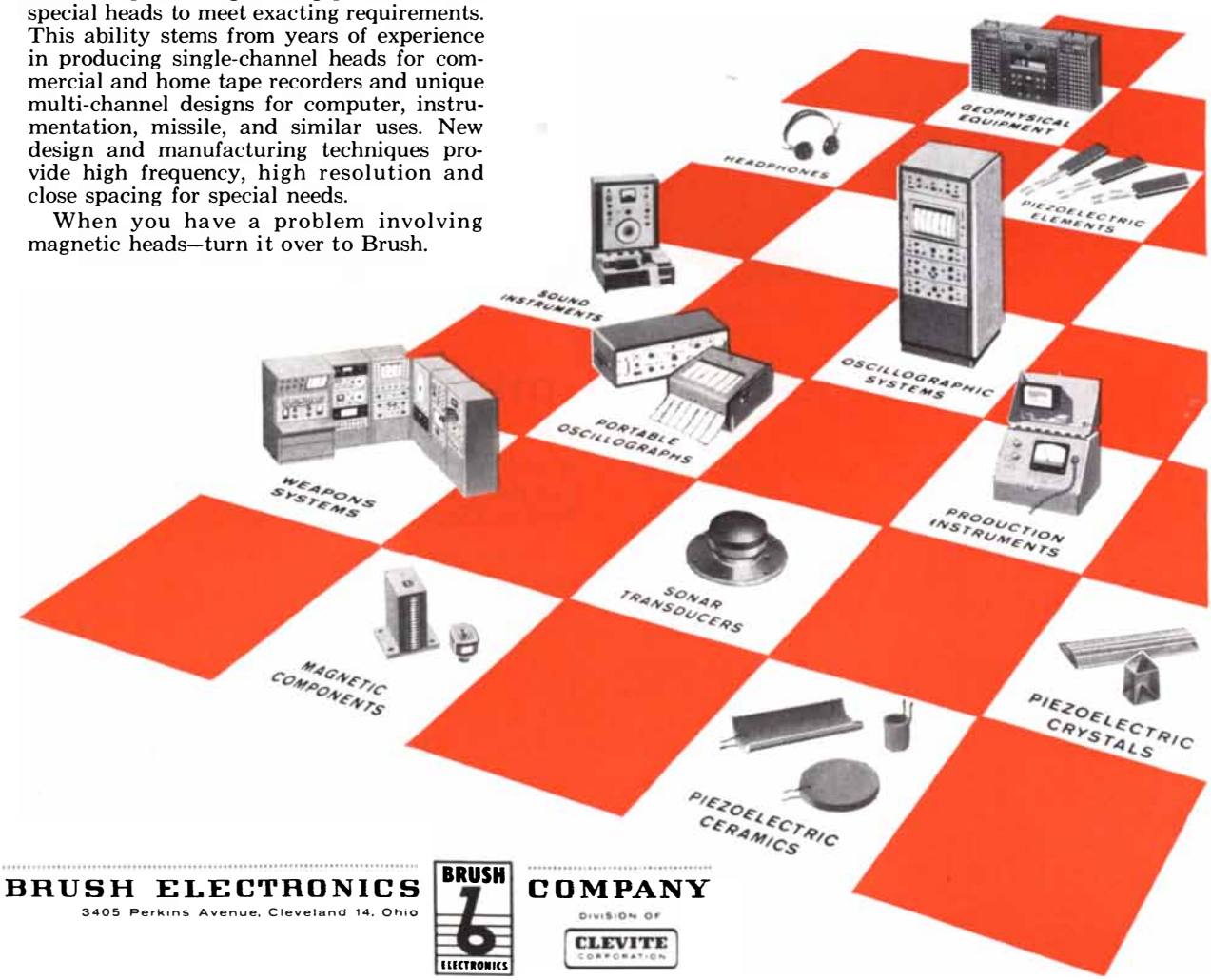
Creative thinking

for new magnetic heads

Virtually every advance in magnetic recording equipment calls for new concepts in magnetic heads. Brush Electronics, largest producer of commercially available magnetic heads, can assume a manufacturer's problem, lighten his engineering load.

Brush undertakes "package assignments" for development-engineering-production of special heads to meet exacting requirements. This ability stems from years of experience in producing single-channel heads for commercial and home tape recorders and unique multi-channel designs for computer, instrumentation, missile, and similar uses. New design and manufacturing techniques provide high frequency, high resolution and close spacing for special needs.

When you have a problem involving magnetic heads—turn it over to Brush.



BRUSH ELECTRONICS COMPANY

3405 Perkins Avenue, Cleveland 14, Ohio

BRUSH 6 ELECTRONICS

DIVISION OF CLEVITE CORPORATION

Established 1845 **SCIENTIFIC AMERICAN** May, 1957 Volume 196 Number 5

ARTICLES

DEPARTMENTS

PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK 17, N. Y. ENTERED AT THE NEW YORK, N. Y., POST OFFICE AS SECOND-CLASS MATTER JUNE 28, 1879, UNDER THE ACT OF MARCH 3, 1879. ADDITIONAL ENTRY AT GREENWICH, CONN. SUBSCRIPTION RATE IN THE U. S. $5 PER YEAR.

THE COVER

The three pairs of birds in the painting on the cover are stuffed specimens in the Peabody Museum of Yale University. The interesting thing about these birds is that, although the members of each pair differ somewhat from each other, both belong to the same species. This phenomenon, known as polymorphism, is associated with the evolution of animal species (*see page 124*). The two birds at upper left are Gouldian finches; the two birds at upper right, banana quits; the two birds at bottom, crossbills.

THE ILLUSTRATIONS

Cover painting by Rudolf Freund

Page	Source
39-43	American Museum of Natural History
44-45	H. A. Bernatzik
47-49	Paul Weller
50	James Egleson
51	Walter Gordy
52-53	Walter Gordy (*top*), James Egleson
54-55	Eric Mose
56-57	Eric Mose (*top*), J. D. French (*bottom*)
58-59	Eric Mose
60	M. and A. Scheibel
75-82	Bunji Tagawa
84	Bruno Kisch
86	Bunji Tagawa
88-89	Jerome Snyder
103	C. Bückle
104-107	Irving Geis
108	Irving Geis (*top and bottom*), F. E. Harris (*middle*)
110	I. Geis (*top*), R. Smoluchowski (*bottom*)
112	Illinois Natural History Survey
113-120	John Langley Howard
122	B. Esther Struckmeyer
124-125	H. N. Southern
126	Rudolf Freund
127	Bunji Tagawa
128	Rudolf Freund (*left*), Bunji Tagawa (*right*)
130-132	Rudolf Freund
159-166	Roger Hayward

new source for a big appetite!

from

CNC ZIRCONIUM

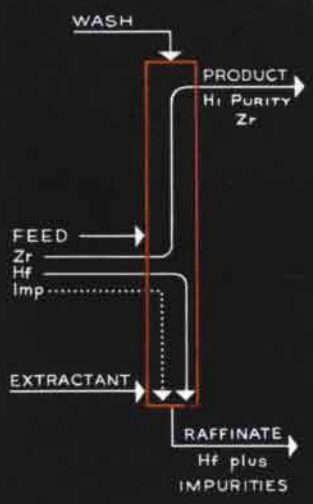
The Zirconium Age has arrived! Columbia-National Corporation with its new sponge producing facility nearing commercial operation offers you a new source of zirconium at a new low price.

Uniform high quality zirconium is assured by the only fully integrated operation converting zircon sand to sponge at one location under the responsibility of one management. The unique "Nitrophos" extraction process is used to separate and purify zirconium and hafnium in this plant.

Reactor-grade and hafnium-containing commercial-grade zirconium sponge will be produced in sufficient quantities to fill government and industry requirements. Leading metal converters and fabricators are now supplying zirconium mill and finished products.

There is new opportunity in the Zirconium Age. You are urged to investigate its use in atomic reactors and in process equipment where corrosion conditions are severe. Columbia-National is ready to help with melting and application assistance. Write for technical data on fabrication, properties and corrosion resistance. Columbia-National Corporation, 70 Memorial Drive, Cambridge, Mass.

CNC "NITROPHOS" PROCESS



The new Columbia-National Zirconium Plant near Pensacola, Florida is the most modern in the world. The "Nitrophos" process continuously and automatically separates hafnium from zirconium and removes impurities, thus assuring uniform, high quality zirconium sponge.

ILLUSTRATION OF TYPICAL REACTOR CORE COURTESY WESTINGHOUSE ELECTRIC CORP.

Columbia-National Corporation

Jointly owned by Columbia-Southern Chemical Corp. and National Research Corporation

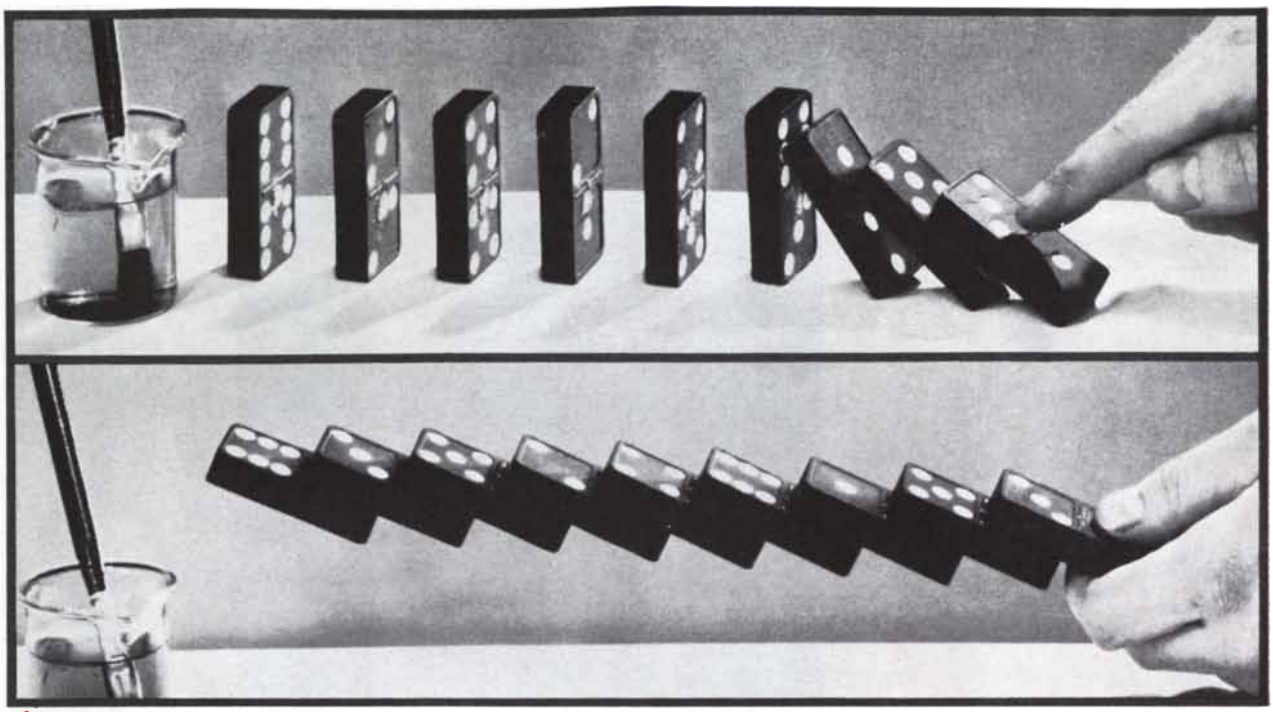
☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ ☆ NEW METALS FOR INDUSTRY

Life on the Chemical Newsfront

OUTDOOR USE OF EMULSION PAINTS GROWS as formulators improve weathering characteristics. For example, polyvinyl acetate emulsions, already popular indoors for easy application, quick dry and freedom from odor, are made more resistant to checking, cracking, chalking and peeling by use of suitable plasticizers. Esters such as dibutyl maleate, derived from maleic anhydride, make effective nonmigrating internal plasticizers which can't be leached out by rainwater. AERO* Maleic Anhydride is one of many chemicals supplied by Cyanamid to the surface coatings industry. (Industrial Chemicals Division, Dept. A)

NEW WAY TO TREAT minor skin cuts and abrasions is by a topical spray of ACHROMYCIN® tetracycline for protection against infection. Sprayed directly on the affected area from this aerosol applicator, the preparation permeates the skin rapidly and dries almost instantly, reducing the possibility of soiled or stained clothing. Nothing touches the treated area but this broad-spectrum antibiotic preparation. (Lederle Laboratories Division)

BOOM IN FOIL FOR DISPLAY PACKAGING followed its shift from purely protective to decorative use with the development of successful color printing methods. Among important new pigments for foil lacquers, can coatings and metal decorating is Cyanamid's Benzidine Yellow Toner T 45-2460. It provides the greenness of tint, high transparency and light permanency essential for such applications. It has the strength and clarity, alkali and soap resistance, and excellent lithographic properties for which Benzidine Yellows are noted. (Pigments Division)

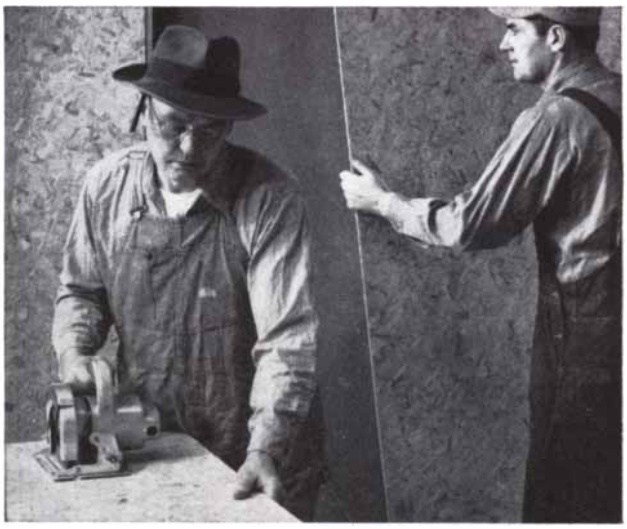


HIGHER INITIAL TACK or "stickiness" in adhesives can be secured with PAM* polyacrylamide, a new water-soluble polymer. Its excellent spreadability and compatibility with water-soluble resins and modified cellulose also recommend it as a component to improve liquid, film or bond properties.

*Trademark

(New Product Development, Dept. A)

CARPETS AND RUGS STAND UP BETTER when treated with Cyanamid's Aluminum Acetate 20% Sulfate Free. A coating of aluminum salts on broadloom and tufted carpets and rugs establishes a foundation for rubber or synthetic latex backing and improves adhesion, reduces migration. Aluminum oxide residues remaining after drying contribute high resistance to water-spotting and staining, particularly on cellulosic fibers. After-treatment with aluminum acetate increases the fastness of many classes of dyes. Combined with certain CYANATEX® Soluble Waxes, it imparts water-repellency to many types of fabrics. (Organic Chemicals Div.)



STRONGER PARTICLE BOARD, made of wood chips bonded with MELURAC® 304 Melamine-Urea Resin, is growing in favor for structural applications. This low-cost particle board has good warp resistance, flexural strength, moisture resistance and easy working and finishing properties. MELURAC 304, developed expressly for this use, imparts no color and improves strength of the panels. In addition to structural uses—walls, sliding doors, partitions, ceilings, subflooring, parquet flooring—it is ideal for furniture cores and underlayment for decorative melamine laminates.

(Plastics and Resins Division)

CYANAMID

AMERICAN CYANAMID COMPANY

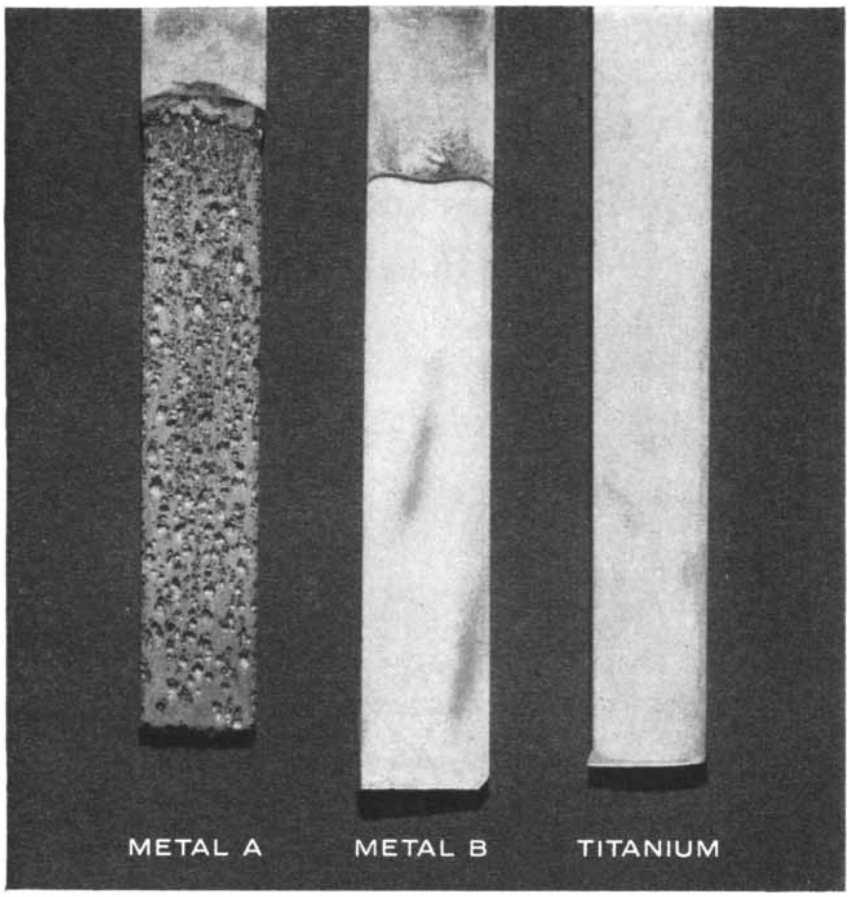
30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

Helping America Make Better Use of its Resources

50 CYANAMID 1907 1957

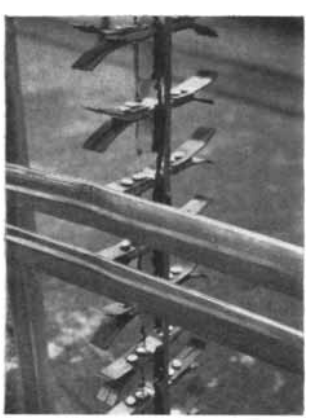
For further information on these and other chemicals, call, write or wire American Cyanamid Company.

Progress with
TITANIUM



Test strips of three different metals after partial immersion for 24 hours in the same solution containing 10% nitric acid and 20% ferric chloride. Only titanium was unaffected. Both other metals are commonly used in certain processing applications.

TITANIUM ...the lowest-cost metal?



Clamps on racks used to hold automotive moldings in anodizing bath. Titanium clamps last up to 30 times longer than other metals tried in electrolytic solution.

● In a surprising number of applications titanium is just that. For titanium has exceptional resistance to many corrosive media that quickly destroy other metals.

For example, titanium is uniquely superior in resisting corrosion by such common industrial chemicals as nitric acid, solutions of chlorine, chlorinated compounds. Also, titanium is not susceptible to stress corrosion. It resists pitting attack in a solution where corrosion does take place. Thus this new metal is being used in more and more places, where corrosion wastes money —in process vessels, piping, filters, heat exchangers, and many other types of equipment.

Titanium has a big future. Let us help you "design ahead" with this exceptional metal. We'll be glad to supply corrosion data, and help you evaluate titanium in your applications. Write Dept. C-3, for complete information.

MALLORY Ti® SHARON

MALLORY-SHARON TITANIUM CORPORATION • NILES, OHIO

Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets

FYI

FOR YOUR INFORMATION

Allied Chemical

DIVISIONS Barrett, General Chemical, National Aniline, Nitrogen, Semet-Solvay, Solvay Process, International

- *electronic grade chemicals*
- *polyethylene lubricants*
- *pollution control*

Electronic chemicals

"Qual and quant" is a phrase not easily forgotten by those who received a chemical education. The phrase has been given a new twist by the electronic industry.

This booming industry is demanding ever greater quantities of special chemicals . . . and it is demanding them in qualities of exceptional purity.

A new line of "electronic grade" chemicals designed to meet the precise specifications of this field has been added to the extensive line of BAKER & ADAMSON laboratory reagents and fine chemicals.

Typical of this new line are 16 highly specialized "electronic grade" chemicals for use in semiconductor production and other super-sensitive electronic applications.

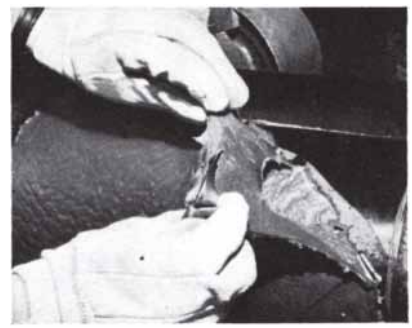
Among the B&A chemicals made to this exacting standard are: acetone, 48% hydrofluoric acid, methyl alcohol, iso propyl alcohol,

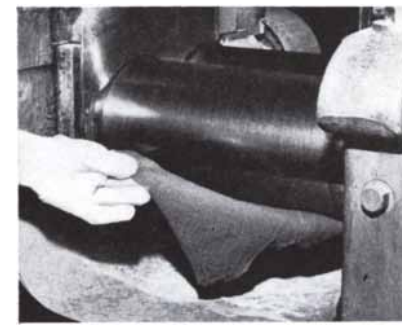
ferrite core for data processing

carbon tetrachloride, anhydrous ether, hydrogen peroxide (3%, 30% and 30% "stabilized" solutions), sodium carbonate (monohydrate) and trichloroethylene.

For radio and black-and-white television production, there are many other B&A chemicals available in bulk, with heavy metals and other undesirable impurities held to "electronic grade" standards.

Other electronic needs for quality in quantity are served from the over 1,000 BAKER & ADAMSON chemicals in reagent A.C.S. or other high-purity grades. These range from sulfur hexafluoride (used as gaseous insulation in television transmitters, X-ray equipment, etc.) to fluoborate plating solutions for printed circuits.





neoprene sticking . . . . ends with lubricants

Polyethylene lubricants

Talk about dilemmas. How about this one?

When elastomers stuck to mills or molds during the manufacturing process, the manufacturer had two alternatives to consider: adding a lubricant which adversely affected the product, or letting the elastomers stick. Sticking meant interruptions in production, lowered output, higher costs and unsatisfactory products. A very unhappy situation.

No cause to be unhappy now. You can have your elastomers—and lubricate them too, with A-C polyethylene lubricants.

They detackify at elevated mill, Banbury, and calender temperatures of 200° F. and higher, aid filler dispersion, improve mold flow and release, increase extruding and calendering speeds, reduce shrinkage of milled stocks.

Most important: they won't bloom in cured or uncured stocks, and are non-staining, non-discoloring, non-migrating and non-toxic.

Just a few parts of A-C polyethylene lubricants added to the mix aids in the manufacture of neoprene, nitrile rubber and butadiene-styrene copolymer (cold), and in processing natural rubber.

BAKER & ADAMSON and A-C are Allied Chemical trademarks

Pollution control

Fish, fowl and farmer all benefit by the development of a new method of removing phenol (carbolic acid) now going into streams and rivers with the waste water from coke operations.

Allied's Wilputte Division has applied this recently patented process using Podbielniak Centrifugal Extractors to remove better than 98% of the phenol from waste liquors. This multi-stage extractor can remove phenols to a final value of less than one-tenth of that possible with other mechanical mixing or static-type extraction equipment.

Benefits are multi-stage too: water returned to streams is purer, costs of recovery operations reduced 25% or more.

Allied Chemical

Information Service
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61 Broadway, New York 6, N. Y.

Please send me further information:

- ☐ Electronic grade chemicals
- ☐ Polyethylene lubricants
- ☐ Pollution control

Name_____

Company_____

Address_____

_____

Position_____

Remarks_____

LETTERS

Sirs:

The letter in the March issue of your magazine complaining of the disappearance of a fellow from the Allen B. Du Mont Laboratories, "down" a hexahexaflexagon, has solved a mystery for us.

One day, while idly flexing our latest hexahexaflexagon, we were confounded to find that it was producing a strip of multi-coloured material. Further flexing of the hexahexaflexagon finally disgorged a gum-chewing stranger.

Unfortunately he was in a weak state and, owing to an apparent loss of memory, unable to give any account of how he came to be with us. His health has now been restored on our national diet of porridge, haggis and whisky, and he has become quite a pet around the department, answering to the name of Eccles.

Our problem is, should we now return him and, if so, by what method? Unfortunately Eccles now cringes at the very sight of a hexahexaflexagon and absolutely refuses to "flex."

ROBERT M. HILL

The Royal College of Science
and Technology
Glasgow, Scotland

Sirs:

I should like to inform your readers of the happy ending (as well as a new be-

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A Man Nobody Wants

This one is always on the move but never on the go. His movement is aided by lead, well placed immediately above the seat of the swing. On the wall of his office is a large sampler lovingly embroidered: "Home, Sweet Home." That is his personal creed and he keeps trying to get the whole company to adopt it.

As his orbit is unchanging, he will never find Rogers. But Rogers will not brood over his continued absence.

For Rogers serves engineers — those men who swoop purposefully across the heavens, searching the stars for new points of reference. An ever-growing body of such men is finding Rogers a dependable ray of light in terms of engineered materials — special formulations as different and daring as the ideas that engendered them.

Samples — and both down-to-earth and up-in-the-clouds literature — will be sent to any engineer. Please let us have your name and address.

ROGERS CORPORATION
ROGERS, CONNECTICUT

DUROIDS—for Gaskets, Filters, Electronic Devices, Thermal Insulation, etc. ELECTRICAL INSULATION—for Motors, Transformers, Generators, etc.
SHOE MATERIALS—for Counters, Midsoles, Liners, etc. PLASTICS—Special Purpose Molding Compounds and Laminates RUBBER—for Floats, Grommets, Gaskets, Bearing Seals, etc.
FABRICATING—Including Converting, Combining, Coating, Embossing, and Molding DEVELOPMENT—Research and Engineering of Unique Materials, Parts and Products

ginning) of Cornell's experiment in applied anthropology in Vicos, Peru ["An Experiment in Applied Anthropology," by John and Mary Collier; SCIENTIFIC AMERICAN, January]. Apparently the results of the Peru-Cornell Project inspired Peru to go even further in improving the status of the Indians. The following report just published in the Mexican *Boletín Indigenista* gives an authoritative account of the expropriation of the lands for the Indians.

"Among the first interventions carried out by the Technical Committee of the Peruvian Indian Institute and the Coordinating Consultative Commission, created by the Supreme Decree of November 7, 1956, with the comprobatory vote of the Cabinet, was the expedition of Supreme Resolution No. 2, of December 11, 1956, commanding the expropriation with compensation and with a federal guarantee, of the Vicos Hacienda in the District of Marcará, village of Carhuaz, property of the Public Beneficence Society of Huarás, on behalf of the present tenant farmers of this property and their descendants. This measure was exercised in accordance with the plans of the Technical Committee; the petition to buy was formulated by the Vicos natives on the recommendations of the Peru-Cornell Project.

"This important resolution corroborates the fact of the magnificent practical and scientific results achieved during a five-year period by the Peru-Cornell Project, created by virtue of the agreement celebrated between the Peruvian Indian Institute and the University of Cornell of the United States (Supreme Resolution No. 99, 1951) for the purpose of carrying out anthropological investigations designed to orient plans of social betterment on behalf of the tenant farmers of the Vicos Hacienda.

"It is fitting to point out that among the reasons cited for the dictation of this important resolution was that 'in spite of the progress achieved, the Vicos project cannot continue to develop itself with the desired efficiency, because, since the natives are subject to the hacienda, the innovating efforts will produce only a minimum change in their transformation; for this reason it is indispensable that they be provided with the means of reaching, by stages, their greatest development.' In addition 'the realization of the just aspirations of the Vicos people will have repercussions of a national nature, in giving them an opportunity to incorporate themselves into the civic and economic life of the country through their own efforts.'

"The Interamerican Indian Institute

some time
some how
some place

Wherever your dreams are taking you...
Whether your designs are earthbound or seagoing,
whether they aim for the troposphere,
the stratosphere,
or outer space;

Whether you dream of the complex or the basic,
regardless of industry or application,
there is a Miracle Material called STAFOAM
that will open new vistas
and remove present limitations.

ready for reality

stafoam

A liquid... poured in place... foams and sets. The miracle material, STAFOAM, results. ... A material with any set of characteristics pre-determined by YOU. It can be formulated to produce a material as hard as steel. It can be formulated to produce a material of sponge-like flexibility. Or it can be formulated to any density between these extremes. STAFOAM can have pre-determined strength, texture, rigidity, porosity, thermal characteristics, insulation characteristics (heat, cold, electrical, shock and sound), and color.

STAFOAM is a polyurethane foam, formed by mixing isocyanates and resinous polymers in liquid form. In some formulas, STAFOAM is thermo-setting; in other, it is thermo-plastic. Consider what just one of STAFOAM'S valuable characteristics... foamed in place... can mean in savings to your manufacturing process... in engineering, in tooling, in assembly and of course in labor. STAFOAM is a material that could well revolutionize your manufacturing methods... or even your product.

The applications of STAFOAM are limited only by your imagination.

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cordially congratulates the Technical Committee of the Peruvian Indian Institute and the Coordinating Consultative Commission for this very important measure, which we do not doubt will be converted into an example of how the Indian problem should be solved in practice by endowing the Indians with their own lands and technical aid."

JOHN COLLIER, JR.

Taos, N. M.

Sirs:

Your fine article about Sir William Perkin [SCIENTIFIC AMERICAN, February] seemed to miss a point which adds to his achievement.

John Read should have pointed out that before Perkin the stress was on synthesizing pure white crystalline compounds. Usually colors were an impurity that had to be removed by crystallization and the use of charcoal.

Today anything unusual appearing in the laboratory is quickly investigated, but Perkin was curious enough to examine an amorphous black precipitate which any of his teachers would have quickly discarded as dirt.

ALVIN GOLUB

Brooklyn, N. Y.

ERRATA

Three illustrations in the article "The Child and Modern Physics" [SCIENTIFIC AMERICAN, March] did not represent with sufficient accuracy the experiments described by the author. The inaccuracies are mentioned for the benefit of those readers who may wish to repeat the experiments.

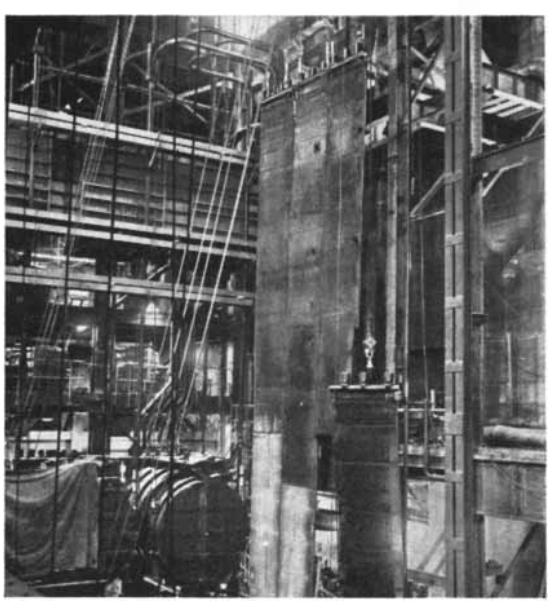
In the illustration on page 46 the object sought by the child is a block; in the illustration on page 47, it is a ball. In both cases the object should be flat, so as not to leave a hump in a piece of cloth placed over it.

In the illustration on page 51 the child sits at one end of two tunnels through which dolls are pushed. The child should actually sit at the side of the tunnels, so that he may see both ends of each.

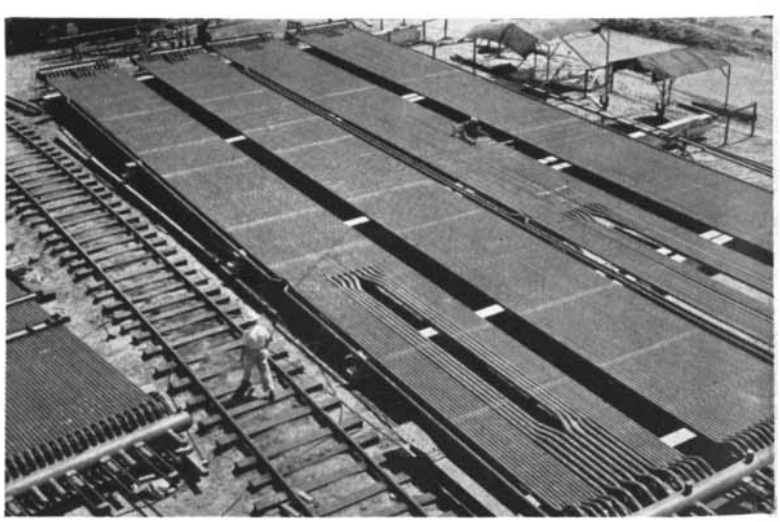
B&W AND ATOMIC ENERGY

How to Put

TONS OF CONCRETE, poured into this web of wire, will form walls of B&W-engineered swimming pool type research reactor.



SUPERCRITICAL pressure steam generator, the world's first, saw B&W engineers solve new design, fabrication, and erection problems.



ERECTION means smooth flow of components into place. Here side wall of high pressure, high temperature boiler is prepared for hoisting.

HERE ARE THE REASONS WHY B&W ENGINEERS KNOW...

a Nuclear Reactor Together

Putting a nuclear reactor together is an exacting engineering task. Research and power reactors are designed and fabricated to meet specific needs. But design and fabrication alone will not assure required operating characteristics. It's the job of the erection engineer to precisely assemble components into a working system.

SAFETY AND ECONOMY in assembling and testing research reactors and nuclear steam generating plants require skill in established construction methods. But with this skill, there must be combined advanced scientific and nuclear engineering techniques. B&W erection engineers have already acquired an extensive backlog of atomic energy experience, and are keeping up with the fast moving developments in the peaceful applications of this new source of energy.

LONG EXPERIENCE with high pressure vessels for example, has been applied by B&W to atomic energy's similar problems. It has been fortified by a continuing, independent program of nuclear research to make the Babcock & Wilcox position unique in design, fabrication, and erection for the atomic energy field.

STEP BY STEP, B&W engineers have followed progress in design and fabrication with improvements in erection methods. New techniques and tools have been developed and tested. Alloy welding, radiography, magnafluxing, and stress relieving processes have been adapted to the particular needs of erection.

HIGHLY SKILLED EXPERTS with special training supervise erection. Precision is their watchword and the newest techniques are at their finger-tips. Behind them stand nearly 100 years of B&W experience and the entire chain of specialized B&W engineering skills.

COORDINATION of all B&W departments assures a continuity of responsibility in one company from planning to starting up operations. Write for Bulletin AED-6, "B&W Builds a Research Reactor." The Babcock & Wilcox Company, Atomic Energy Division, 161 East 42nd Street, New York 17, N. Y.

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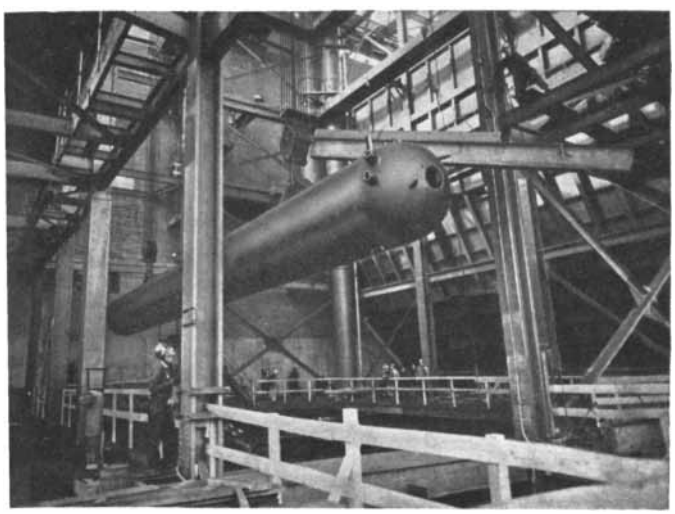
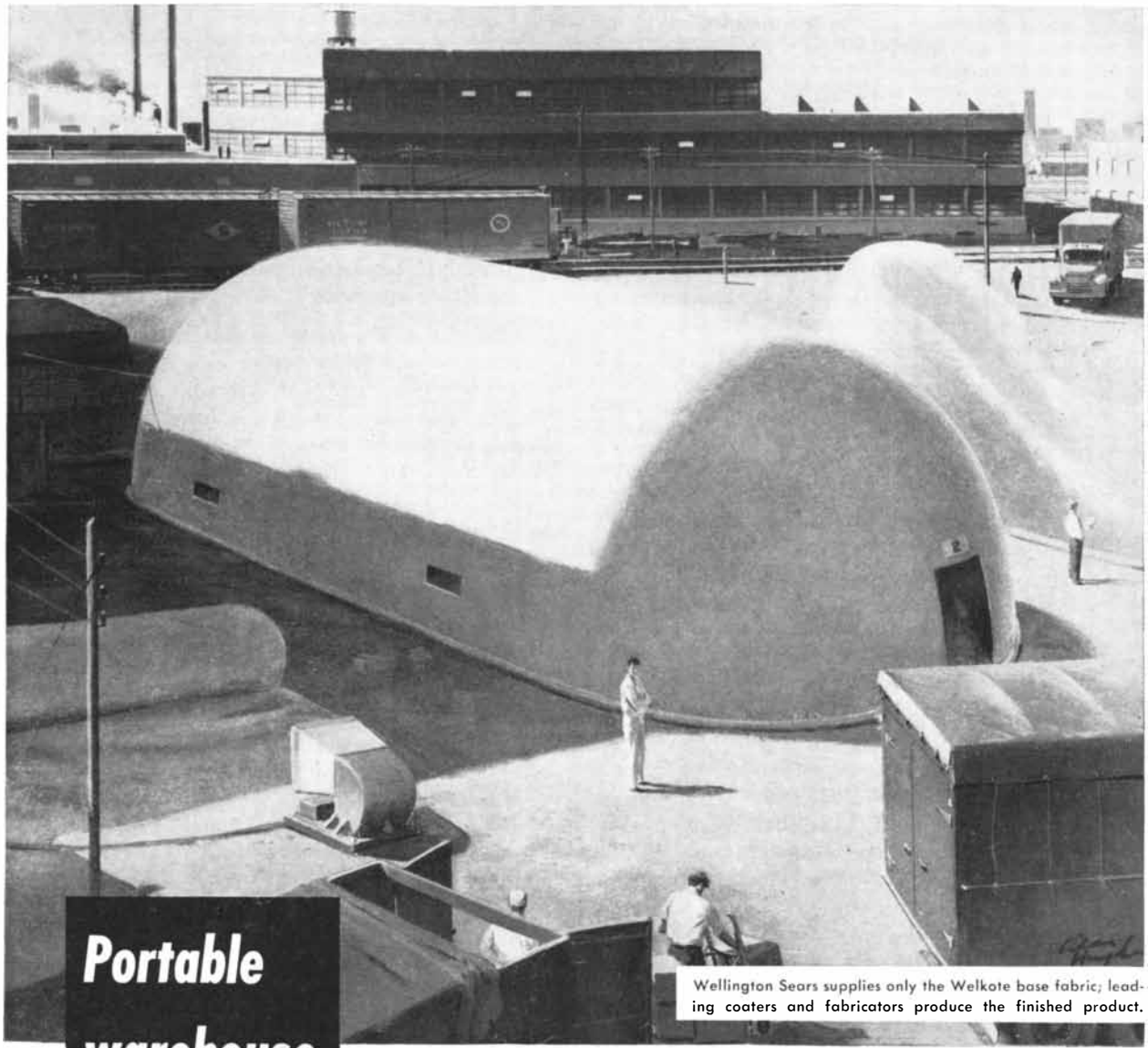
B&W

ATOMIC ENERGY DIVISION



KNOTTY erection problems, like hoisting a many-ton drum into position often over 100 feet above ground level, are taken in stride by specially trained engineers.

B&W'S STORE of high pressure welding experience is added to newest welding metallurgy refinements required for atomic energy projects.



Wellington Sears supplies only the Welkote base fabric; leading coaters and fabricators produce the finished product.

Portable warehouse made of fabric "lives" on air!

No visible means of support: *air* does it! Now huge vinyl-coated nylon buildings can be easily packed, transported swiftly to a site, inflated on the spot, and start receiving goods for storage in a matter of hours. And constant, regulated air pressure keeps walls and roofs taut even when doors are open!

As in so many new industrial uses of textiles, the rugged nylon base fabric, *Welkote,* is produced by the mills of West Point Manufacturing Company and supplied by Wellington Sears. Welkote is engineered specifically as a base for vinyl and neoprene coating, and is just one aspect of our textile service to all kinds of industries, for all kinds of uses. We've been doing this for more than a century. Surely you can use this experience to help in solving *your* fabric problems!

For informative booklet, "Fabrics Plus," write Dept. F-5.

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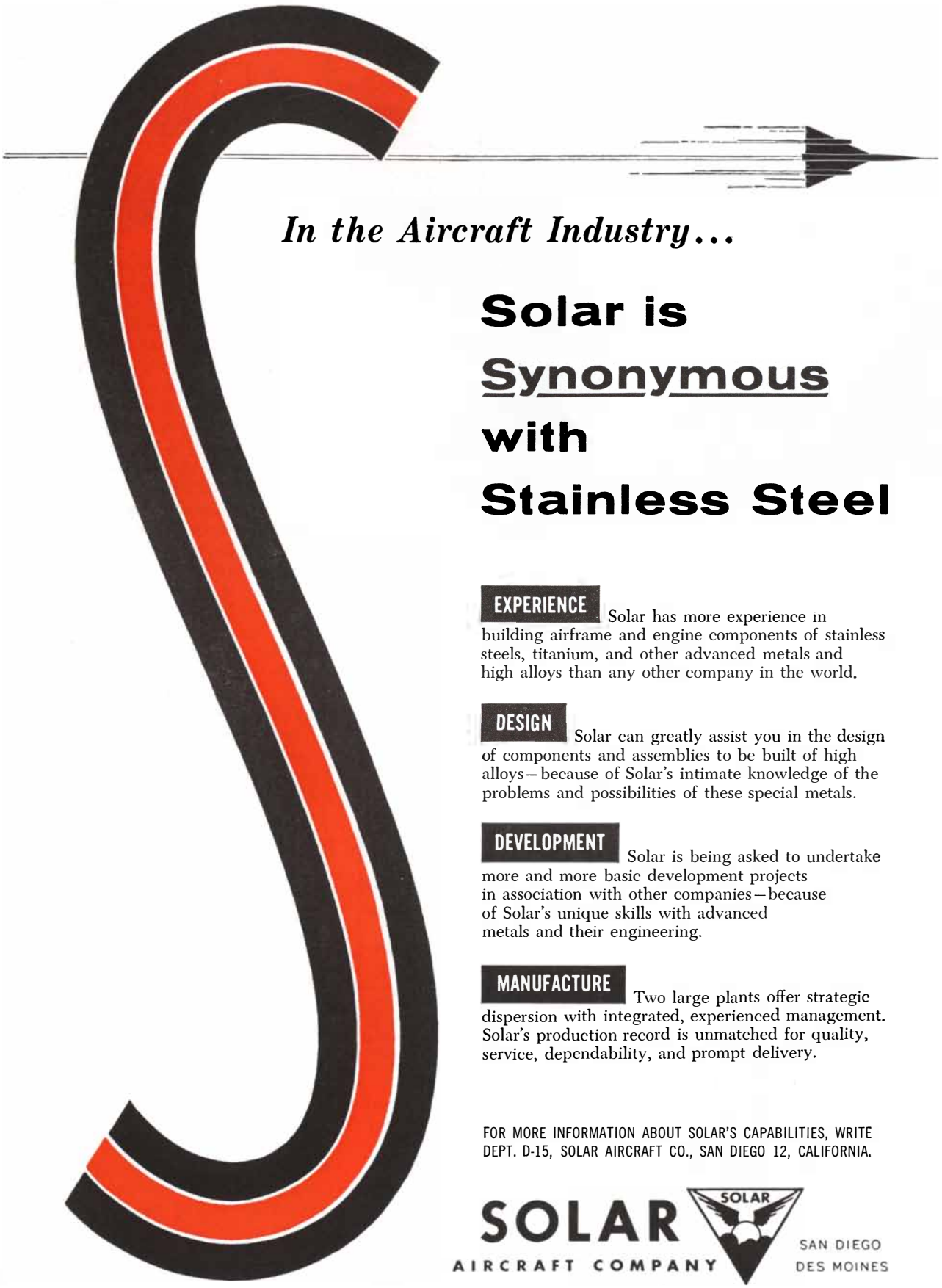

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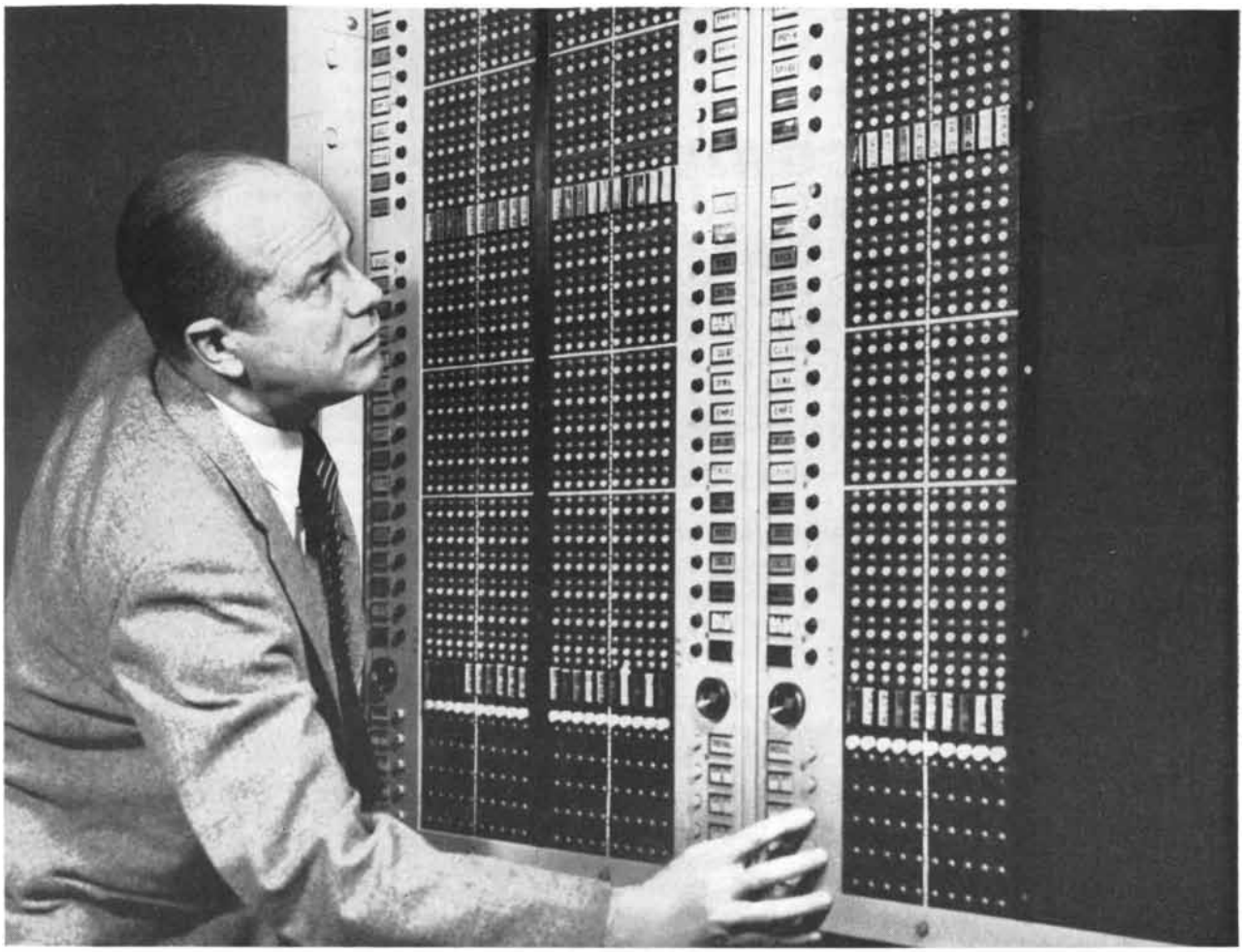
50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MAY, 1907: "The last monthly report of the Sanitary Department at Panama, which has been doing such successful work under Col. Gorgas, shows that health conditions continue steadily to improve, both in the laboring force and the civil population. The two causes of highest mortality among the working force were pneumonia, which was responsible for 26 deaths, and malarial fever, from which 15 deaths occurred. In the total working force of 5,554 white Americans there were two deaths during the month, one from fever and the other from consumption; although the consumption case cannot be charged to conditions at the Isthmus, since the patient was well advanced in that disease when he arrived from the United States, and worked only a few days before being entered upon the sick reports. There has been no case of yellow fever on the Isthmus since May of 1906. It is evident from this report that, when the Department claims for the Canal Zone health conditions that compare favorably with those in the more southerly states of the Union, it is making a statement which is well within the truth."

"Attention is called to the subject of submarines by the competitive trials now being carried out by the Government at Newport. Of the two main classes of American submarines, the diving and even-keel type, the former has been adopted by our Navy. The present trials at Newport are being held between the Holland and Lake types. The eight submarine boats now in service are 63 feet long and 12 feet in their greatest diameter, and have a displacement when awash of 105 tons, and when submerged of 120. The four new and larger ones which have just been finished, *viz.*, the *Cuttlefish*, *Tarantula*, *Viper* and *Octopus*, the last named now being tested at Newport, are 105 feet long and 200 tons displacement. They are of greater structural strength and are said to be able to stand the pressure of being submerged 300 feet, though 200 is the official depth required at the Newport



Bell Laboratories engineer Cyril A. Collins, B.S. in E.E., University of Washington, demonstrates new TV switching control panel for black and white or color. Complex switching connections are set up in advance; in a split-second a master button speeds dozens of programs to their destinations all over the nation. Special constant-impedance technique permits interconnection of any number of broadband circuits without picture impairment.

Telephone science speeds TV enjoyment

Telephone science plays a crucial part in your TV entertainment. An interesting example—one of many—is the latest TV switching center developed at Bell Telephone Laboratories.

Switching centers control the transmission of programs which come to your local TV station over Bell System facilities. To be available exactly on cue, programs must be switched at high speed and with very great accuracy.

To create the new switching center Bell Laboratories engineers borrowed from the switching control art which handles your dial telephone calls. They developed a special control panel which puts complex switching patterns within the easy grasp of one man. By pushing buttons, he sets up—and double-checks—forthcoming network changes far ahead of time. On cue he presses a master button which sends the programs racing to their respective destinations around the nation.

To connect the broadband circuits, the Laboratories engineers developed a new video switch which operates on a constant-impedance principle. The new switch permits the interconnection of any number of circuits, without the slightest impairment of transmission quality.

Thus the technology which serves your telephone also works for your TV enjoyment.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

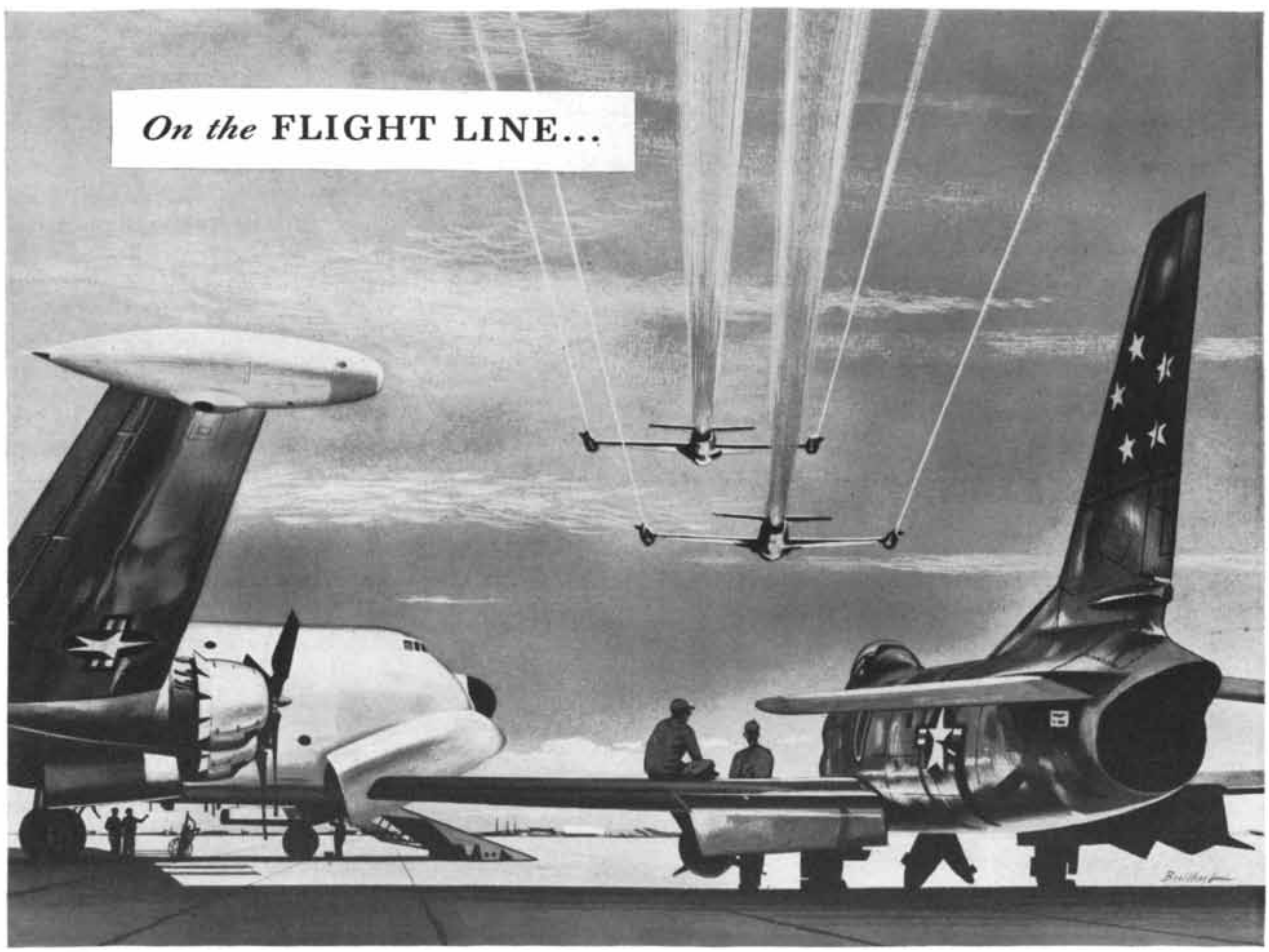
trials. The *Octopus* is supplied with a new system of submarine bell signals, whereby communication can be had with the surface. The radius of action is about 100 miles from base. She is equipped for warfare with two 18-inch torpedo tubes. The motive power is a powerful gasoline engine for surface running and an electric motor for submerged running. The speed is from 11 to 12 knots on the surface, and about 9 knots when submerged."

"The United States Weather Bureau has sent to Yuma, Ariz., Frank H. Bigelow, a meteorologist connected with the Weather Bureau, and C. E. Grunsky of the Reclamation Service, for the purpose of conducting a series of elaborate tests in the Salton Sea. With the final closure of the Colorado River, the great Salton Sink, which was inundated as the result of a poorly constructed headgate of an irrigation canal, and rapidly converted into an inland sea, will gradually dry up. Inasmuch as there are practically no outlets for this vast body of water, the Sink must naturally evaporate to dryness. It is for the purpose of ascertaining the rate of this evaporation that the government officials have been sent to Yuma. Such tests will be valuable because they will give definite evaporation data, which will be of considerable value in the Reclamation Service. According to one opinion, the Salton Sea will dry up in about eight years."

"Professor Alexander Graham Bell has received the honorary degree of Doctor of Science from Oxford University, in recognition of his efforts to teach the deaf and dumb to speak, as well as for his invention of the telephone."

SCIENTIFIC AMERICAN

MAY, 1857: "A correspondent writing to us from Los Angeles, Calif., states that there are two openings in that county for branches of the arts which will make a permanent business and prove profitable. 'The locality,' he says, 'is one of the choicest spots on earth, as regards climate and good fruits.' These latter involve the requirements of the two branches of business alluded to. They are glassmaking and the manufacture of pottery ware. The glass will be required for wine bottles, as that section will yet supply vast quantities of wines, the grapes being of superior



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quality, and yielding wine surpassing that which we now import from Europe. There is no glass manufactured at present in California, and there is but one pottery furnace in operation, and that is in the upper part of the state. Preserved fruits will yet constitute an important business in Los Angeles, and great quantities of earthenware vessels to contain them will yet be needed."

"The Pacific wagon road provided for at the last session of Congress will soon be under way. The Secretary of the Interior, we understand, is prosecuting with vigor the arrangements for its construction. It is to be divided into several sections under the control of separate superintendents."

"For a long period astronomers unsuccessfully endeavored to determine the distance between the stars and the earth, and it is only within a comparatively short time that the interesting problem can be said to have been solved. The distance which separates us from the nearest stars is, according to M. Arago, about 206,000 times the distance of the sun from the earth—more than 206,000 times 95,000,000 of miles. Alpha, in the constellation of Centaur, is the star nearest to the earth; its light takes more than three years to reach us, so that, were the star annihilated, we should still see it for three years after its destruction. If the sun were transported to the place of this, the nearest star, the vast circular disk, which in the morning rises majestically above the horizon, and in the evening occupies a considerable time in descending entirely below the same line, would have dimensions almost imperceptible, even with the aid of the most powerful telescopes, and its brilliancy would range among the stars of the third magnitude only."

"English papers record the decease of Frederick S. Archer, the inventor of the 'collodion process' in photography. After numerous experiments, he discovered the mode of rendering collodion sensitive and obedient to the photographic process, by means of which the most interesting objects in nature as well as art are now portrayed, not only with unerring correctness, but are also transfixed almost as quickly as lightning's flash. The collodion process has enabled skillful artists to take copies of shore scenes while passing along on a steamboat."

"A submarine telegraph cable has been laid across the Mississippi at St. Louis."

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For information about the Federal AUTOPILOT address Federal Telephone and Radio Company, a division of IT&T, Clifton, N. J.

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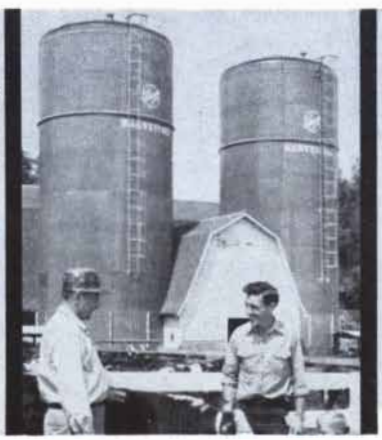
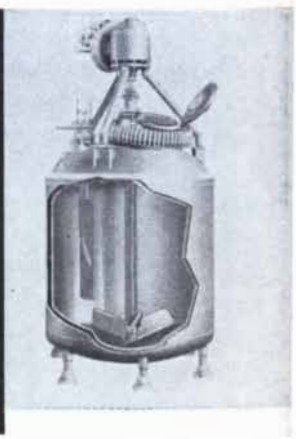
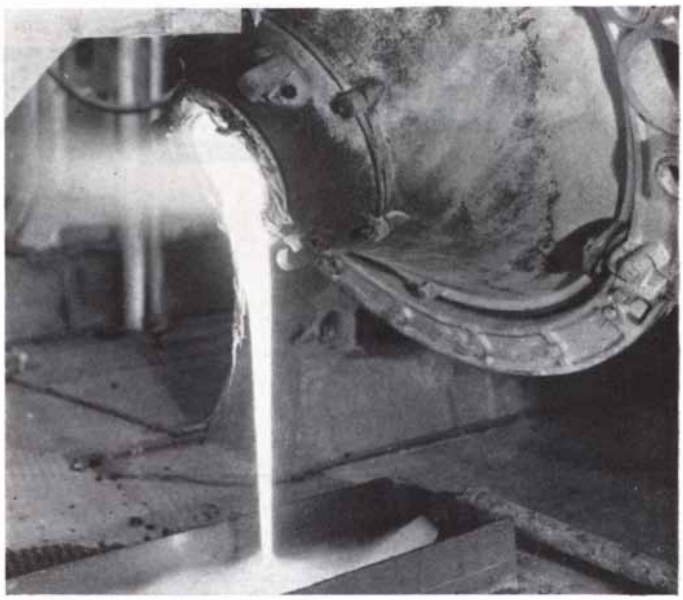


HARVESTORES for farm feed processing . . . *Permaglas* mechanized storage structures, handling industrial bulk materials, turn losses to profits.

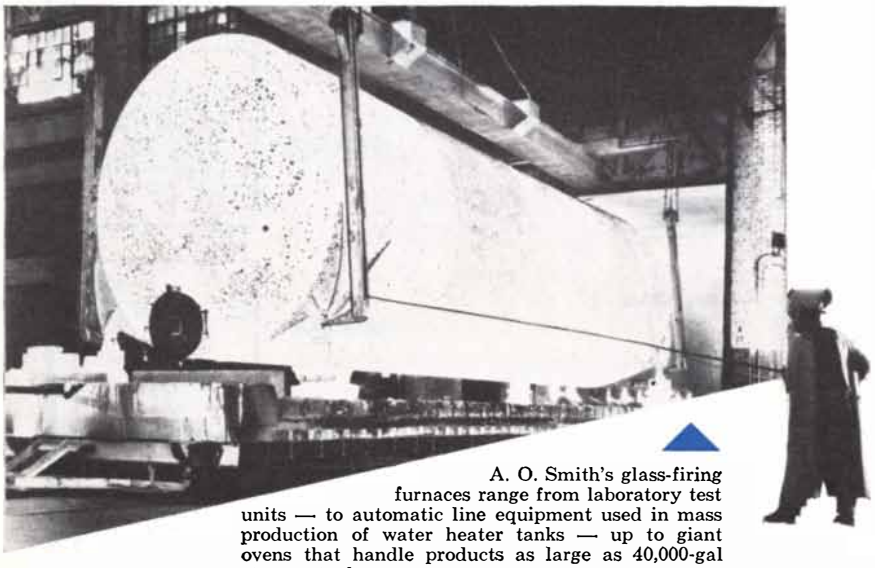


GLASCOTE subsidiary products for severest chemical processing service . . . defeat corrosion and contamination.

Each glass formula starts with the careful weighing of sands, clays and other specified ingredients. These are then thoroughly mixed and screened to uniform consistency.

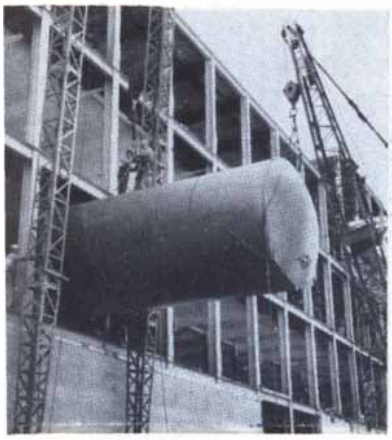


A special smelter liquifies the mixture at 2300° F. This molten "lava" is poured into cold water where it solidifies and shatters into glass particles called *frit*. (Not illustrated: *Frit* is ground with special clays and soft water in giant ball mills to produce a creamy liquid called *slip*. This is applied to steel surfaces that have been cleaned and etched to provide a perfect bonding texture).



A. O. Smith's glass-firing furnaces range from laboratory test units — to automatic line equipment used in mass production of water heater tanks — up to giant ovens that handle products as large as 40,000-gal storage tanks.

The actual fusing of glass to steel takes place in special furnaces super-heated to 1600° F. The bond is both physical and chemical . . . and the glass will not separate from the steel until the metal's yield point has been exceeded.



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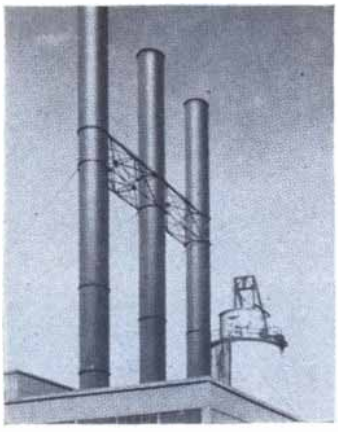

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TO OPERATE

just provide a simple power supply and indicator . . . connect the desired capacitance configuration to the DECKER DELTA UNIT . . . and an analogous output signal is immediately available.

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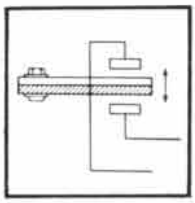
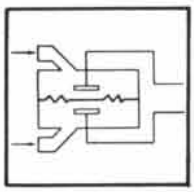
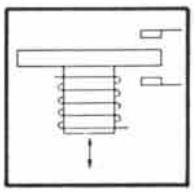


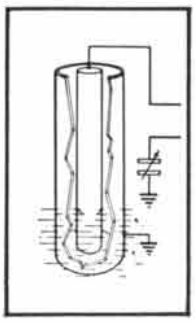
PRESSURE



VIBRATION



LIQUID LEVEL



Detailed information on the DECKER DELTA UNIT—priced at $115.00, complete with probe and cable—is in Instrument Data Sheet 901-1, available upon request to Technical Literature Section.

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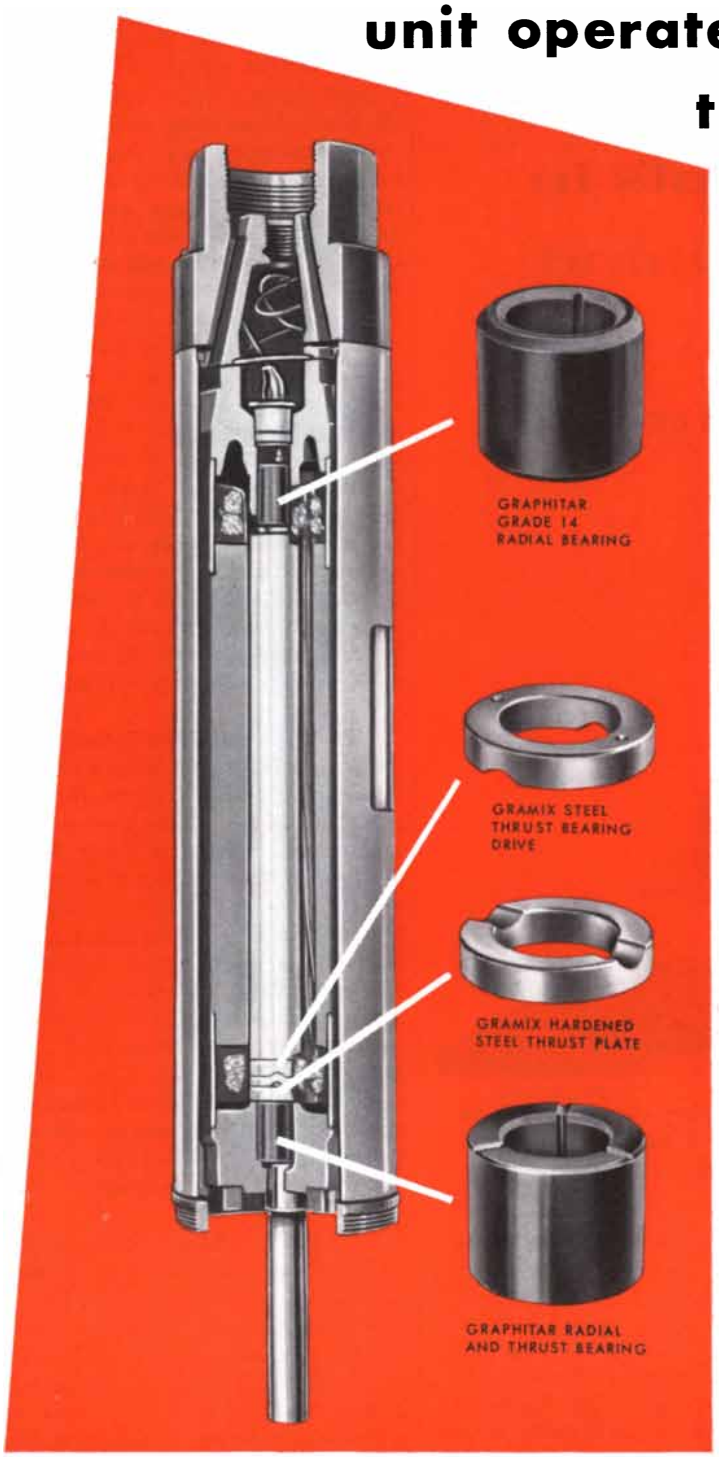
bearings in Leland submersible motor unit operate with gasoline as the only lubricant



Running directly in gasoline, this superbly-designed Leland submersible motor embodies two GRAMIX thrust washers and two GRAPHITAR bearings to keep the operation of this amazing explosion-proof pump motor safe and smooth.

Thirty years ago the manufacturer of these pumps—the Leland Electric Co., Dayton, Ohio, a division of American Machine and Foundry Co., developed the first gasoline curb-pump motor to receive Underwriters' Laboratories' approval. Throughout their long experience, they have selected every component with great care. It is thus significant that for Leland's submersible motor they selected GRAPHITAR and GRAMIX bearings.

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THE AUTHORS

ROBERT HEINE-GELDERN ("Vanishing Cultures") is professor of Asian ethnology and archaeology at the University of Vienna and a research associate of the American Museum of Natural History. While trying to crack the Easter Island script in 1937, he became convinced that a crash program for research on vanishing cultures was needed. Heine-Geldern was born in 1885 on his grandfather's baronial estate in Lower Austria, and studied philosophy and art history at the universities of Vienna and Munich. His first contact with primitive tribes came during a big-game hunting expedition to India and Burma in 1910 and 1911. He was inspired to return to the University of Vienna as a student of anthropology. There he studied and taught until the Nazi invasion of his country in 1938. At the time Heine-Geldern was lecturing in the U. S., and in the following years he taught at several U. S. institutions, including Columbia University and the University of California. He returned to the University of Vienna in 1949.

J. D. FRENCH ("The Reticular Formation") followed his father's example in becoming a brain surgeon. He is director of research at the Veterans Administration Hospital in Long Beach, Calif., as well as professor of surgery at the University of California School of Medicine at Los Angeles. After taking an M. D. at the University of Southern California School of Medicine, he served as intern and resident at Strong Memorial Hospital in Rochester, N.Y., and joined the teaching staff of the University of Rochester School of Medicine in 1943. In 1948 he returned to California to become head of neurosurgery at the Long Beach veterans' hospital.

WALTER GORDY ("The Shortest Radio Waves") first thought of using microwaves to study the structure of matter while he was working on radar in the Radiation Laboratory at the Massachusetts Institute of Technology during World War II. As soon as the war was over, he set to work on his idea at Duke University, where he is now professor of physics. Gordy was born in 1909 in Lawrence, Miss. He went to school in a one-room schoolhouse. At Mississippi College he took up physics under the influence of an inspiring teacher, D. M. Nelson. After earning a

Here's all you need to install flexible pipe of TENITE POLYETHYLENE

Polyethylene pipe is a booming new market for the plastics industry. For example—farmers, homeowners, and industry are finding numerous jobs for pipe made of Tenite Polyethylene because of the specific advantages it offers as a material for cold-water lines. Polyethylene pipe is now the *preferred* material for these jobs and is no longer considered a mere substitute for metal pipe.

Amazingly light in weight, pipe made of Tenite Polyethylene is easily handled even by non-professionals. It's flexible and can be curved around obstructions, practically eliminating the need for angle fittings. It's available in coils for long, coupling-free runs. Where short lengths are needed, this plastic pipe can be cut with a knife and joined with simple inserts and ring clamps. No threading is necessary. What's more, pipe of Tenite Polyethylene resists weathering and the corrosive attack of alkali soil, dissolved chemicals, and electrolysis.

Pipe is just one of many uses for versatile Tenite Polyethylene. This tough, resilient Eastman plastic also goes into electrical insulation...packaging film...coatings for paper, film, and foil...containers...housewares and many other molded products. For information about Tenite Polyethylene properties and uses, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

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POLYETHYLENE
an Eastman plastic

1932—EASTMAN'S 25TH YEAR IN PLASTICS—1957

Ph.D. at the University of North Carolina, he went to teach in a small Texas college, and just before the war was a National Research Fellow at the California Institute of Technology under Linus Pauling.

CARL J. WIGGERS ("The Heart") retired in 1953 as professor of physiology at Western Reserve University, where he had taught since 1913. He is now honorary professor at the Bunts Educational Institute in Cleveland and editor of *Circulation Research*, a journal which he founded five years ago. Wiggers received his M.D. from the University of Michigan, taught there for several years, and did advanced work at the Physiological Institute in Munich before going to Western Reserve. He has written books titled *The Physiology of Shock* and *Circulatory Dynamics*, served as president of the American Physiological Society and won the Gold Heart Medal of the American Heart Association and the Lasker Award. His greatest pride is that more than 24 of his former students now hold university professorships in the U. S. and abroad.

PAUL R. HALMOS ("Nicolas Bourbaki") is associate professor of mathematics at the University of Chicago, which is known to be a hotbed of Bourbakiste activity. He was born in Budapest, emigrated to the U. S. at 13, and graduated from the University in 1934. He was John von Neumann's assistant for two years at the Institute for Advanced Study and worked at the Radiation Laboratory of the Massachusetts Institute of Technology during the war. His publications, which include four books, have had to do with Hilbert space, probability theory and algebraic logic; in 1946 he won the Chauvenet prize of the Mathematical Association of America for mathematical exposition. "By way of extracurricular activity I abstain from exercise on every possible occasion; I play poker (well), go, the Japanese board game (badly), and piano (execrably)."

B. D. CULLITY ("Diffusion in Metals") is associate professor of metallurgy at the University of Notre Dame. He was born in Montana but grew up in Canada, where he worked for two years in the assay office and mill of a northern Quebec gold mine before entering McGill University. After several years of teaching at the Montana School of Mines and the University of Minnesota, Cullity was made a group leader in a branch of the Manhattan Project

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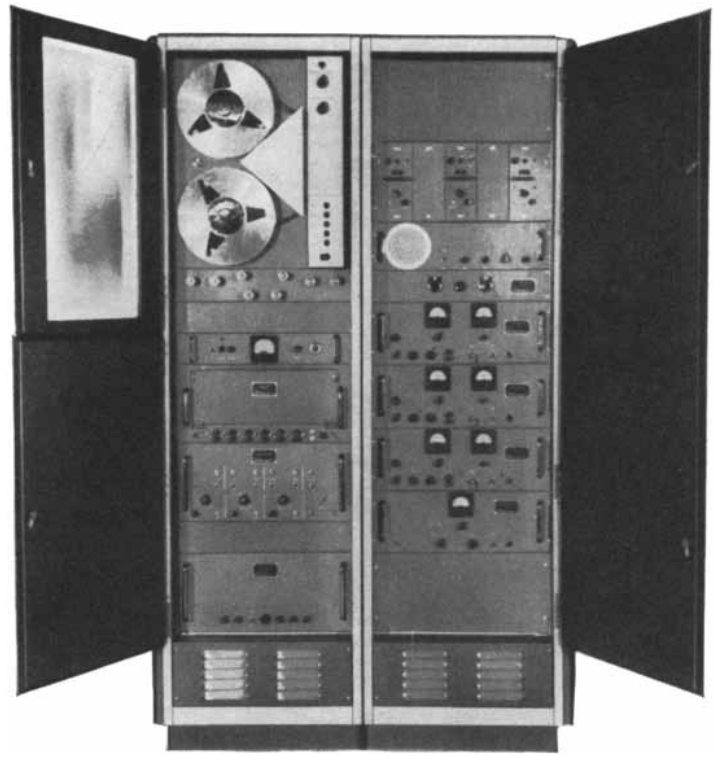

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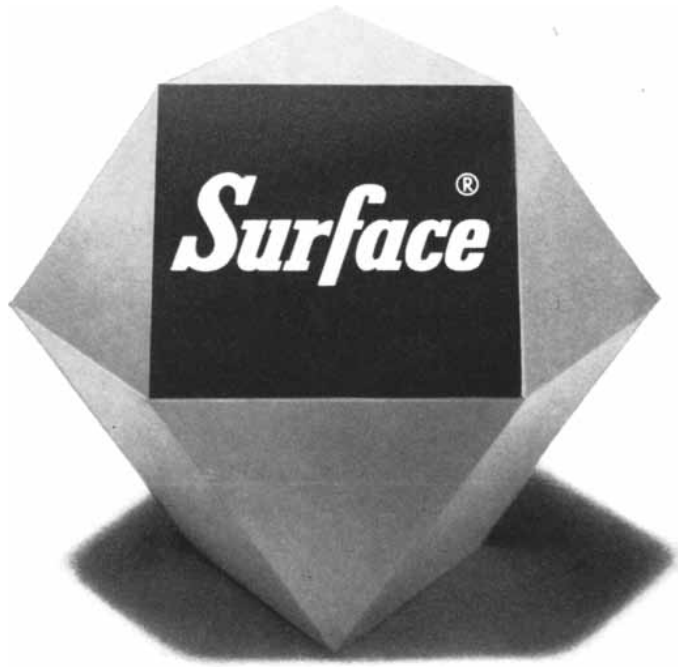
at the Massachusetts Institute of Technology. He received a Sc.D. from M.I.T. in 1947, then went to Europe on a fellowship, where he studied at the Ecole des Mines in Paris. He became a liaison officer for the Office of Naval Research, visiting all the major laboratories in Western Europe.

GEORGE S. AVERY, JR. ("The Dying Oaks") is president of the Botanical Society of America and directs the Brooklyn Botanic Garden. Born in Michigan, he grew up on a Mississippi plantation and graduated from Tulane University in 1924. After two years of graduate work at Dartmouth College, he gave up plans for a diplomatic career when offered a fellowship in botany at the University of Wisconsin. Avery has devoted 25 years and some 50 scientific papers to the study of plant growth hormones. He taught at Duke University, was a National Research Fellow at Columbia University in 1930, and later a Rockefeller Fellow at the University of Copenhagen's Carlsberg Laboratory. He came to his present post in 1944, after a number of years as director of the Connecticut Arboretum. His interest in plants has led him to such areas as Lapland and the Sahara Desert.

H. N. SOUTHERN ("A Study in the Evolution of Birds") is senior research officer in the Bureau of Animal Population, a part of the Department of Field Zoology of the University of Oxford. There he studies the role of owls and other predators in controlling the population of voles and mice. In his spare time he observes guillemots and other birds, accompanied by his wife, who paints landscapes in watercolor. Southern contributed an article entitled "Nocturnal Animals" to the October, 1955, issue of SCIENTIFIC AMERICAN.

J. BRONOWSKI, who reviews Roy Harrod's *Foundations of Inductive Logic* in this issue, is a writer and mathematician who now directs the Coal Research Establishment of Britain's National Coal Board. Educated at Jesus College, Cambridge, he was a senior lecturer at University College in Hull until 1942, when the British Government sent him to Washington. After V-J Day he served with the Chiefs of Staff mission to Japan, directed statistical research on industries for the British Ministry of Works and worked with UNESCO. Bronowski's books include a biography of William Blake and several radio plays. One of these, entitled *The Face of Violence*, won the Italia Prize in 1951.



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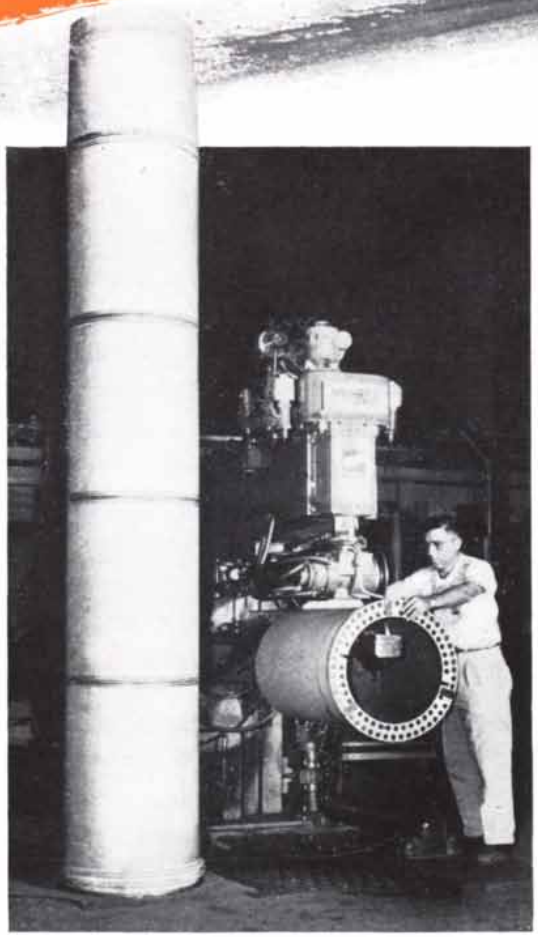

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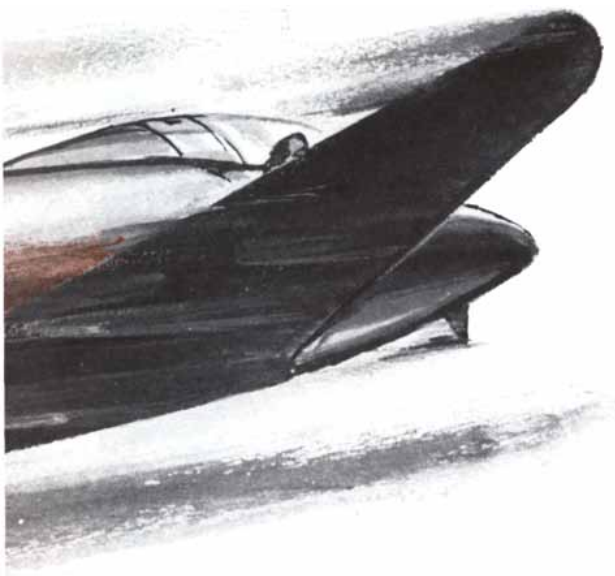

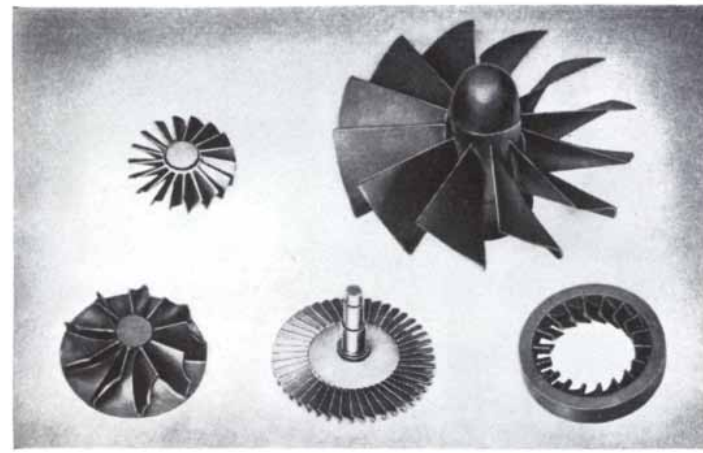

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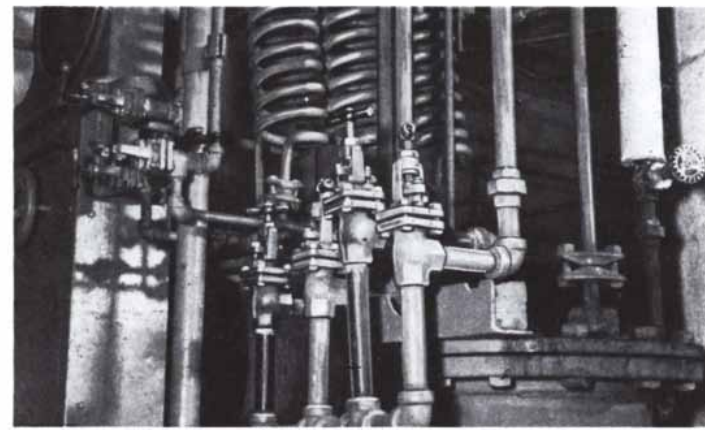

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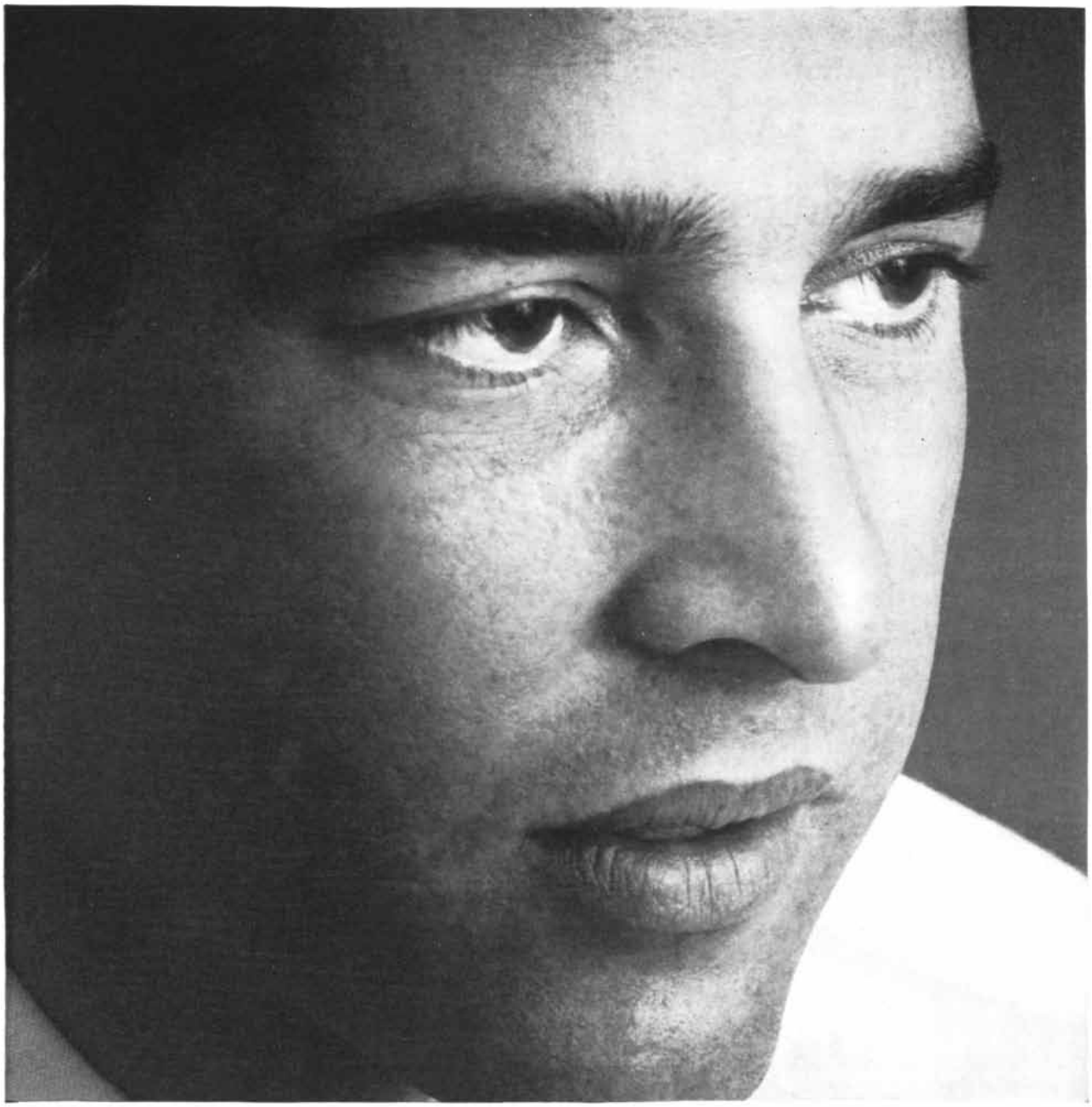

YAVNO

...on science and impossibility

"Scientific knowledge is derived from observations of the world. Our imaginations, however, are not bounded by this constraint—we can easily imagine physical nonsense. Not everything is possible. We sometimes get the opposite impression because new scientific discoveries force us to modify an old theory, and give rise to new and unexpected possibilities. But the point is that the old theory was verified for some class of physical phenomena, and a domain of validity was established. The new theory, however radically it may differ from the old one in its conceptual basis, must always agree with the old theory in the predictions it makes for that class of phenomena. Despite the greater generality of quantum mechanics, Newton's laws still apply to macroscopic objects. Parity is still conserved for the strong interactions. The old impossibilities still remain. Within the limits defined by the impossibilities, there is plenty of room for man's inventiveness to operate. In fact, the game is even more challenging that way."

—*Richard Latter, Head of the Physics Division*

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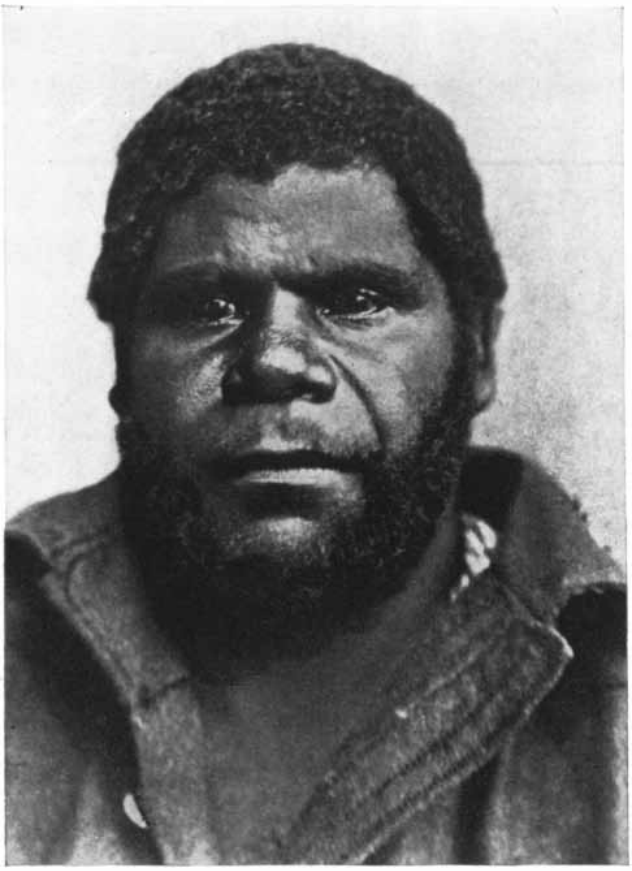
Vanishing Cultures

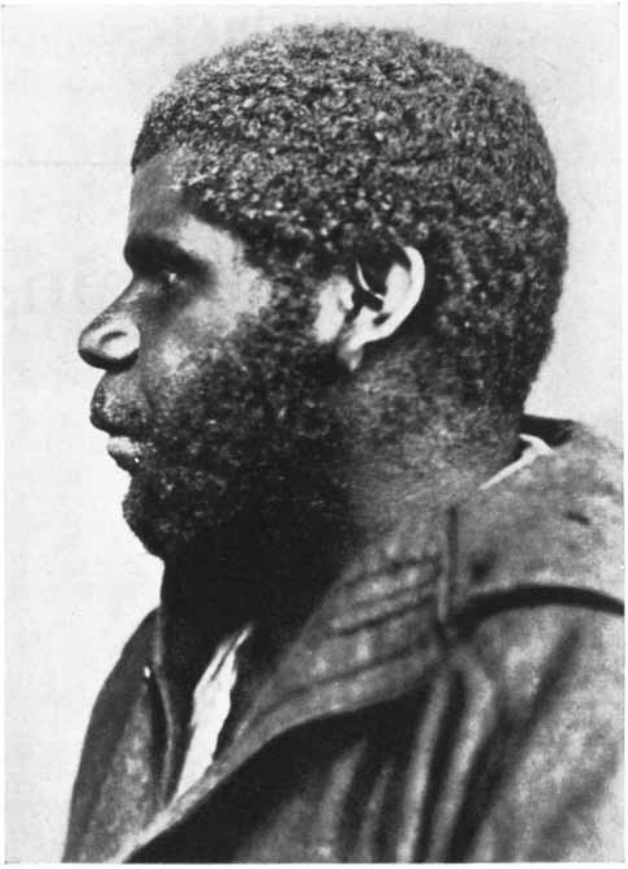
Small groups of men who live in the Stone Age may still be studied in remote corners of the world. They are fast dying out, presenting anthropologists with an emergency

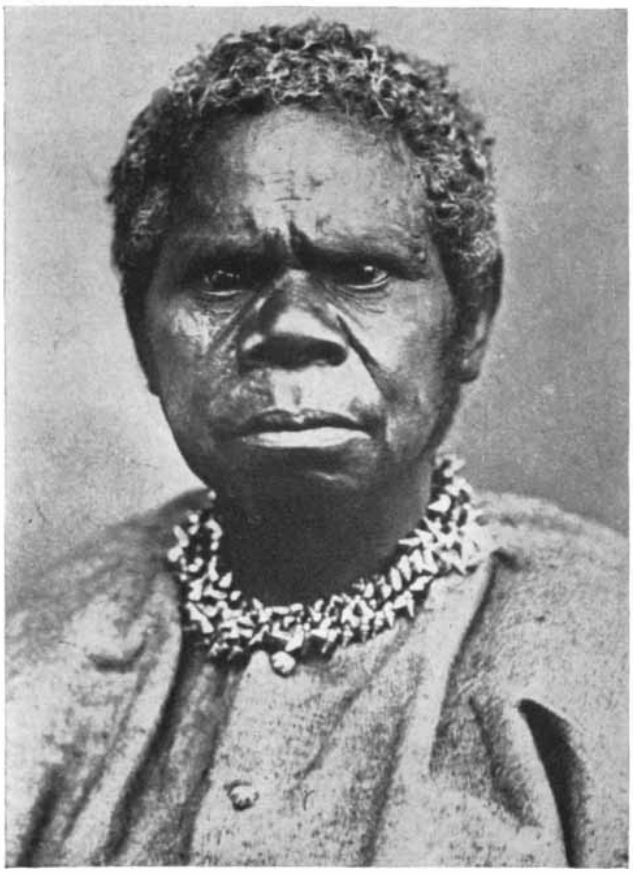
by Robert Heine-Geldern

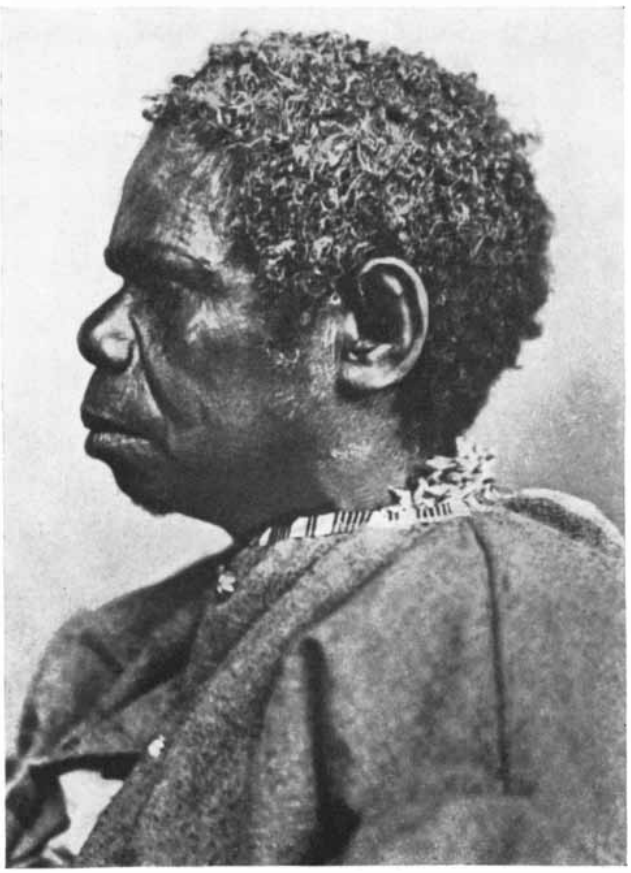
Imagine that, on an island in some remote corner of the earth, an explorer were to discover a tribe of people still living in the Old Stone Age more or less as man lived 50,000 years ago. One might suppose that scientists would be eager to rush off to that anthropological paradise to study the miraculously preserved living remnant of man's long-lost past. Well, precisely such a discovery was made not too long ago, and men allowed the opportunity to slip from their fingers. Toward the end of the 18th century French and British explorers came to the island of Tasmania, off the southern coast of Australia. They found a dark, woolly-haired people with an incredibly primitive culture—more primitive even than that of the Australian aborigines. The Tasmanians lived by hunting and food-gathering; they had no

LAST TASMANIANS to survive the impact of European culture were photographed at the Oyster Cove Aboriginal Establishment in the 1860s. These inhabitants of the island south of Australia had a culture even more primitive than that of the Australian bushmen.









LAST TASMANIAN MAN AND WOMAN are shown in these remarkable portraits from the front and side. At top is William Lanney, who became a whaler and died in 1869 at the age of 34. At bottom is Truganini, daughter of a chief, who died in 1879 at about 70.

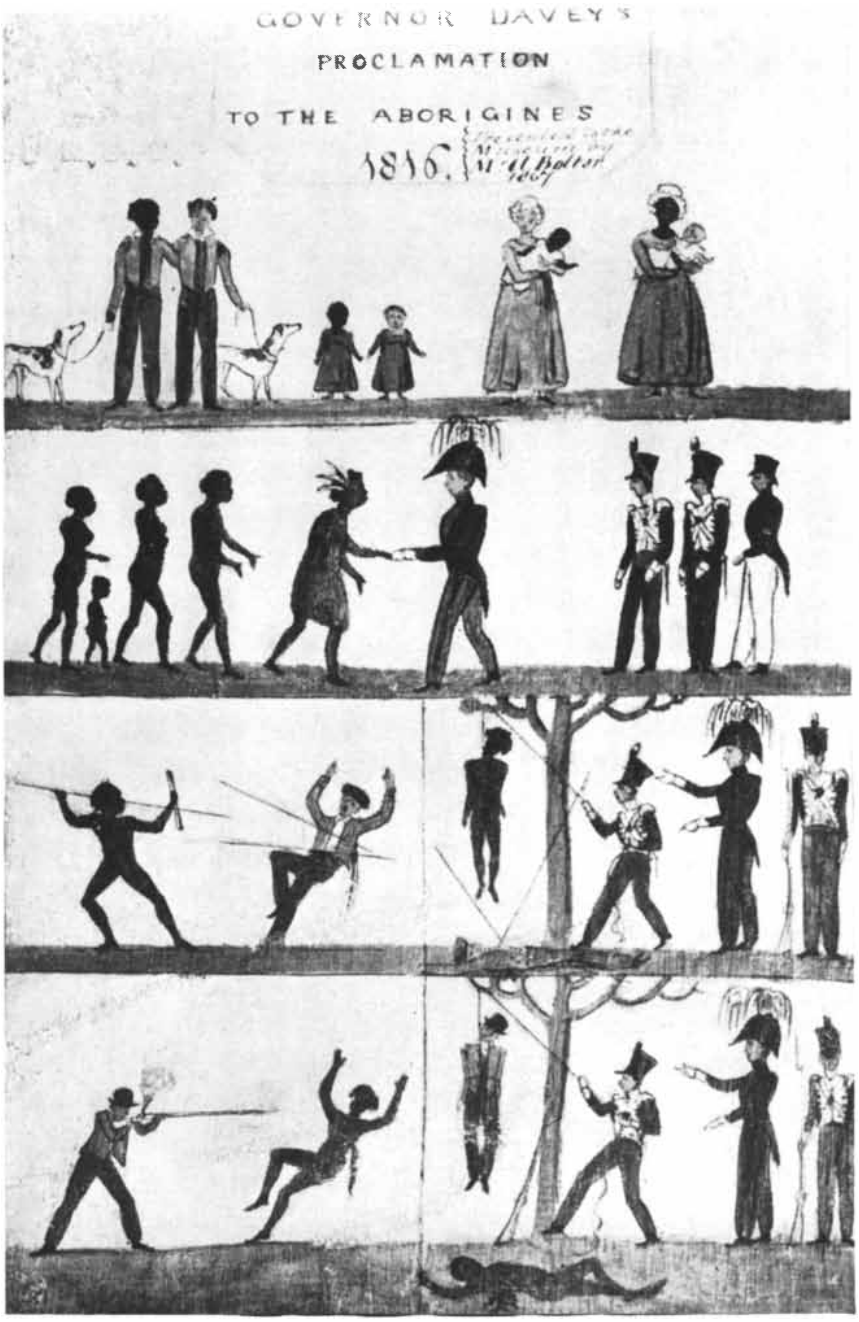
domesticated animals, not even dogs; their only weapons were clubs, stones and pointed sticks shaped like early Stone Age spears; their chipped-stone implements were as crude as those of Neanderthal man. These people would have been looked down upon as savages even by men of the latter part of the Old Stone Age, who had advanced to specialized flint and bone tools and cave painting. The Tasmanians offered, or, rather, could have offered, to modern science the closest surviving approach to the sort of culture that our human ancestors may have had before the last Ice Age.

Yet no anthropologist ever visited the Tasmanian aborigines. Instead they were hunted like wild animals by the white settlers who followed the explorers to the island. By 1830 no more than 200 of the thousands of natives who had inhabited the island were left, and the last Tasmanian died in 1876. An invaluable opportunity was lost forever.

In 1890 the great British anthropologist Sir Edward Tylor wrote of the Tasmanians: "Looking at the vestiges of a people so representative of the rudest type of man, anthropologists must join with philanthropists in regretting their unhappy fate. We are now beginning to see what scientific value there would have been in a minute careful portraiture of their thoughts and customs." And H. Ling Roth, who collected the all too meager scraps of knowledge we possess about the Tasmanians and published them in a book, woefully observed: "The sad and untimely destruction of this interesting primitive race is one of the greatest losses anthropology has suffered."

Of course there are understandable reasons for the failure to appreciate and exploit this opportunity at the time. Anthropology was then still in an embryonic stage. But what should concern us now is whether or not we have learned the lesson. I am afraid we have not, or at least not sufficiently.

It is true that in recent years anthropologists have carried out many investigations of still-extant hunting and food-gathering tribes, notably among the Eskimos, the Australian aborigines, the Pygmies of central Africa and the Negritos of the Malay Peninsula. But many others have been completely neglected, and disease and changed conditions of life are destroying them, or at least their cultures, with appalling rapidity. The urgency of time is particularly well illustrated by the case of the primitive Indian tribe known as the Yamana, on the island of Tierra del Fuego off the tip of South America. In the 1920s the anthropologists Martin Gusinde and Wilhelm Koppers, then working in Chili, found these people in the nick of time. Their magnificent reports on the Yamana tribe show how much we would have lost had they come a few years later. The tribe has now disappeared.



PROCLAMATION of friendship by Lieutenant Governor Thomas Davey of Tasmania was made known to the natives by painted signs nailed to trees. This sign promised that amicable relations (*first row*) would follow an agreement (*second row*) guaranteeing equal justice for whites and blacks (*third and fourth rows*). Unfortunately the white settlers, most of whom were convicts, could not be controlled. None was ever hanged for killing a Tasmanian.

The list of lost opportunities is long and tragic. On the small island of Enggano, southwest of Sumatra, until about 60 years ago there lived a people with a unique and archaic culture. They had tiny huts shaped like beehives and set on high stilts; they planted tubers but did not know rice; they used iron but worked it cold, hammering it with stones. Apparently they had emerged from the Stone Age not much more than a century before. There are good reasons to believe that they represented the cul-

KAFIR STATUE honors an ancestral spirit of this fierce mountain people of the Hindu Kush, who preserved much of the ancient Aryan religion and culture. They were forcibly converted to Islam in 1895, before Western scholars could study them thoroughly.

ture of an early wave of Neolithic immigrants into Indonesia. Yet the island was never visited by an anthropologist. The only substantial account of their life we have comes from a zoologist. Under the impact of foreign contacts the population was cut down by malaria and their original culture vanished. Some of their artifacts are preserved in museums, but we shall never know what their social organization and their religion really were like.

In 1890 Sir George Scott Robertson encountered in the Hindu Kush Mountains, between Afghanistan and what now is Pakistan, the fierce tribes called the Kafirs. They were an isolated people who spoke Indo-European languages, had an ancient pagan religion, hunted with bows and arrows and erected stone monuments and wooden statues in honor of their dead. The whole country must have been a living museum of cultural remnants dating back to various periods of antiquity. Here was a living culture still reflecting the social institutions and religious beliefs of some group of ancient Aryans. But Robertson's book on the Kafirs, with its all too scanty details, is practically our only source of information on their ancient culture, for it has now vanished. A few years after Robertson's visit the Afghans conquered the Kafirs and converted them forcibly to Islam.

One of the great lost opportunities was Easter Island, about which probably more nonsense has been written than about any other spot on the earth. When it was discovered by Europeans in the 18th century, its enormous stone statues at once excited the imagination, and later the island's interest was enhanced for anthropologists by the surprising discovery that its inhabitants possessed a script and written documents. But no one thought of sending competent scholars to investigate its culture. In the second half of the 19th century a curious notion seems to have prevailed, according to which navy paymasters were particularly qualified to carry out field research on Easter Island. In 1882 the paymaster of a German warship was given such an assignment and was allowed three and a half days for the task. In 1886 W. J. Thomson, paymaster of the U.S.S. *Mohican*, was given 11 days on the island for investigation of its mysteries. Fortunately Thomson was a person of unusual ability and zeal, and he accomplished a remarkable amount of valuable work. But Easter Island was a task for extended research by trained scholars. When at last the first scientific

expedition arrived on the island in 1914, it was too late. The old culture had disintegrated.

Mrs. Scoresby Routledge, the head of the expedition, came just in time to discover that there had been two different kinds of script on Easter Island. The first, preserved in about two dozen tablets in museums, was no longer known to any living native on the island. Mrs. Routledge found an old man who knew how to write the second script, but he died within a few weeks, leaving her only a single sheet of paper with a few undeciphered lines.

Mrs. Routledge and the few anthropologists who visited the island in later expeditions collected every scrap of knowledge and tradition that was still to be found, but despite all their endeavors our knowledge of the island's old culture remains fragmentary. It is exasperating to realize that we might easily have learned a great deal about this fascinating culture had our predecessors had more vision and recognized in time the importance and urgency of research. The full scope of our loss became apparent recently when Thomas S. Barthel of the University of Hamburg succeeded in deciphering some of the tablets and showed that they throw light on the cultural history not only of Easter Island but also of a large part of Polynesia.

It would be easy to list similar instances of lost opportunities by the dozen and from every part of the world. Ever since the great era of world exploration began in the 15th century, the extermination of non-European cultures and ancient tribes has been going on in wholesale fashion. Now the Second World War and its aftermath have greatly accelerated this process. All over the world ancient cultures are being broken up and annihilated at unprecedented speed. Tribes are being absorbed by the larger neighboring populations. Cultures and languages which have never been properly recorded are disappearing. Modern technology and economic developments are proving more efficient in erasing traditional cultures than were the firearms of the conquerors of former centuries.

Anthropologists have speeded up their field research and accomplished an impressive amount of work since the war. But we must face the hard fact that we are racing against time. Within 10 or 15 years many of the ancient cultures and languages still surviving will be gone.

The fifth International Congress of Anthropological and Ethnological Sciences, which met in Philadelphia last September, appointed a "Committee for Anthropological and Ethnological Research on Populations Threatened with Change, Disintegration or Extinction"—admittedly a rather cumbersome title. UNESCO agreed to sponsor the project and voted a subsidy for its initial organizational work. Its first task will be to establish and publish lists of tribes, cultures and languages which were never properly investigated and which may be expected to disappear or disintegrate in the near future. The Committee will be available to advise foundations and research institutions on the relative importance and urgency of projects submitted to them. It will also make suggestions of its own and will try to stimulate research in every way possible.

Let me list just a few of the most obvious and most urgent survivals that we ought to investigate before it is too late.

Some say that the most primitive tribe still left on the earth are the Kubus who rove the jungles of southern Sumatra. They are even alleged to have no trace of religion, which would make them unique among all the peoples of the world. But no anthropologist has ever seen these people in their home in the jungle. In the interior of certain small islands south of Singapore and in the jungles of Borneo there are tiny remnants of other very primitive tribes about whom little or nothing is known. The coasts of the Malay Peninsula and some parts of Indonesia are frequented by enigmatic groups of nomad fishermen called "People of the Sea." Not a single one of their numerous branches has been thoroughly investigated.

In the Great Andaman Islands of the Bay of Bengal there is a remnant of a culture which has long been recognized as one of the most archaic in the world. When the British first put a settlement on these islands in 1857, they were inhabited by 11 tribes of naked, pygmy-like Negritos roaming the jungle. Fortunately an excellent amateur observer, a government officer named Edward Horace Man, took it upon himself to describe some of the tribes and their culture while they were still intact, but no professional anthropologist came to investigate them until A. R. Radcliffe-Brown arrived in 1906. By then the population had dwindled to not much more than one tenth of its original size, and the culture was already in the process of disintegrating. Today only one of the original 11 tribes on the Great Andaman Islands remains. This group, the Jarawa,

EASTER ISLAND SCRIPT was another lost opportunity of anthropology. Recently deciphered by Thomas S. Barthel of the University of Hamburg, it eluded anthropologists who landed on the island in 1914 a few weeks before the last man who knew it died.

has been fighting the British and their Indian successors with bows and arrows for 100 years and is inaccessible to scientific investigators. However, there is a less warlike tribe of Andamanese Negritos on Little Andaman Island; these people have been studied by the anthropologist Lidio Cipriani of Florence, who lived among them for some time. He emphasizes the urgency of further research. We can only hope that this will be done before the Andamanese vanish like the Tasmanians.

For many years there were rumors of a mysterious people in northern Siam who were called "Spirits of the Yellow Leaves" because the only signs of their existence ever seen were rude little shelters of wilted leaves that they left in the jungle. At last in the 1930s the late H. A. Bernatzik of Vienna and his wife made a firm contact with them and spent a little time traveling about with them in the forest. They found this tribe, who call themselves the Yumbri, to be a Mongoloid people of small stature and primitive mentality, living on wild tubers, jungle fruits, caterpillars, snails, lizards and various small animals. The Yumbri had been numerous and had inhabited a large territory, but a high infant mortality, tigers and human enemies had reduced them to a few hundred. Their number continues to diminish. The importance of this interesting tribe is underlined by the fact that leafy huts of other ghostly tribes with a similar culture but perhaps different racial origin have been found in the mountains of Vietnam. The study of all these small remnants might provide clues to the early racial history of southeastern Asia.

A complete list of the obscure tribes of our world would easily fill a whole volume. Large areas of India, Burma and Indochina, some islands of Indonesia, parts of Africa, great tracts in South America—these and other places remain practically unexplored from the anthropological point of view.

Why are we so interested in the cultures and languages of these small, eccentric tribes of a few hundred or a few thousand people? Is it justified to spend a great deal of labor and money to search them out? The president of an important international organization remarked not long ago: "If these languages will disappear anyway, why should we study them?"

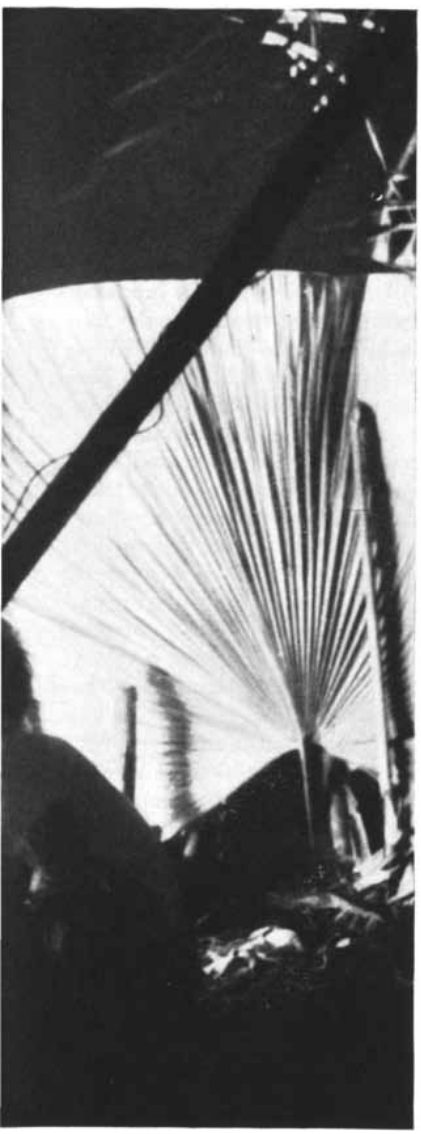
Any anthropologist or linguist can give many important reasons. An almost

"SPIRITS OF THE YELLOW LEAVES" are an extremely primitive people who roam the wooded hills of northern Siam. They received their poetical name because until the 1930s the only trace of them was the withered leaves of the simple shelters they left

dead language spoken by only a few dozen people may occasionally hold the key to the solution of problems of enormous scope. For instance, there is in central India a small tribe, the Nahal, whose language is said to be very unlike the major languages now spoken in India. Could this possibly be a remnant of the languages spoken by the aboriginal inhabitants of India (the "Veddoids") before the invasions by the Aryans and Dravidians from the west and the Mundarians from the east? If so, its importance can hardly be overestimated. Not only would it tell us about the original tongues of the "Veddoids" (whose descendants now number 20 million) but it might well show influences on the Aryan, Dravidian and Mundarian languages. Therefore the language of the small Nahal tribe might help us understand certain aspects of the languages of the hundreds of millions who today inhabit India.

Looking at the situation from another point of view, suppose that the Negrito tribes on the Andaman Islands had died many thousands of years ago and an archaeologist suddenly discovered some of their artifacts. *The Illustrated London News* might publish a sensational article on this new discovery of a surprisingly primitive Stone Age culture, and the diggers would get busy excavating the remains. Why must peoples and cultures be dead and gone in order to stimulate the imagination of the general public? From excavations of the dead past we can get only the bones of a culture, but in the living tribes we have its flesh. To be sure, it would be wrong to assume that any of the present primitive cultures correspond exactly to those of the distant past, but they do give us the only certain guide to what man's economy, society and religion may have been like in prehistoric antiquity.

We have been spending comparatively enormous sums to conquer Mount Everest and other mountain peaks—sums which could finance anthropological expeditions beyond our wildest dreams. Let us reflect that the mountains will still be there hundreds or thousands of years from now, but many of the vanishing cultures will not last another generation. The critical situation in anthropology, all the world over, should call for a supreme effort on the part of scientific workers and for support by those who are able to provide the means for research. Otherwise a vast part of the human heritage will be lost forever.



behind in their wanderings. At that time the anthropologist H. A. Bernatzik and his wife made contact with them. They are a Mongoloid people who call themselves the Yumbri. These photographs of a group and of a mother with her child were made by Bernatzik.

The Shortest Radio Waves

At the border between infrared and radio waves lie electromagnetic ripples measured in millimeters. They are now made in the laboratory, where they are used to study the properties of atoms and molecules

by Walter Gordy

In 1800 the English astronomer Sir William Herschel, holding an ordinary thermometer behind a prism which spread out the sun's light into its spectrum, moved the thermometer into the darkness beyond the red end of the spectrum and to his amazement found that the thermometer registered hotter radiation there than anywhere within the visible span. This act—it is almost too simple to call an experiment—must be regarded, symbolically at least, as one of the most significant ever performed in a laboratory. It opened the door to the great and possibly limitless sea of radiation which lies beyond the reach of the eyes of man. One year later Johann Wilhelm Ritter in Germany discovered invisible radiation on the other side of the rainbow colors—the ultraviolet. Before the close of the century, radio waves had been discovered beyond Herschel's infrared, X-rays beyond Ritter's ultraviolet. Today man has detected and explored the whole vast range of radiation from miles-long radio waves to the billionth-of-an-inch gamma rays [*see chart on page 52*].

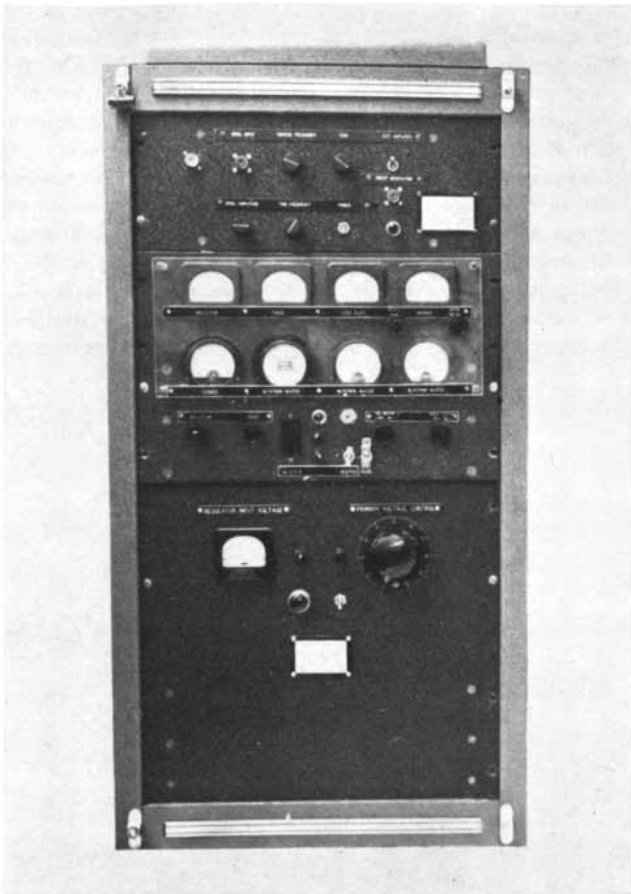
The expansion of man's spectrum of observation has led to an explosive increase in his physical knowledge and to unparalleled changes in his way of life. It has brought forth such inventions as radar, radio, television, medical uses of radiation, machines for chemical analyses, automatic factories and so on. It has in fact become our major instrument for investigating the nature of matter and many other mysteries of the universe.

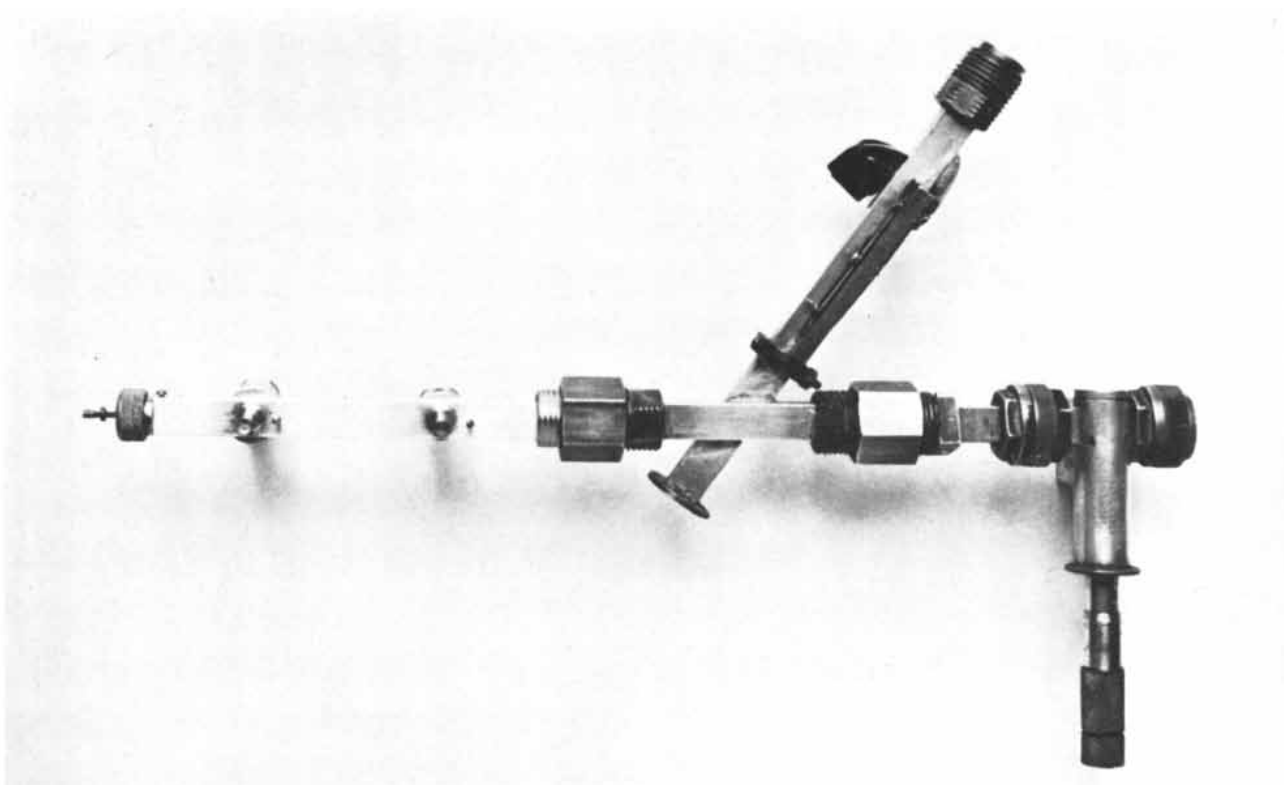
The subject of this article is a new frontier region within the spectrum—namely, the millimeter and submillimeter range of radio microwaves. Centimeter microwaves were exploited for radar during World War II, but the millimeter range is only now beginning to be used extensively. The millimeter wavelength lies at the border between radio and the infrared. It was the last gap in the spectrum to be closed. The closing of the gap was not completed, in a practical sense, until three years ago, when our group at Duke University penetrated the submillimeter region with radio methods and L. Genzel and W. Eckhardt of Germany overlapped from the infrared side with an optical spectrometer.

Radio waves in this range are short enough to "see" molecules, atoms, the nuclei of atoms and electrons, and thus to give information about the shapes, sizes and other properties of submicroscopic particles of matter. The technique is still in too early a stage for commercial use. Scientifically, however, our millimeter-wave "eyes" are beginning to open.

How are such short radio waves generated? There are various possible methods: essentially the one we are using at Duke derives them from centimeter waves by developing harmonics—*i.e.,* multiples of the original frequency. Centimeter waves from a klystron tube are sent through a waveguide where they are picked up by a "cat whisker" assembly (like the crystal detector of the early radio sets). The small silicon crystal in this assembly distorts the pure sine wave of the received frequency into a complex wave containing higher harmonic components as well as the fundamental frequency of the centimeter radiation. The complex wave is rebroadcast by the tungsten whisker into a smaller waveguide—small enough to reject the low-frequency components and transmit only the higher harmonics. The particular harmonic selected as the frequency for studying a sample of matter is picked up by a second cat whisker of appropriate size at the other end of this waveguide. The sample of matter is placed in the path of the radiation, and its absorption of the radio energy at the selected frequency is measured [*see diagram on page 50*].

Since the harmonic frequencies are exact (or very nearly exact) multiples of the generating frequency, they are measurable with the same accuracy as the original centimeter frequency, which can be determined with high precision by reference to the standard radio frequencies broadcast by Station WWV of the National Bureau of Standards. The gratifying result is that this system gives the spectroscopist an instrument of extraordinarily high resolution and high precision. The sharpest lines detectable with an infrared spectroscope are thousands of times broader than those that can be obtained with a microwave spectroscope in the overlapping radio region. This considerable difference in resolution is due to a basic difference between the optical and radio methods. The infrared spectroscopist produces radiation by heating something very hot. What he gets is a jumbled mixture of waves; he spreads out the component frequencies with a grating or prism and selects a small band of frequencies from this spectrum by means of a narrow slit. The narrowness of the band he is able to obtain for spectroscopic use, and therefore the sharpness of his resolution, is limited by the fact that the slit must be wide enough to let through a detectable amount of energy. The radio spectroscopist, on the other hand, obtains his radiation not from the haphazard vibrations of electrons agitated by heat but from the ordered motions of electrons waltzing in unison to the tune of a single





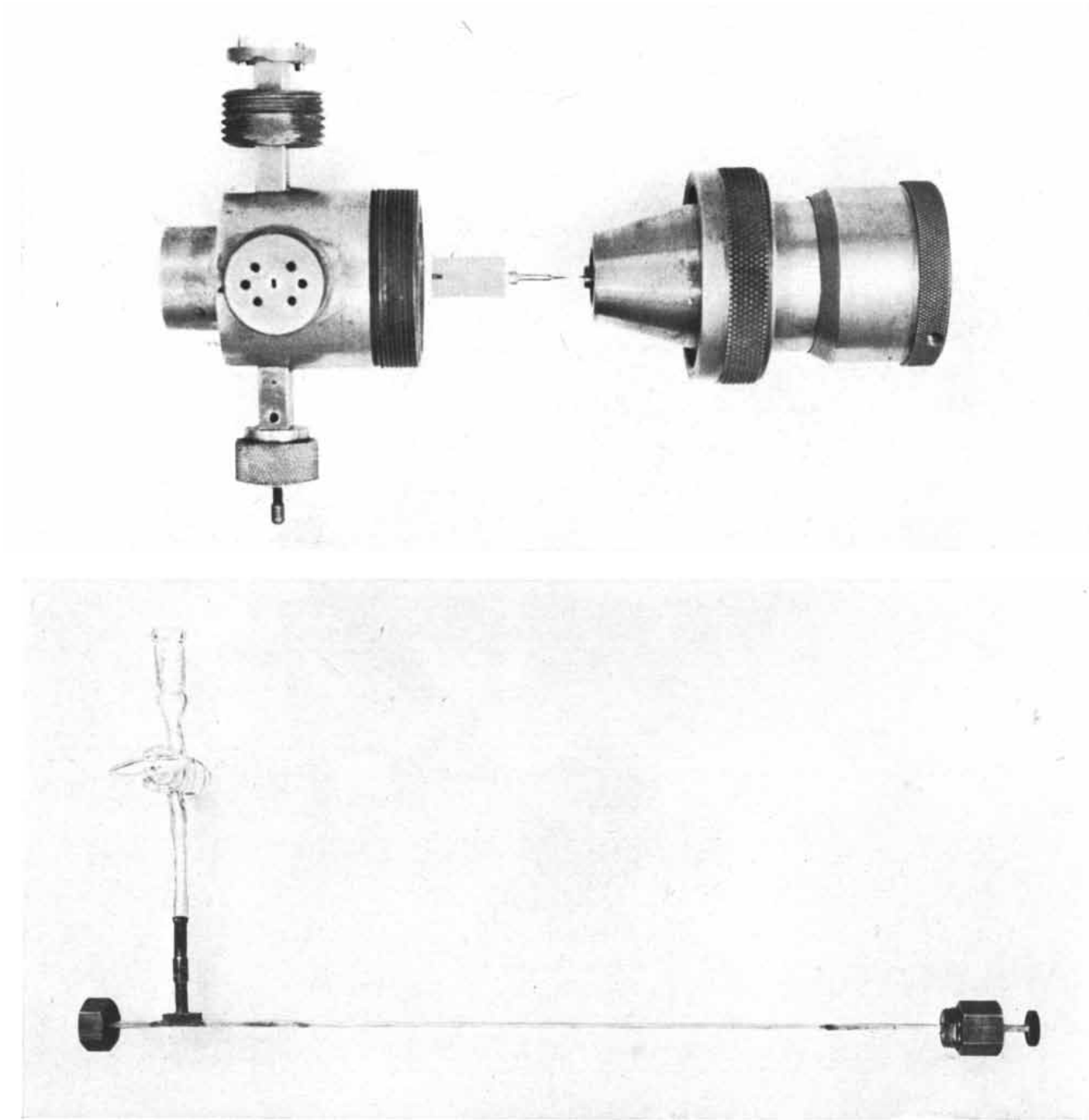
MILLIMETER WAVES ARE GENERATED at Duke University by means of the components shown on this and the next two pages. At upper left is a power supply. At upper right is a klystron tube capable of converting the power into waves measured in centimeters. These waves are fed into the short waveguide which runs diagonally across the picture at the bottom. The horizontal structure is a device to measure the length of waves passing through the waveguide. The objects in the pictures are not in the same scale.

man-controlled circuit. Their radiant energy is concentrated in an extremely narrow band of frequencies. Thus the radio spectroscopist can detect narrow absorption lines and obtain higher resolution.

At Duke we have extended the range of microwaves usable for spectroscopic measurements down to wavelengths as short as .58 of a millimeter. This work has opened a whole new region for precision spectroscopy—a region consisting of about four octaves (from 60,000 megacycles to 510,000 megacycles) where accurate measurement of spectral lines has become possible for the first time.

The spectroscopist's objective is to measure the absorption of radiation by matter at specific frequencies, for this tells him a number of specific things about the properties of the atoms or molecules. A radio spectroscopist tunes his oscillator through the frequency at which the material he is examining is expected to absorb, in the same manner as you tune your radio set through the expected frequency of a broadcasting station. When the oscillator hits the precise frequency at which the substance under study has an absorption peak, a pip appears on his screen.

What sort of information do we get from absorptions in the microwave region? One of the chief items is information on the rotation, or spin, of molecules. In the gaseous state, molecules are constantly rotating. Their spin has a peculiarity which runs counter to com-

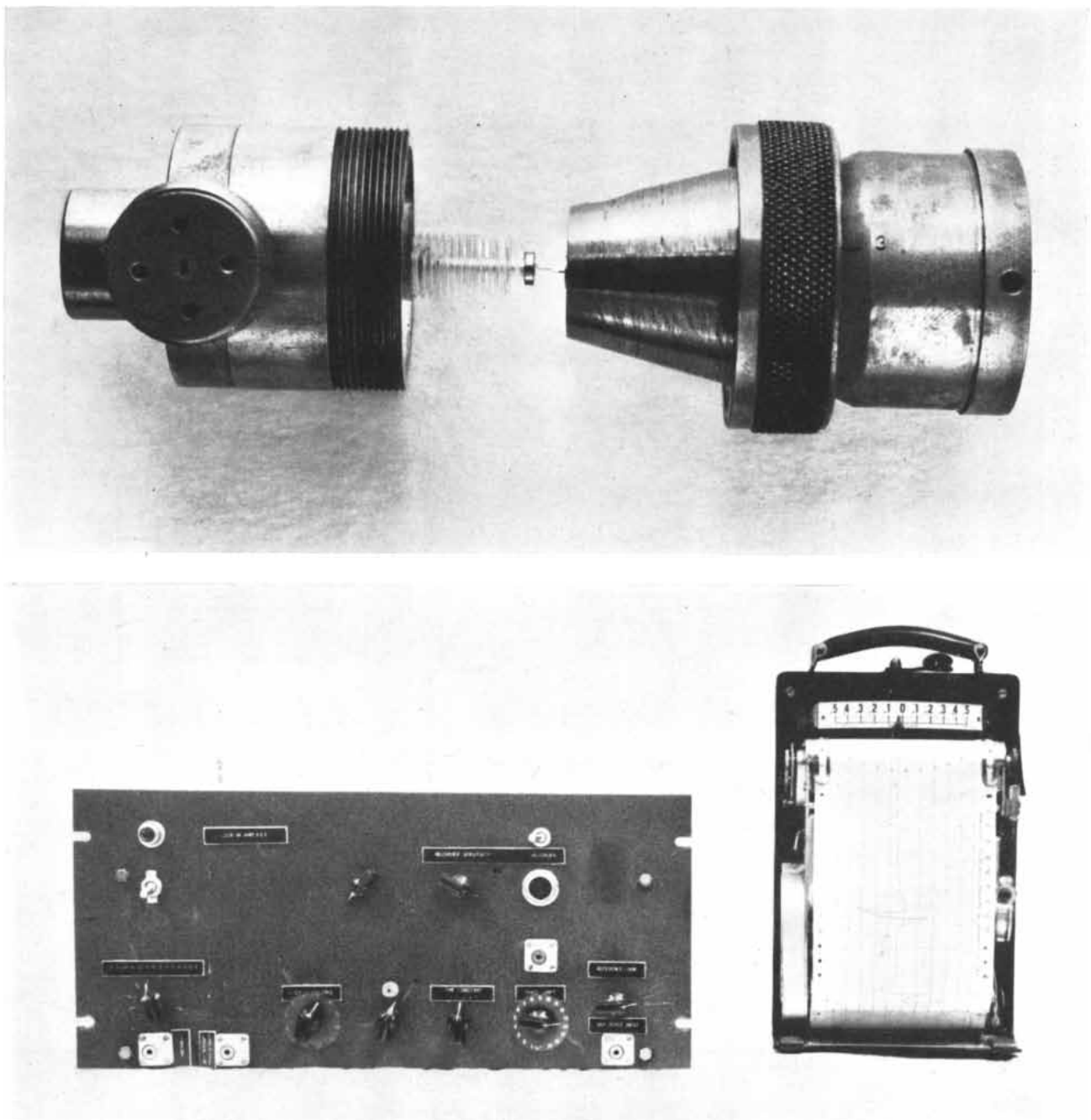


CRYSTAL AND CAT WHISKER at upper left, which are mounted at the end of the waveguide at the bottom of the preceding page, absorb the waves of centimeter length and distort their form. The distorted wave is then fed into the smaller waveguide at

mon sense. A spinning top slows down gradually, but a spinning molecule cannot. Nor can it rotate at just any rate. It is constrained to rotate only at certain discrete rates, according to quantum rules. If it is to slow down, it must drop suddenly to the next lower permitted rate, and in doing so it gives up a specific amount of energy. Likewise it cannot speed up unless it receives a certain amount of energy—the energy needed to raise it to the next higher rotational rate. Microwave radiation will give the molecule this energetic promotion, provided that it is at the precise frequency which supplies the necessary energy. The quantum of energy required is defined by the famous formula $h\nu$—ν being the frequency and h a constant. This remarkable equation is a connecting link between electromagnetic radiation and all energy transformations of molecules, atoms and nuclei.

Thus molecules and atoms, in their strange quantum way, act as radio transmitters and receivers. I have indicated that a spectroscopist uses microwaves to look at molecules and atoms; it is perhaps more accurate to say that he uses radio to communicate with them.

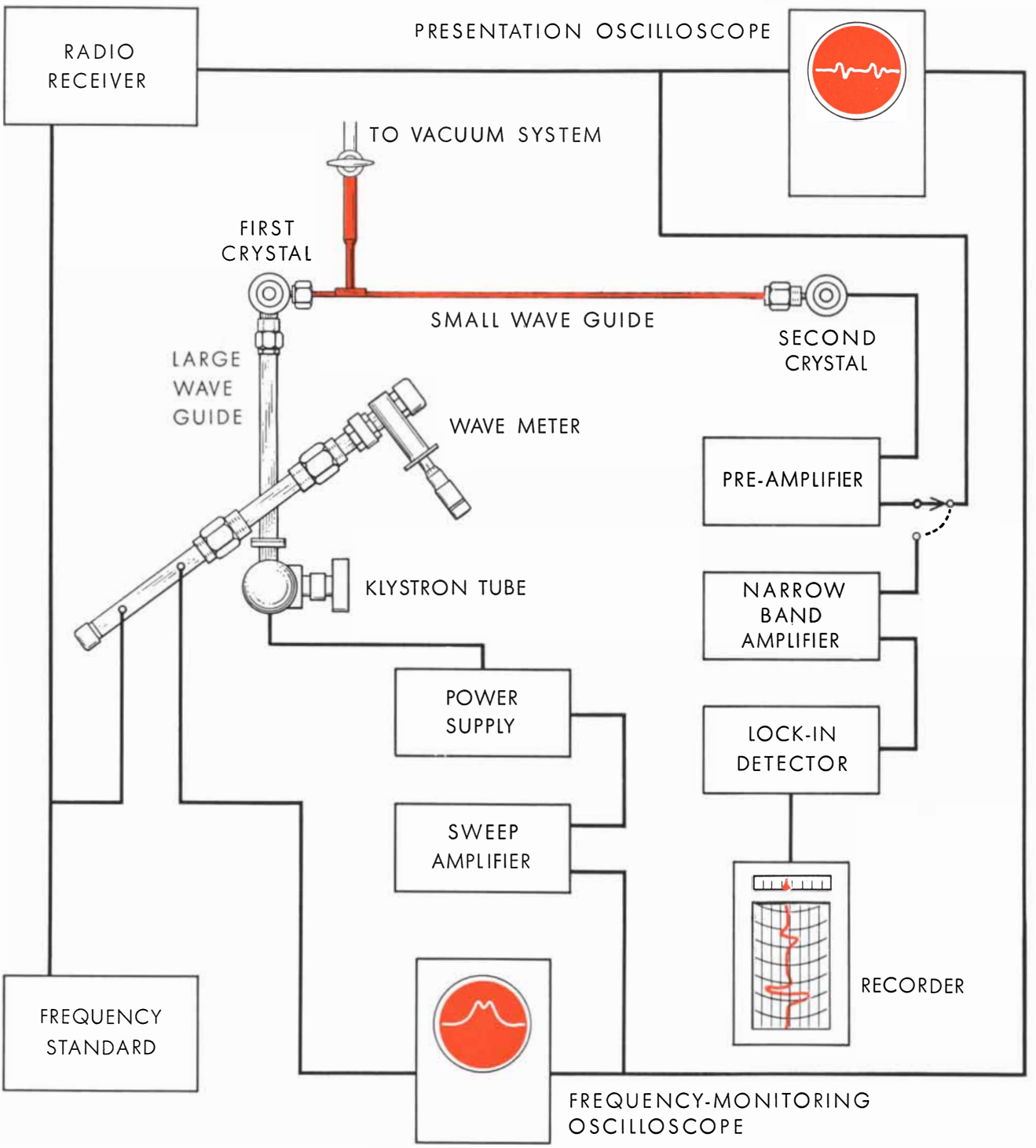
From the rotational absorption spectra of molecules the microwave spectroscopist obtains basic information of several types. From them he can calculate very accurately the distances between the atoms in a molecule and can gain important information about how the molecule is held together by its electrons. From them he can find the rela-



lower left, which passes only its millimeter-wave component. The crystal and cat whisker at upper right, which are mounted at the end of the smaller waveguide, detect the millimeter-wave signal. They are amplified and recorded by the apparatus at lower right.

tive weights of the different isotopes of an atom. From them he can determine whether the nucleus of an atom is spinning about an internal axis, can measure its magnetism and can even learn something about its shape: for example, whether the nucleus's field of charge is spherical like a basketball, elongated like a football or flattened like the hypothetical flying saucer.

For exploration of these properties the best subjects are simple molecules consisting of two or three atoms, and such molecules usually show rotational absorption lines only in the millimeter or submillimeter wave region, because they turn over too fast to absorb the centimeter waves. Many lightweight molecules have already been examined with microwaves shorter than four millimeters. Among them are hydrogen, deuterium and tritium halides (compounds with chlorine, bromine or iodine), carbon monoxide, nitrous oxide, hydrogen cyanide, phosphine (PH_3), arsine (AsH_3) and hydrogen sulfide. The millimeter-wave frequencies of hydrogen cyanide and carbon monoxide have been used in measurements of the velocity of light [see "The Speed of



SCHEMATIC DIAGRAM OF GENERATOR relates all of its components. If the investigator wishes to study the absorption of millimeter waves by a gaseous substance, he evacuates the air from the small waveguide and admits the substance to it (*colored area*).

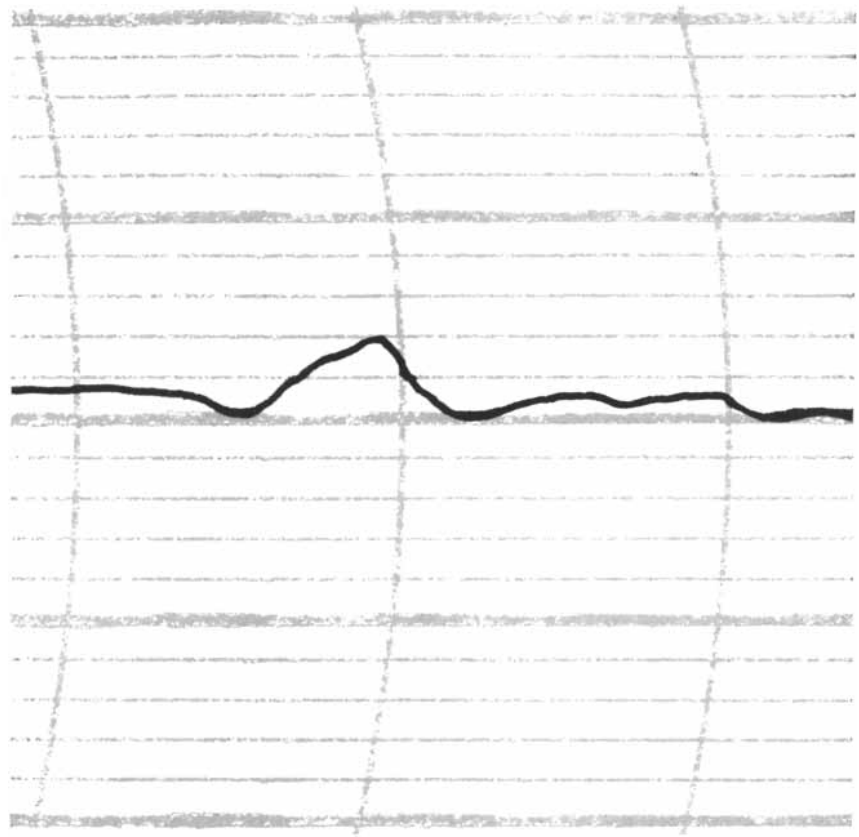
Light," by J. H. Rush; SCIENTIFIC AMERICAN, August, 1955]. The ratio of the millimeter-wave frequencies of deuterium bromide and tritium bromide was used to "weigh" the tritium atom.

Millimeter waves offer a promising means of measuring properties of radioactive isotopes which can be produced only in very small amounts. They can show absorption spectra in samples of material amounting to less than a millionth of an ounce. Three radioactive isotopes of iodine have already been studied, and other likely candidates are isotopes of chlorine, bromine, phosphorus, arsenic, antimony and selenium.

Industrial chemists sometimes ask me when microwave spectroscopy will become a practicable tool of analysis in industry. I think this will come when the technique in the millimeter region can be reduced to a routine procedure. In the centimeter region analysis is almost impractical because of the sparseness of spectral lines; at millimeter and submillimeter wavelengths the lines are far stronger and more plentiful.

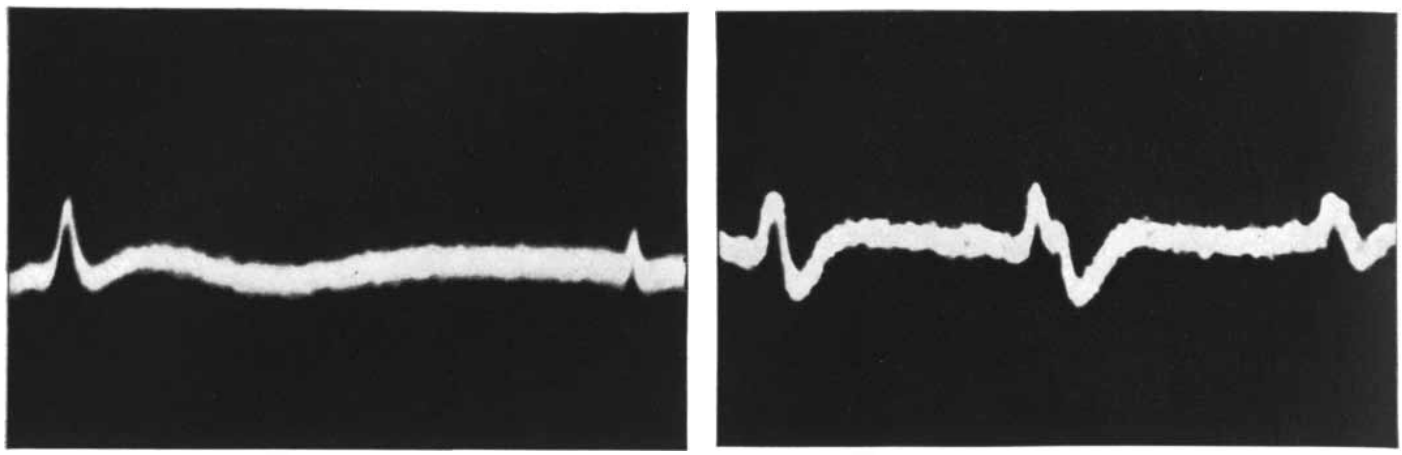
Chemistry is only one of many fields in which these short waves will be useful. Much of the radio astronomy of the future may be in the millimeter region. Already the 50-foot parabolic reflector of the Naval Research Laboratory is being used to look at the sun with eight-millimeter waves. To demonstrate that even shorter waves can penetrate the earth's atmosphere, a group of us at Duke recently picked up three-millimeter waves from the sun at Durham, N. C., a notoriously humid location. Our antenna was a discarded searchlight reflector, and we used a highly selective superheterodyne receiver with a harmonic multiplier.

What can be learned in astronomy with millimeter waves that has not already been learned with the longer radio waves or the optical telescope? I am glad I do not know the many answers to this question, for research would not be fun without its surprises. (Physicists still work partly for fun.) I have the hopeful opinion that new information will be gained about the earth's upper atmosphere, about the sun and possibly even about the outer spaces. One of the enticing possibilities is a more intensive study of sunspots. At the three-millimeter wavelength it would be practicable to make an antenna large enough to focus on a single sunspot: a 100-foot reflector would do it, whereas it would take one many times that size to focus centimeter waves on a sunspot. Obvi-



SPECTRAL LINE OF CARBONYL SULFIDE, represented by the pip on this curve, is the shortest wavelength measured by radio methods. The wavelength is .58 of a millimeter.

SPECTRAL LINE OF CYANOGEN BROMIDE, represented by a valley, has a wavelength of .87 of a millimeter. The frequency of this line is 345,837 million cycles per second.



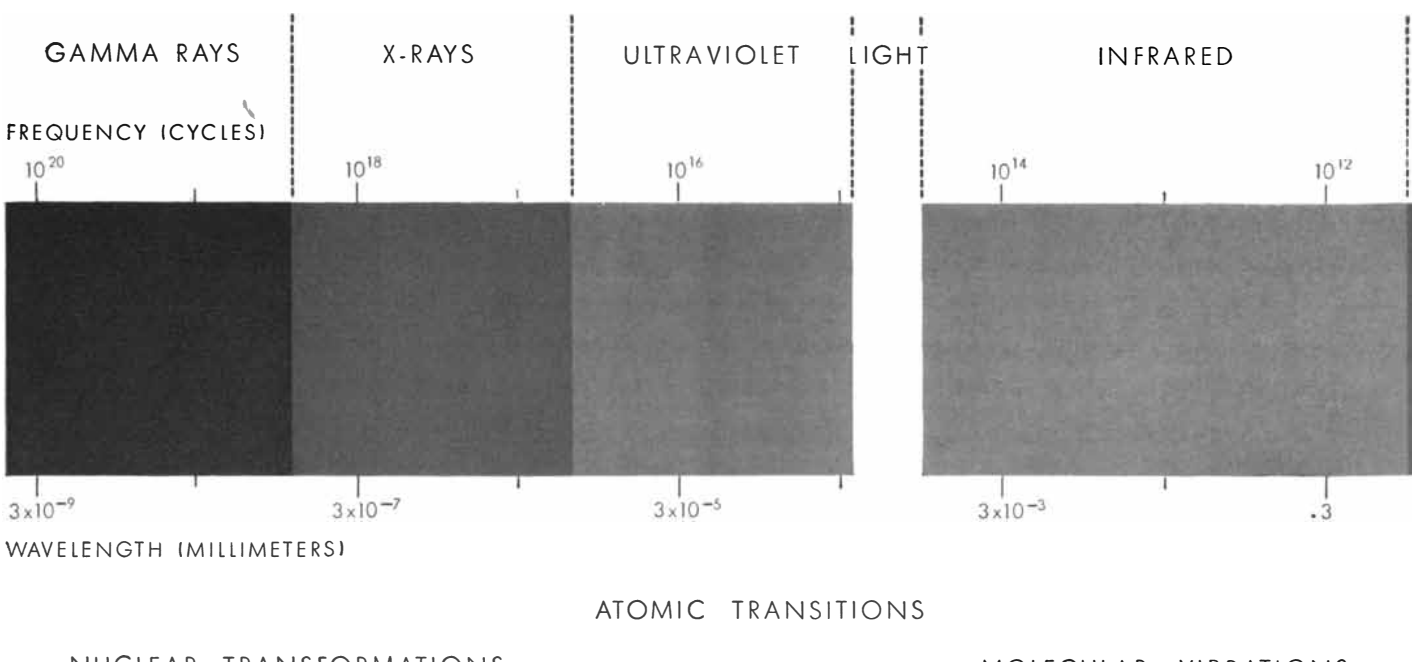
SPLIT SPECTRAL LINES of hydrogen iodide (*left*) and deuterium chloride (*right*) are shown by these photographs of oscilloscope traces. The wavelength of the hydrogen iodide line is .78 of a millimeter; of the deuterium chloride line, .93 of a millimeter.

ously the millimeter waves begin to have some of the advantages of light while retaining the advantages of radio waves.

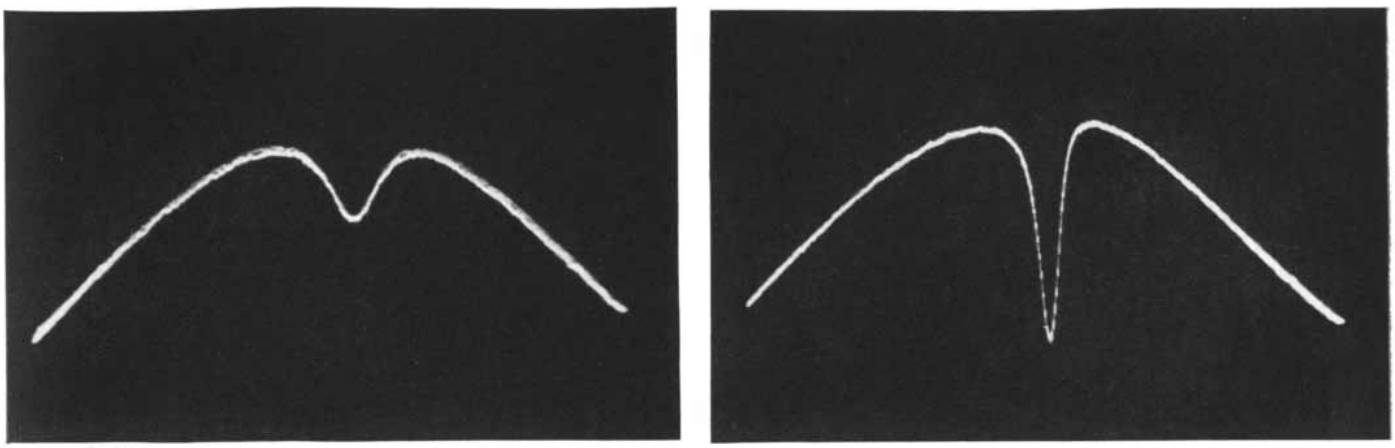
The shortest radio waves may throw some light on the mystery of superconductivity. In certain metals at a temperature near absolute zero you can start a current flowing, disconnect the battery, walk away and come back three months later to find the current still flowing. This puzzle attracts us all—whether through holy curiosity or a submerged desire to get something for nothing. Newton would seem to have lifted part of the veil from this mystery almost 300 years ago when he announced that an object doesn't really have to be pushed along to keep moving—provided nothing gets in the way. But how can trillions of electrons move around in a piece of metal without ever suffering from collisions with the trillions of atoms? The late Fritz London of Duke made the boldest and possibly the best guess about the way such a phenomenal traffic problem may be solved in the superconducting metal. After describing his guess we shall see how the shortest radio waves may provide a test of it.

As is well known, or generally believed, the electrons in an atom or a molecule can move indefinitely in their orbits without dissipating energy. Electrons in the benzene ring, for example, travel around and around the ring with no evident traffic jams. London suggested that quantum conditions might account for the "perpetual motion" of electrons in a superconducting metal as they do for unimpeded travel in atomic orbits. Superconducting electrons might somehow form a well-defined quantum state of substantially lower than normal energy and thus avoid collisions.

Could appropriate energy quanta lift these electrons from the superconducting state to the normal state? Radio waves at frequencies up to 36,000 megacycles fail to do this, for superconductivity persists in tin for currents gener-



ELECTROMAGNETIC SPECTRUM is arrayed to show the location of millimeter radio waves with respect to radiation of other wavelengths. The shorter electromagnetic waves (and higher frequencies) are to the left; the longer waves (and lower frequencies)

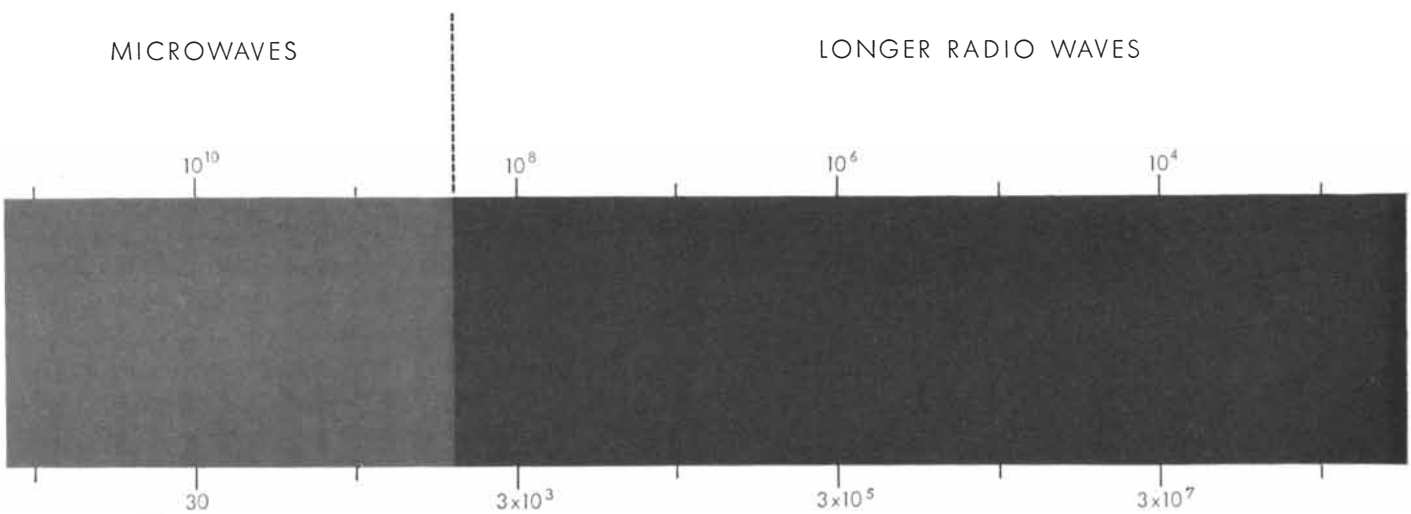


SUPERCONDUCTIVITY OF TIN was explored with currents of 150,000 million cycles (two-millimeter waves). The dip in the trace at left is the response curve of a non-superconducting cavity of tin; the dip at right, of the cavity when it is superconducting.

ated with this frequency. But suppose we used frequencies 10 times higher, which would multiply the energy quantum tenfold? We are investigating this question at Duke. So far we have gone only to 150,000 megacycles, sending alternating currents with this frequency through tin waveguides and resonant cavities at low temperatures. The preliminary evidence indicates that there is indeed a quantum gap between the superconducting and normal states of electrons, and that the gap may become larger as the temperature is lowered below the critical temperature for direct-current superconductivity.

Undoubtedly, many solid-state phenomena besides superconductivity will be studied with the shortest radio waves.

The method I have described for generating and detecting millimeter waves is but one of several, though it is the only one yet used for scientific measurements. In 1923 E. F. Nichols and James D. Tear produced millimeter radio waves with a spark-gap generator. The Columbia University Radiation Laboratory has developed magnetrons which operate in the three-millimeter wave region and has detected harmonics at wavelengths as low as 1.1 millimeters. Stephen J. Smith and Edward M. Purcell of Harvard University have crossed the gap between radio and light by passing 300,000-volt electrons near the slits of an optical grating and generating visible light. A group at Stanford University is reported to have generated infrared rays by directing million-volt electrons through a bumpy magnetic field. It remains to be seen whether these methods will prove feasible for spectroscopy or for gadgets such as radar. Whenever a practical method is developed for generating high-power radio waves in the region between one-half millimeter and five millimeters—a source which is tunable and produces highly monochromatic waves—it will be of great value to science and to industry.



are to the right. The wavelength is given in millimeters; the frequency, in cycles per second. The millimeter waves are at the left end of the microwave region. The phenomena that are associated with the various wavelengths are roughly indicated at the bottom.

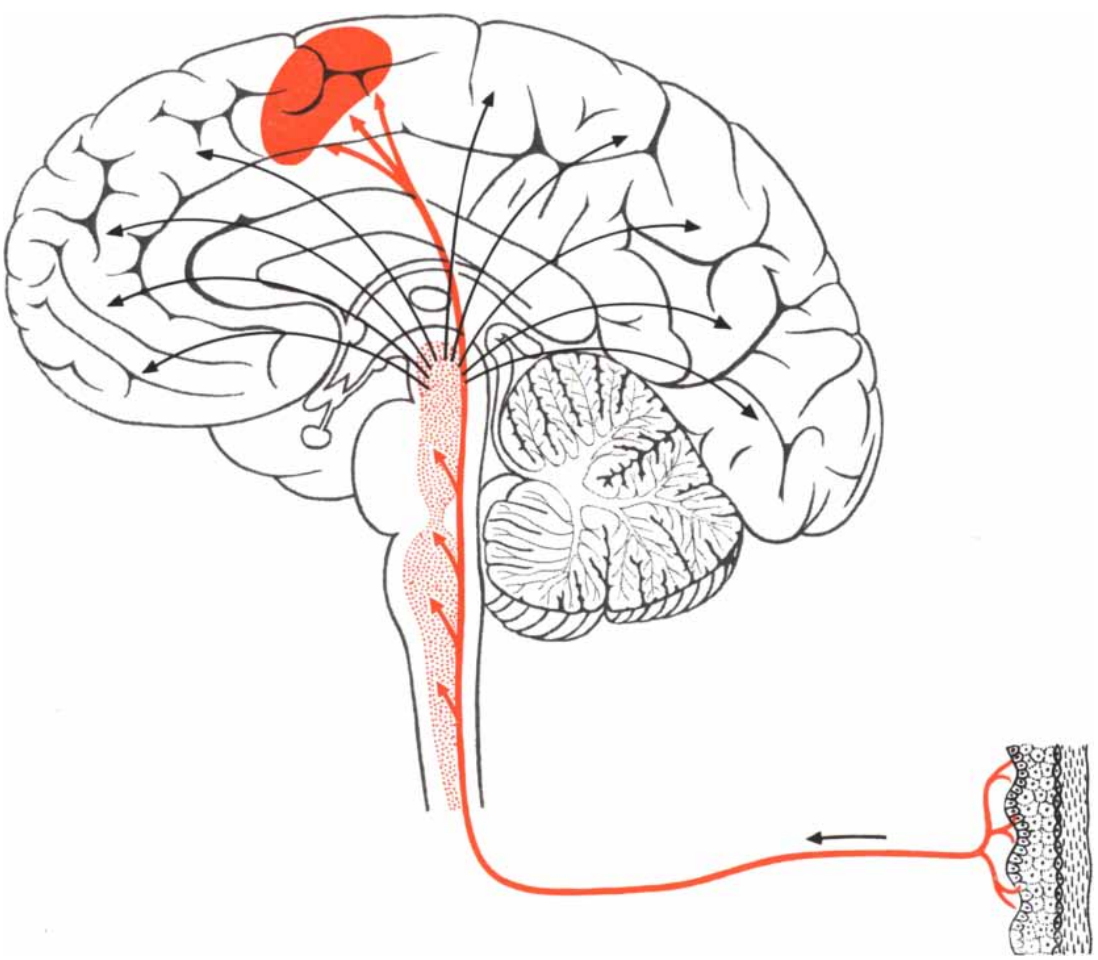
THE RETICULAR FORMATION

This recently discovered network of cells in the brain has many vital functions, notably arousing and maintaining consciousness and choosing between important and unimportant sensory messages

by J. D. French

The title "reticular formation" might suggest various things—a football line-up, a chess gambit, a geological structure or whatnot—but as readers of SCIENTIFIC AMERICAN well know, it is actually a part of the brain, a once mysterious part which has recently come in for a great deal of attention from biologists. The reticular formation is a tiny nerve network in the central part of the brain stem. Investigators have discovered that this bit of nerve tissue, no bigger than your little finger, is a far more important structure than anyone had dreamed. It underlies our awareness of the world and our ability to think, to learn and to act. Without it, an individual is reduced to a helpless, senseless, paralyzed blob of protoplasm.

The actual seat of the power to think,



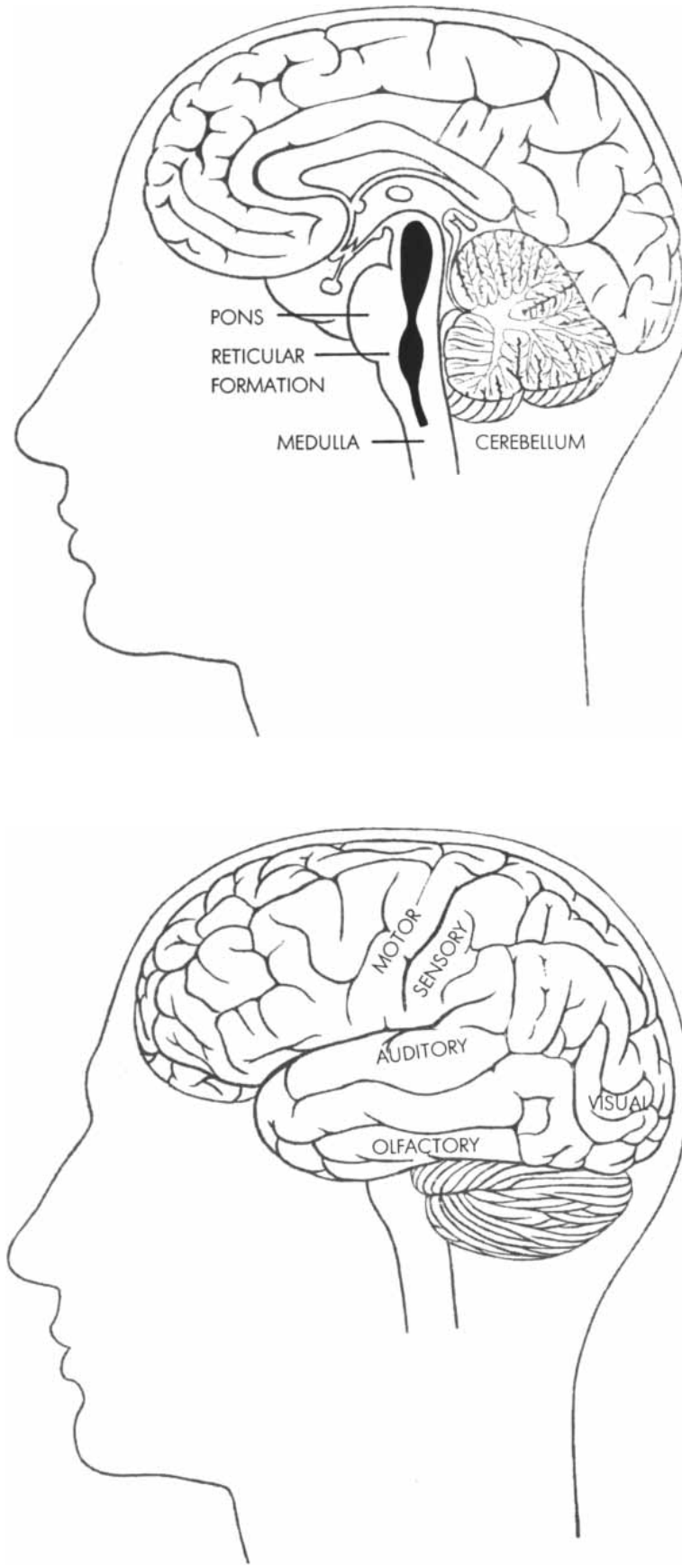
THE RETICULAR FORMATION is the area stippled with red in this cross section of the brain. A sense organ (*lower right*) is connected to a sensory area in the brain (*upper left*) by a pathway extending up the spinal cord. This pathway branches into the reticular formation. When a stimulus travels along the pathway, the reticular formation may "awaken" the entire brain (*black arrows*).

to perceive, indeed to respond to a stimulus with anything more than a reflex reaction, lies in the cortex of the brain. But the cortex cannot perceive or think unless it is "awake." Consider the alarm ring that awakens you in the morning: several seconds pass before you recognize the disturbance and can respond to stop the painful jangle. A sensory signal arriving at the cortex while it is asleep goes unrecognized. Experiments on anesthetized individuals have shown further that stimulation of the cortex alone is not sufficient to awaken the brain. Something else must arouse the cortex: that something is the reticular formation.

It was only about eight years ago that two eminent physiologists, H. W. Magoun of the U. S. and Giuseppe Moruzzi of Italy, working together at Northwestern University, discovered this fact. They were exploring the mystery of the reticular formation's functions by means of an electrode planted in this area in the brain of a cat. They found that stimulation of the area with a small electric current would awaken a drowsing cat as peacefully as a scratch on the head. The animal's behavior, and recordings of changes in its brain waves with the electroencephalograph, showed all the signs of a normal arousal from sleep. Magoun and Moruzzi decided that the reticular formation acted as a kind of sentinel which aroused the cortex, and they named it the RAS (reticular activating system).

Now mysteries began to clear—not only with regard to the function of the reticular formation but also as to some previously puzzling features of the nervous system's anatomy. All the great sensory nerve trunks in the body have brush-like branches which stream into the reticular formation. Sensory signals from all parts of the body go to the cortex by direct pathways, but on the way through the brain stem they also feed into the reticular formation. Evidently the reticular formation, when so stimulated, sends arousing signals to the cortex. The awakened cortex can then interpret the sensory signals it is receiving directly.

The RAS is a kind of general alarm: that is to say, it responds in the same way to any sensory stimulus, whether from the organs of hearing, seeing, touch or whatever. Its response is simply to arouse the brain, not to relay any specific message. Its signals spray the entire cortex rather than any one center of sensation. A noise, a flash of light, a pinch on the hand, the smell of burning wood, a



RELATIONSHIP OF THE RETICULAR FORMATION (*black area*) to various parts of the brain is indicated at the top. The functional areas of the brain are outlined at bottom.

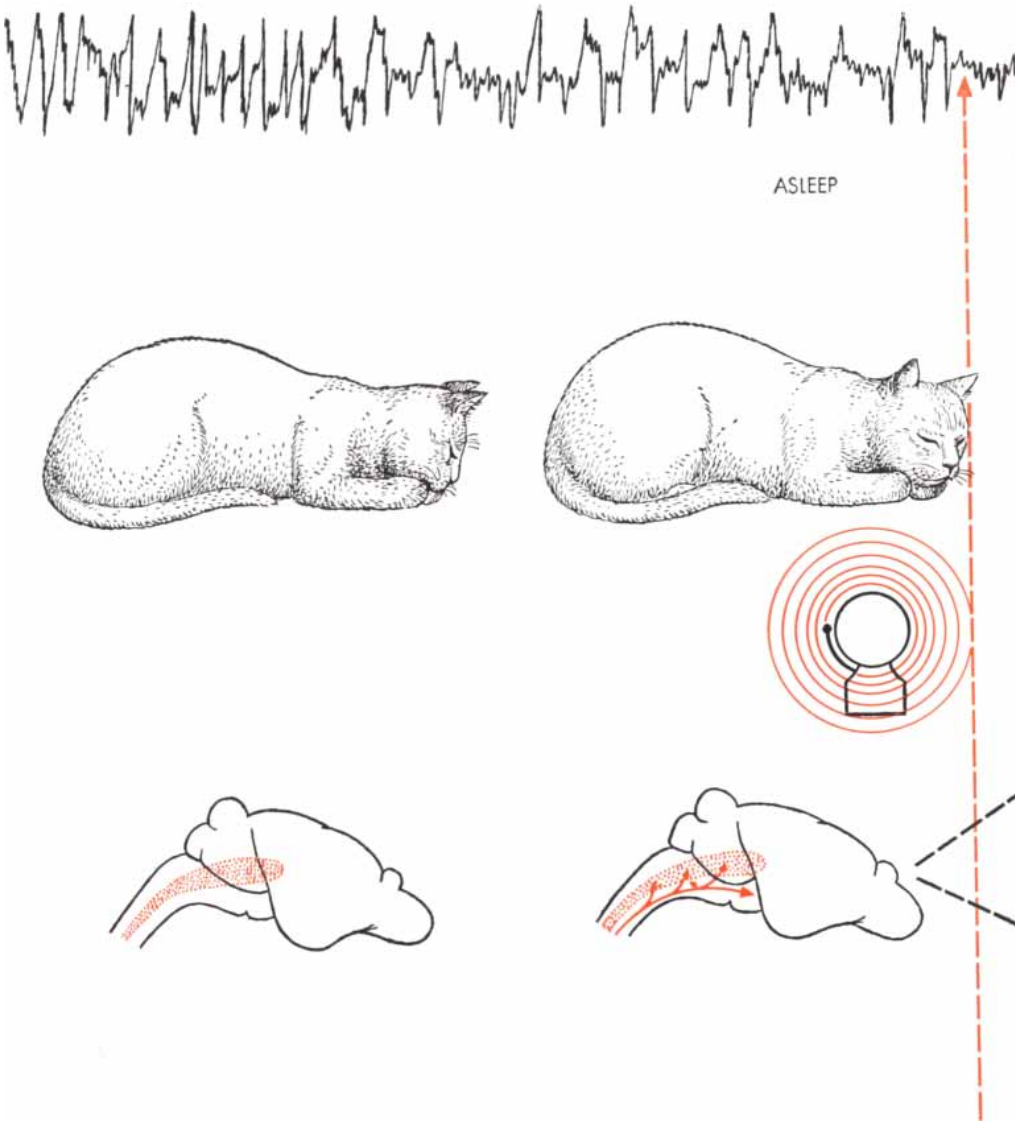
pain in the stomach—any of these excites the reticular formation to alert the cortex to a state of wakefulness, so that when the specific stimulus arrives at the appropriate center in the cortex, the brain can identify it.

Apparently the RAS learns to be selective in its sensitivity to particular stimuli. A mother may be instantly awakened by the faintest whimper of her baby. Father, on the other hand, may sleep through baby's fiercest bellowings but be aroused by a faint smell of smoke. A city dweller may sleep peacefully in the midst of the riotous din of traffic while his visitor from the country spends a sleepless night wishing he were elsewhere. It is as if the RAS becomes endowed by experience with the ability to discriminate among stimuli, disregarding those it has found unimportant and responding to those that are helpful. Happily so. Imagine how unbearable life would be if you could not shut out most of the environment from consciousness and were at the mercy of the thousands of sights and sounds simultaneously clamoring for attention.

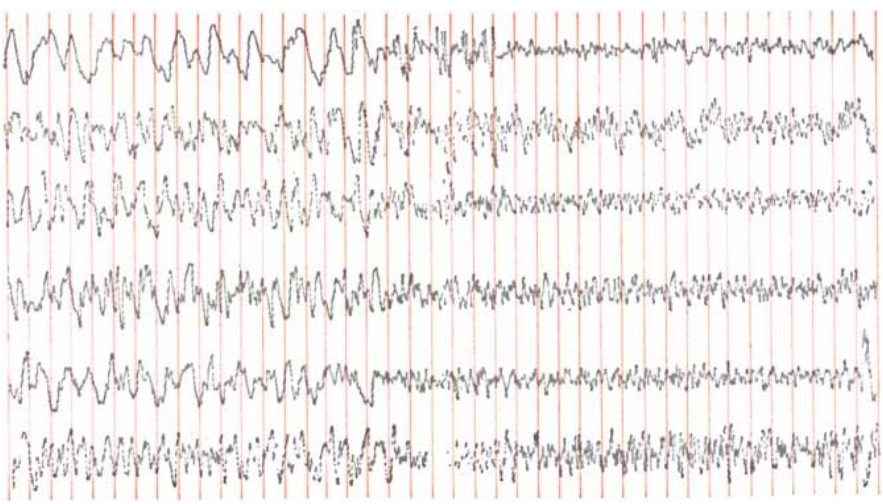
The RAS, like the starter in an automobile, starts the brain engine running, but this is by no means the end of its job. It goes on functioning to keep the individual in a conscious state. ("Consciousness" is a controversial word among psychologists, but for our purposes its meaning is clear enough.) If the RAS cannot function normally, consciousness is impossible. A person whose reticular formation has been permanently injured or destroyed falls into a coma from which he can never recover. He may live on for a year or more, but he remains as helpless and shut off from communication as a vegetable.

If uninjured, the RAS can maintain a wakeful state (but not consciousness) even in the absence of the cortex. In a newborn baby the cortex has not yet begun to function, but the infant nevertheless has short periods of wakefulness throughout the day. The same is true of the tragic creatures born without any cortex at all (called anencephalic monsters). Such a child (sometimes kept alive for three or four years) never achieves any understanding or real contact with its surroundings, but it has periods of wakefulness during which it swallows and digests food, smiles and coos when fondled and cries when treated roughly. We must conclude, therefore, that wakefulness of a very crude sort is possible without the cortex, so long as the RAS can function.

For sustained wakefulness, however,

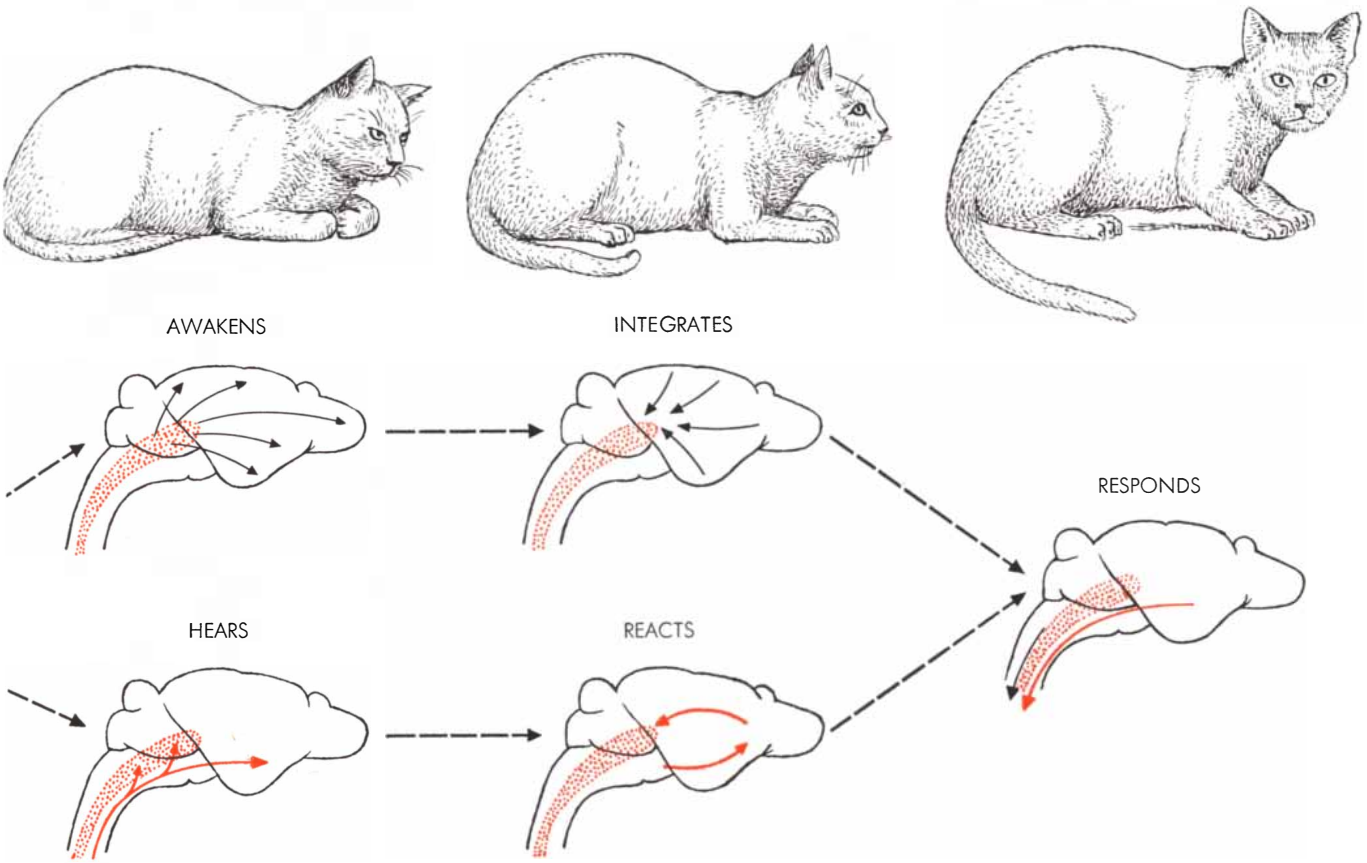


CAT IS AWAKENED by the sound of a bell. The sound stimuli (*incoming red arrows*) reach the reticular activating system, or RAS, and the auditory area of the brain. The RAS acts (*black arrows*) to awaken the cortex so that it can "hear" signals arriving in the auditory

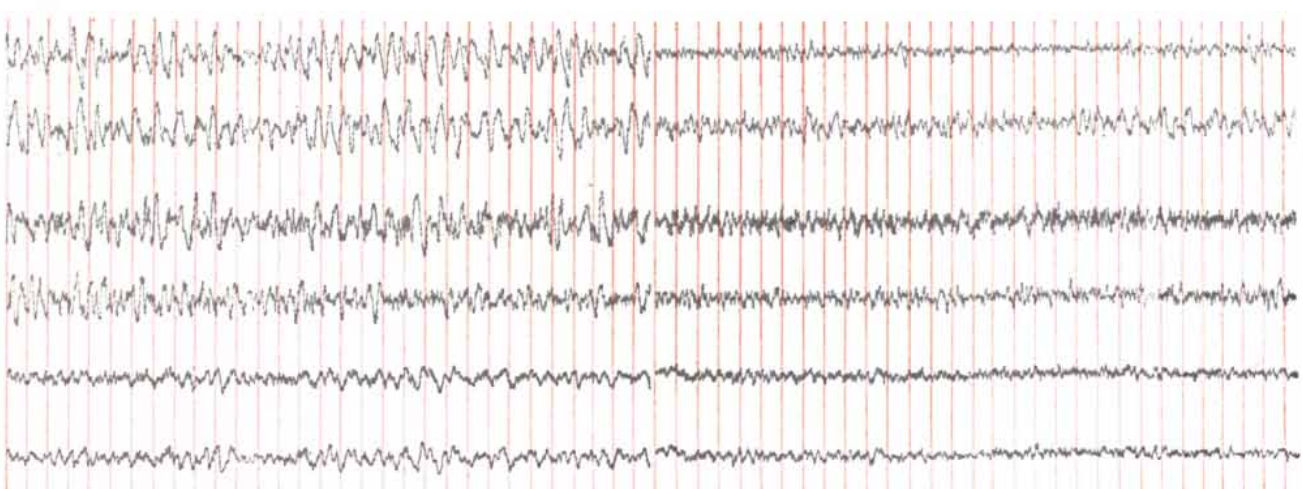


CORTEX IS STIMULATED by passing an electric current to the brain surface of a sleeping monkey. Six recording electrodes show the RAS has been activated to awaken the brain.

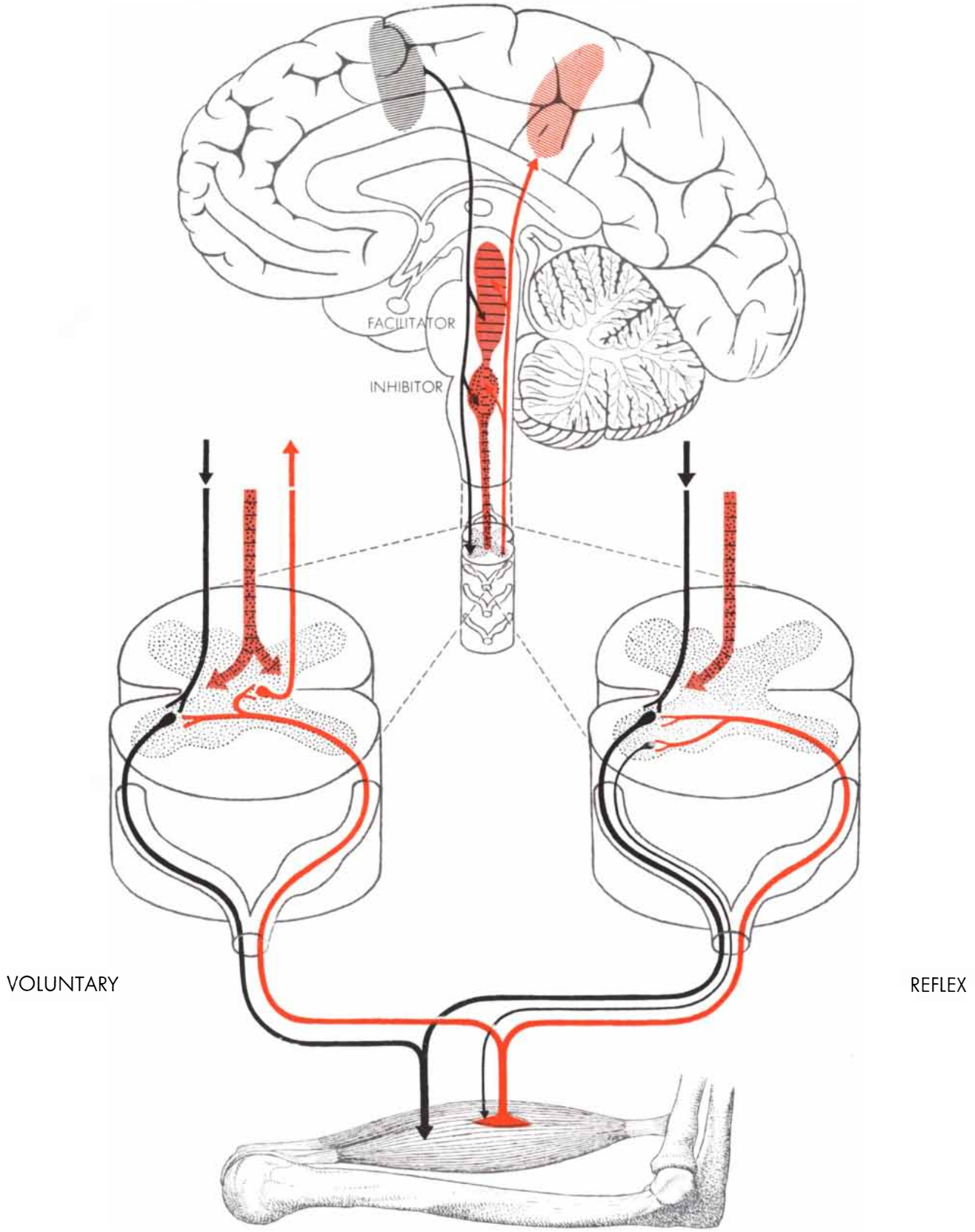
AWAKE



area. The brain waves at the top change from a pattern of sleep to one of wakefulness. The RAS then integrates the brain's activity so that the brain can react as a whole. The cat finally responds with a motor impulse (*outgoing red arrow*) that is regulated by the RAS. The cat then jumps to its feet and runs away. The entire process takes place in a matter of a few seconds.



RAS IS STIMULATED by passing an electric current into the brain stem of a sleeping monkey. Recording electrodes show a more abrupt transition from sleep to wakefulness. The waves become sharp, short and more frequent. This is a typical waking pattern.



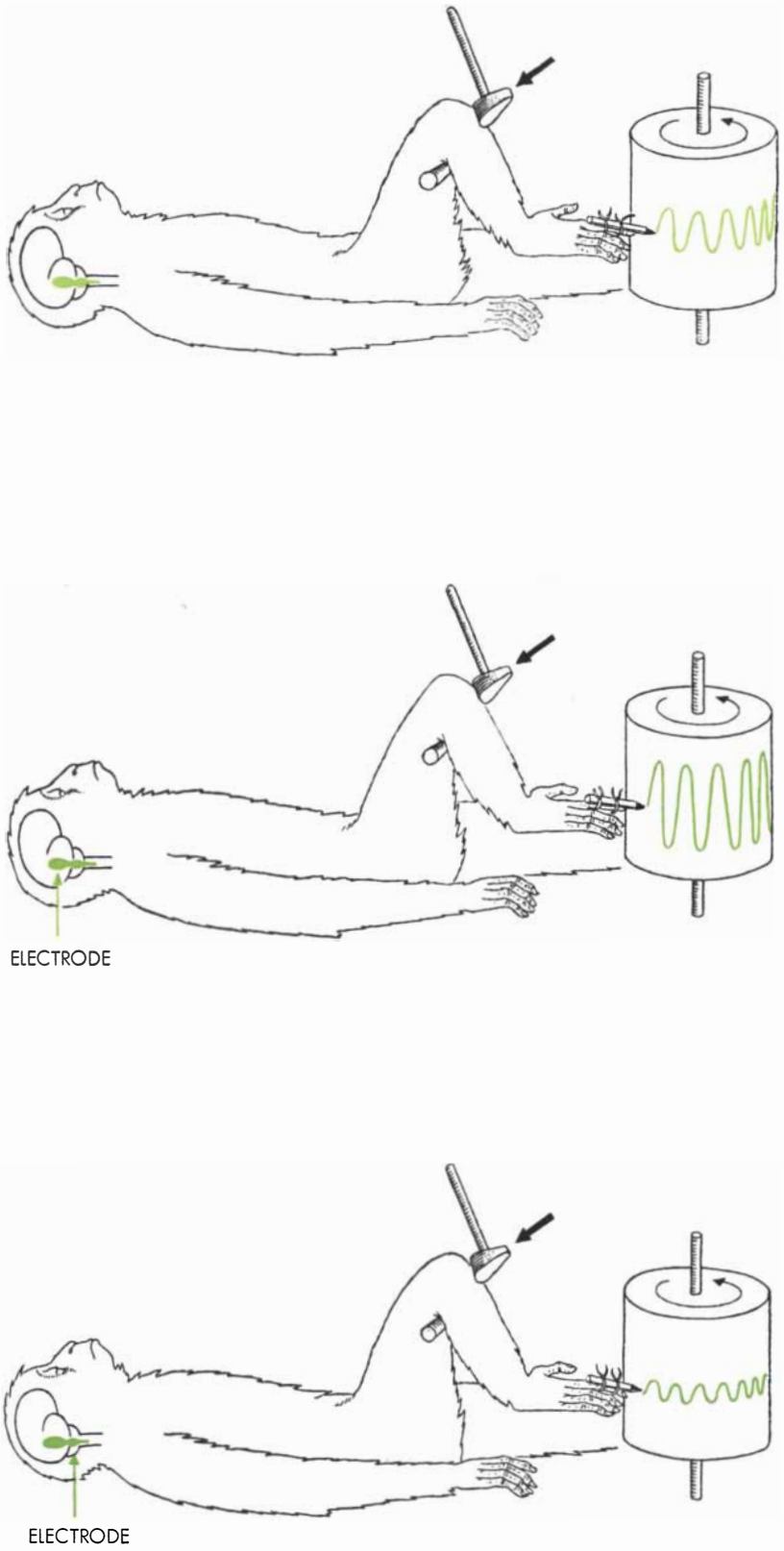
MOVEMENTS ARE MODIFIED by the RAS. In voluntary movement sensory nerves (*red*) conduct impulses from the muscle spindle (*bottom*) to a sensory area in the brain (*red hatching*). Motor nerves (*black*) conduct impulses from the motor area (*black hatching*) to the muscle. Both nerve systems branch into the RAS. The RAS sends down impulses (*heavy red arrows*) that facilitate or inhibit the response. In reflex movement sensory impulses are passed on immediately to motor nerves in the spinal cord. One nerve activates the muscle and maintains its "tone." The other (*thin black line*) sensitizes the spindle. The RAS controls both.

the cortex certainly is essential. The alert state seems to depend upon an interplay between the cortex and the RAS. The reticular formation is stimulated not only by the sensory nerves but also by impulses from some parts of the cortex. This has been demonstrated by electrical stimulation of certain areas of the cortex in monkeys: such stimulation will awaken a sleeping monkey. When the experiment is tried on a monkey that is awake, it evokes a dramatic response. The monkey instantly stops whatever it is doing and looks about intently and slightly puzzled, as if to say: "What was that?" It does not seem distressed or agitated—only warily alert. So it would seem that in the waking state the RAS plays a part, in combination with the cortex, in focusing attention and probably in many other mental processes.

All this raises the possibility that the RAS may be importantly involved in mental disorders. Investigations of this possibility have already begun by means of experiments with drugs. It is natural to start with anesthetic and sleep-inducing drugs, to see how they affect the RAS. The results of these experiments are illuminating but not surprising. They show that the drug blocks the flow of nerve impulses in the reticular formation but has little effect on the flow along the direct pathways from sense organs to the cortex. As the anesthesia wears off, the flow in the RAS returns to normal. A stimulating drug, on the other hand, has the opposite effect: it enhances the conduction of impulses in the RAS. It will be interesting to extend these experiments to the new tranquilizing drugs and the substances that produce experimental psychoses. Already there is evidence that these drugs do affect the functioning of the RAS.

Still another domain is under the control of this amazingly cogent bit of tissue in the brain. The RAS apparently has a hand in regulating all the motor activities of the body. It can modify muscle movements of both the voluntary type (controlled by the brain) and the reflex type (controlled in the spinal cord).

Just as the brain cortex has specific centers of sensation, it also has specific motor centers which generate muscle contractions. If one stimulates a motor center with an electric current, the appropriate muscles will respond, but the resulting body movements are jerky and uncontrolled. These powerful movements are normally controlled and polished by other motor centers of the



CONTROL OF REFLEX MOTOR REACTIONS by the reticular formation was demonstrated by this experiment on an anesthetized monkey. When the monkey's knee is tapped regularly, its knee jerks record a series of regular curves on a rotating drum (*top*). When the upper part of the monkey's reticular formation is stimulated, the jerks are larger (*middle*). When the lower part of the formation is stimulated, the jerks are smaller (*bottom*).

cortex, acting through the reticular formation. If the RAS is not stimulated or does not function properly, the movements will be jerky.

More surprising is the fact that the RAS can also act on the reflexes, centered in the spinal cord. The reflex apparatus has two functions. First, it generates automatic muscle movements. When signals from a sudden and alarming sensory stimulus (*e.g.*, touching something hot) arrive at the spinal cord, they are passed on immediately to an adjacent motor nerve and travel right back to the affected part of the body to jerk it away. In general, the automatic, reflex activities are protective—responses to danger or sudden challenges in the surroundings. But some of them can be tricked into action by suddenly stretching a muscle: for example, a tap on the knee elicits the well-known knee jerk.

The second function of the reflex system is to keep the muscles ready for action by maintaining "tone"—that is, a state of partial contraction. Just as a violin string must be stretched to a certain tension before it can emit music, so a muscle must be maintained at a certain tension to respond efficiently to a stimulus. The mechanism that regulates its resting tension, or "tone," is a small structure within the muscle called a "spindle." When a muscle contracts, it squeezes the spindle; when it relaxes, the pressure on the spindle loosens. Either departure from normal tone causes the spindle to send signals by way of a sensory nerve to the spinal cord; there they excite a motor nerve to correct the contraction or relaxation of the muscle. This feedback system automatically keeps each muscle at precisely the right tone. And the appropriate tone itself is adjusted to suit the needs of the moment by nerve impulses which regulate the sensitivity of the spindle.

Now experiments have clearly demonstrated that the RAS exerts some control over voluntary and reflex motor reactions. Let us take for illustration an experiment on the reflex knee jerk, which is easy and convenient to perform. A monkey is anesthetized and a pen is tied to its toe to record the size of its knee kicks on a rotating drum. We keep tapping its knee and we get a uniform response, recorded as a nice series of regular curves on the drum. Then we suddenly stimulate the reticular formation electrically. The knee jerks immediately become larger: the RAS has enhanced them. When we stop stimulating it, the kicks return to normal size. Now in the course of exploratory experiments along the reticular formation a new fact emerges. If we stimulate the formation at a point toward its lower end in the brain stem, the kicks are not enhanced but instead are inhibited!

Following up this finding, we discover that these centers can enhance or inhibit sensory as well as motor impulses. In short, the RAS acts as a kind of traffic control center, facilitating or inhibiting the flow of signals in the nervous system.

The astonishing generality of the RAS gives us a new outlook on the nervous system. Neurologists have tended to think of the nervous system as a collection of more or less separate circuits, each doing a particular job. It now appears that the system is much more closely integrated than had been thought. This should hardly surprise us. A simple organism such as the amoeba reacts with totality toward stimuli: the whole cell is occupied in the act of finding, engulfing and digesting food. Man, even with his 10 billion nerve cells, is not radically different. He must focus his sensory and motor systems on the problem in hand, and for this he obviously must be equipped with some integrating machine.

The RAS seems to be such a machine. It awakens the brain to consciousness and keeps it alert; it directs the traffic of messages in the nervous system; it monitors the myriads of stimuli that beat upon our senses, accepting what we need to perceive and rejecting what is irrelevant; it tempers and refines our muscular activity and bodily movements. We can go even further and say that it contributes in an important way to the highest mental processes—the focusing of attention, introspection and doubtless all forms of reasoning.

EXTENSIVE BRANCHING OF CELLS in the reticular formation is depicted by this photomicrograph of a section of the reticular formation in the brain of a dog. The dark areas in the photomicrograph are cells of the formation which have been stained with silver. The section was lent by Drs. M. and A. Scheibel of the Medical School of the University of California at Los Angeles.

Kodak reports to laboratories on:

modifying the spectral distribution of radiant energy . . . trooping the colors in competition . . . freezing patterns written at hundreds of miles per second

Filters: plea and offer

Once every few years a queer sense of obligation compels us to spend our hard-earned money on advertising to acquaint the next cadre of technical people with the existence of *Kodak Wratten Filters*. Of these precisely dyed little sheets of gelatin we offer at present 116 different species, and though in truth they make little direct contribution to our prosperity, they do seem to contribute to the convenience of those who desire to modify the spectral distribution of radiant energy by simple and reasonably reproducible means.

The data book "Kodak Wratten Filters," which describes them all in the fullest, most quantitative spectrophotometric and colorimetric detail, has recently appeared in its 19th edition. Kodak dealers sell it for 75¢. The one niggardly favor we would ask in return for our magnanimity in selling the filters is that before an order is placed, this edition, and not one of its 18 predecessors, be consulted for current specifications and designations.

As for the newer-fangled and much costlier multi-layer interference filters, we make them but so also do several of our distinguished optical-manufacturing contemporaries. We shall not feel at all badly about your giving them your custom if you need transmission in the range up to 1.4μ. But if you find it necessary to specify a wavelength between 1.4μ and 4.5μ as a narrow transmission band or *any* wavelength above 1.4μ as a cut-off for a blocking filter—there we think you need us.

In that event, just state your problem to Eastman Kodak Company, Military and Special Products Sales Division, Rochester 4, N. Y.

The dye game

Under "people's capitalism," a social system with a brilliant future still in prospect, analytical chemistry often becomes a competitive weapon. We not only run a stand on the sidelines of the fray where we sell reagents and other *Eastman Organic Chemicals* useful in playing the game, but under a different hat we also play ourselves. It's a happy, invigorating game with many, many winners.

As player, one of our most interesting recent moves has been the launching of nine new dyes for polyester fabrics. They are as much definite chemical entities as 2-(p-dimethylaminostyryl)-1-ethylpyridinium iodide is a definite chemical entity. Such *Chemical Abstracts* nomenclature is quite proper in patents and in the Eastman Organic Chemicals catalog, but under the rules by which gentlemen play, on dye-trade label, invoice, and promotional leaflet, names like *Eastman Polyester Yellow 5R* and *Eastman Polyester Navy G* designate the compounds evolved from our long experience in making dyes for synthetic fibers.

In the new group are dyes which excel most predecessors in the fastness they exhibit on polyester fibers despite various combinations of light, laundering, dry cleaning, and other paling influences. Some are new prototype structures from which new lines of descent may stem. Some are not so different from dyes previously successful on other hydrophobic fabrics. Some cost less to make (or develop) than others and are so priced.

Deciding which to use, how, in combination with which others—is another game. (When invited, we coach from dye service laboratories at Lodi, N. J., and Kingsport, Tenn.) Meanwhile, each band of analytical chemists silently reconnoiters the field, so intent they even forget at times who awards the points. It's that lady over there, clutching her purse.

Eastman Polyester Dyes *are sold by Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company); exegetically labeled* Eastman Organic Chemicals, *by Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Oscillographic opinion

Call us ingenuous (if not ingenious). Still it's easy to be amazed that it has become humdrum routine for patterns to be written at hundreds of miles per second and then frozen nigh forever for the minutest examination and debate. (Even the seemingly agile stream of electrons in your TV picture tube plods its monotonous course at scarcely 3½ miles to the second.)

The credit is not all ours. The manufacturers of oscillographs have contributed nobly to the feat. One of them recently was kind enough to offer us the rostrum of his company publication to vent our latest opinions about film for high speed oscillography.

Our opinions are that

1) It is going to be extremely difficult to improve on the speed and image quality you get from simply developing *Kodak Tri-X Film* in *Kodak Developer D-19* at 68 F for 10 minutes. (True the new *Kodak Royal-X Pan Film* enjoys a fourfold speed advantage over *Kodak Tri-X Film* for picture taking, but a force-developed line-image that's just over the threshold between being there and not being there is an entirely different proposition from picture taking.)

2) Development for 12 minutes in *Kodak Developer SD-19a* gives higher contrast. Under some circumstances this is as good as a gain in speed. But you pay in granularity.

3) Under some conditions, an overall postexposure of 1/500 meter-candle for one second helps the oscillographic speed a little.

4) P-16 phosphors seem in many cases to be more satisfactory photographically than P-11 phosphors.

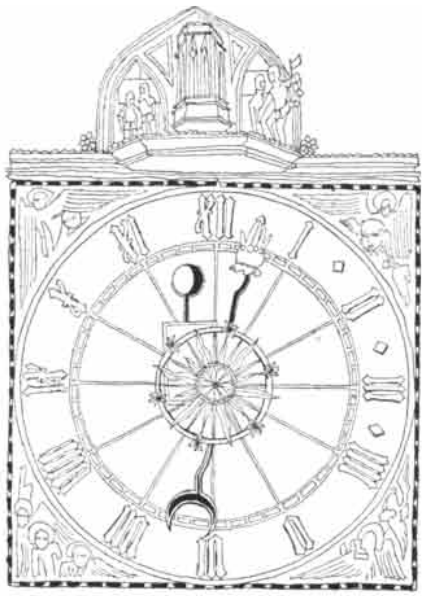
The most convenient way to get further details is to persuade Mr. L. Arthur Hoyt, Allen B. DuMont Laboratories, Inc., 760 Bloomfield Avenue, Clifton, N. J., that your technical sophistication entitles you to a place on the mailing list for "DuMont Instrument Journal," beginning with the May, 1957, issue.

Price quoted is 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
TRADEMARK

SCIENCE AND



Hotter Than the Sun

A device which produces a steady temperature of 26,000 degrees Fahrenheit has been developed by physicists at the University of Chicago and the General Electric Company. This is the highest man-made temperature ever to be maintained for more than a small fraction of a second. It is some 14,000 degrees hotter than the surface of the sun. The fierce heat is manufactured in an electric arc of special design and is delivered in the form of a fast jet of highly ionized gas or "plasma."

To achieve the very high temperatures the large current of an electric arc is compressed into a narrow pencil by means of a surrounding whirlpool of water, a method originally developed in Germany several years ago. The current contains carbon atoms evaporated from the positive electrode and water evaporated from the inner surface of the vortex. This mixture moves to the negative electrode at nearly the speed of sound, and passes through a hole in the electrode into an evacuated chamber.

The use of the plasma jet so far has been to test refractory materials for supersonic airplanes and missiles.

Award for Bohr

Niels Bohr has been named the first winner of the $75,000 Atoms for Peace Award, for his contributions to the peaceful uses of atomic energy. The 71-year-old physicist, director of the Institute for Theoretical Physics at Copenhagen, constructed the first modern model of the atom.

The new prize was established by the Ford Motor Company Fund in memory of Henry and Edsel Ford. It is administered by a board of trustees whose chairman is James R. Killian, Jr., president of the Massachusetts Institute of Technology. In announcing the award to Bohr, Killian said: "By his example he has inspired scientists everywhere to seek out science as an instrument for human welfare."

Growing Pains

The oncoming atomic age seemed last month to have developed a slight limp. *Nucleonics* reported that "far from beginning to approach competitive levels, nuclear power costs are headed in the opposite direction." Hearings of the Joint Congressional Committee on Atomic Energy disclosed that capital costs for the first full-scale power reactor at Shippingport, Pa., are up to $55 million from the original estimate of $37.5 million. Its power will cost 75 mills per kilowatt hour instead of the expected 52. Consolidated Edison Company's projected nuclear power plant on the Hudson River is now expected to cost $70 million instead of $55 million, and a reactor which a Nebraska group planned to build for $24.3 million is now in the range of $40 to $50 million.

At the Los Alamos Scientific Laboratory a critical lump of naked uranium known as Godiva blew up in the course of an experiment, the Atomic Energy Commission reported. A sheet of polyethylene was placed too near the core and reflected a large number of outgoing neutrons back into the chain-reacting uranium.

The Commission also announced that a research reactor at North Carolina State College, the first such facility to be installed on a college campus, sprang a leak in June, 1955, and has been out of operation ever since.

Basic Research Institute

With an anonymous gift of $2,750,000 the University of California has set up an Institute for Basic Science Research along the lines of the Institute for Advanced Study in Princeton. In the words of the nameless philanthropist, its chief purpose is "to discover and encourage the work of individuals of

THE CITIZEN

great talent and promise." The Institute has now announced the first appointments to research professorships, for periods ranging from six months to two years. The appointees, all from the University of California, are Daniel C. Mazia, professor of zoology; Jerzy Neyman, director of the Statistical Laboratory, and Stephen P. Diliberto, assistant professor of mathematics. Mazia plans to work on the life history of the cell. Neyman will do further statistical research on the distribution of galaxies and the expansion of the universe. Diliberto will study the stability of the moon's orbit and the astronomical three-body problem.

So far the Institute has put out $170,000 in grants, salaries and other administrative costs. Five more appointments will become effective July 1.

Unfinished Business

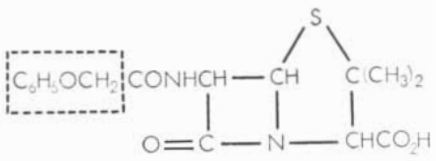
The National Research Council reports that in June its Chemical-Biological Coordination Center in Washington, D.C., will be forced to shut down because of shrinking support by Government and private agencies.

Now in its eleventh year of operation, the Center had organized to collect the entire literature on the biological effects of some 63,000 chemicals and reduce it to a coded form for rapid sorting and correlation by IBM machines. More than 1.5 million entries had been made. The project promised to be a unique research instrument for discovering chemical-biological relationships which might otherwise remain unknown. Although the Center has been prevented from reaching its ultimate objective, it will leave behind a tested and practical method for handling vast stores of scientific information.

Penicillin Synthesis

John C. Sheehan and K. R. Henery-Logan of the Massachusetts Institute of Technology last month reported the first practical method for synthesizing penicillin. They have made the natural penicillin V [*see diagram on next page*] and 10 forms not produced by the *Penicillium* molds.

The penicillin molecule is not very complex, but it is extremely fragile. The



Formula of synthetic "natural" penicillin

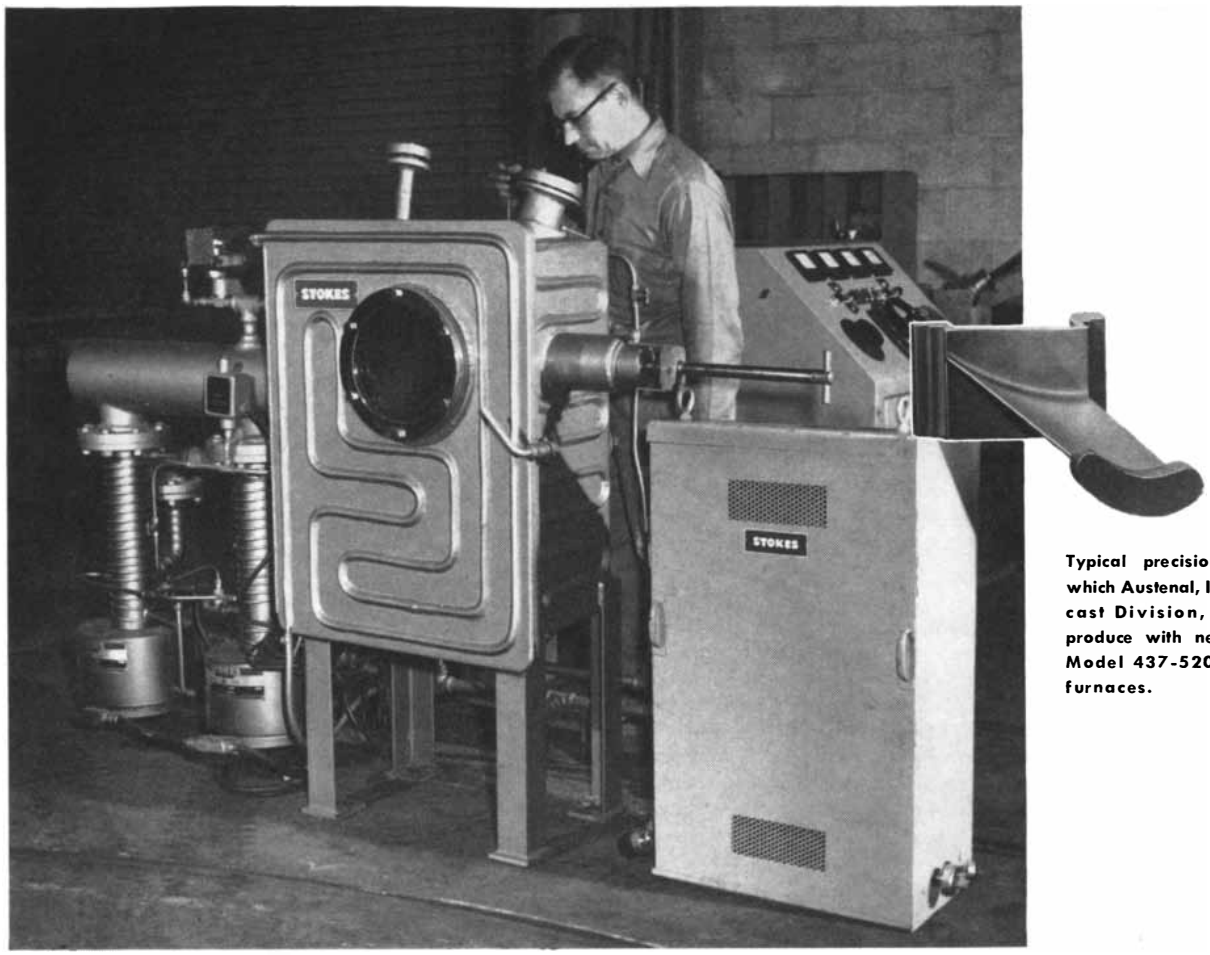
principal problem was to devise methods of building the molecule without breaking it down as rapidly as it was put together. Except for the final step of closing the ring in the molecule. Sheehan had to discard all the methods of synthesis worked out in previous attempts at the problem and develop entirely new methods. He starts with about half a dozen common compounds and gives them the gentlest kind of treatment with specially devised reagents and techniques. The reactions are largely carried out in neutral *p*H, and the last five steps are done at or below room temperature. Sheehan thinks his technique may be applicable to other molecules with similar properties.

New types of penicillin are being synthesized by this method at the laboratories of Merck & Company. Modifications in the last half of the process permit changes in the side-chain of the molecule. A step toward a good oral penicillin was made with the synthesis of a variety more stable in acid than any of the natural penicillins. New forms are also being designed to give fewer allergic reactions and to be more effective against penicillin-resistant organisms.

Rockets for Research

To satisfy their growing curiosity about the upper atmosphere, scientists need to probe it more often and in more places. Rocket designers are struggling not only to achieve greater altitudes but also to build less expensive vehicles. Progress toward these ends was summarized in a recent issue of *Jet Propulsion*, the journal of the American Rocket Society.

At present the highest flying rockets are liquid-fueled. They are costly and tricky to operate. The big Viking rockets, which have reached altitudes of more than 150 miles, cost $300,000 to $400,000 each. The Aerobee, a smaller rocket, costs about a tenth as much. An improved model known as the Aerobee-Hi recently carried a 145-pound payload of instruments to a height of 164 miles. Vikings and Aerobees can be fired only from elaborately equipped bases and by trained crews. An Aerobee firing base set up for the International Geophysical Year cost "many millions of



Typical precision casting which Austenal, Inc., Microcast Division, plans to produce with new Stokes Model 437-520 vacuum furnaces.

A significant forward step for Vacuum Metallurgy

New Stokes precision casting furnaces pave the way for important advancements in the science of putting metals to work.

The potentials of vacuum casting of familiar metals and special alloys can now be explored—on a research or production basis—with these new Stokes, low-cost "package" units.

Capable of melting and pouring single casts of up to 30 pounds, under vacuums as low as 1 micron or less—these furnaces incorporate operating features specifically requested by precision casters. Units are now in operation with charging and mold locks for semi-continuous production. Popular tandem arrangement is operated by one man.

If you are planning to investigate the challenging potential of modern vacuum metallurgy—plan, too, to take advantage of the undisputed leadership in equipment and experience which Stokes can apply to your problem. Prime supplier of vacuum furnaces for diversified uses—induction and arc melting, heat-treating and sintering—Stokes is in a position to help you select the most suitable unit for your work, and to engineer modifications to meet special requirements.

Others are profiting by Stokes advanced vacuum technology. Isn't it time for you to invite a discussion of your own profit-making opportunities?

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STOKES

dollars," according to Homer E. Newell, Jr., of the Naval Research Laboratory. He says that rockets driven by a solid fuel would be substantially less costly and easier to launch. The Aerobee is now being adapted to use a solid propellant.

Solid-fuel rockets, such as the Deacon and a new version, the Cajun, now go no higher than about 10 miles. But they can be launched in the stratosphere from a balloon (the combination is known as Rockoon) and will then lift a 50-pound payload to about 60 miles. The Cajun is being used as the second half of a two-stage rocket together with the anti-aircraft missile Nike. This combination has achieved an altitude of more than 100 miles.

In a novel scheme now being tested, small rockets are launched from a high-flying jet airplane which noses straight up to aim and release the vehicle. A small rocket carrying a Geiger counter has been shot to about 35 miles.

Automation

The word "automation," a journalistic coinage, has undeservedly become "a source of fear," according to the Earl of Halsbury, an English authority on industrial technology. In the British journal *Impact* he attempts to correct the impression created by journalists that automatic processes in industry "will cause widespread unemployment."

Lord Halsbury divides these processes into four types: control engineering, communication engineering, transfer processing and automatic assembly. Control engineering, he says, is in wide use only in the chemical industry, which employs relatively few workers who "are more likely to be assisted than displaced" by automation. In communication engineering the automation advances are largely in the realm of computing machines, and Halsbury points out that accountants, the most likely victims of "computerization," are in short supply.

Transfer processing, the linking together of several manufacturing steps formerly done separately, is used mainly in the manufacture of parts for automobiles, refrigerators and similar products. Automatic assembly of parts, employed chiefly in the electronics field, is not new in this industry, Halsbury points out: "Electric lamp bulbs and radio valves have been automatically assembled for a generation at least."

The introduction of any sort of automation requires a large investment, and must be a slow and gradual process. The changes require factories to be re-

DOW CORNING

SILICONE NEWS

Silicones Ease the "Profit Squeeze"

- Silicone lubricant for plastic parts smooths refrigerator sales
- Simplify production of oven thermometer with Silicone paint
- Silicone adhesive tape doubles for weld, doubles production, too

HELPING HAND FOR HARRIED PROFITS—Oft-heard complaint from businessmen today is that profits are slimming despite a diet of heavy sales. Rising production costs and product improvements frequently mean added expense that can't be passed along. But . . . by utilizing the varied forms of Dow Corning Silicones, many alert manufacturers are marketing better products with no increase in cost.

"SLIDER" PITCH — Now, Kelvinator refrigerator designers have licked the problem of sticking shelves, without throwing costs out of line, by lubricating plastic parts with silicones. The big new "Foodarama" boasts

smooth-sliding shelves and free-opening compartment doors that will keep the buyer pleased for years. Yet the silicone lubricants cost next to nothing. Dow Corning 200 fluid, for example, puts the slip on crisper covers at a cost of only six hundredths of a cent!

Unlike many oils, this silicone fluid is an excellent lubricant for plastic or rubber parts in contact with metal . . . an essential factor here. And silicones don't thicken when temperatures head for the deep freeze: another essential. In all, Kelvinator has added a pleasing new sales feature at practically no extra expense. No. 49

IT GETS THE BENDS, but not the breaks. That's the story of the silicone finish on this kitchen oven thermometer. The Taylor Instrument

Companies coat sheet stock with silicone-based paint before the metal is sheared, stamped and bent into the shape you see. Through all the punishment of the forming operations, the flexible silicone finish never chips or cracks.

Production-wise, pre-painting saves all kinds of costs . . . it's more expensive and difficult to paint finished units. Product-wise, Taylor finds there's no need to worry about discoloration at oven temperatures. The paint made with Dow Corning silicone resins by Stanley Chemical Company is recommended for up to 500 F . . . others will take as much as 1000 F! Taylor gets a permanently attractive paint and a lower-cost production method . . . both due to Dow Corning Silicones. No. 50

SKIRTS TAPED ON — No Dior creations, the metal skirts that cover gas burners on hot water heaters. Generally, they are welded on. But White Products Corp. found that hand welding each skirt to the heater base caused a production bottle-neck with too much overtime resulting. Then they discovered a pressure sensitive tape coated with a Dow Corning silicone adhesive . . . a tape that completely eliminates welding!

The tape, made by Mystik Adhesive Products, is simply wrapped around the 48-inch joint where skirt meets heater base. It holds the two together with a grip like iron. Strong, waterproof, and exceptionally heat-resistant, the taped joint meets all tests of the American Gas Association. Result: a saving of 7c material cost per heater, and plant production doubled! No. 51

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designed and new ones built. Lord Halsbury likens a factory to a lobster which must shed its shell or framework in order to grow. "We must accordingly wait for a new generation of factories to see the full consequences of automation."

The net effect on labor, he believes, is "in the direction of increasing skill . . . at the expense of un-skill." Machines require trained men to maintain them. Displacements occur mainly in the ranks of the unskilled, who have a high rate of turnover anyway. Lord Halsbury urges that the training and relocation of the unskilled should be financed as "part of the *true cost* of the technical development."

Lord Halsbury believes that the old-fashioned, monotonous assembly line is becoming a thing of the past and that automation is a sign of the partial emergence of our society from "the worst of the machine age into better times." He is concerned for the man who is *not* going to be affected by automation—the coal miner, the stevedore and others "who do the heavy laboring work for a society which does not know how to lighten their task."

Social Experiment

Social scientists are chided for failure to make any systematic study of the current integration of Southern schools, one of the largest social experiments in history, by Stuart W. Cook of the department of psychology at New York University in an article in *The American Psychologist.*

He says that the magnitude of the program—some 150,000 Negro and 500,000 white children are going to unsegregated schools for the first time this year—provides an unprecedented variety of conditions in which different variables can be observed. It also insures enough closely similar situations to give a good check on conclusions. He suggests as problems that might be investigated: the relation between what people say they think and how they act; the relative influence of distant authority and local opinion; the effect of mixing in school on Negro-white relations outside; the influence of personal acquaintance on attitudes toward a group as a whole.

"Social scientists are agreed on the unparalleled opportunity which the situation presents," observes Cook, "yet I am afraid that the die has been cast and that little or no research is to be done. . . . Funds for research are not available. Government agencies which sponsor research have felt they could not incur the enmity of Congressmen who might

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reduce support for their research as a whole. . . . The major foundations having interests in this area have all been asked for assistance and the answer has been uniformly negative."

Whatever the reason, the author concludes, the failure to study the psychology of desegregation is "a scientific tragedy of the first order."

Life with Brother

Psychologists at the University of Pennsylvania are getting a new slant on the psychology of large families by interviewing persons raised in families with six or more children. Each informant was asked to rate brothers and sisters over 12 years of age for the ability to make personal adjustments.

Although the oldest and youngest of the family may be favored in some respects, in this survey they received a low grade in adaptability from the possibly prejudiced siblings. First daughters made a particularly poor showing. Fourth children turned out the best, in the opinions of their brothers and sisters: those not altogether happy with their own position in birth-order showed a distinct preference for the number four spot. In general, in-between children were considered to be well-adjusted.

Only 51 of the 457 family members in the study were rated as poorly adjusted. Thirteen of the 33 families from which they came had a history of a domineering parent whose hand of authority seemed to fall most heavily on the first children.

Mental Health

What are the prospects for obtaining more physicians to deal with mental illness, the most serious U. S. health problem? Not very bright, says a report in *The American Psychologist* by George W. Albee and Marguerite Dickey of Western Reserve University.

They find there is an immediate need for 20,000 therapists—10,000 psychiatrists and 10,000 clinical psychologists—but no significant increase, despite strenuous recruiting efforts, in the small number of university graduates training for psychiatry or clinical psychology. The shortage holds also for psychiatric social workers (9,000 needed).

While therapists have hailed the tranquilizing drugs as an aid to speedier and more effective treatment, they may soon be worse off than they were before. Patients who were once hospitalized will now be lining up outside the therapist's door. The picture is no more en-

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couraging at the preventive end: only a trickle of child psychiatrists—about 40—enter the field each year.

The Sugar Shuffle

The remarkable beehive dance of bees is not unique: there are flies that behave much the same way, says V. G. Dethier, professor of biology at Johns Hopkins University. Dethier has discovered in the behavior of the blowfly "a basis for removing the phenomenon of bee dancing from the realm of mysticism and for explaining it in physiological terms."

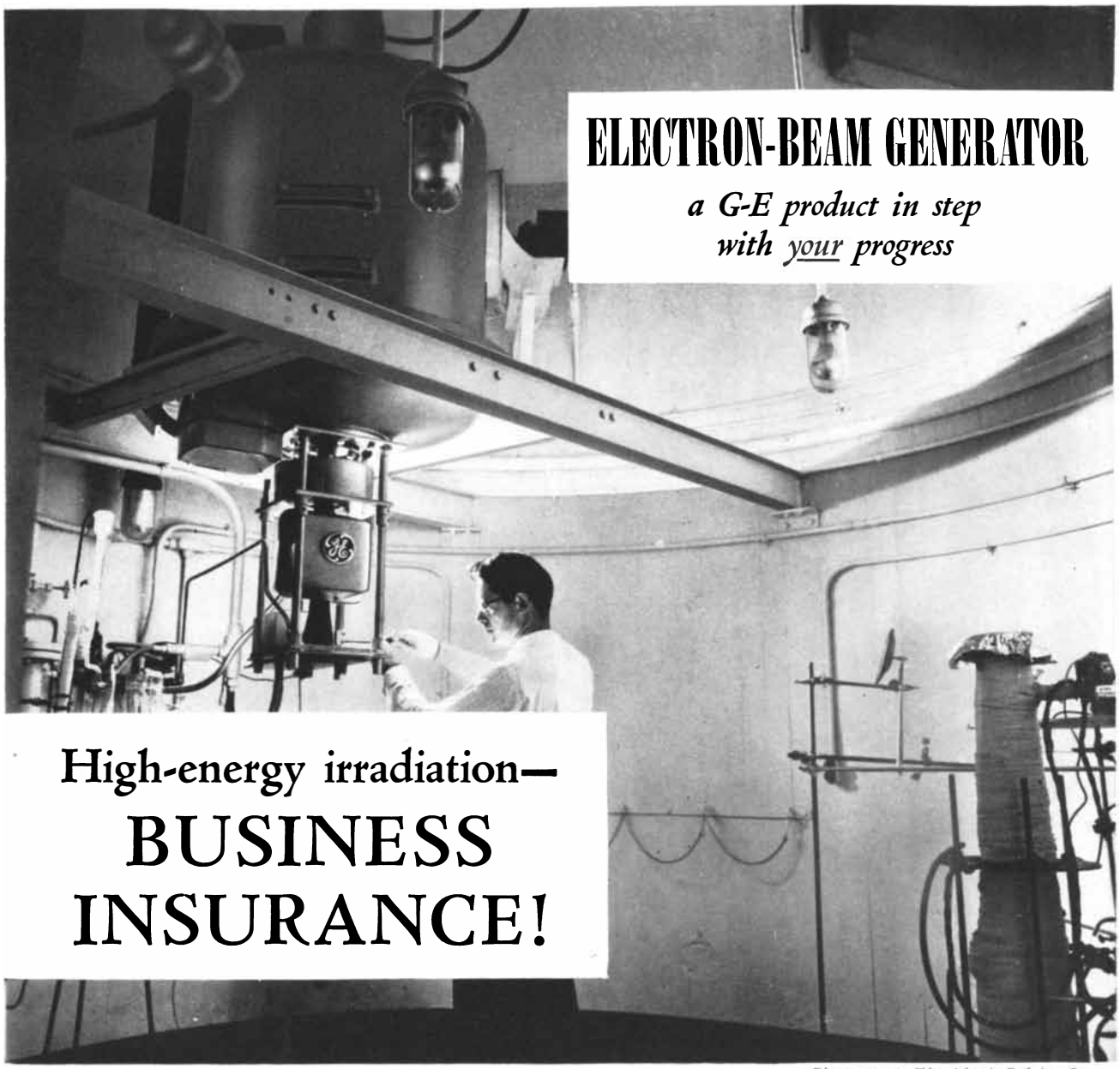
When forager bees return to the hive after a successful nectar hunt, they report to their fellows by performing a waggling dance on the comb. The orientation of the dance tells the direction of the source of food; the intensity and duration specify its distance and quality.

Writing in *Science*, Dethier describes a strikingly similar, though less complex pattern in flies. When these insects alight on a flat surface, they normally run about aimlessly in short straight lines broken by random changes in direction. But if they encounter a drop of sugar solution, they stop to drink it up, then begin a curious weaving dance. The pattern, says Dethier, has every resemblance to purposeful searching, but it is completely stereotyped.

The fly dances harder and longer when the stimulating solution is concentrated than when it is dilute. The response can be delayed for several minutes if the insect is restrained after eating, but the longer the wait, the shorter and weaker the gyrations. After a fly fills its crop, it usually regurgitates some of the contents, and, if there are other flies nearby, they feed on the regurgitated sugar. When performing in a beam of light, a dancing fly tends to line up its movements with the beam.

These features clearly foreshadow the more complex behavior of the bee: the long, intense dance to indicate a rich nectar supply; the decrease in intensity for more distant sources (*i.e.*, for greater delays between eating and dancing); the sharing of nectar with other bees; the orientation of the dance with respect to the direction of the sun or to the direction of polarization of its light.

It is a mistake, Dethier believes, to regard an individual bee as a mere cog in a larger machine or "superorganism." With bees, as with flies and people, it is essentially every man for himself. But colonies of insects put to use stereotyped aspects of behavior already evolved in solitary insects.



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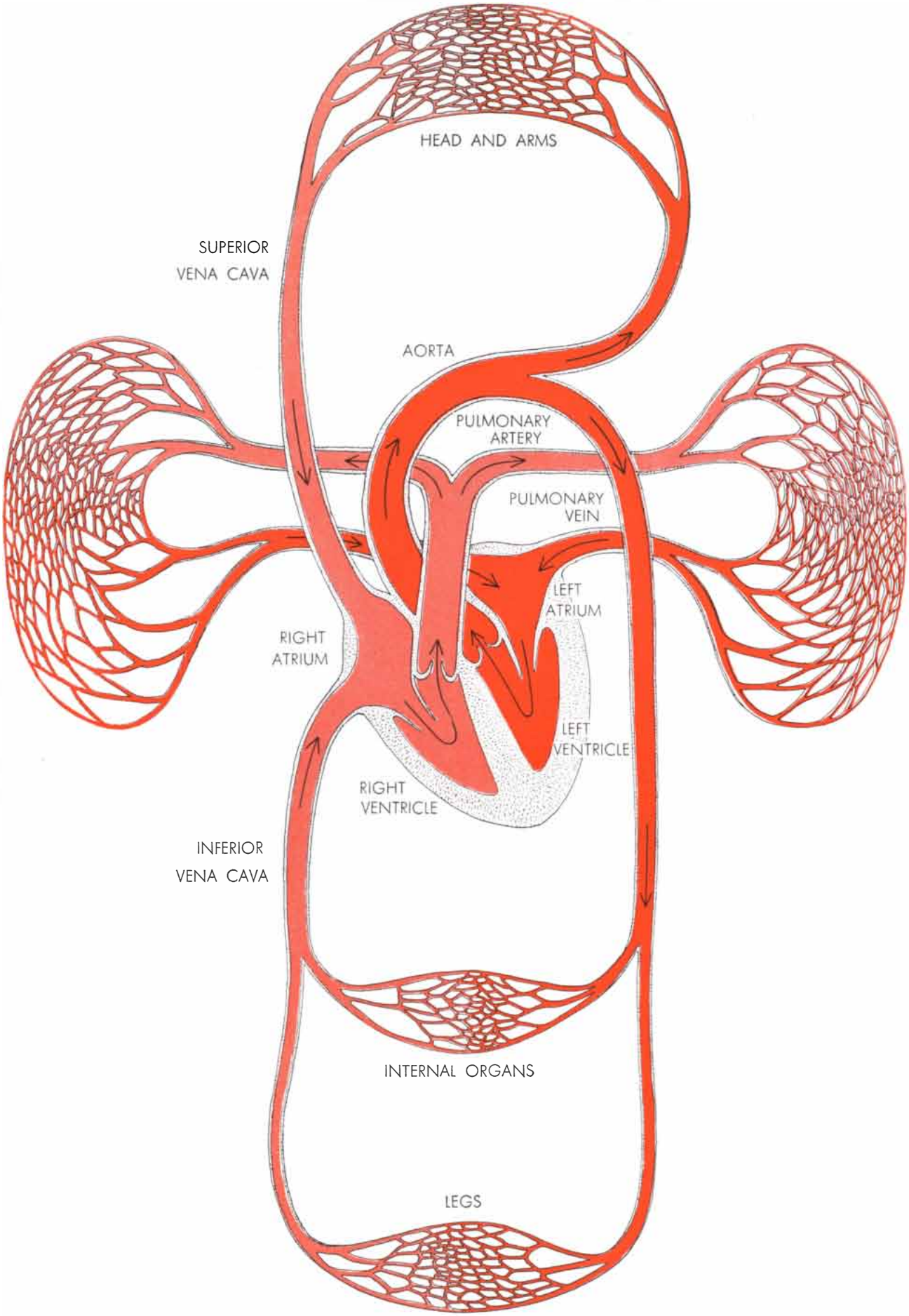


THE HEART

It pumps five quarts of blood in a minute, 75 gallons in an hour, 70 barrels in a day and 18 million barrels in 70 years. It does this by means of the most intricately woven muscle in the body

by Carl J. Wiggers

The blood bathes the tissues with fluid and preserves their slight alkalinity; it supplies them with food and oxygen; it conveys the building stones for their growth and repair; it distributes heat generated by the cells and equalizes body temperature; it carries hormones that stimulate and coordinate the activities of the various organs; it conveys antibodies and cells that fight infections—and of course it carries drugs administered for therapeutic purposes. No wonder that William Harvey, the discoverer of the circulation, ardently defended the ancient belief that the blood is the seat of the soul.

The blood cannot support life unless it is kept circulating. If the blood flow to the brain is cut off, within three to five seconds the individual loses consciousness; after 15 to 20 seconds the body begins to twitch convulsively; and if the interruption of the circulation lasts more than nine minutes, the mental powers of the brain are irrevocably destroyed. Similarly the muscles of the heart cannot survive total deprivation of blood flow for longer than 30 minutes. These facts emphasize the vital importance of the heart as a pump.

The work done by this pump is out of all proportion to its size. Let us look at some figures. Even while we are asleep the heart pumps about two ounces of blood with each beat, a teacupful with every three beats, nearly five quarts per minute, 75 gallons per hour. In other words, it pumps enough blood to fill an average gasoline tank almost four times every hour just to keep the machinery of the body idling. When the body is moderately active, the heart doubles this output. During strenuous muscular efforts, such as running to catch a train or playing a game of tennis, the cardiac output may go up to 14 barrels per hour. Over the 24 hours of an average day, involving not too vigorous work, it amounts to some 70 barrels, and in a lifetime of 70 years the heart pumps nearly 18 million barrels!

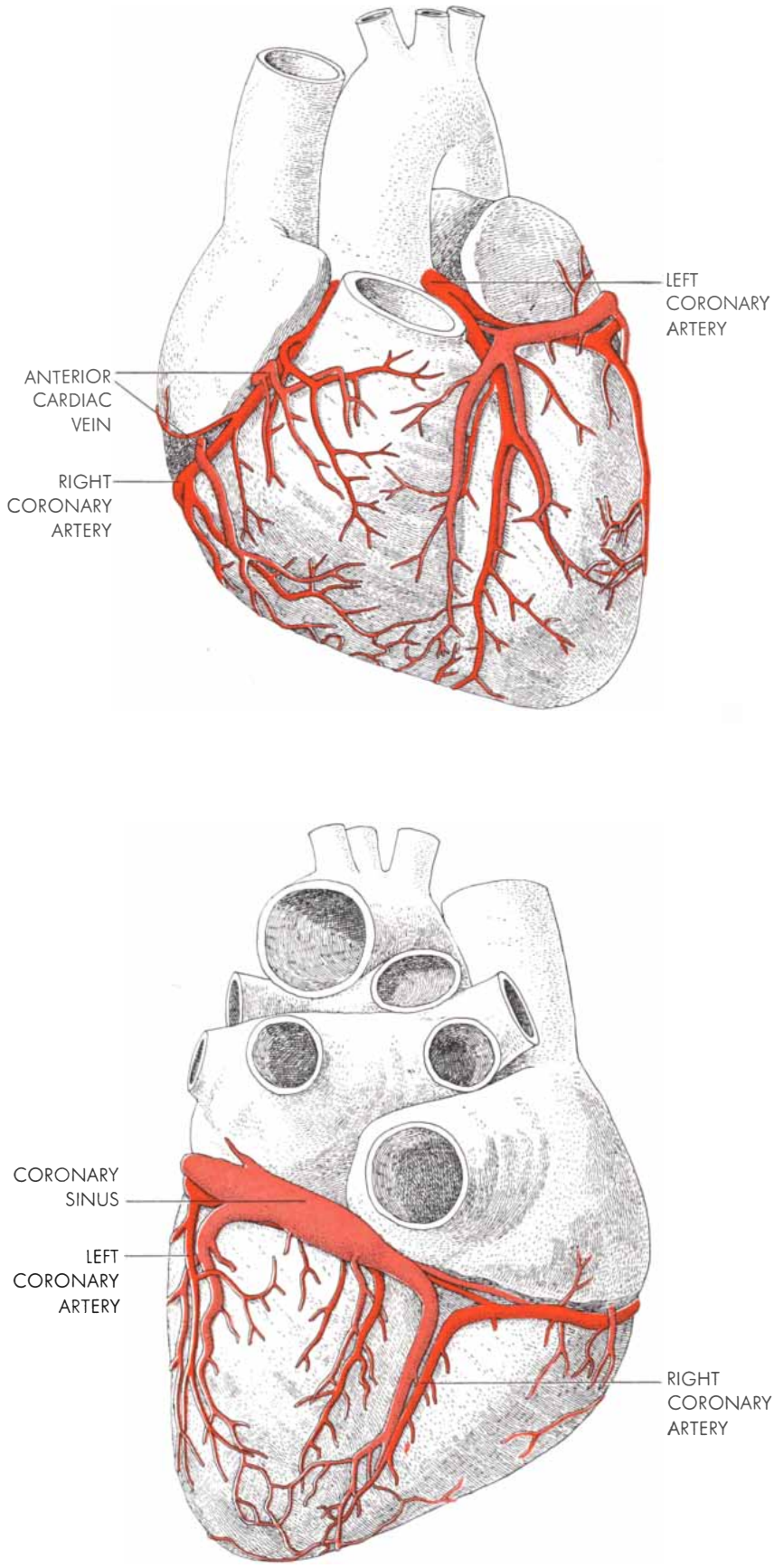
ANATOMY OF THE HEART and its relationship to the circulatory system is schematically depicted on the opposite page. The arterial blood is represented in a bright red; venous blood, in a somewhat paler red. The capillaries of the lungs are represented at left and right; the capillaries of the rest of the body, at top and bottom. The term atrium is now used in preference to auricle.

The Design

Let us look at the design of this remarkable organ. The heart is a double pump, composed of two halves. Each side consists of an antechamber, formerly called the auricle but now more commonly called the atrium, and a ventricle. The capacities of these chambers vary considerably during life. In the human heart the average volume of each ventricle is about four ounces, and of each atrium about five ounces. The used blood that has circulated through the body—low in oxygen, high in carbon dioxide, and dark red (not blue) in color—first enters the right half of the heart, principally by two large veins (the superior and inferior venae cavae). The right heart pumps it via the pulmonary artery to the lungs, where the blood discharges some of its carbon dioxide and takes up oxygen. It then travels through the pulmonary veins to the left heart, which pumps the refreshed blood out through the aorta and to all regions of the body [*see diagram on opposite page*].

The thick muscular walls of the ventricles are mainly responsible for the pumping action. The wall of the left ventricle is much thicker than that of the right. The two pumps are welded together by an even thicker dividing wall (the septum). Around the right and left ventricles is a common envelope consisting of several layers of spiral and circular muscle [*see diagrams on page 77*]. This arrangement has a number of mechanical virtues. The blood is not merely pushed out of the ventricles but is virtually wrung out of them by the squeeze of the spiral muscle bands. Moreover, it is pumped from both ventricles almost simultaneously, which insures the ejection of equal volumes by the two chambers—a necessity if one or the other side of the heart is not to become congested or depleted. The effectiveness of the pumping action is further enhanced by the fact that the septum between the ventricles becomes rigid just before contraction of the muscle bands, so that it serves as a fixed fulcrum at their ends.

The ventricles fill up with blood from the antechambers (atria). Until the beginning of the present century it was thought that this was accomplished primarily by the contractions of the atria, *i.e.*, that the atria also functioned as pumps. This idea was based partly on inferences from anatomical studies and partly on observation of the exposed hearts of frogs. But it is now known that in mammals the atrium serves mainly as a reservoir. The ventricles fill fairly completely by their elastic recoil from contraction before the atria contract. The contraction of the latter merely completes the transfer of the small amount of blood they have left. Indeed, it has been found that the filling of the ventricles is not significantly impaired when



ARTERIES AND VEINS which carry blood to and from the muscles of the heart are shown from the front (*top*) and back (*bottom*). The arteries are bright red; the veins, pale red.

disease destroys the ability of the atria to contract.

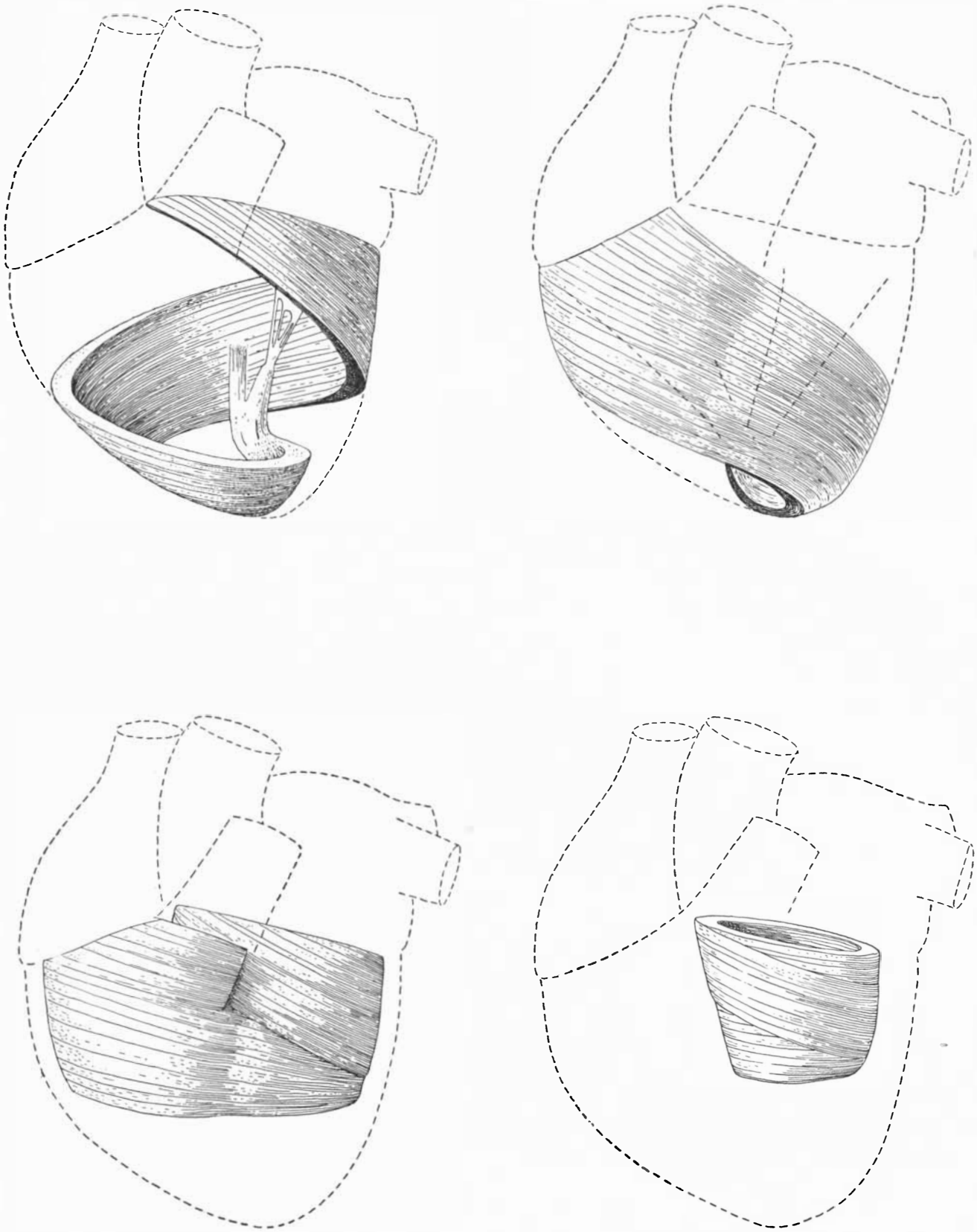
Factors of Safety

Since most of us believe that every biological mechanism must have some purpose, the question arises: Why complicate the cardiac pump with contractions of the atria if the ventricles alone suffice? The answer is that they provide what engineers call a "factor of safety." While the atrial contractions make only a minor contribution to filling the ventricles under normal circumstances, they assume an important role when disease narrows the valve openings between the atria and the ventricles. Their pumping action then is needed to drive blood through the narrowed orifices.

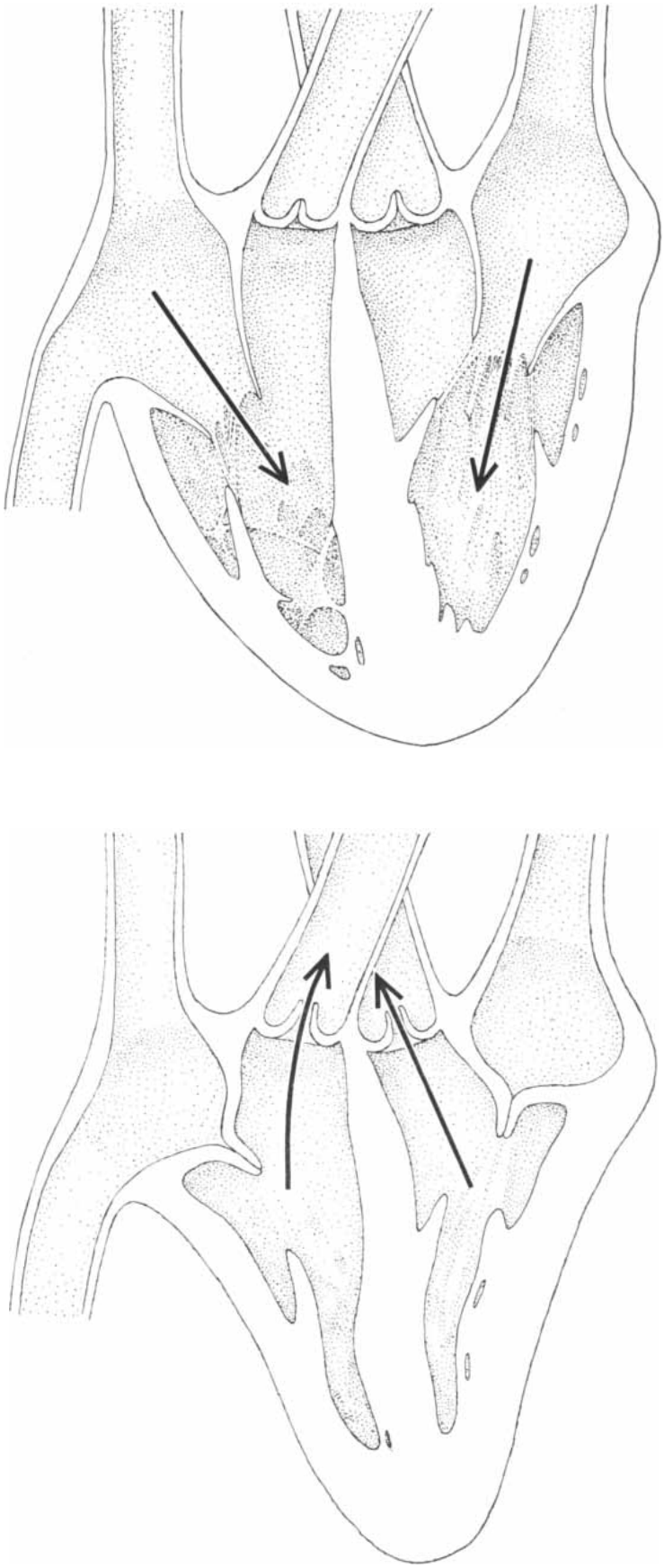
The ventricular pumps also have their factors of safety. The left ventricle can continue to function as an efficient pump even when more than half of its muscle mass is dead. Recently the astounding discovery was made that the right ventricle can be dispensed with altogether and blood will still flow through the lungs to the left heart! An efficient circulation can be maintained when the walls of the right ventricle are nearly completely destroyed or when blood is made to by-pass the right heart. Obviously the heart is equipped with large factors of safety to meet the strains of everyday life.

This applies also to the heart valves. Like any efficient pump, the ventricle is furnished with inlet and outlet valves; it opens the inlet and closes the outlet while it is filling, and closes the inlet when it is ready to discharge. The pressure produced by contraction of the heart muscles mechanically closes the inlet valve between the atrium and ventricle: shortly afterward the outlet valve opens to let the ventricle discharge its blood—into the pulmonary artery in the case of the right ventricle and into the aorta in the case of the left. Then as the muscles relax and pressure in the chambers falls, the outlet valves close and shortly thereafter the inlet valves open. The relaxation that allows the ventricles to fill is called diastole; the contraction that expels the blood is called systole.

While it might seem that competent valves are indispensable for the forward movement of blood, they are in fact not absolutely necessary. The laws of hydraulics play some peculiar tricks. As every farmhand knew in the days of hand well-pumps, if the valves of the pump were worn and leaky, one could



MUSCLE FIBERS of the ventricles are divided into four groups, one of which is shown in each of these four drawings. Two groups of fibers (*two drawings at top*) wind around the outside of both ventricles. Beneath these fibers a third group (*drawing at lower left*) also winds around both ventricles. Beneath these fibers, in turn, a fourth group (*drawing at lower right*) winds only around the left ventricle. The contraction of all these spiral fibers virtually wrings, rather than presses, blood out of the ventricles.



SYSTOLE AND DIASTOLE is the pumping rhythm of the heart. At the top is diastole, in which the ventricles relax and blood flows into them from the atria. The inlet valves of the ventricles are open; the outlet valves are closed. At the bottom is systole, in which the ventricles contract, closing the inlet valves and forcing blood through the outlet valves.

still draw water from the well by pumping harder. Similarly doctors have long been aware that patients can maintain a good circulation despite serious leaks in the heart valves. The factors of safety concerned are partly physical and partly physiological. The physical factor is more vigorous contraction of the heart muscles, aided by a structural arrangement of the deep muscle bands which tends to direct the blood flow forward rather than backward through the leaky valve. The physiological factor of safety is the mechanism known as "Starling's Law." In brief the rule is that, the more a cardiac muscle is stretched, the more vigorously it responds, of course within limits. The result is that the more blood the ventricles contain at the end of diastole, the more they expel. Of course they will fill with an excess of blood when either the inlet or the outlet valves leak. By pumping an extra volume of blood with each beat, the ventricles compensate for the backward loss through the atrial valves. In addition, the sympathetic nerves or hormones carried in the blood may spur the contractile power of the muscles. Under certain circumstances unfavorable influences come into play that depress the contractile force. Fortunately drugs such as digitalis can heighten the contractile force and thus again restore the balance of the circulation even though the valves leak.

Like any sharp closing of a door, the abrupt closings of the heart valves produce sounds, which can be heard at the chest wall. And just as we can gauge the vigor with which a door is slammed by the loudness of the sound, so a physician can assess the forces concerned in the closing of the individual heart valves. When a valve leaks, he hears not only the bang of the valves but also a "murmur" like the sigh of a gust of wind leaking through a broken window pane. The quality and timing of the murmur and its spread over the surface of the chest offer a trained ear considerable additional information. Sometimes a murmur means that the inlet and outlet orifices of the ventricles have been narrowed by calcification of the valves. In that case there is a characteristic sound, just as the water issuing from a hose nozzle makes a hissing sound when the nozzle is closed down.

Blood Supply

In one outstanding respect the heart has no great margin of safety: namely, its oxygen supply. In contrast to many other tissues of the body, which use as

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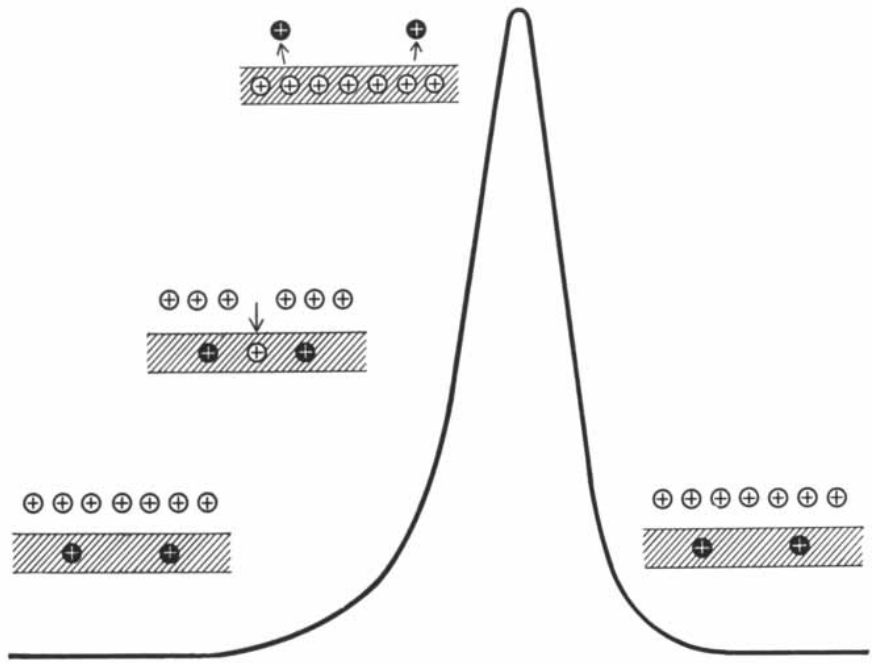
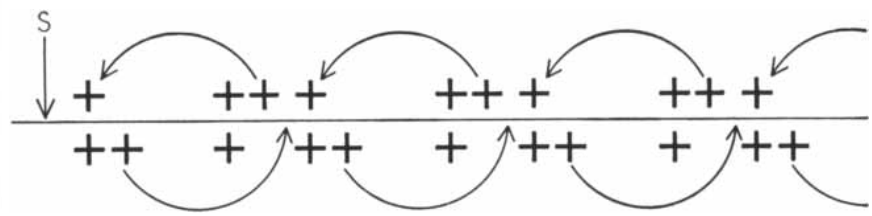


ELECTRICAL IMPULSE IS GENERATED by a cell in the "pacemaker" of the heart, a system of specialized muscle tissue (*see diagram on next page*). At lower left is a cross section of the cell; positively charged potassium ions (*black*) are inside it and a larger number of positively charged sodium ions (*white*) are outside. Because there are more positive charges outside the cell than inside, the inside of the cell is negatively charged with respect to the outside. When the cell is stimulated (*second cross section*), a sodium ion leaks across the membrane. Then many sodium ions rush across the membrane and potassium ions rush out (*third cross section*); this reverses the polarity of the cell and gives rise to an action potential (*peak in curve*). The original situation is then restored (*fourth cross section*).

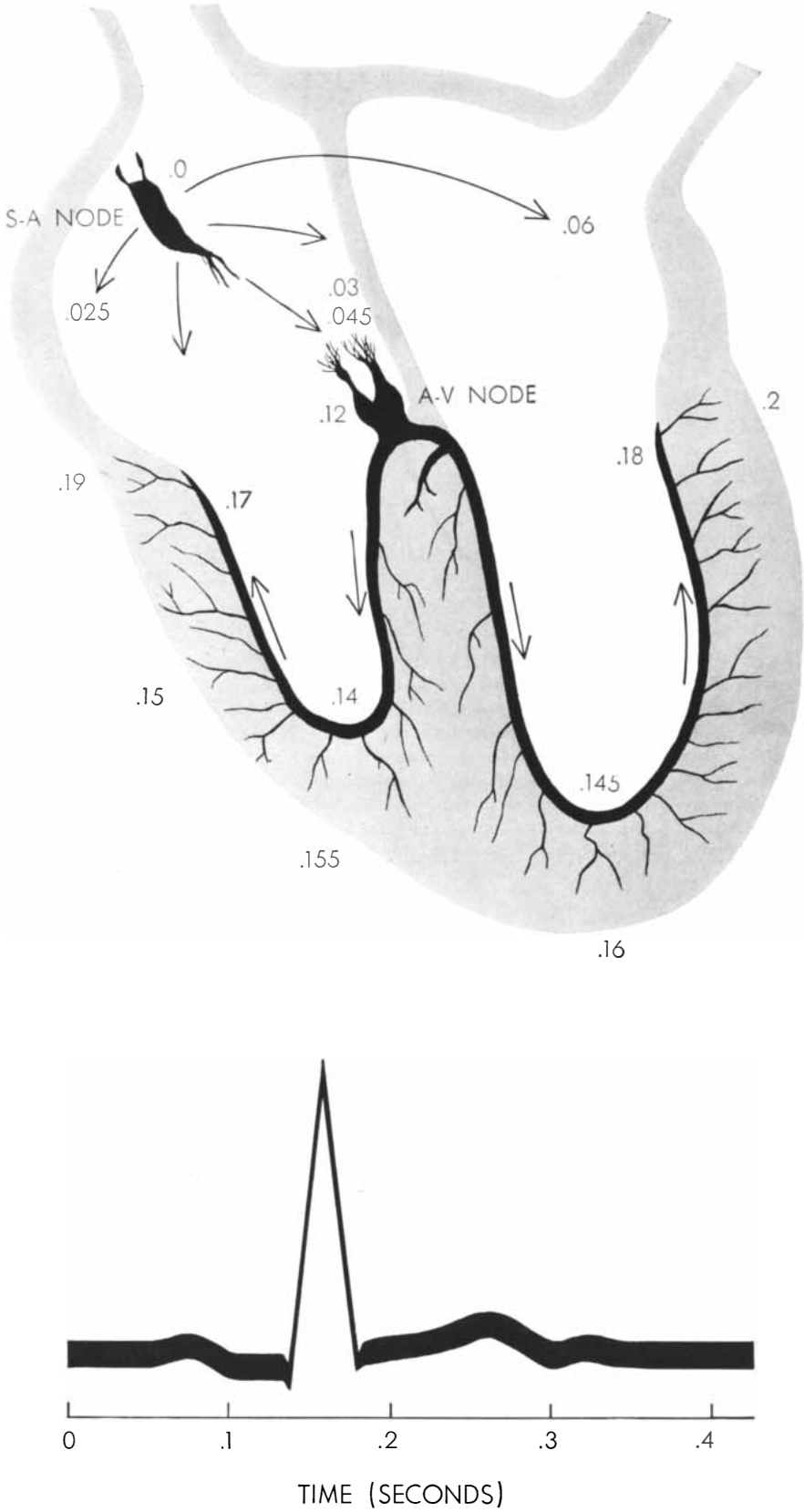
little as one fourth of the oxygen brought to them by the blood, the heart uses 80 per cent. The amount of the blood supply is therefore all-important to the heart, particularly when activity raises its demand for oxygen.

Blood is piped to the heart muscles via two large coronary arteries which curl around the surface of the heart and send branchings to the individual muscle fibers [*see diagrams on page 76*]. The left coronary artery is extraordinarily short. It divides almost immediately into two branches. A large circumflex branch runs to the left in a groove between the left atrium and ventricle and continues as a large vessel which descends on the rear surface of the left ventricle. It supplies the left atrium, the upper front and whole rear portion of the left ventricle. The other branch circles to the left of the pulmonary artery and then runs downward in a furrow to the apex. It supplies the front wall of the left ventricle and a small part of the rear right ventricle. Close to its origin the left coronary artery gives off several twigs which carry blood to the septum. The right coronary artery, embedded in fat, runs to the right in a groove between the right atrium and ventricle. It carries blood to both of them.

From the surface branches vessels run into the walls of the heart, dividing re-



ELECTRICAL IMPULSE IS TRANSMITTED through the pacemaker system not as an electric current but as an electrical chain reaction. When a pacemaker cell is stimulated (S), it discharges and generates a local current which causes the depolarization and discharge of adjacent cells. In effect a wave of positive charge passes through the system (*curved arrows*).



PACEMAKER SYSTEM generates and transmits the impulses which cause the contraction of the heart muscles. The impulse is generated in the sino-atrial (S-A) node and spreads across the atria, causing their contraction and stimulating the atrio ventricular (A-V) node. This in turn stimulates the rest of the system, causing the rest of the heart to contract. The numbers indicate the time (in fractions of a second) it takes an impulse to travel from the S-A node to that point. The electrocardiogram curve at bottom indicates the change in electrical potential that occurs during the spread of one impulse through the system.

peatedly until they form very fine capillary networks around the muscle elements. Eventually three systems of veins return the blood to the right heart to be pumped back to the lungs.

In the normal human heart there is little overlap by the three main arteries. If one of them is suddenly blocked, the area of the heart that it serves cannot obtain a blood supply by any substitute route. The muscles deprived of arterial blood soon cease contracting, die and become replaced by scar tissue. Now while this is the ordinary course of events, particularly in young persons, the amazing discovery was made some 20 years ago that the blocking of a main coronary artery does not always result in death of the muscles it serves. It has since been proved that new blood vessels grow in, from other arteries, if a main branch is progressively narrowed by atherosclerosis over a period of months or years. In other words, if the closing of a coronary artery proceeds slowly, a collateral circulation may develop. This biological process constitutes another factor of safety. Recent experiments on dogs indeed indicate that exercise will accelerate the development of collaterals when a major coronary artery is constricted. If this indication is confirmed, it may well be that patients with atherosclerosis will be encouraged to exercise, rather than to adopt a sedentary life.

We have seen that there are many structural and functional factors of safety which enable the heart to respond, not only to the stress and strain of everyday life, but also to unfavorable effects of disease. Their existence has long been recognized; modern research has now thrown some light on the fundamental physiological and chemical processes involved.

Contraction

The heart's transformation of chemical energy into the mechanical energy of contraction has certain similarities to the conversion of energy in an automobile engine; but there are also essential differences. In both cases a fuel is suddenly exploded by an electric spark. In both the fuel is complex, and the explosion involves a series of chemical reactions. In each case some of the energy is lost as unusable heat. In each the explosions occur in cylinders, but in the heart these cylinders (the heart muscle cells) not only contain the fuel but are able to replenish it themselves from products supplied by the blood. The mechanical efficiency of these cells,

i.e., the fraction of total energy that can be converted to mechanical energy, has not been equaled by any man-made machine designed in the pre-atomic age. The mechanism responsible for this efficiency is unique and very complex.

Under the microscope we can see that cardiac muscle consists of long, narrow networks of fibers, with connective tissue and tiny blood vessels filling the spaces between. Each muscle fiber is made up of innumerable fibrils embedded in a matrix. It has been demonstrated that these fibrils are responsible for the contraction of the muscle as a whole. By special and clever techniques the fibrils can be washed free of the matrix, and it has been shown that when brought into contact with the energy-rich substance ATP, the fibrils shorten.

Examinations with the polarizing and electron microscopes and with X-rays have produced a fairly good picture of the ultimate design of these microscopic fibers. Each fibril is composed of many smaller filaments, or "protofibrils," just distinguishable under the highest microscopic magnification. The fibrils of a single muscle fiber may contain a total of some 10 million such filaments. The filaments are the smallest units known to stiffen and shorten. It has been possible to extract the actomyosin of which they are composed and to reconstitute filaments by squirting the extracted protein into a salt solution. These synthetic filaments can be made to contract.

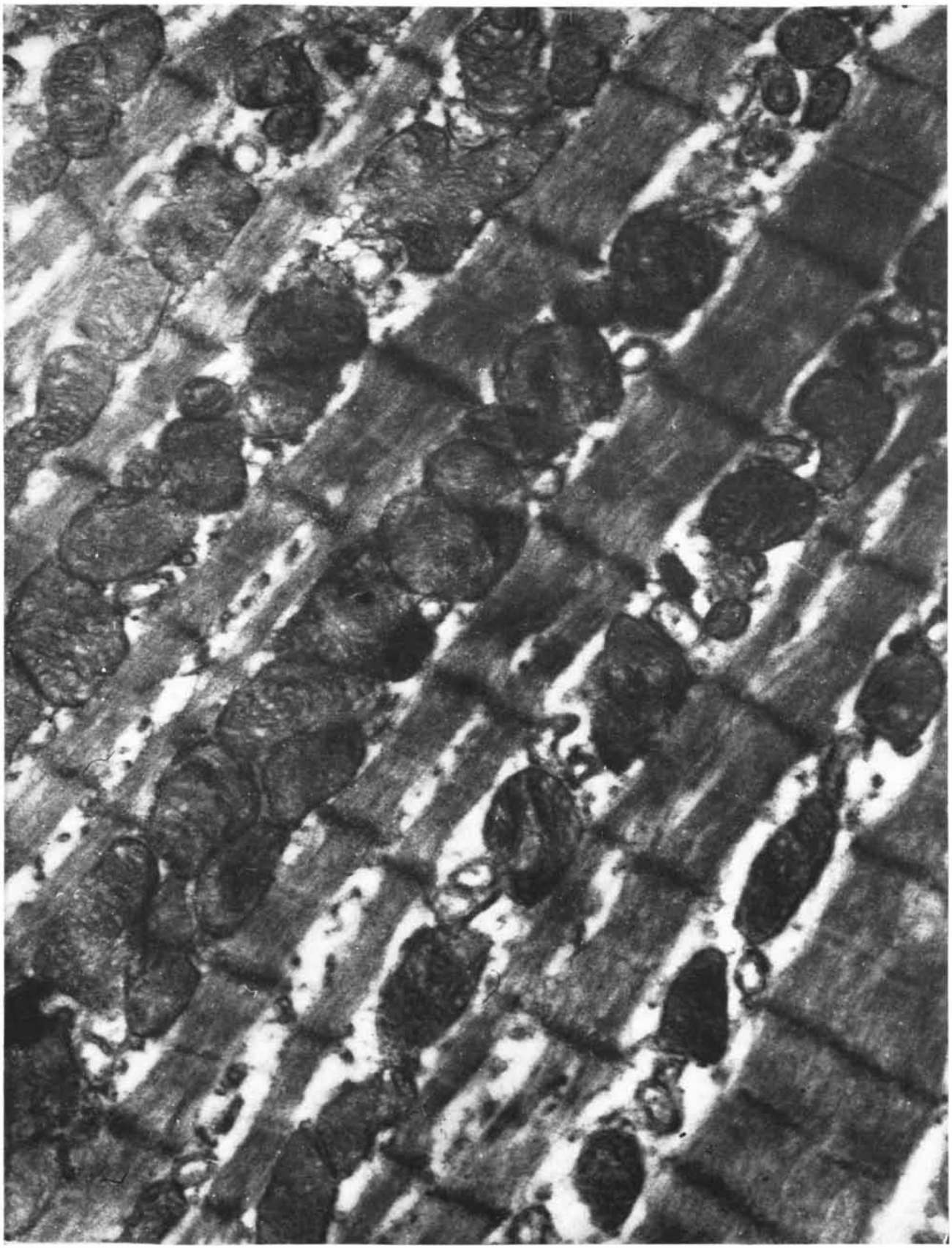
The filaments themselves remain straight during contraction; therefore the kinking or coiling necessary for their contraction must take place at a still lower level—the level of molecules. Here the picture is clouded. We know from X-ray diffraction analyses that the molecules composing myosin filaments are arranged as miniature stretched spiral springs or stretched rubber bands. But just how they effect the filaments' contraction can only be guessed. Regardless of the mechanism, there is no doubt that the stiffness and shortening which are the features of contraction are mediated by changes in the molecular arrangement. This rearrangement requires energy. The consensus is that a tiny electric spark delivered to each individual cell causes the explosion of ATP. Not all the energy released is used for shortening of the actomyosin filaments. Some of it is converted to heat and some is used to initiate a series of complex chemical reactions which replenishes the fuel by reconstituting ATP. The explosion of ATP differs from that of gasoline in that no oxygen is required. But oxygen is indispensable for the rebuilding of ATP.

The millions of cardiac cylinders, as in an automobile engine, must fire in proper sequence to contract the muscle effectively. When they fire haphazardly, there is a great liberation of energy but no coordinated action. This chaotic condition is called fibrillation—*i.e.*, independent and uncoordinated activity of the individual fibrils.

The Beat

What causes the heart to maintain its rhythmic beat? The ancients, performing sacrificial rites, must have noticed that the heart of an animal continues to beat for some time after it has been removed from the body. That the beat must originate in the heart itself was apparently clear to the Alexandrian anatomist Erasistratus in the third century B.C. But anatomists ignored this evidence for the next 20 centuries because they were convinced that the nerves to the heart must generate the heartbeat. In 1890, however, Henry Newell Martin at the Johns Hopkins University demonstrated that the heart of a mammal could be kept beating though it was completely separated from the nerves, provided it was supplied with blood. And many years before that Ernst Heinrich Weber of Germany had made the eventful discovery that stimulation of the vagus nerve to the heart does not excite it but on the contrary stops the heart. In short, it was established that the beat is indeed generated within the heart, and that the nerves have only a regulating influence.

The nature and location of the heart's "pacemaker" remained enigmatic until comparatively recent times. Within the span of my own memory there was considerable evidence for the view that the pacemaking impulses were generated by nerve cells in the right atrium and transmitted by nerve fibers to the heart-muscle cells. At present the evidence is overwhelming that the impulses are actually generated and distributed by a system of specialized muscle tissue consisting of cells placed end to end. Seventy-two times per minute—more or less—a brief electric spark of low intensity is liberated from a barely visible knot of tissue in the rear wall of the right atrium, called the sino-atrial or S-A node. The electric impulse spreads over the sheet of tissue comprising the two atria and, in so doing, excites a succession of muscle fibers which together produce the contraction of the atria. The impulse also reaches another small knot



MUSCLE FIBRILS of the heart, which make up its muscle fibers, are revealed in this electron micrograph made by Bruno Kisch of the American College of Cardiology in New York. The fibrils, which are from the heart of a guinea pig, are the long bands running diagonally across the micrograph. The round bodies between the fibrils are sarcosomes, which are found in large numbers in heart muscle and which appear to supply the enzymes that make possible its tireless contractions. The fibrils themselves are made up of protofibrils, which may barely be seen in the micrograph. The micrograph enlarges these structures some 50,000 diameters.

of specialized muscle known as the atrioventricular or A-V node, situated between the atria and ventricles. Here the impulse is delayed for about seven hundredths of a second, apparently to allow the atria to complete their contractions; then from the A-V node the impulse travels rapidly throughout the ventricles by way of a branching transmission system, reaching every muscle fiber of the two ventricles within six hundredths of a second. Thus the tiny spark produces fairly simultaneous explosions in all the cells, and the two ventricles contract in a concerted manner.

If the heart originates its own impulses, of what use are the two sets of nerves that anatomists have traced to the heart? A brief answer would be that they act like spurs and reins on a horse which has an intrinsic tendency to set its own pace. The vagus nerves continually check the innate tempo of the S-A node; the sympathetic nerves accelerate it during excitement and exercise.

Normally, as I have said, the S-A node generates the spark, but here, too, nature has provided a factor of safety. When the S-A node is depressed or destroyed by disease, the A-V node becomes the generator of impulses. It is not as effective a generator (its maximum rate is only 40 or 50 impulses per minute, and its output excites the atria and ventricles simultaneously), but it suffices to keep the heart going. Patients have survived up to 20 years with the A-V pacemaker substituting for a damaged S-A node.

There are still lower pacemakers which can maintain a slow heartbeat when the higher ones fail. When all the pacemakers are so weakened that, like an old battery, they are barely able to emit impulses, an anesthetic administered during an operation may stop the heart. In that case the beat can often be restored by rhythmic electric shocks —a system now incorporated in an apparatus for revival of the heart.

The Spark

What sort of mechanism exists in nodal tissues that is able to emit electric sparks with clockwork regularity 104,000 times a day? We must look first to the blood. The fact that an excised heart does not long continue to beat unless supplied artificially with blood shows that the blood must supply something essential for preservation of its beat. In the 19th century physiologists began to experiment on isolated hearts, first of frogs and turtles and later of rabbits and cats, to determine what constituents of blood could be spared without halting the rhythmic heart contractions. They found that the serum (the blood fluid without cells) could maintain the beat of a mammalian heart, provided the serum was charged with oxygen under pressure. What constituents of the serum, besides the oxygen, were necessary? Attention first focused on the proteins, on the theory that the beating heart required them for nourishment. The heart was, in fact, found to be capable of maintaining its beat fairly well on a "diet" of blood proteins or even egg white or oxygenated milk whey. But the nourishment idea received a blow when it was discovered that the heartbeat could be maintained on a solution of gum arabic! It was then suggested that serum proteins act by virtue of their viscosity. This is an example of how experimenters are sometimes led astray in trying to uncover nature's secrets.

An eventful discovery in 1882 by the English physiologist Sydney Ringer changed the direction of thinking. He showed that a solution containing salts of sodium, potassium and calcium and a little alkali, in the concentrations found in the blood, would sustain the beat of a frog's heart. It was but a step to show that Ringer's solution, when oxygenated, also keeps the mammalian heart beating for a short time. Later it was found that the addition of a biological fuel—glucose or, better yet, lactic acid—would extend the heart's performance.

Summing up the evidence, it was known at the beginning of the present century that the beat of the mammalian heart, and obviously also the generation of the spark, depends primarily on a balanced proportion of sodium, potassium and calcium plus a supply of oxygen and an energy-yielding substance such as glucose.

During the present century the scientific minds have sought to learn how these inorganic elements are involved in the initiation and spread of impulses. In order to understand the intricate mechanisms we must recall what most of us learned in high school: *viz.*, the theory that, when a salt is dissolved in water, the elements are dissociated and become ions charged with positive and negative electricity.

The delicate enclosing membrane of all cells is differentially permeable: that is, ordinarily (at rest) it allows potassium ions to enter the cell but excludes sodium ions. We may say that the potassium ions have admission tickets, while the sodium ions do not. Since sodium ions predominate in the body fluids, the positively charged potas-

sium ions within a cell are greatly outnumbered by positively charged sodium ions around the outside of the cell; the net result is that the outside is more positive than the inside, and the interior can therefore be regarded as negative with respect to the exterior. The potential difference is about one tenth of a volt. Each cell thus becomes a small charged battery. Now in the case of cells of the S-A node, the membrane leaks slightly, allowing some sodium ions to sneak in. This slowly but steadily reduces the potential difference between the inside and the outside of the membrane. When the difference has diminished by a critical amount (usually about six hundredths of a volt), the tiny pores of the membrane abruptly open. A crowd of sodium ions then rushes in, while some of the imprisoned potassium ions escape to the exterior. As a result the relative charges on the two sides of the membrane are momentarily reversed, the inside being positive with respect to the outside. The action potential thus created is the release of the electric spark.

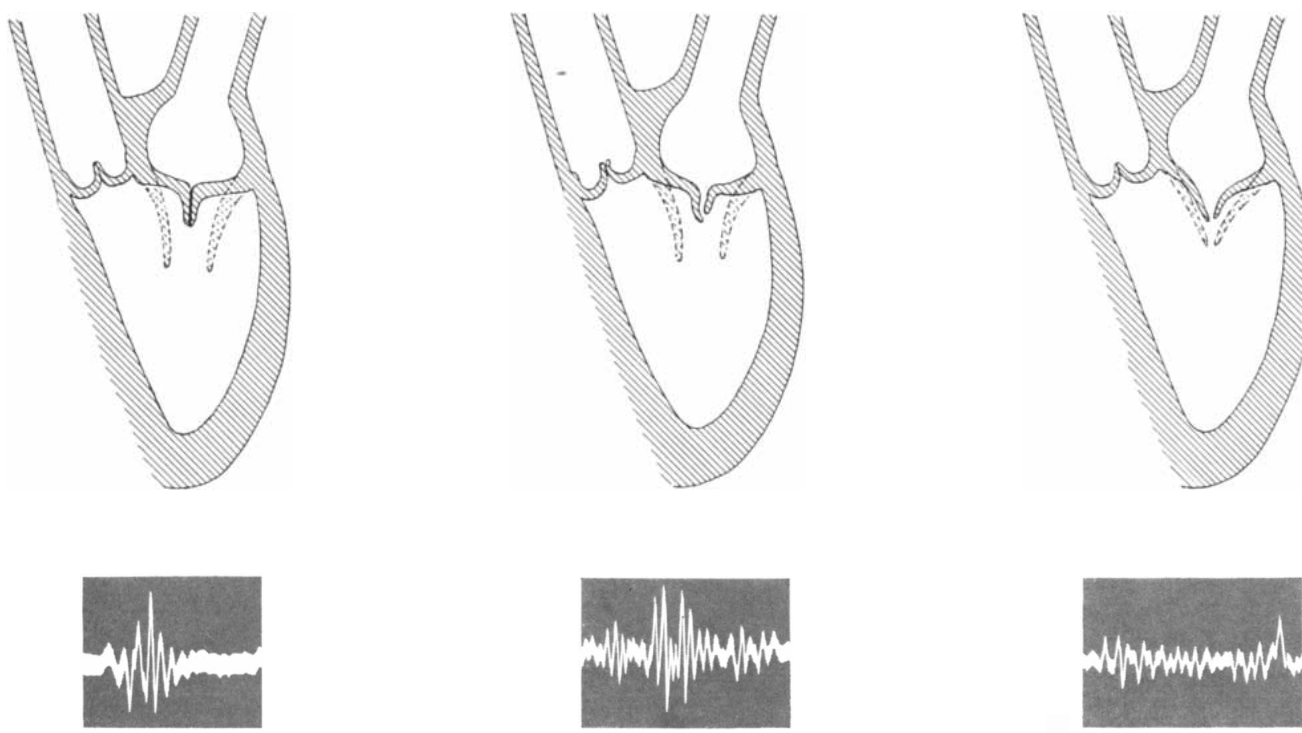
As soon as activity is over, the membrane repolarizes, *i.e.,* reconstitutes a charged battery. How this is accomplished is little understood, beyond the fact that oxidation of glucose or its equivalent is required. The mechanism is pictured as a kind of metabolic pump which ejects the sodium ions that have gained illegal admittance, allows potassium ions to re-enter and closes the pores again. Then the cells are ready to be discharged again.

A little reflection should make it evident that the frequency with which such cells discharge depends on at least two things: (1) the rate at which sodium ions leak into the cell, and (2) the degree to which the potential across the membrane must be reduced in order to discharge it completely. The rate of sodium entry is known to be increased by warming and decreased by cooling, which accounts in part for the more rapid firing of the pacemakers in a patient who has a fever. The magnitude of the potential difference required to discharge the cell depends on the characteristics of the membrane. In this the concentration of calcium ions plays a basic role. Calcium favors stability of the membrane: if its concentration falls below a certain critical value, the rate of discharge by the cells increases; if calcium ions are too abundant, the rate is slowed. The rate of discharge is also affected by other factors. The vagus nerves tend to reduce it, the sympathetic nerves to increase it. The blood's content of oxygen and carbon dioxide, its degree of alkalinity, hormones and drugs—these and other influences can change the stability of the membranes and thus alter the rate of cell discharge.

Transmission of Impulses

The spark from a pacemaker is transmitted to the myriads of cylinders constituting the ventricular pumps by way of the special conducting system. When we say that the impulse travels over this system, this does not mean that electricity flows, as over wires to automobile cylinders. The electric impulse spreads by a kind of chain reaction involving the successive firing of the special transmitting cells. When pacemaker cells discharge, they generate a highly localized current which in turn causes the depolarization and discharge of an adjacent group of cells, and thus the impulse is relayed to the muscle cells concerned with contraction. An advantage of this mechanism is that the strength of the very minute current reaching the contracting fibers is not reduced.

Such a mode of transmission is not unknown in the inanimate world. There is a classic experiment in chemistry which illustrates an analogous process. An iron wire is coated with a microscopic



HEART SOUNDS indicate the normal and abnormal functioning of the heart valves. The three drawings at the top show the left side of the heart in cross section. The aortic, or outlet, valve is at upper left in each drawing; the mitral, or inlet, valve is at upper right. The first drawing shows the normal closing of the mitral valve; the trace below it records the sound made by this closing. The second drawing shows the partial closing of a leaky mitral valve; the trace below it records the murmur of blood continuing to flow through the valve. The third drawing shows the partial closing of a mitral valve with stiff leaves; the trace below it records a fainter murmur.

film of iron oxide and suspended in a cylinder of strong nitric acid. Protected by this coating, the iron does not dissolve. But if the coat is breached (by a scratch or by an electric current) at a spot at one end of the immersed wire, a brown bubble immediately forms at this spot and a succession of brown bubbles then traverses the whole length of the wire. An electrical recorder connected to a number of points along the wire shows that a succession of local electric currents is generated down the wire as it bubbles. At each spot the current breaks the iron oxide film and the ensuing chemical reaction generates a new action potential. The contact between bare iron and nitric acid is only momentary, because the break in the film is quickly repaired.

Summarizing, the passage of electric impulses over the conduction system of the heart represents a series of local bioelectric currents, relaying the impulses step by step over special tissue to the contracting cells. On arrival at these cells the electric charges trigger the breakdown of ATP and so release the chemical energy needed for contraction.

Diagnosis

Considering the complexity of the cardiac machinery, it is remarkable that the heartbeat does not go wrong more often. Like a repairman for an automobile or a television set, a physician sometimes has to make an extensive hunt for the source of the disorder. It seems appropriate to close this article with a list of the points at which the machinery is apt to break down.

1. The main (S-A) pacemaker, or in rare instances all the pacemakers, may fail.

2. There may be too many pacemakers. The secondary pacemakers occasionally spring into action and work at cross purposes with the normal one, producing too rapid, too slow, or ill-timed beats.

3. The system for conduction of the pacemaker impulses may break down, leading to "heart block."

4. The heart muscle cylinders may respond with little power because of poor fuel, lack of enough oxygen for building fuel, fatigue or lack of adequate vitamins, hormones or other substances in the blood.

5. Some of the cylinders may be put out of commission by blockage of a coronary artery.

6. The heart valves may leak, and in its gallant effort to compensate, the heart may be overworked to failure.

"Nicolas Bourbaki"

Using this whimsical pseudonym, derived from the name of a general in the Franco-Prussian War, a group of young French mathematicians has written 20 volumes of an extraordinary treatise on mathematics

by Paul R. Halmos

His name is Greek, his nationality is French and his history is curious. He is one of the most influential mathematicians of the 20th century. The legends about him are many, and they are growing every day. Almost every mathematician knows a few stories about him and is likely to have made up a couple more. His works are read and extensively quoted all over the world. There are young men in Rio de Janeiro almost all of whose mathematical education was obtained from his works, and there are famous mathematicians in Berkeley and in Göttingen who think that his influence is pernicious. He has emotional partisans and vociferous detractors wherever groups of mathematicians congregate. The strangest fact about him, however, is that he does not exist.

This nonexistent Frenchman with the Greek name is Nicolas Bourbaki (rhymes with *Pooh-Bah key*). The fact is that Nicolas Bourbaki is a collective pseudonym used by an informal corporation of mathematicians. (The charming French phrase for corporation, "anonymous society," is quite apt here.) The pseudonymous group is writing a comprehensive treatise on mathematics, starting with the most general basic principles and to conclude, presumably, with the most specialized applications. The project got under way in 1939, and 20 volumes (almost 3.000 pages) of the monumental work have appeared.

Why the authors chose to call themselves Bourbaki is shrouded in mystery. There is reason to think that their choice was inspired by an army

NICOLAS BOURBAKI is fancifully represented by this milling throng of French mathematicians. Bourbaki appears to consist of 10 to 20 men at any one time. Any resemblance between these men and the individuals in the drawing is entirely coincidental.

officer of some importance in the Franco-Prussian War. General Charles Denis Sauter Bourbaki was quite a colorful character. In 1862, at the age of 46, he was offered a chance to become the King of Greece, but he declined the opportunity. He is remembered now mainly for the unkind way the fortunes of war treated him. In 1871, after fleeing from France to Switzerland with a small remnant of his army, he was interned there and then tried to shoot himself. Apparently he missed, for he is reported to have lived to the venerable age of 83. There is said to be a statue of him in Nancy. This may establish a connection between him and the mathematicians who are using his name, for several of them were at various times associated with the University of Nancy.

One of the legends surrounding the name is that about 25 or 30 years ago first-year students at the Ecole Normale Supérieure (where most French mathematicians get their training) were annually exposed to a lecture by a distinguished visitor named Nicolas Bourbaki, who was in fact an amateur actor disguised in a patriarchal beard, and whose lecture was a masterful piece of mathematical double-talk.

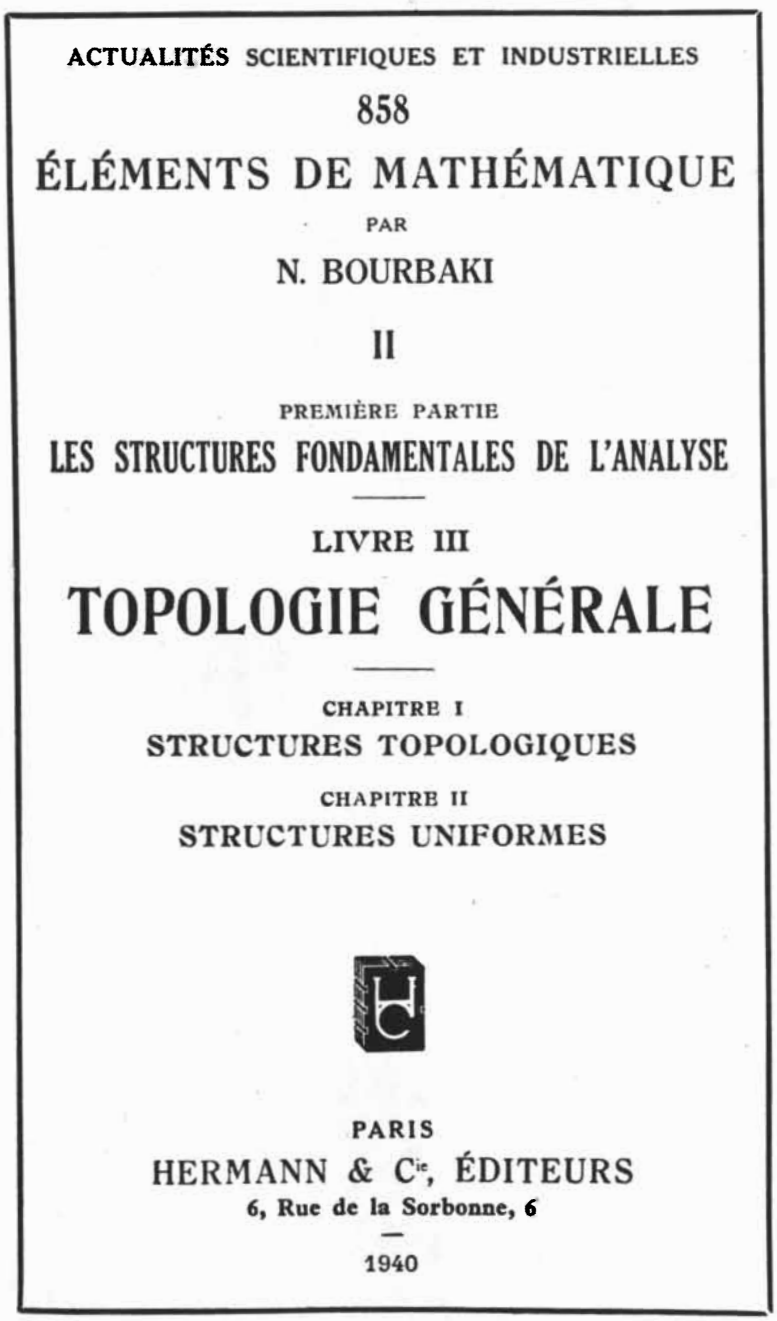
It is necessary to insert a word of warning about the unreliability of most Bourbaki stories. While the members of this cryptic organization have taken no blood oath of secrecy, most of them are so amused by their own joke that their stories about themselves are intentionally conflicting and apocryphal. Outsiders, on the other hand, are not likely to know what they are talking about: they can only report an often-embellished legend. The purpose of this article is to describe Bourbaki's scientific accomplishments and relate a few samples of the stories told about him (them). Some of the stories are unverifiable, to say the least, but that doesn't make them any less entertaining.

Scientific publication under a pseudonym is not, of course, original with this group. The English statistician William Sealy Gosset published his pioneering work on the theory of small samples under the name of "Student," probably to avoid embarrassing his employers (the brewers of Guinness). At about the time Bourbaki was starting up, another group of wags invented E. S. Pondiczery, a purported member of the Royal Institute of Poldavia. The initials (E.S.P., R.I.P.) were inspired by a projected but never-written article on extrasensory perception. Pondiczery's main work was on mathematical curiosa. His

GENERAL BOURBAKI, whose name was not Nicolas but Charles Denis Sauter, is depicted in this drawing based on an engraving. He was once offered the crown of Greece.

proudest accomplishment was the only known use of a second-degree pseudonym. Submitting a paper on the mathematical theory of big-game hunting to *The American Mathematical Monthly*, Pondiczery asked in a covering letter that he be allowed to sign it with a pseudonym, because of the obviously facetious nature of the material. The editor agreed, and the paper appeared (in 1938) under the name of H. Pétard.

Primitive tribes, and occasionally scientists, may find magic in a name. This accounts for a publication which would never have been conceived if the authors' names had been different. George Gamow and his friend Hans Bethe saw and took advantage of a wonderful opportunity when a bright young physicist with an unusual name appeared on the scene. On April 1, 1948, they published in *The Physical Review* a perfectly straight-faced paper on the origin of chemical elements whose only unusual


ACTUALITÉS SCIENTIFIQUES ET INDUSTRIELLES

858

ÉLÉMENTS DE MATHÉMATIQUE

PAR

N. BOURBAKI

II

PREMIÈRE PARTIE

LES STRUCTURES FONDAMENTALES DE L'ANALYSE

LIVRE III

TOPOLOGIE GÉNÉRALE

CHAPITRE I

STRUCTURES TOPOLOGIQUES

CHAPITRE II

STRUCTURES UNIFORMES

PARIS

HERMANN & Cie, ÉDITEURS

6, Rue de la Sorbonne, 6

1940

PAPER-BACKED BOOK, of which this is both the title page and the cover, is only a part of Book III of Part I of the Bourbaki treatise. Book III is entitled *General Topology*.

feature was the by-line. It read, of course, Alpher, Bethe and Gamow.

While we are on the subject of articles appearing under strange names, it is appropriate to mention the case of Maurice de Duffahel. This gentleman achieved mathematical immortality by the very simple device of publishing, under his own name, some of the classical papers of the great masters. He made only the feeblest attempt to disguise his activities. In 1936 he republished as his own a paper which had been published only 24 years earlier by Charles Emile Picard. Duffahel's version was identical with Picard's, word for word, symbol for symbol, except for one omission: he left out, for understandable reasons, a footnote in which Picard had referred to one of his earlier papers. Scholarship eventually caught up with Duffahel. You can fool some editors some of the time, but you can't fool all reviewers all of the time. A reviewer of the Picard-Duffahel paper happened to know the works of Picard well enough to recognize the repetition, and Duffahel's publishing career came to an abrupt end.

The works of Bourbaki do not have to be concealed from the executives of a brewery, they are not mere innocent merriment but serious mathematics, and they are definitely not plagiarized from anyone else. The group originally adopted the pseudonym half in jest and half to avoid a boringly long list of authors on the title page; they continue its use more as a corporate name than as a disguise. The names of the members are an open secret to most mathematicians. The membership of Bourbaki, like that of most corporations, changes from time to time, but the style and the spirit of the work stay the same. It is handy to be able to describe a certain style and spirit by one adjective (the accepted term is *Bourbachique*) rather than by a reference to the "young French school" or a similar circumlocution.

Bourbaki's first appearance on the scene was in the middle 1930s, when they began to publish notes, reviews and other papers in the *Comptes Rendus* of the French Academy of Sciences and elsewhere. The major treatise on which they later embarked was explained in a paper which was translated into English and printed (in 1950) in *The American Mathematical Monthly* under the title "The Architecture of Mathematics." A footnote reads: "Professor N. Bourbaki, formerly of the Royal Poldavian Academy [shades of Pondiczery!], now residing in Nancy, France, is the author of a comprehensive treatise

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of modern mathematics, in course of publication under the title *Eléments de Mathématique* (Hermann et Cie., Paris, 1939–), of which 10 volumes have appeared so far." The paper, by the way, is an interesting statement of Bourbaki's view of the concept of "structure" in mathematics; it is a masterful description of the Bourbaki spirit. Another paper, which appeared in *The Journal of Symbolic Logic* for 1949, has the ambitious title "Foundations of Mathematics for the Working Mathematician." It is quite technical, but the authors' personality shows through the symbolism. It concludes: "On these foundations I state that I can build up the whole of the mathematics of the present day; and if there is anything original in my procedure, it lies solely in the fact that, instead of being content with such a statement, I proceed to prove it in the same way as Diogenes proved the existence of motion; and my proof will become more and more complete as my treatise grows."

This paper gives the author's home institution as the "University of Nancago" (Nancy plus Chicago). The main reason for the combination is that one of the founding fathers is now on the staff of the University of Chicago. His name is André Weil (and he is, by the way, the brother of the well-known religious mystic Simone Weil). Although André Weil is not known to the general public, many of his colleagues are prepared to argue that he is the world's greatest living mathematician. His work on algebraic number theory and algebraic geometry is profound and important; his influence on the development of 20th-century mathematics is great, and even some of his more offhand contributions (for example, uniform structures and harmonic analysis on topological groups) have opened up new directions and inspired further researches. Nancago, incidentally, crops up again in a new series of advanced mathematical books which is being published under the impressive heading *Publications de l'Institut Mathématique de l'Université de Nancago.*

S-CURVE in the Bourbaki treatise indicates a "dangerous turn" in the argument.

According to one of the Bourbaki legends, their major work, whose general title is *Elements of Mathematics*, owes its origin to a conversation between Weil and Jean Delsarte on how calculus should be taught. Whatever the motivation of the work may originally have been, its present purpose is certainly not elementary pedagogy. It is as if a discussion of the best way to teach an understanding of popular music gave rise to a complete treatise on harmony and musicology. (Mathematicians consider the calculus to be as "trivial" as musicians consider the music of Victor Herbert.) Bourbaki's treatise (written in French) is a survey of all mathematics from a sophisticated point of view.

The whole will presumably consist of several parts, but the 20 volumes that have appeared so far do not even complete Part I, titled *The Fundamental Structures of Analysis.* The names of the six subdivisions of Part I are a mild shock to the layman (or the classical mathematician) who thinks of mathematics in terms of arithmetic, geometry and other such old-fashioned words. They are: (1) Set Theory, (2) Algebra, (3) General Topology, (4) Functions of a Real Variable, (5) Topological Vector Spaces and (6) Integration.

Each volume comes provided with a loose insert of four pages constituting a set of directions on the proper use of the treatise. They go into detail about the necessary prerequisites for reading the treatise (about two years of university mathematics), describe the organization of the work and specify the "rigorously fixed logical order" in which the chapters, books and parts must be read. The directions also explain the authors' pedagogical tricks, and some of them are very good tricks indeed. One trick, which other authors could profitably copy, is to warn the reader whenever the subject becomes especially slippery, that is, when he is likely to fall into an error: the slippery passages are flagged by a conspicuous S-curve ("dangerous turn") in the margin.

A less admirable Bourbachique trick is their slightly contemptuous attitude toward the substitution of what they call "abuses of language" for technical terms. It is generally admitted that strict adherence to rigorously correct terminology is likely to end in being pedantic and unreadable. This is especially true of Bourbaki, because their terminology and symbolism are frequently at variance with commonly accepted usage. The amusing fact is that

often the "abuse of language" which they employ as an "informal" replacement for a technical term is actually conventional usage: weary of trying to remember their own innovation, the authors slip comfortably into the terminology of the rest of the mathematical world.

Almost every Bourbaki volume contains an excellent set of exercises. Mathematics cannot be learned passively, and the Bourbaki exercises are a challenge to activity. The authors used a lot of ingenuity in inventing new exercises, and in rephrasing and rearranging old ones. As a matter of policy they usually do not give credit to the original authors of the exercises they have revised, but no one seems to mind. A mathematician is even likely to consider it an honor to have one of his papers "stolen" by Bourbaki and used as an exercise.

The Bourbaki gadgetry includes fold-out sheets that summarize important definitions and assumptions, a dictionary for each book that serves also as a comprehensive index and a guide to both non-Bourbachique terminology and basic Bourbakese. The only important thing missing is adequate bibliographical guidance. The Bourbaki presentation of each subject is systematic and thorough, and often includes a brilliant historical review of the subject. But the historical essays make only a few grudging references to the classics and fail almost entirely to mention the sources of the modern contributions. No deception is intended (Bourbaki does not claim to have discovered all of modern mathematics), but the practice may have the effect of confusing the future mathematical historian.

These are the external trappings of Bourbaki. The Bourbaki style and spirit, the qualities that attract friends and repel enemies, are harder to describe. Like the qualities of music, they must be felt rather than understood.

One of the things that attracted students to Bourbaki from the start was that they gave the first systematic account of some subjects (for example, general topology and multilinear algebra) which were not available anywhere else in book form. Bourbaki pioneered in reducing to orderly form a large mass of papers which had appeared over several decades in many journals and in several languages. The main features of the Bourbaki approach are a radical attitude about the right order for doing things, a dogmatic insistence on a privately invented terminology, a clean and economical organization of ideas and a style of presentation which is so bent on saying everything that it leaves nothing to the imagination and has, consequently, a watery, lukewarm effect.

A typical sample of the thoroughness and leisurely pace of the Bourbaki treatment is their approach to defining the number "1." They devote almost 200 pages to preparation before they get to the definition itself. They then define the number 1 in terms of highly condensed abbreviating symbols, explaining in a footnote that the unabbreviated form of the definition in their system of notation would require several tens of thousands of symbols. In all fairness to Bourbaki it must be said that modern mathematical logicians have known for some time that concepts such as the number 1 are not so elementary as they look.

How does a cooperative work of this magnitude ever get written? A large part of the credit goes to Jean Dieudonné (originally from Nancy, now at Northwestern University) who has been Bourbaki's chief scribe almost from the beginning. Since Dieudonné is a prolific writer on mathematics under his own name, there is a certain difficulty about distinguishing his private work from his efforts for Bourbaki. According to one story, he manages to keep the record straight in a truly remarkable manner. The story is that Dieudonné once published, under Bourbaki's name, a note which later was found to contain a mistake. The mistake was corrected in a paper entitled "On an Error of M. Bourbaki" and signed Jean Dieudonné.

The membership of Bourbaki seems to vary between 10 and 20. With one conspicuous exception all the members have always been French. The exception is Samuel Eilenberg (originally from Warsaw, now at Columbia University). Known to the friends of his youth as S^2P^2 (for Smart Sammy the Polish Prodigy), Eilenberg is a charming extrovert who learned more about the U. S. within six months of his arrival than most Americans ever find out. (One of the first things he did was to go on an extended hitchhiking tour.) Since he speaks French like a native and knows more about algebraic topology than any Frenchman, the unwritten rule restricting Bourbaki to Frenchmen was waived to admit him.

The French orientation of Bourbaki is not mere chauvinism but a linguistic necessity (since Frenchmen started it). When a collection of prima donnas such as Weil, Dieudonné, Claude Chevallier and Henri Cartan get together with their colleagues, the rate and volume of the flow of French is impressive. To follow

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and take part in the conversation under such circumstances you must not only speak French fast and loud, but you must know the latest Parisian student slang. Even if everyone in the room fulfills these conditions, it is difficult to see how any work ever gets done at the famous Bourbaki congresses. But it does get done. The members convene each year, usually in some pleasant French vacation spot, to make major policy decisions. Since their treatise has proved a commercial success (to Bourbaki's considerable surprise), there is ample royalty money to pay travel expenses and to provide the French food and wines that lubricate the proceedings. (The commercial success, by the way, is due mainly to the American market. Four of the five senior members of Bourbaki are now residents in the U. S.)

A lot of work goes into the preparation of a Bourbaki volume. Once a particular project has been decided on, some member agrees to write the first draft. In so doing he gets himself in for a trying experience. When his draft is finished, it is duplicated and copies are sent around to the others. At the next congress the draft is mercilessly criticized, and, quite possibly, completely rejected. The first draft of the Bourbaki book on integration, for instance, was written by Dieudonné and became known as "Dieudonné's monster." Rumor has it that in spirit and content Dieudonné's monster was very similar to a well-known American book on the subject, written by an author whose name we shall simply give here as Blank. Dieudonné's monster was never published; his confreres hooted it down. What settled the matter was Weil's snort: "If we're going to do that sort of thing, let's just translate Blank's book into French and have done with it."

After the first draft has been dealt with, a second draft is begun, possibly by a different member. The process goes on and on: six or seven drafts are not unknown. The result of this painstaking work is not a textbook that it is safe to put into a beginner's hands (even Bourbaki admit that), but it is a reference book, almost an encyclopedia, without which 20th-century mathematics would be, for better or for worse, quite different from what it is.

Bourbaki's youthful exuberance augurs well for the future of their labors, but it is one of the main annoyances to their enemies. The officials of the American Mathematical Society were not amused when they received an application for membership signed N. Bourbaki. They considered the joke sophomoric,

Nevins shoal-draft 40-foot yawl, "Series A," cut away to show a few of the many places Anaconda marine metals are used in building a fine boat. Designed by Sparkman & Stephens, N. Y. Built by Nevins Yacht Yard, City Island, N. Y.

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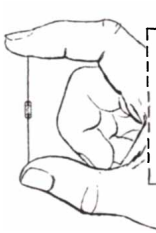

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and they rejected the application. The secretary of the Society coldly suggested that Bourbaki might apply for an institutional membership. Since the dues for institutional membership are substantially higher than those for individuals, and since Bourbaki did not wish to admit that he does not exist, nothing more was heard of the matter.

Yes, the joke may be sophomoric, but sophomores are young, and mathematics is a young man's profession. Bourbaki's emphasis on youth is laudable. Upon reaching the age of 50 recently, Dieudonné and Weil, though founding fathers of Bourbaki, announced their retirement from the group. They had declared their intention to get out at 50, and they kept their promise.

It is appropriate to conclude by warning the reader to be on the lookout for Bourbaki-inspired rumors about the author of this article, and to be prepared to take such rumors with a generous grain of salt. The corporation does not like to have its secrets told in public, and it has demonstrated its ability to take effective measures against informers. To be sure, the fiction has been exposed in print before this. In 1949 André Delachet, in his little book on mathematical analysis, referred to the "polycephalic mathematician" N. Bourbaki, and went so far as to mention some of the heads by name. A year or two before that, the *Book of the Year* of the *Encyclopaedia Britannica* had a brief paragraph about Bourbaki as a group. The author of the paragraph was Ralph P. Boas, then executive editor of the journal *Mathematical Reviews*, now a colleague of Dieudonné at Northwestern. Soon afterward the editors of the *Britannica* received an injured letter signed by N. Bourbaki, protesting against Boas's allegation of Bourbaki's nonexistence. The editors' confusion and Boas's embarrassment were not reduced when a member of the University of Chicago mathematics department wrote a truthful but shrewdly worded letter, implying, but not saying, that Bourbaki did indeed exist. The situation was cleared up for the editors by a letter from the secretary of the American Mathematical Society (the same secretary who had refused to approve Bourbaki's membership application).

Bourbaki got its revenge. Calling forth all its polycephalic, international resources, the corporation circulated a rumor that *Boas* did not exist. Boas, said Bourbaki, is the collective pseudonym of a group of young American mathematicians who act jointly as the editors of *Mathematical Reviews*.

in the **Plastics Industry**

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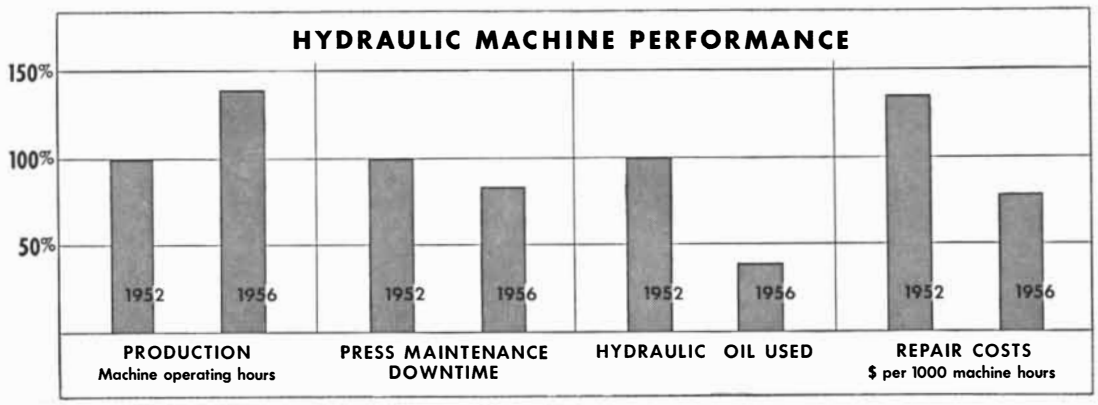
Graph shown here gives an accurate picture of results achieved for Amos Plastics through Mobil Correct Lubrication. Some ways this remarkable record was accomplished are detailed below.



Machine downtime cut — Excessive downtime of molding machines was found to be due to oil leakage and oil contamination. Mobil engineers recommended improved oil seals . . . set up periodic laboratory analyses . . . proposed annual cleaning of hydraulic systems. This cut downtime 17% . . . saved $13,800 over 1952 figures.

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These savings and many more helped Amos Molded Plastics increase profits. For information on how Mobil Correct Lubrication can cut costs, improve production, contact your Mobil representative.

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CORNING GLASS BULLETIN

FOR PEOPLE WHO MAKE THINGS

Library of Congress Catalog No. 56-12659

To those learned in the lore of libraries, this simple phrase tells a great deal. It signifies that a book has been received and categorized by the people in Washington.

The volume so designated is "*This is Glass*," a new and completely up-to-date survey of the special glasses and glass products developed by Corning research.

We suspect no usual kind of book club will offer this book as a bonus to its members. But, you can get a copy, free, just by asking us for it.

Here's what the cover looks like.

Why should you want such a book? Because within its 64 pages (sized 8½" x 11" for easy filing) you'll find words, pictures, and tables dealing with glass as a basic material of design and construction.

Sample—pages 12 and 13 tell about the following special types of glasses: Colored, Electrically-Conducting, Multiform, Fiber, Opal, Radiation-Absorbing, Cellular, Radiation-Sensitive, and Optical.

The table on pages 18-19 is devoted to data for 8 *much-in-demand* glasses. It tells of Viscosity Reference Points (working, softening, annealing, and strain); Specific Gravity; Expansion Coefficient; Young's Modulus; Electrical Properties (volume resistivity, dielectric properties); and Refractive Index.

For example, from this table you learn that PYREX brand glass No. 7740, a borosilicate glass, has an expansion coefficient of 32.5 x 10^{-7} per ° C., between 0 and 300° C.

This ability to cope with thermal change, along with immunity to most acids and alkalies, makes 7740 the top choice for diverse applications such as drainlines for waste acids; pipes for corrosive fluids; flasks for coffee (no adding to or taking *from* the taste); heat exchangers; sight glass windows; precision laboratory ware; dental sterilizer trays, humidity chambers—in fact, quite an eye-opening list.

Specifics of this nature are somewhat out of place here, except, we hope as a means of tempting you to expose yourself to the practical and profitable ways in which glass can be used.

"*This is Glass*" is a fine starting point. And it's the type of book that any number of people you know will find both fascinating and useful. Use the coupon.

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You're looking at a product that's both warming like a hearth, and heart-warming.

It's Arvin's latest entry in the small, portable put-it-where-you-want electric heater field.

We agree—small electric heaters are not exactly new. But this electric heater uses *glass* as the heating element. That's right, glass—specifically glass by Corning.

These PYREX® radiant heating panels are quite fantastic when you consider that glass normally serves as an excellent *insulator*. But such panels are covered with a permanently bonded, transparent, slightly blue, extremely thin metal oxide coating. It's the coating that carries the dielectric current and puts forth an astoundingly uniform heat.

Permanent and portable heaters are one use to which this glass has been put so far. In other applications it's proven an excellent electrostatic shield.

And turned around with the coating facing a high-heat source it acts as a reflector, bouncing away the unwanted infrared.

As we said—electrically conducting glass can be like a hearth; also heart-warming because here's a material that might just be the answer to some tricky design or engineering problem facing you.

Heavy glass for weighty problems

What can you do with glass that has a density of 6.22, lets you see through, but still is the equal of the same-thickness iron in stopping gamma radiation?

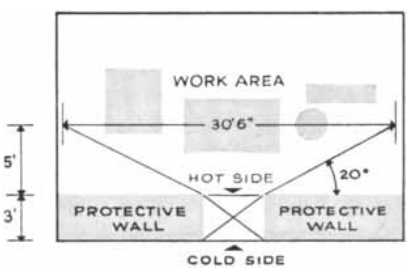
You'll be in good company if you use blocks of this optical-quality glass (along with some other special Corning varieties) to build windows for "hot labs."

These *ponderous peepholes* (that's what LIFE dubbed them) are often constructed with three unusual glasses.

Code 8362 is a nonbrowning lead glass with a density of 3.27 and is practically water-white. 8363 is straw-colored, a really heavy glass, density 6.22. And 8365, weighing in at 2.67 gm./cm.^{3}, is water-white.

In combination (especially as ready-to-install assemblies with oil "baths" between the glass layers) these windows provide protection, plus extremely good visibility.

Glass quality, plus high indices of refraction make for effectively large viewing fields, even with smaller area window on the "cold" side.



Here's a schematic of the field of view provided by a 3-foot thick, standard oil-filled assembly of Corning glass, Code 8362. A number of special glasses by Corning permit visual control plus protection from gamma radiation.

All the facts, including suggestions for radiation shielding window design, are packed into a 12-page Bulletin, PE-51. This recent addition to our literature file is titled "*Corning Radiation Shielding Windows*." One or more copies free with the coupon.

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DIFFUSION IN METALS

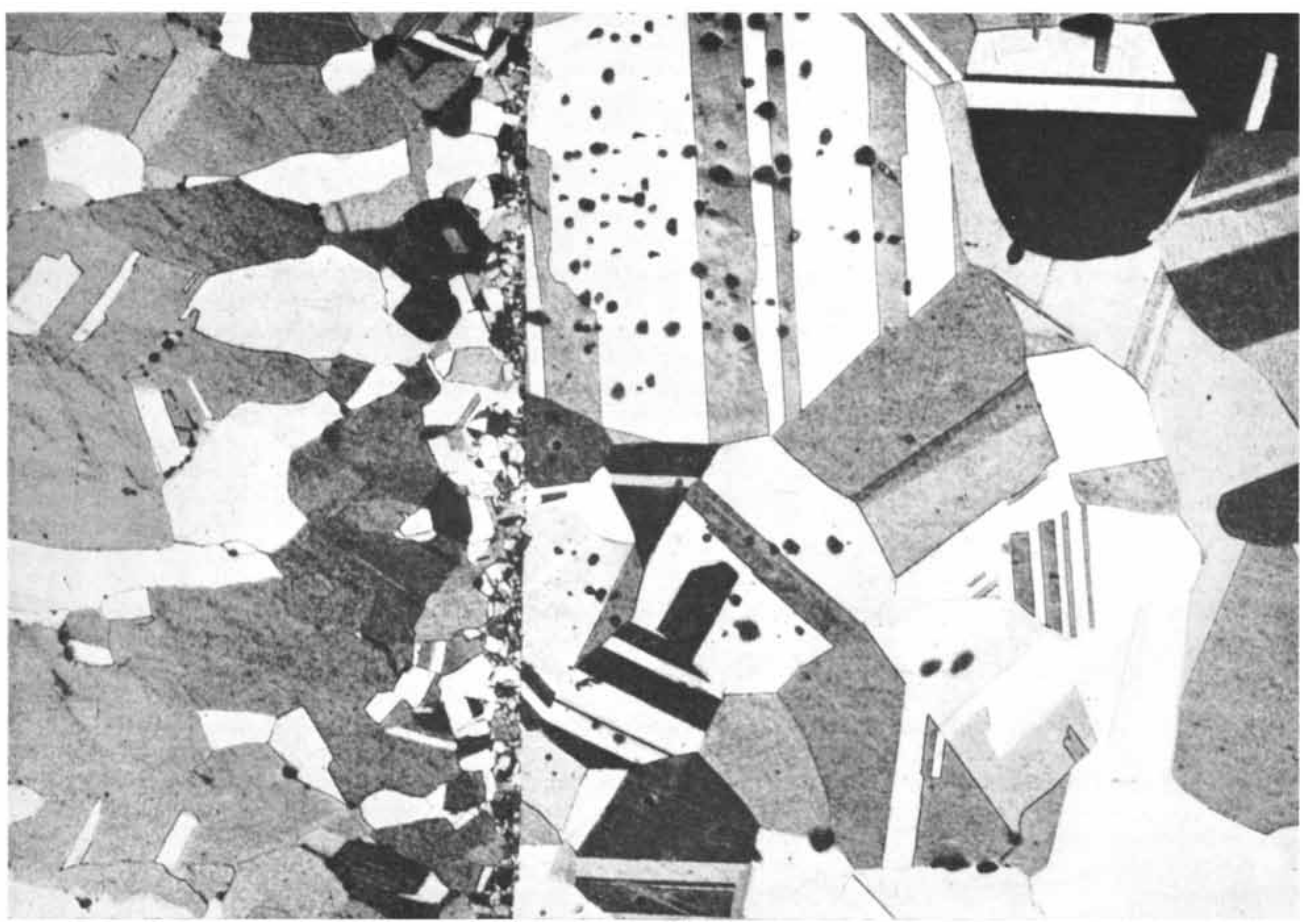
At the atomic level a metal is not as solid as it seems. Atoms, including its own, may wander through it. They may even diffuse out of one metal into another which is in close contact with it

by B. D. Cullity

The effectiveness of a lady's perfume depends, at least in part, on its scent reaching someone's nose —and the effect can be fairly far-reaching, because perfume vapor diffuses quite easily through the air. Likewise in the liquid case a drop of liquid dye readily diffuses throughout a glass of water. But it is less easy to observe, or to understand, diffusion in a solid. By that very token, diffusion in solids affords one of the most fascinating, and useful, investigations in present-day physics.

As in many other areas, the art preceded the science. For centuries workers welded metals together and made steel by heating solid iron in contact with carbon without having much notion of the diffusion processes involved. It was not until 1896 that scientific study of the subject began.

Sir William Roberts-Austen, an English metallurgist who held the office of Chemist and Assayer of the Mint, meas-



DIFFUSION OF A METAL into another metal is depicted in this photomicrograph of a polished and etched section of two metals in close contact with each other. The metal to the right of the vertical boundary at left center is brass (an alloy of copper and zinc); the metal to the left of the boundary is copper. Zinc atoms diffuse out of the brass into the copper faster than the copper atoms move in to replace them. This creates holes (*dark spots*) in the brass. The irregular light and dark areas are the grains of the metals. The section was prepared by Mme. C. Bŭckle of the French Office National d'Etudes et de Recherches Aéronautiques.

GOLD WAS FUSED TO LEAD (*cylinder at left*) **and heated in an early diffusion experiment. The result** (*cylinder at left center*) **was that gold migrated down through the lead, and lead diffused into the gold. When the cylinder was cut into sections and analyzed, the sections at the top showed the highest concentration of gold. The curve shows how the concentration of gold decreased from the top.**

ured the diffusion of gold into lead by a simple experiment. He fused a thin disk of gold on the end of an inch-long cylinder of pure lead, put the cylinder in a furnace at 200 degrees centigrade and kept it there for 10 days. He then sliced up the cylinder in thin sections and measured the amount of gold that had diffused into each successive slice of lead. He found that a measurable amount had traveled all the way to the other end of the lead cylinder; also that lead had diffused in the opposite direction into the gold disk. Going on with his experiments, Roberts-Austen discovered that one heated metal would diffuse into another even when their surfaces were merely pressed tightly together.

In the atomic age the penetrability of solids is no longer either surprising or mysterious. We realize now that even the most rigid solid is, after all, a rather loose collection of atoms. In the crystals that compose a metal the atoms are arranged in a fixed lattice from which they are hard to displace, but no crystal lattice is perfect and fully packed. It always has some vacancies, or "holes," into which diffusing atoms can jump. Having jumped into a vacancy, an atom leaves a vacancy behind in its former place; an adjacent atom can move into this; and so, via a continual shuffling of the atoms, a given atom can migrate through the crystal [*see diagrams on page 106*].

What makes an atom jump out of its position in the lattice into a vacancy? The truth is that the atoms in the lattice are not really anchored in rigidly fixed positions. They are in continual thermal vibration around a mean or average position. The extent of this vibration can vary considerably from atom to atom and from moment to moment. Occasionally an atom tears itself loose from its position and jumps into an adjoining vacancy. This tendency of course is enormously enhanced when heat is applied, making the atoms vibrate more strongly. The rate of diffusion therefore rises very rapidly with an increase in temperature. For example, zinc diffuses in copper about 100 million million times faster at 300 degrees C. than at room temperature.

In the Roberts-Austen experiment the gold atoms, vibrating quite strenuously at 200 degrees, begin to jump into lattice vacancies (as the lead atoms do also). Ultimately, if the experiment were continued long enough, the gold atoms would be distributed uniformly throughout the cylinder, just as, if you put a few black marbles in a box full of white marbles, the black would become evenly distributed among the white if you shook the box long enough. If you think of the marbles as atoms and the shaking as akin to thermal vibration, you have a fairly accurate picture of how diffusion occurs.

The diffusion of atoms within a pure metal (called "self-diffusion") can be measured by means of radioactive tracer atoms. To measure the rate of self-diffusion in copper, say, the experimenter electroplates a small amount of a radioactive copper isotope on the end of a cylinder of ordinary copper and heats it to a constant temperature. After the lapse of a certain time to allow diffusion, he slices up the bar and measures the radioactivity of each successive slice with a Geiger counter. From this he can calculate the diffusion rate.

A metal can diffuse in a metal only by virtue of vacancies, because the atoms even of two different metals (*e.g.*, gold and lead) are of about the same order of size. But an element whose atoms are much smaller than metal atoms can squeeze between the atoms

New trends and developments for design engineers . . .

How to combat abrasion by "wearproofing" critical components with Carboloy® cemented carbides

This is what abrasion can do to a piece of steel:

FIGURE 1 — Abrasive damage caused by pivoting arm on pill press.

There is some disagreement among scientists over how the abrasion process actually works. But there is universal agreement among designers over the havoc it wreaks: it shreds, gouges, galls, pits, grinds, and cuts the surface of a material. It ruins equipment, causes excessive repairs and downtime . . . and wastes literally millions of dollars annually in almost every industry.

There is no practical way to eliminate abrasion on most applications. It occurs wherever there is friction between two materials.

There is, however, a simple way to slow down its ravages: "Wearproof" critical machine and product parts with harder, smoother materials.

The hardest materials designers have available are cemented carbides. Carboloy cemented carbides range up to 93 on the Rockwell "A" scale . . . compared to only 84 for SAE 1095 heat-treated carbon steel. Carbides can outwear steel by 10, 50, or as much as 100 to 1.

As for smoothness, cemented carbides take so fine a finish they are in widespread use as gage-blocks accurate to millionths of an inch.

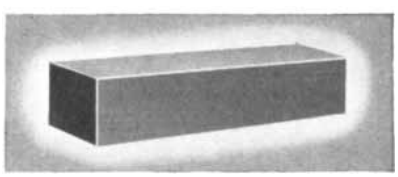


FIGURE 2 — Gage blocks made of cemented carbide. Surface finish of .0005".

This combination of extreme hardness and smoothness has lead to thousands of applications for cemented carbides throughout industry.

For example, nozzles handling abrasive liquids from centrifuges at 1200 psi (Figure 3) are made entirely of Carboloy cemented carbide. The carbide provides a service life of 8 to 12 months — twice that of the rubber-lined nozzles previously used.

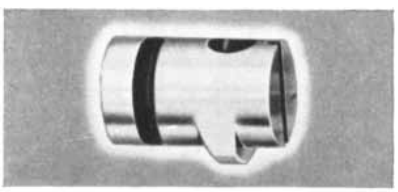


FIGURE 3 — Carbide nozzles on Merco Centrifugal Co. equipment withstand separating forces 9000 times that of gravity.

In the textile industry, carbide guides for high-speed braiders (Figure 4) wear as long as 6 years — compared to an average of 2-3 weeks for conventional hardened steel. The carbide provides more uniform finish, and easily resists the abrasive synthetic fibers.

FIGURE 4 — Carbide stop eyes for high-speed Mossberg braider.

In subsurface pumps for oil wells, Carboloy cemented carbide balls and seats (Figure 5) resist acids and abrasive sands. They outlast steel up to 20 times, and the balls maintain sphericity under the severest conditions of impact and pressure.

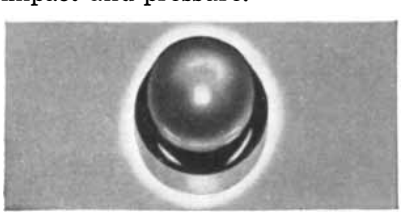


FIGURE 5 — Carbide balls and seats for oil-well pumps.

For power socket wrenches, sockets equipped with Carboloy cemented carbide inserts (Figure 6) outlast ordinary materials 15 to 20 times. The carbide stops product damage from slippage, cuts socket replacement costs.

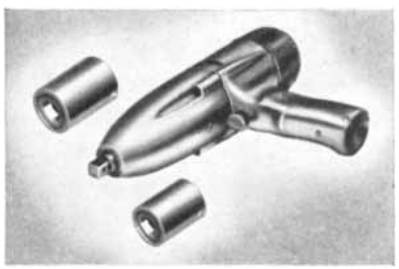


FIGURE 6 — R. J. Williams power socket wrench uses carbide inserts in sockets.

From the designer's viewpoint, one of the major advantages of carbides is their versatility.

Carbides can be produced in a broad assortment of sizes and shapes — hence there is almost no limit to their design possibilities. And they are available in a wide range of grades — hence almost any combination of physical properties can be produced.

Carbides have high compressive strength—1 to 6 times that of steel. They have tremendous resistance to twisting and deformation under load — 2½ to 3 times that of steel.

These and other unique physical properties are the reasons that carbides are now in use throughout industry, protecting valuable equipment from premature scrapping due to wear. If you have a wear problem—whether abrasion, erosion, friction, or corrosion — carbides may well be the answer.

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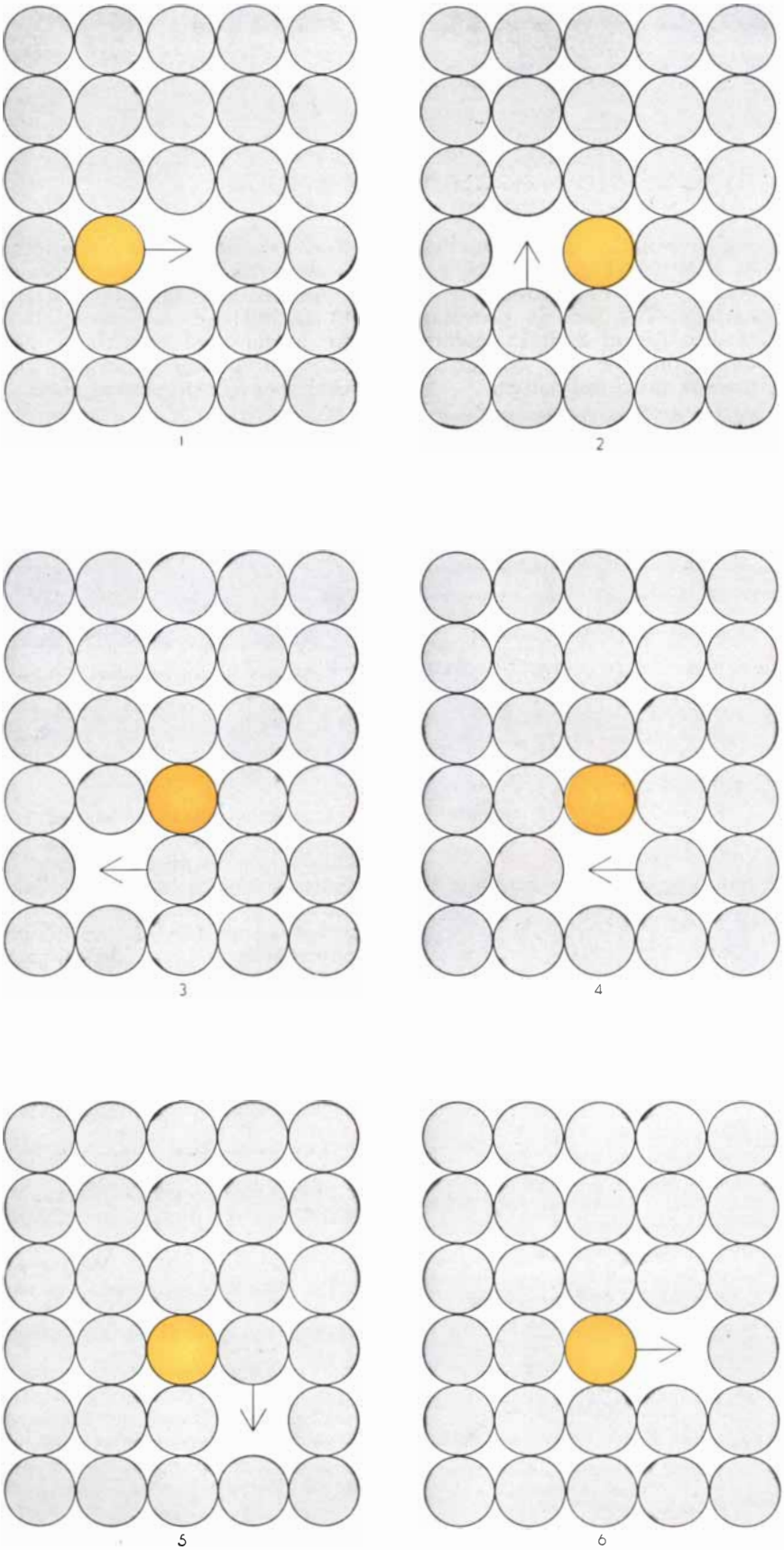


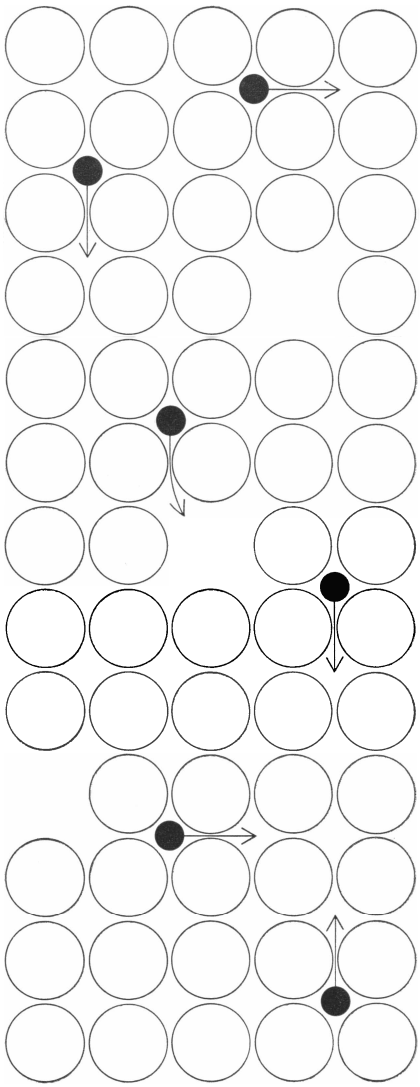
LAYER OF ATOMS IN A CRYSTAL LATTICE will have an occasional vacancy. This sequence of drawings illustrates how a gold atom may diffuse through a crystal of lead. The gold atom can progress toward the right with the help of only a single vacancy.

in a metal crystal. Diffusion then does not depend on vacancies and therefore takes place more rapidly. One of the most important examples is the diffusion of carbon in iron.

In its simplest form steel is an alloy of carbon and iron. The properties of the steel are modified by varying the proportion of carbon. A low-carbon steel (say one fourth of 1 per cent carbon) is not particularly hard but is ductile. Increasing the carbon content makes the steel harder but more brittle. A machine part, such as a gear, which needs a hard surface to resist wear and a ductile interior to stand up to sudden shocks without breaking, is given these properties by the process called case-hardening. The piece is heated to a high temperature and exposed to a carbon-bearing gas, such as methane. Carbon atoms from the gas slowly diffuse into the steel. After a few hours they have penetrated to a depth of about one twentieth of an inch. The surface, or "case," now has a carbon content of about 1.2 per cent, while the interior of the piece still has only one fourth of 1 per cent.

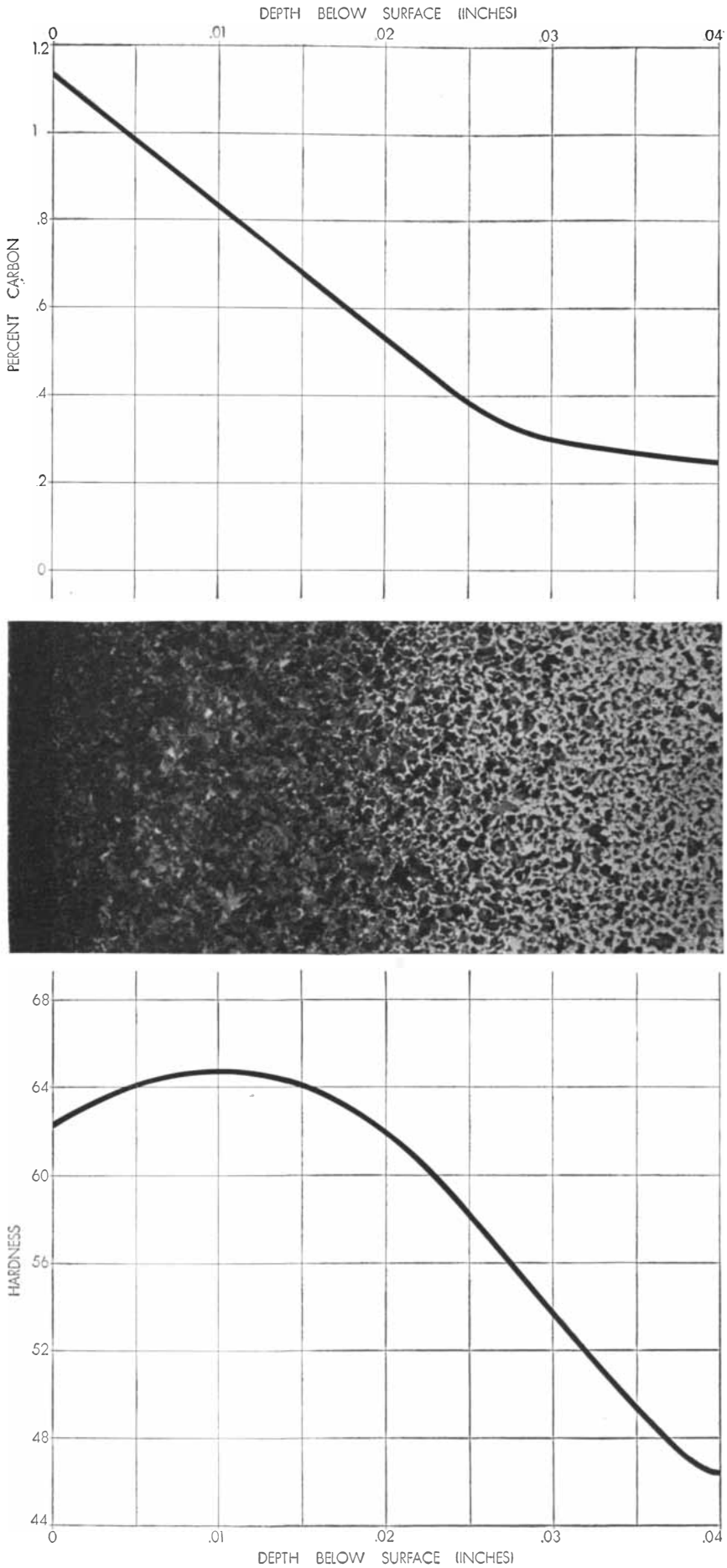
The diffusion behavior of atoms in a metal turns out to be, among other things, a tool for exploring the internal structure of the metal. Generally speaking, a piece of metal is a collection of small crystals, or "grains." The internal structure of a grain is remarkably regular—a perfect lattice except for occasional vacancies or other slight imperfections. But the grains as a group form no orderly array. They lie together in a haphazard fashion, like bricks in a heap rather than fitted together in a regular stack. Very rarely one grain may be butted flat against its neighbor so that their lattice rows match, but usually their contact is askew—the divergence is called the "angle of misfit" [*see diagram on page 110*]. In that case the boundary between two grains is a region of atomic chaos. The atoms in the boundary area between two crystals are attracted by both crystals and end up by joining neither. As a result they are loosely packed and disorganized. Hence diffusing atoms should pass along such boundaries much more rapidly than through the regular lattice of a grain itself. And indeed it is a known fact that metal atoms diffuse much faster in a fine-grained metal, which is fairly honeycombed with grain boundaries, than in one made up of large crystals.

M. R. Achter and R. Smoluchowski at the Carnegie Institute of Technology set up an experiment to see how misfit angles between grains would affect diffusion rates. They prepared a stick of



DIFFUSION OF CARBON IN IRON does not depend on the presence of vacancies. The carbon atoms (*black*) are small enough to slip between the iron atoms (*white*).

copper formed of large, rod-shaped crystals aligned in such a way that their lattice rows formed various angles [*see drawing at upper right on page 110*]. They then welded a copper-silver alloy to the end of their copper specimen and heated it to 675 degrees C. After 10 days they cut through the rod at various distances from the end and examined the sections with a microscope for evidence of diffusion of the silver. Sure enough, the silver had diffused more rapidly along the grain boundaries than through the grain interiors. More silver had traveled along some boundaries than others. Achter and Smoluchowski measured the misfit angles at the boundaries by means of X-ray diffraction and found a fairly regular relationship. When the angle was less than 20 degrees, diffusion along the grain boundary was no faster than



through the grains. Beyond 20 degrees the rate of boundary diffusion increased, up to a maximum at an angle of 45 degrees; then the rate declined again. Of course 45 degrees represents the maximum misfit, because, when a symmetrical lattice is rotated to 90 degrees (at right angles) with respect to its neighbor, the lattice rows again are lined up parallel so that the two make a perfect fit.

The discovery of the vacancy mechanism of diffusion in metals revolutionized theories in metallurgy. It was established firmly only 10 years ago by an experiment designed by E. O. Kirkendall of Wayne University. Kirkendall was testing an assumption which had been the basis of all experimental and theoretical work on diffusion since the days of Roberts-Austen. Taking it for granted that a crystal was a perfect structure, theorists had supposed that, if a certain number of atoms diffused in one direction, an equal number had to move in the opposite direction, to maintain the perfection and continuity of the crystal. But in 1942 Kirkendall, then a young instructor at Wayne, published some contrary evidence. He had been studying diffusion in brass, an alloy of copper and zinc, and his measurements forced him to the conclusion that the zinc atoms were diffusing faster than the copper ones.

Kirkendall's report was dismissed as a case of experimental error by most of those who read it. To convince the doubters he began another investigation, in collaboration with Alice D. Smigelskas. They plated a thick layer of copper on a piece of brass, enclosing fine wires of molybdenum on opposite sides of the brass core as markers to show the position of the boundary between the brass and the copper. Then they heated the specimen to a high temperature. If copper atoms diffused into the brass core as fast as zinc atoms diffused out of it, the core should maintain its original dimensions, which would be indicated by the markers remaining in their original positions. But the markers

CASE-HARDENED STEEL is the result of carbon atoms diffusing into steel. The photomicrograph in the middle shows the distribution of carbon in a piece of steel, the surface (*to the left*) of which had been exposed to a hydrocarbon gas. The curve at the top shows the percentage of carbon in relation to depth below the surface of the steel. The curve at bottom shows corresponding hardness of the steel in Rockwell numbers.

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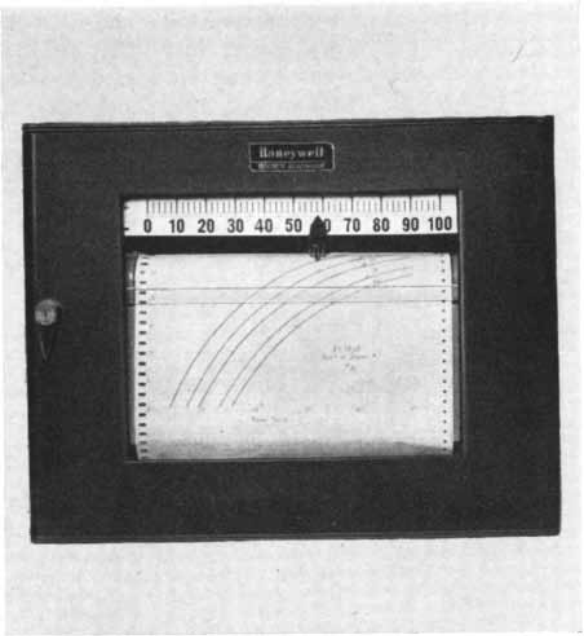

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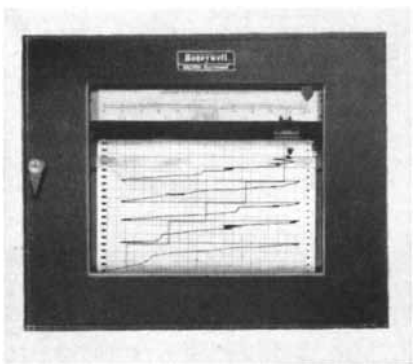

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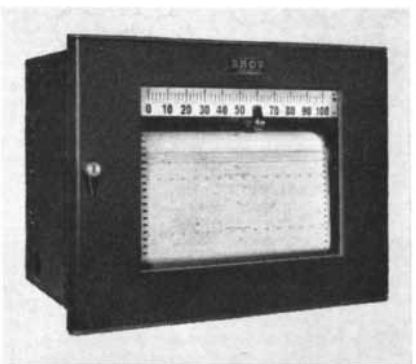

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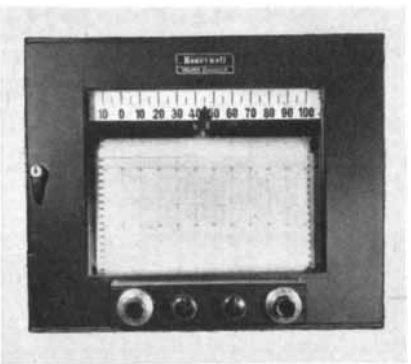

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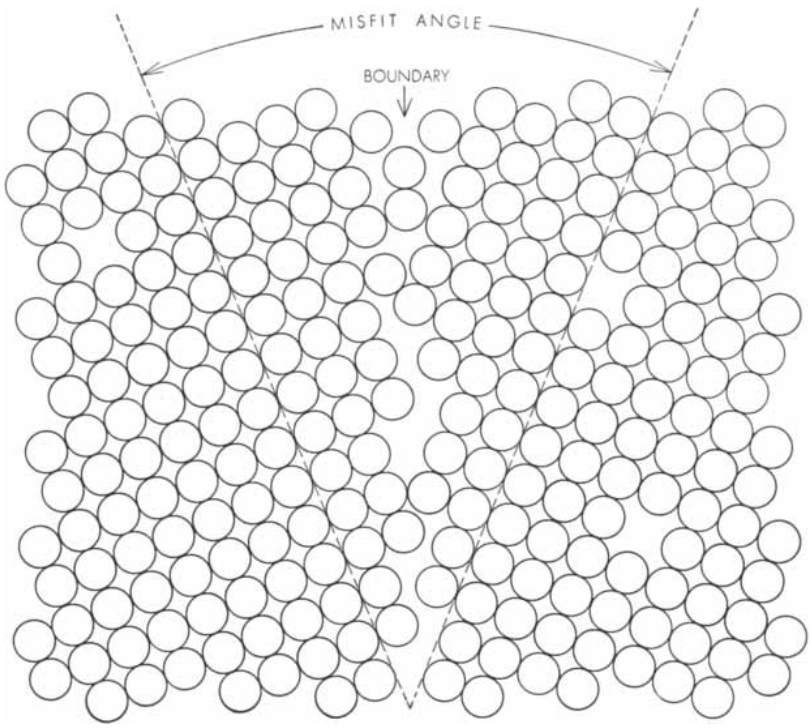
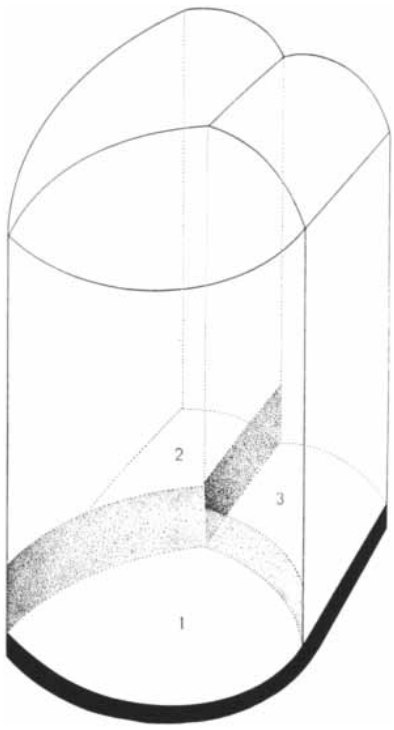
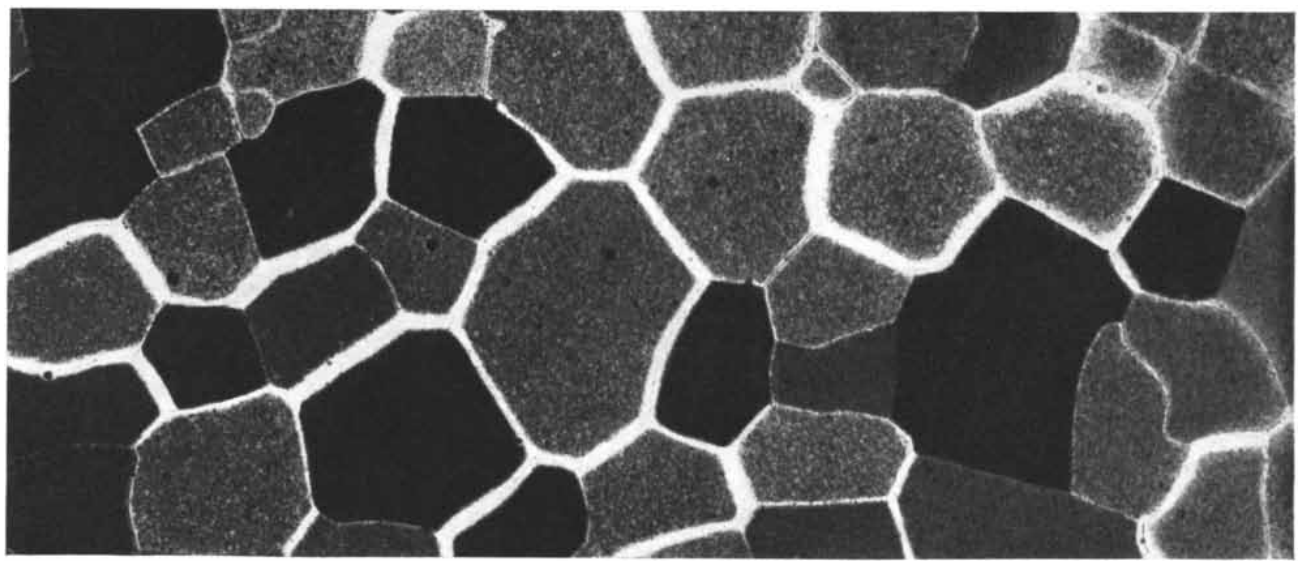
actually moved closer together. proving that the brass core was shrinking: that is, that zinc atoms were moving out faster than copper atoms were coming in. Furthermore, under the microscope one could see fairly large pores, formed by coalesced atomic vacancies left in the core by the rapid departure of the zinc atoms.

These results were published in 1947, and what has since become known as the "Kirkendall effect" immediately created a sensation among metallurgists and others interested in solid-state diffusion. Old experiments were re-examined and new ones made. Since then the Kirkendall effect has shown up in many alloys, and there is no doubt whatever about its general validity. It has established the existence of atomic vacancies more firmly than any other evidence, because that is the only possible explanation of the pores and of the observed movement of the markers.

Without doubt continued research in diffusion will not only increase our knowledge of diffusion itself but also deepen our understanding of the solid state and of all the industrial processes in which diffusion plays a major role.







BOUNDARY BETWEEN METAL GRAINS is diagrammed at upper left. When two such crystals do not fit perfectly, spaces are left between atoms at the boundary. The number of spaces depends upon the "misfit angle." Because of these holes, diffusing atoms move more readily through grain boundaries than through other parts of a metal. The diagram at upper right represents three crystals of copper welded atop a copper-silver alloy. The stippled areas indicate the penetration of silver. The misfit angle between 1 and 3 is fairly small; thus the silver has not penetrated far. It has traveled farther along the other boundaries, which have greater misfit angles. The photomicrograph at the bottom shows a section cut at right angles to the long axes of the copper grains. The lighter areas show where silver has diffused along the crystal boundaries from below. Since the silver also travels from the boundaries into the adjoining crystals, the width of each light area indicates the amount of silver diffused along that boundary.

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THE DYING OAKS

During the past 30 years a deadly fungus disease has been steadily spreading through the U. S. oak population. Fortunately the disease can be controlled, but to control it will require strong measures

by George S. Avery, Jr.

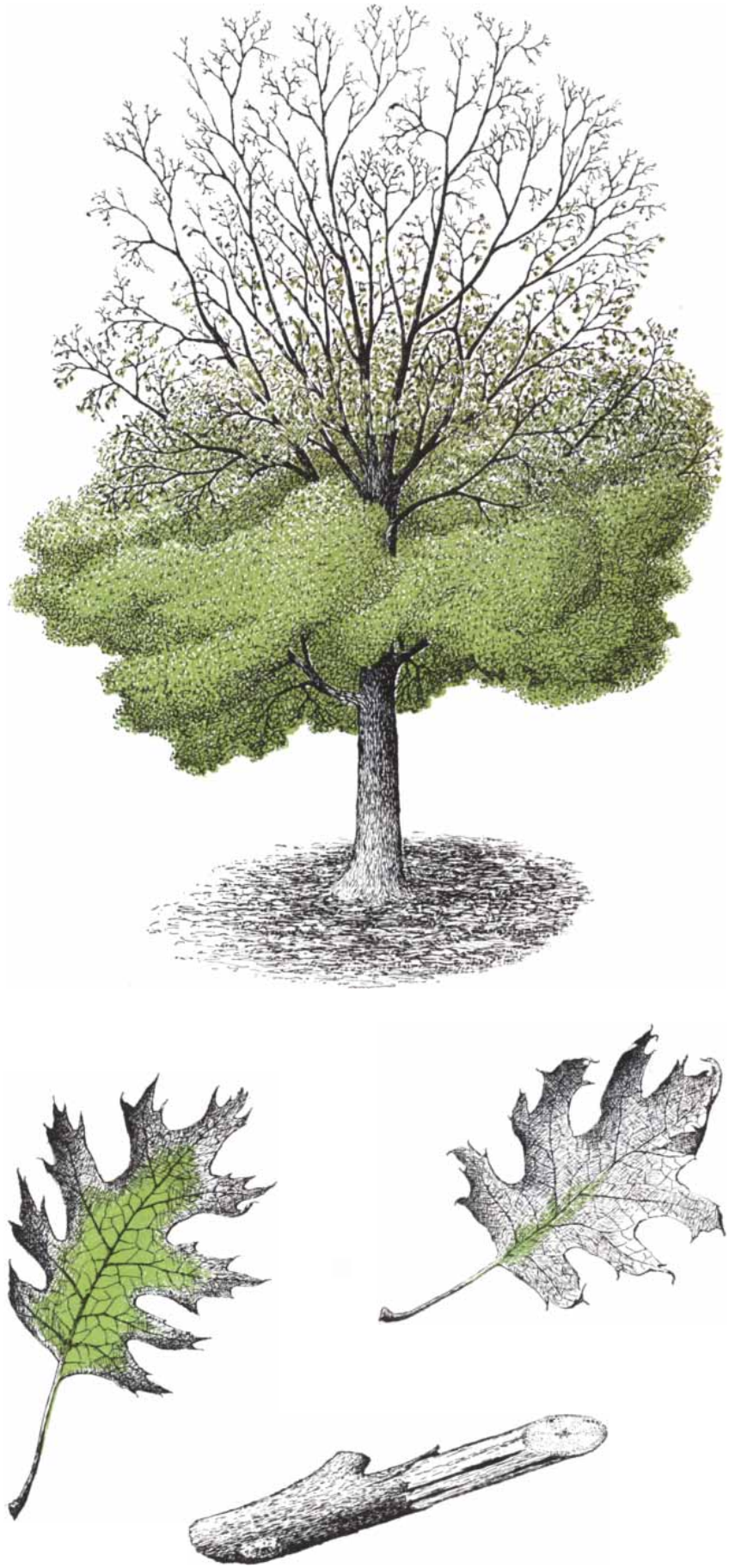
Over a wide area of the U. S. the mighty oak is in distress. The nation's best-loved tree is threatened by a creeping disease which already has taken hold in most of the Midwestern states. The disease is so leisurely and undramatic that for many years it went unnoticed. Death steals over the tree unobtrusively: its high crown begins to wilt and turn brown; the leaves gradually fall; eventually the tree stands bare and lifeless. At least 30 years ago occasional oaks began to sicken and die in this way in woodlands of Iowa, Minnesota and Wisconsin. But the disease was not definitely recognized until 1942. By then it had begun to expand alarmingly. The "oak wilt" disease has now spread to thousands of oak stands in 18 states, from Nebraska on the west to Pennsylvania in the east. To many people it is ominously reminiscent of the blight that wiped out the American chestnut a generation ago. Fortunately oak wilt seems more likely to be brought under control. But there are reasons to be uneasy.

FUNGUS of the oak wilt disease grows in a mat beneath the bark of an oak. The bark, which here has been removed to expose the mat of fungus, is cracked open by its growth.

The oak blight is incomparably more dangerous than Dutch elm disease—the only other tree-killer now widespread in the U. S. The elm gives us no useful lumber, but the oak is one of our great natural resources. It accounts for nearly one tenth of our total lumber production, and the current value of the oaks in our commercial timberlands is estimated to be more than $2 billion. For flooring alone we now use each year nearly a billion board feet of oak, worth more than $200 million. Oak is probably our most widely useful hardwood: we depend on it not only for floors but also for furniture, architectural woodwork, barrels, railroad ties and scores of other products. For some purposes—*e.g.*, bourbon-whisky barrels and, until recently, ship timbers—it has been the only acceptable wood. And the value of the oak as a noble ornamental and shade tree in the American scene is beyond all estimate.

The alarmed lumber industry, the U. S. Department of Agriculture, the several states affected, agricultural experiment stations and universities have joined forces with the National Oak Wilt Research Committee, and during the last few years many hundreds of thousands of dollars have been provided for studying and fighting the disease. Much has

TWO GROUPS OF OAKS are represented by leaves. Above are leaves of six members of the white oak group: white oak (*top left*), post oak (*top center*), burr oak (*top right*), chinquapin oak (*bottom left*), swamp white oak (*bottom center*) and chestnut oak (*bottom right*). Below are five members of the red oak group: scarlet (*top left*), black (*top right*), red (*center*), pin (*bottom left*) and shingle oak (*bottom right*). Oak wilt disease may kill red oaks in a few weeks. White oaks may survive for five years.



been learned about the cause of the disease and possible ways of combatting the infection.

Like the chestnut blight and the Dutch elm disease, oak wilt is caused by a fungus. The particular fungus responsible for the attack on the oaks has been rather difficult to classify. It is currently called *Ceratocystis fagacearum;* the species name indicates its partiality for the *Fagaceae* family, which includes oaks, chestnuts and beeches. (The *Fagaceae* family has had more than its share of sickness.) This fungus can grow in the ash, hickory, dogwood, wild cherry and other trees as hosts, but up to now it has been found to produce wilting symptoms only in the oak, certain chestnuts and the apple tree. The fungus can reproduce itself by either sexual or asexual spores. It is a hermaphrodite (*i.e.*, capable of acting either as male or female), and individual fungi can cross-fertilize one another.

The organism gets into a tree through the roots or through wounds in the trunk or branches. It spreads through the tree's system by way of the sapwood under the bark. The strands of the growing fungus and a gummy secretion clog the tree's water-conducting vessels, and this is evidently responsible for the wilting of the leaves. Leaves at the top of the tree and the ends of branches begin to wilt and turn yellow or bronze. Gradually they die and fall. The early stages of the disease usually go undetected from the ground, because the wilting crown is concealed from view by the green foliage of the lower part of the tree.

Every species of oak so far tested is susceptible to the infection. Trees of the red oak group (red, black, scarlet, shingle, chestnut and pin oaks) commonly lose all their leaves and die within a single season; red oaks may be killed in a few weeks. Even the biggest and most vigorous specimens succumb. The disease kills the tree down to its roots, so that the stump does not sprout new shoots later, as blighted chestnuts are apt to do.

The white oak group (white, post,

SYMPTOMS of the disease in the red oak are depicted at left. The leaves at the top of the tree turn yellow or bronze and litter the ground (*top*). The green of the leaf fades (*shown in two stages in middle*). When a twig of the tree is cut and peeled, there are discolored areas just beneath its bark and dark areas in its cross section (*bottom*).

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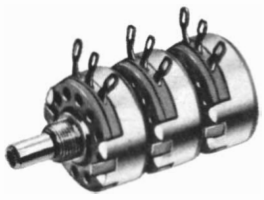

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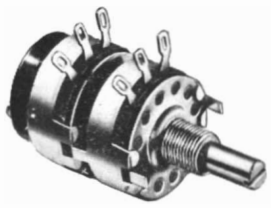

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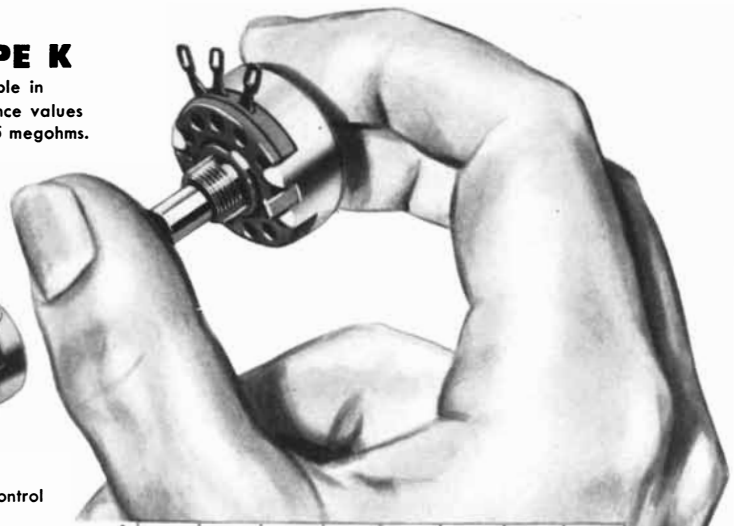

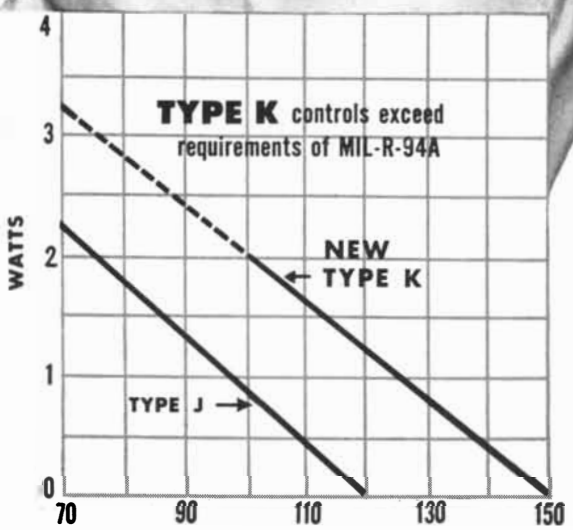

COMPARISON BETWEEN TYPE K AND TYPE J VARIABLE RESISTOR POWER RATINGS VS. AMBIENT TEMPERATURE

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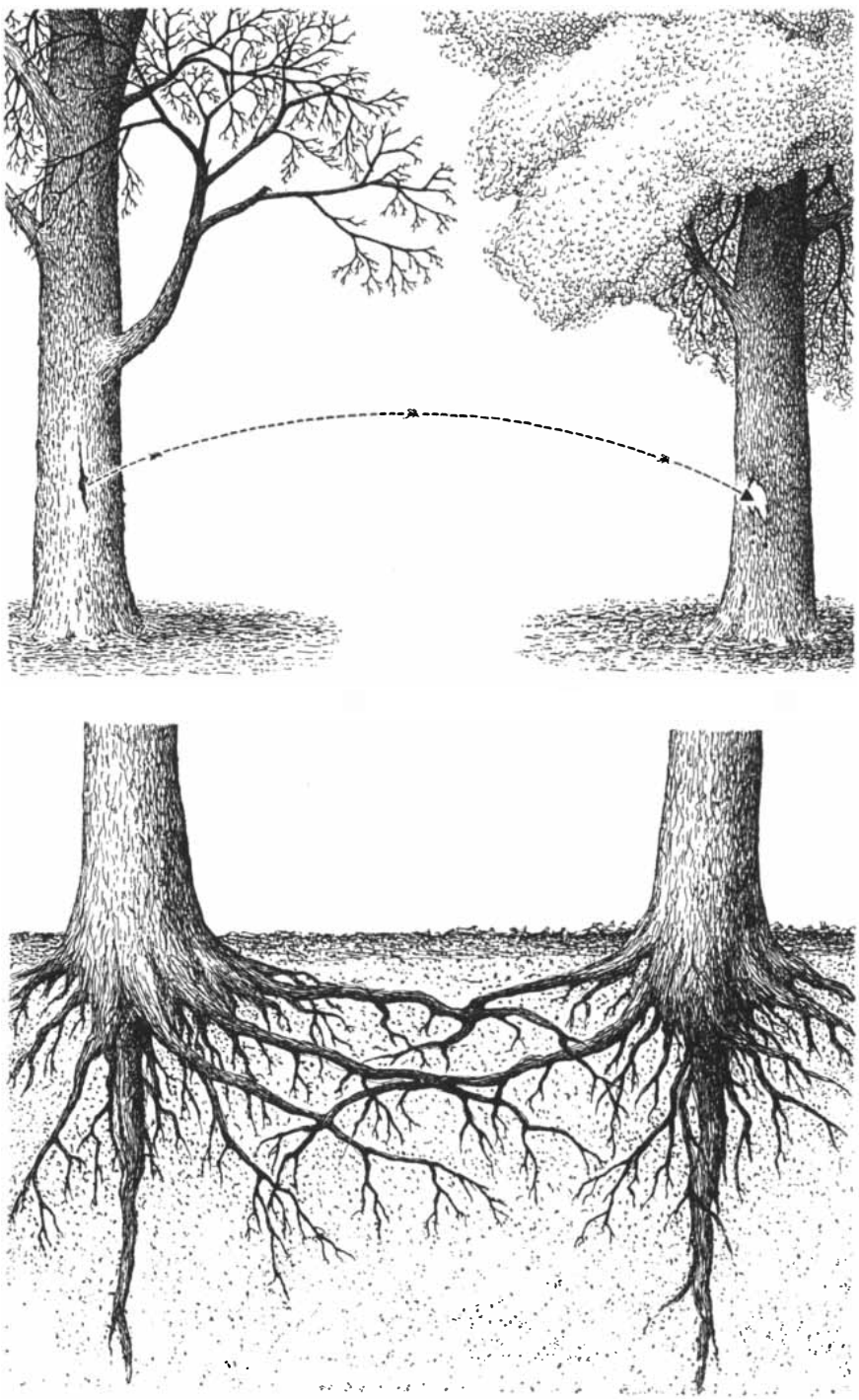
burr, swamp white and chinquapin) resist the disease longer than the red, but within five years they too generally die. Their branches expire one by one, and the dead, defoliated upper branches may stand out from the green body of the tree like the antlers of a giant stag.

How does the disease spread? One way is underground, through the roots from tree to tree. In a stand of oaks growing close together, the roots of neighboring trees become grafted to one another. The fungus can grow through the joined roots. Like ripples from a stone dropped in a pond, the infection spreads out to widening circles from a center of infection.

But the disease also jumps overland for considerable distances. Presumably insects are the chief carriers in this transmission. Several species of insect, notably certain nitidulid beetles and fruit flies, are attracted to the mats of fungus spores in diseased trees, and these insects have been found to carry the fungus internally and externally. The mats of spores grow under the bark of killed trees, mainly in the fall or spring. A single dead tree may have as many as 200 such mats, some of them as big as a man's hand. The growth of mats cracks open the bark. The beetles, attracted by the fruity odor, invade the cracks and feed on the mats. Squirrels also eat the mats; they may well carry the disease from one tree to another, and it is possible that birds also are carriers.



DISEASE IS SPREAD by contact under the ground or at a distance by air. An insect may feed on a mat of fungus in a diseased tree; if the insect then feeds on sap oozing from a spring wound in a healthy tree, it may transmit the spores of the fungus (*top*). The fungus can also be transmitted by way of roots that have become grafted together (*bottom*).

The dangerous season for spread of the disease is late spring and early summer. The sapwood is then forming, and climatic conditions are ideal for the fungus and the beetles that spread it. Tracer studies with radioactive iodine have shown that the beetles begin to be active in spreading the spores when the seasonal temperature rises to 70 degrees; the fungus itself grows best at temperatures between 65 and 75 degrees. (It does not live long in hot weather, so there is hope that the oak wilt disease will not spread to the South below Arkansas and Tennessee.)

A tree with its bark intact is protected from insect carriers; it is the trees with bleeding wounds that become infected. The insects gain entry into trees which have been pruned, torn by lightning, broken by storms, cut or blazed by lumbermen or otherwise laid open. Therefore one thing that can be done is to avoid injuring or cutting oak trees in the spring. Apparently they can be cut or pruned safely later in the summer, for trees wounded at that time have not shown evidence of infection.

Fortunately the vectors that spread the disease are not very efficient, else it might have swept over the country and killed off most of our oak forests by now. As it is, the areas of infection are scattered. Ohio has reported more than 500 centers of the oak wilt disease; Michigan more than 100; Pennsylvania about 200. Wisconsin, Illinois, Minnesota, Iowa and Missouri are heavily infested. In West Virginia 39 of the 55 counties are riddled with infection centers.

The disease can virtually wipe out an entire stand of oaks. In Iowa's Nob Hill State Park, for example, oak wilt has killed thousands of trees and almost

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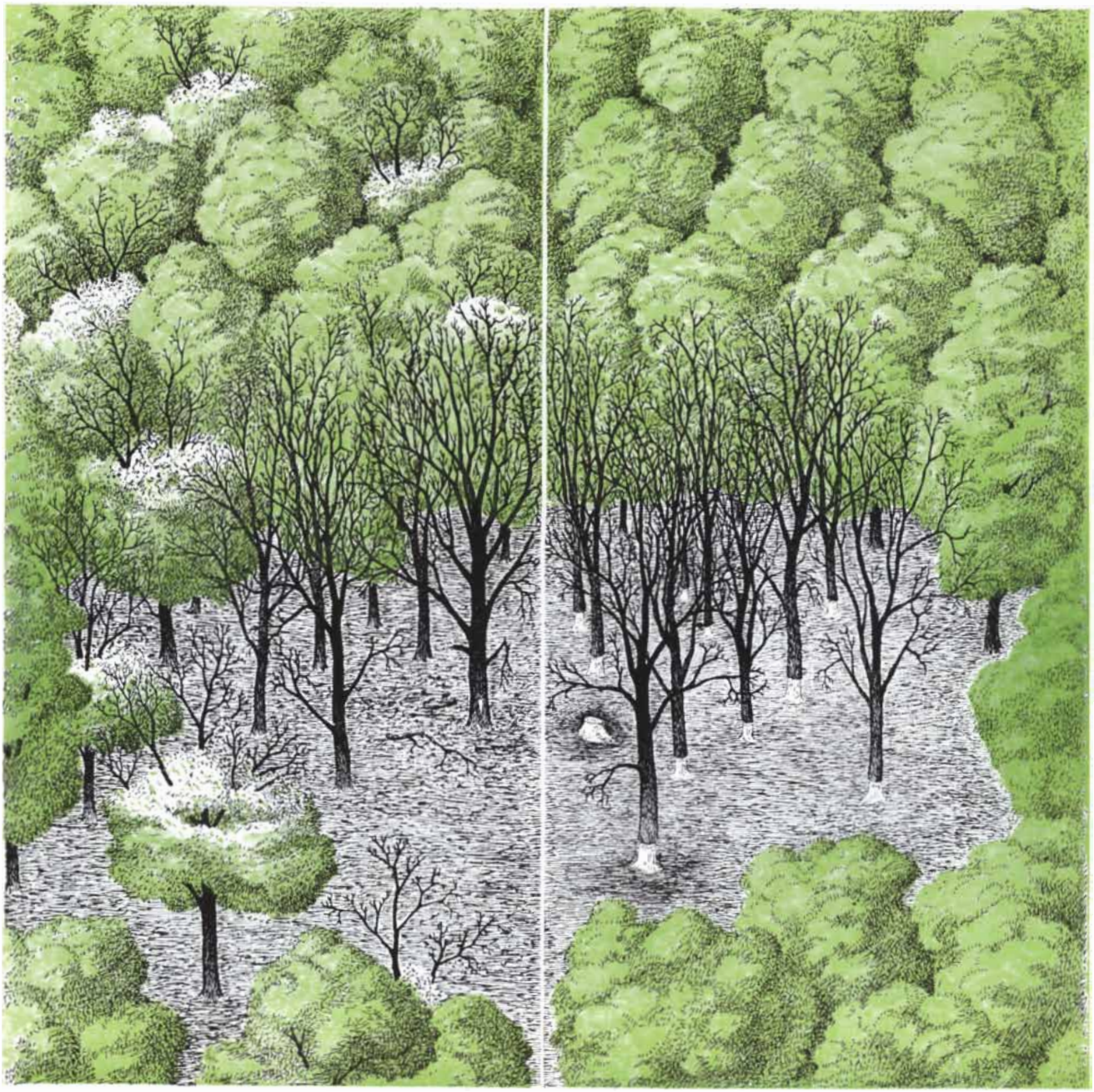

PREVENTION OF THE SPREAD of the disease is illustrated by this drawing. At left is a section of forest with a cluster of dead trees which had become infected with the disease in the preceding year. The disease has now spread to nearby trees. At right is a section of forest in which the diseased trees had been deeply girdled in the preceding year, while their leaves were still in the wilting stage. This has killed the trees but prevented the formation of fungus mats and controlled the aerial spread of the disease.

ruined the park. Once the disease has taken hold, nothing can save the infected trees.

Nevertheless the slowness of its spread has given time to take countermeasures, and the disease is being fought with a number of different methods. The first need is to spot the centers of infection at an early stage. This is difficult from the ground, as we have noted, so surveys are made by airplane to detect the browning tree crowns. Where the disease is spreading underground via the roots, steps have been taken to isolate the infection center, in some cases by cutting the roots in a circle around it with trenching machines, in others by poisoning the trees surrounding the center. The roots of infected trees must be killed, because the fungus can live on in them for at least three years. The bark, branches and twigs of killed trees should be burned immediately, but their useful lumber can be saved. If it is sawed up and kept off the ground, the fungus disappears in a matter of weeks as the wood dries. No infection can spread from the dried oak wood, and the wood itself is not damaged by the wilt disease.

For checking the overland spread of the disease, the simplest method tried so far is to girdle infected trees, cutting deep into the heartwood. This is fairly effective in preventing the formation of the spore mats on which carrier insects feed. The state of West Virginia, after an 18,000-square-mile aerial survey

Dr. Fritiof Sjostrand, Karolinska Institute, Stockholm, examining tissue magnified 30,000 times.

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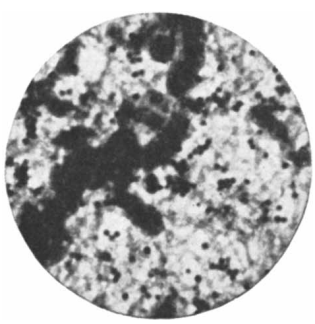

Small area of a tumor cell from a mammary gland carcinoma. Magnification 14,700X. (Courtesy Rockefeller Institute, New York, N.Y.)

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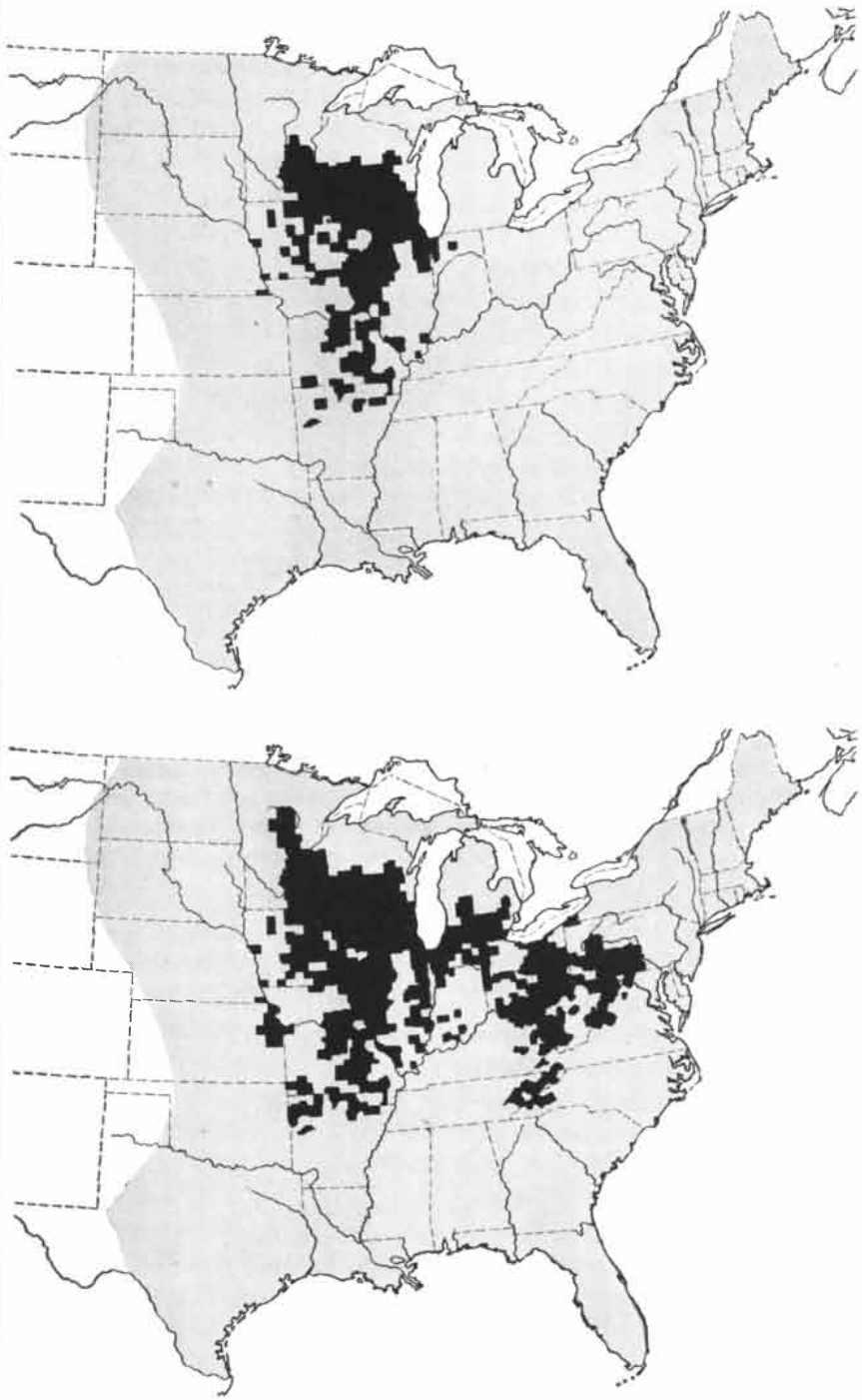
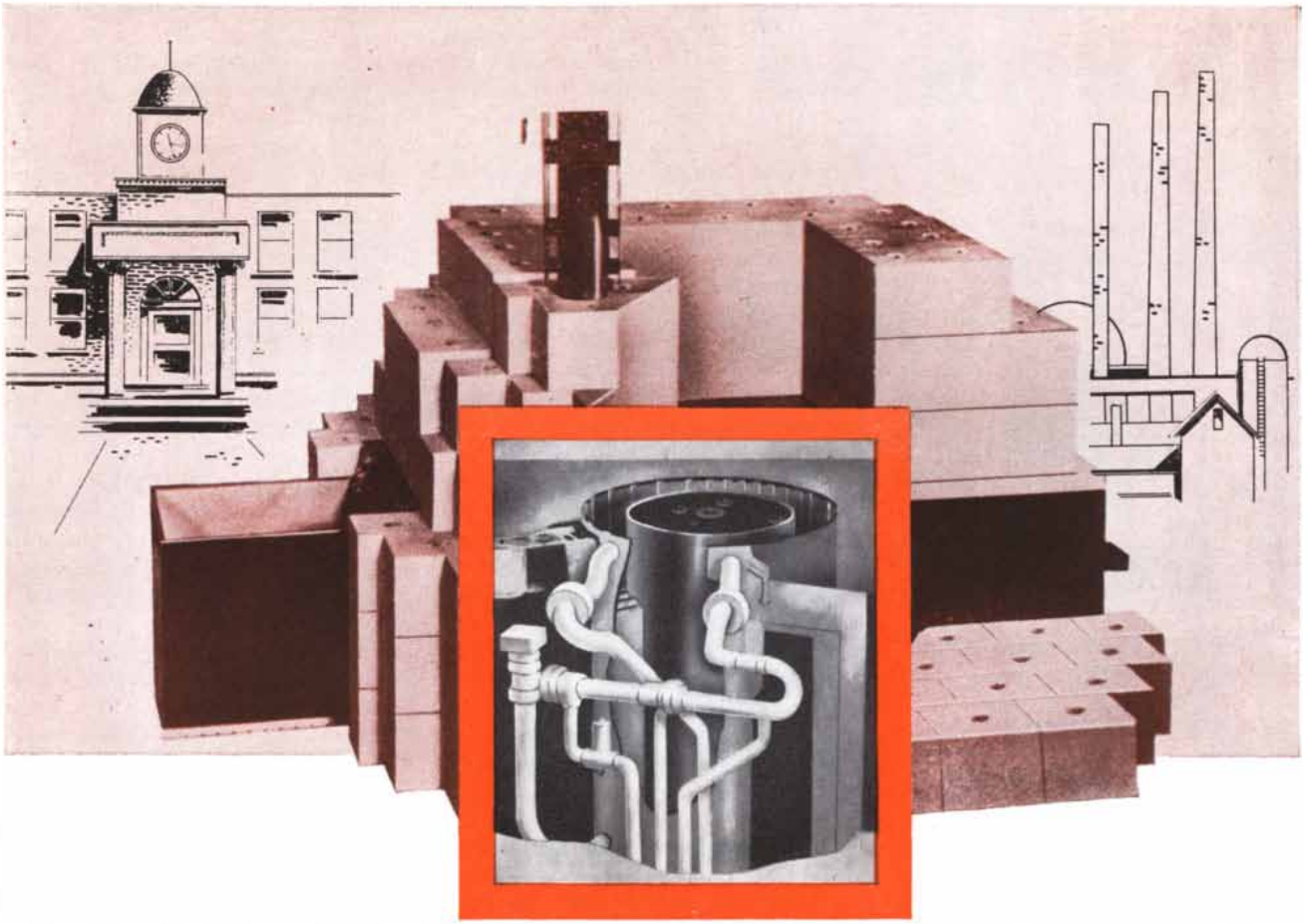
which located 912 centers of infection, last year girdled 1,176 wilting oak trees for that purpose.

Certain antibiotics have shown some effectiveness against the oak wilt fungus in experiments. But such treatment is expensive, and at present impracticable on any large scale, although we may be on the threshold of a major advance in attacking tree diseases with antibiotics [see "Antibiotics against Plant Diseases," by David Pramer; SCIENTIFIC AMERICAN, June, 1955].

Epidemics in the plant world are a totally different problem from those in the human population. As the oak wilt makes so clear, thousands of trees over thousands of square miles may have a disease for years before anyone is seriously aware of it. When the epidemic is discovered, treatment has to be carried to the trees: a sick tree cannot come to



COUNTIES REPORTING THE DISEASE in 1950 are shown in black at the top; counties reporting the disease in 1954, at bottom. Oaks subject to the disease grow in the gray area.



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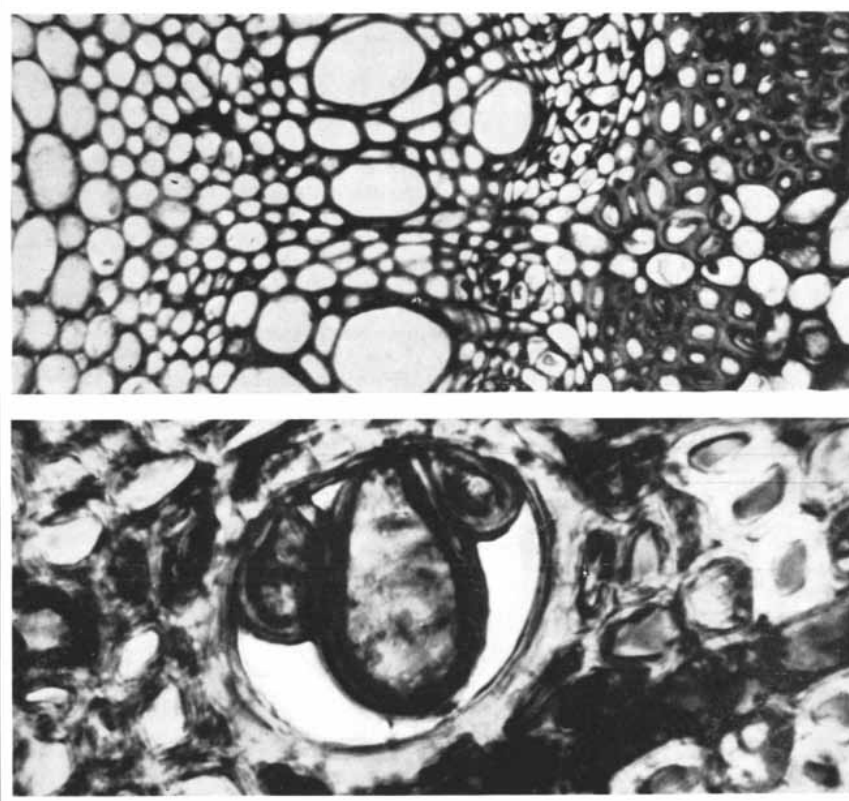
the doctor's office. A plant does not develop immunity against infection, nor can it be given artificial immunity by vaccination or inoculation. And no one would propose spending as much money to save trees as to save human life. Given a virulent and widely distributed plague in the tree world, the odds for successful control are little better than for the human plagues that swept Europe before the era of modern medicine.

Nevertheless, plant pathologists do not expect the oaks of the U. S. to meet the fate of the chestnut. With sanitation methods (*e.g.*, burning diseased trees), and with cooperation from timbermen and homeowners, they believe oak wilt can be brought under control. (The National Oak Wilt Research Committee urges that suspected trees be reported promptly to state experiment stations.) Most pathologists doubt that the disease could be eradicated, but they are inclined to be confident that it can be reduced from a menace to a nuisance. However, active and widespread measures must be taken if we are not to lose most of our oak trees during the coming century.

The devastation wrought by a killer like chestnut blight or oak wilt raises the interesting philosophical question whether disease can completely wipe out a species of plant or animal. Biologists have long held it to be an axiom that no species is ever destroyed by disease alone. Actually this is an unproved theory, and one may ask: What happened to the many organisms of the past that are now extinct? Were they *all* wiped out by cataclysms such as glaciers or revolutionary changes in the environment? A biologist, defending the tenacity of life against disease, points to the fact that a disease, however virulent, always leaves some survivors. There are always individuals that somehow remain immune to almost any scourge. And indeed some oaks have shown a degree of immunity to oak wilt.

Even the deadly chestnut blight did not completely destroy the American chestnut. The moribund tree is making a valiant effort to live on as a species. Sucker trees continue to grow from stumps long dead, and as the suckers die, new ones come up in their place. The root systems have held tenaciously to life. Year by year enough shoots rise into the sunlight to supply the roots with enough food to keep them alive. Sooner or later, in the great tradition of living things, a disease-resistant mutation should emerge and restore the chestnut to its former stature.



STALK OF A HEALTHY LEAF of the pin oak is shown in cross section in the photomicrograph at top. At bottom a water-conducting cell in the stalk of a wilted leaf is obstructed. The photomicrographs are by B. Esther Struckmeyer of the University of Wisconsin.

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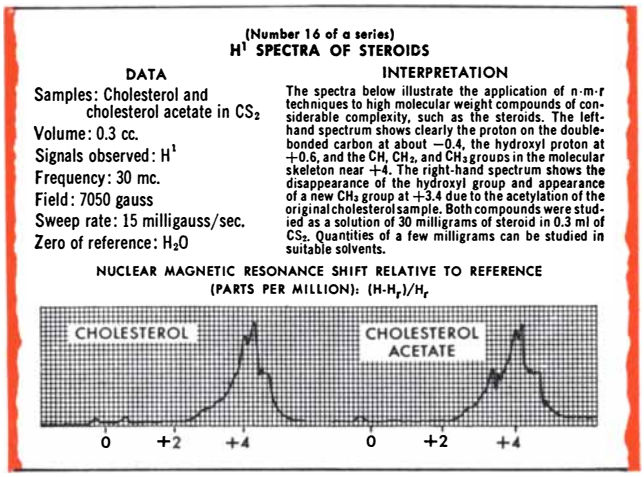

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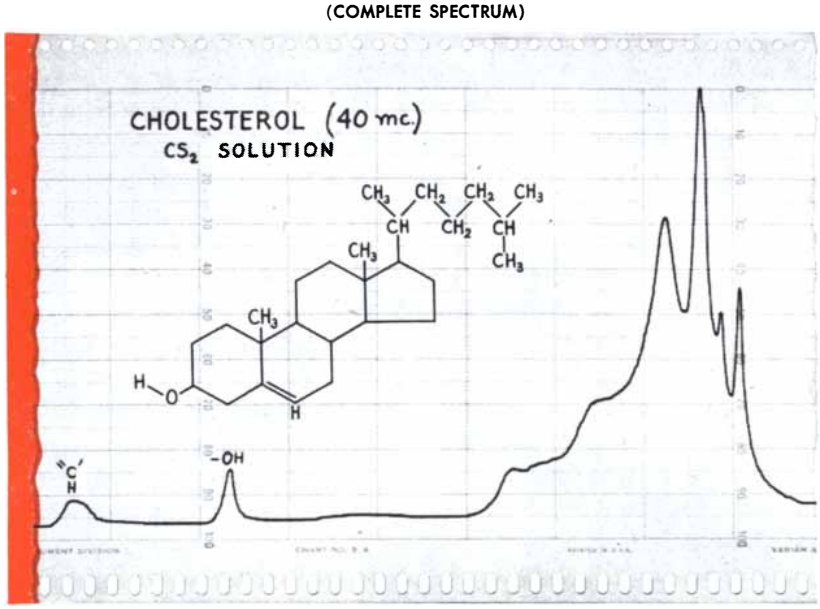
(COMPLETE SPECTRUM)



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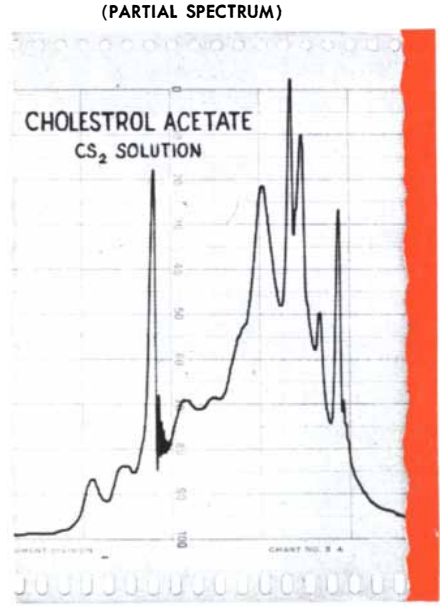

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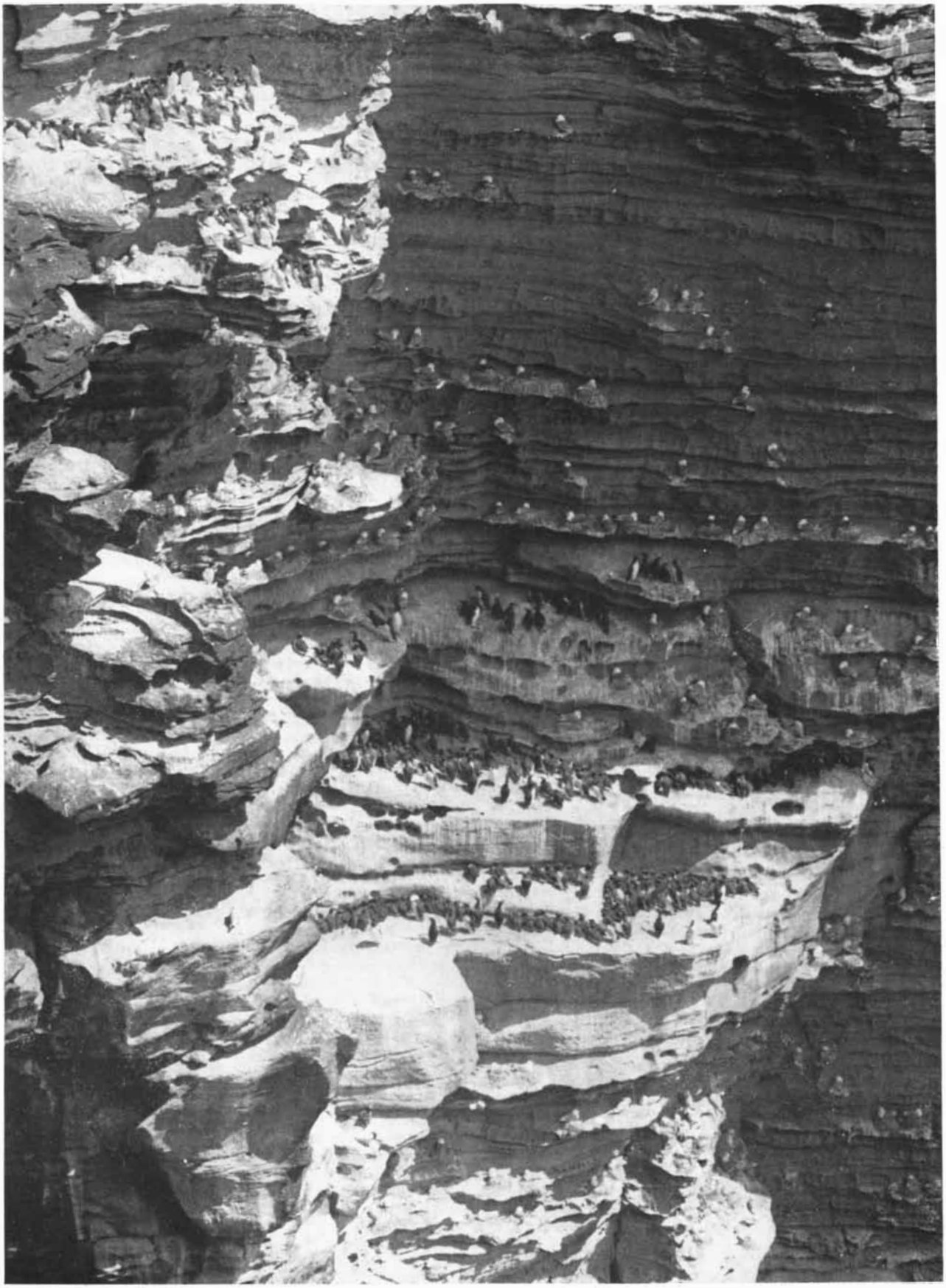


COLONIES OF GUILLEMOTS and kittiwakes nest on the ledges of a cliff on Noss Island, in the Shetlands north of Scotland. Among the guillemots are both bridled and nonbridled forms. The proportion of bridled birds is larger than in colonies to the south.

A Study in the Evolution of Birds

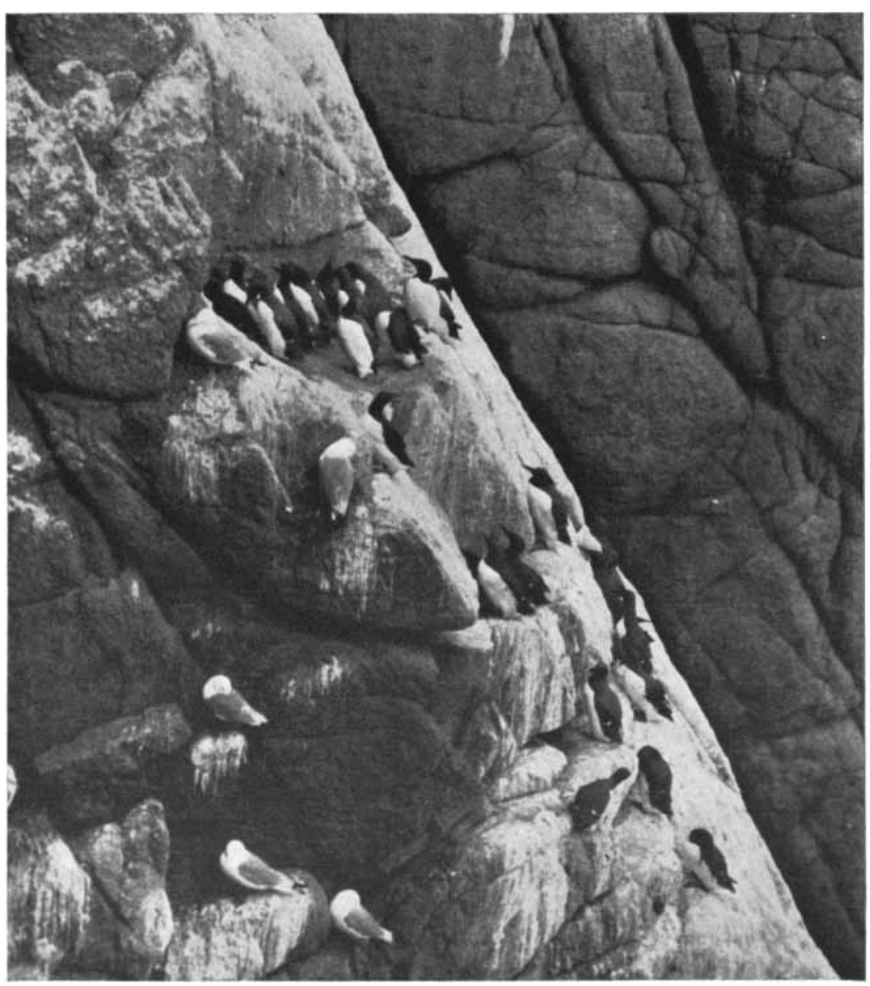
The head of the guillemot is either all black or bridled, i. e., decorated with markings resembling spectacles. This phenomenon, known as polymorphism, is a clue to the operation of evolution

by H. N. Southern

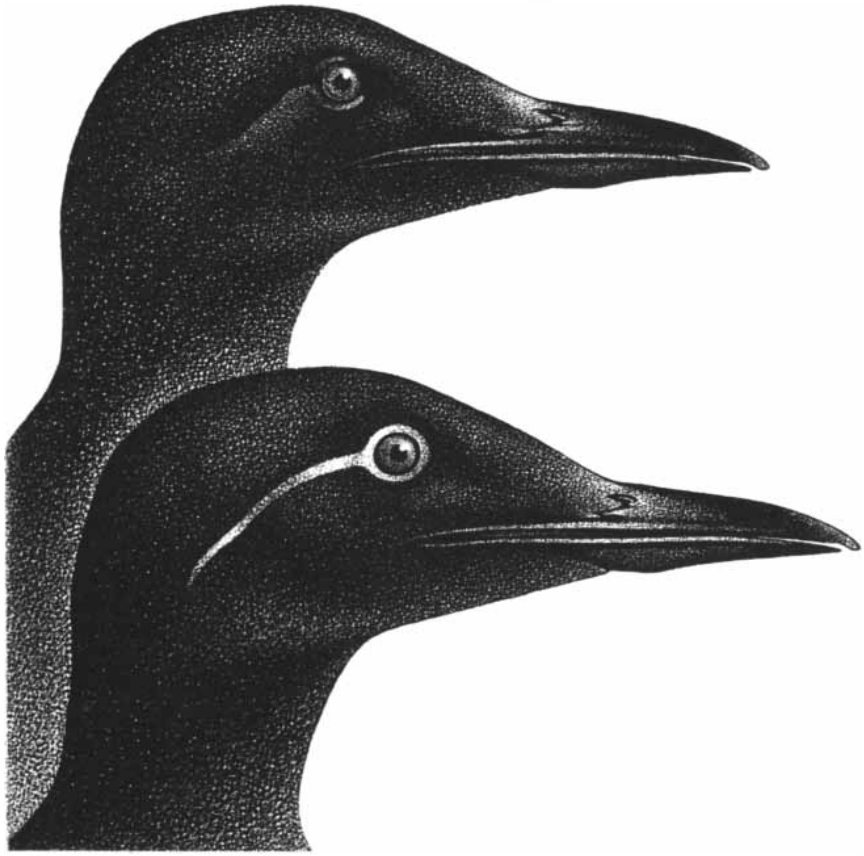
On the seacoasts around the North Atlantic lives a bird of the auk family which is known in Europe as the common guillemot and in America as the murre. The bird has a white breast and black back: it looks not unlike a small penguin [*see photograph on this page*]. Generally the guillemot's head is all black, but there is a mutant form with white rings around its eyes, giving the appearance of spectacles. For well over a century the spectacled, or bridled, guillemot was a subject of controversy among naturalists. It was long classified as a separate species, but many maintained that it must be merely a variant of the common guillemot (*Uria aalge*), because the bridled and nonbridled forms were found living side by side in the same groups. It is now definitely established that the two forms are actually of the same species and represent only different color "phases" of the species.

The main topic of my article is a study of the guillemots, now in its second decade, which has cast significant light on the processes of adaptation and evolution. But first let us look into this matter of "phases," or the phenomenon called polymorphism. Among birds variations of form within a species are most commonly observed in the colors of the plumage, but they may apply to other traits. For instance, the crossbill, a bird whose upper beak crosses over the lower in scissor fashion, has two phases: in one variety the upper beak crosses to the right, in the other to the left. The bird lives mainly on the seeds of coniferous trees, and its curious beak is well adapted to prying apart the cones' tough scales to get at the seeds. I have watched crossbills dealing with the very hard cones of the Scots pine at the rate of one every two minutes, and since each cone has 20 to 50 seeds to be extracted, this is no mean achievement. While working on a cone, "right-handed" birds always hold it in one particular direction, "left-handed" birds in the opposite way. The curious thing about this dimorphism is that in Europe right-handed crossbills predominate, while in America the left-handed seem to be in the majority. It would be an interesting point to investigate further.

Color polymorphism among birds is very common. Most frequently the phase variations express themselves in darken-



SUBCOLONY OF GUILLEMOTS was photographed at the Bullers of Buchan, a turbulent inlet on the east coast of Scotland. The guillemot is a large bird; it stands about a foot high.



BRIDLED PHASE OF THE GUILLEMOT is depicted at the bottom of this drawing; the nonbridled is at the top. Some naturalists believed bridled phase was a separate species.

ing, whitening or reddening of the normal plumage color. Many species of heron have both white and slate-blue forms —a situation which was highly confusing to early classifiers. Among the hawks certain species (*e.g.*, the Australian gray goshawk and Eleanora's falcon) show strikingly different color phases. Some jaegers have both white-breasted and dark-breasted versions; buzzards vary over a wide range of phases from predominantly dark to predominantly light; many owls may have either gray or foxy-red plumage. There are also a number of cases of color polymorphism in the vast order of passerine birds (the small, perching birds). The Caribbean sugarbird, or banana quit, normally has a yellow and gray plumage, but on two islands in the Caribbean the sugarbird populations are almost entirely black. In Australia the Gouldian finch, a colorful little bird with a gay body plumage of amethyst, blue, green and yellow, usually has a black face but sometimes it is scarlet.

All this, of course, is of great interest to biologists. It is not surprising to find mutant forms within a species, but ordinarily mutants are very rare: the proportion of mutant genes maintained in a wild population of animals, it has been estimated, is only about one in 100,000 or one in a million. Mutations are usually detrimental. Many geneticists believe that populations are so sensitive to small selection pressures in the environment that there is virtually no such thing as a neutral gene: therefore any mutant gene must either completely replace its allele (opposite number) because it is advantageous, or be reduced to an extremely rare variant because it is disadvantageous.

How, then, can a mixed, polymorphic population persist, as it does in the color phases of birds? The English geneticists Ronald A. Fisher and Edmund B. Ford have proposed that this can be explained on the basis of the interplay of opposing factors, which maintain a balance between the contrasting phases. Ford cites the case of the butterflies whose coloring mimics that of distasteful species, so that they are unmolested by predators. Since the predators have to learn by experience, and since the mimics are not distasteful, it is obvious that they will not long survive if they come to predominate over their inedible models. Therefore a mimetic form never outnumbers the distasteful species that it imitates. I have suggested that a somewhat similar mechanism controls the populations of the cuckoo. The cuckoo deposits its eggs in the nest of another bird (always one certain species) for hatching. If a particular "race" of cuckoos becomes too successful in getting its eggs hatched by the species it is parasitizing, the exploited host will decline in numbers and so too will the cuckoo.

Another factor supporting polymorphism is the phenomenon called heterosis, or "hybrid vigor." A mixture of genes often improves the viability of an animal species. The Australian finch I mentioned may be a case in point. In the wild, about one in three or four of these finches is red-headed. But bird breeders have found it very difficult to produce a pure line of red-headed finches, for many of the offspring suffer from fits. It is known that a single dominant gene is responsible for the red-headed phase of this finch. The breeding experiments certainly indicate that the heterozygote (individual with mixed genes) is far more viable than the homozygous red.

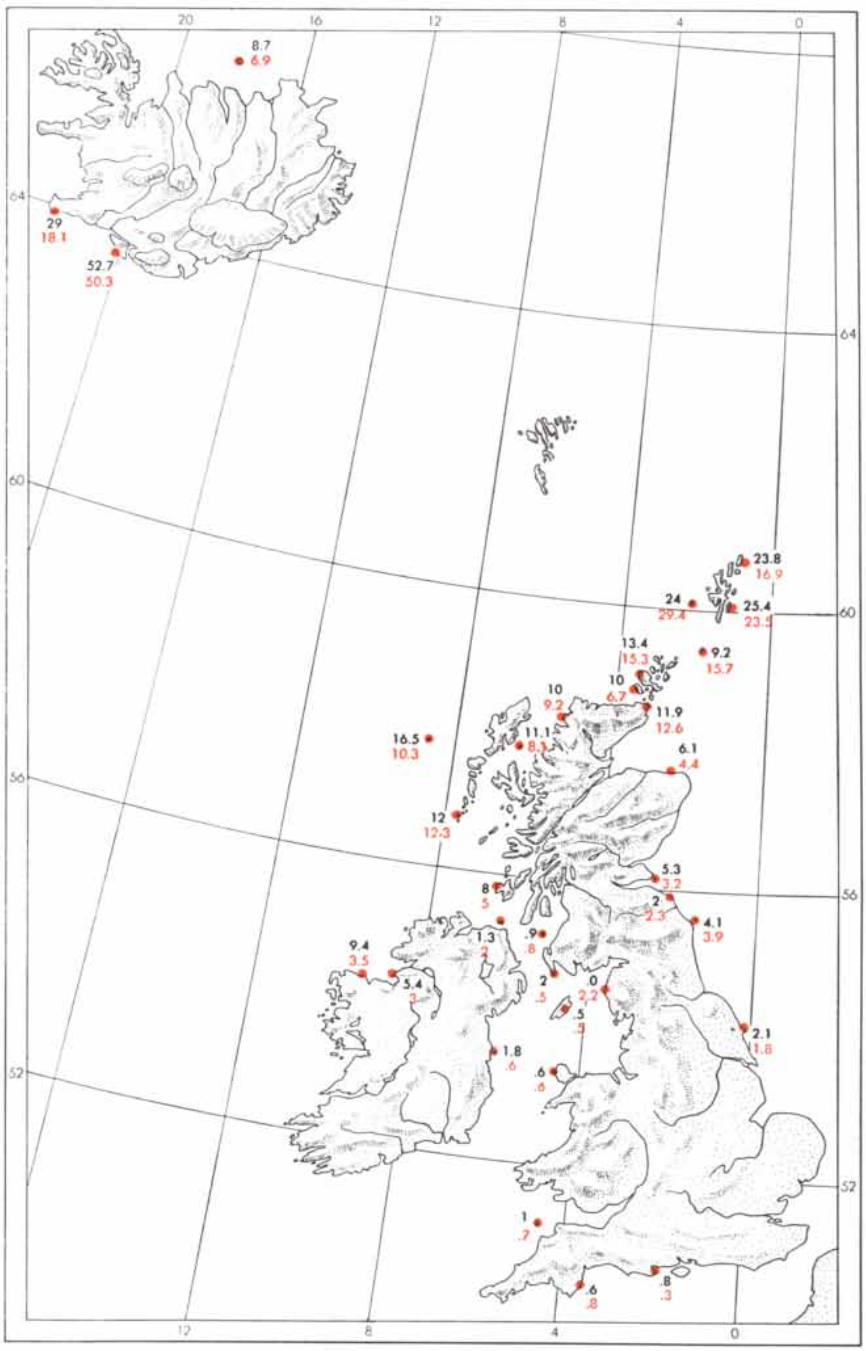
Now the most significant fact about the possession of a reservoir of mutant genes by a species is that it gives the species adaptability: it can respond readily to a change in its environment. Ford has illustrated this very convincingly with an instance of a color change in moths. The moths in question are species with camouflaging color schemes that hide them from predators in the wild. During the past 100 years many of these species, living in city areas where their former predators are absent, have become predominantly black—a change which is described as "industrial melanism." The black mutant used to be rare, but apparently it is more viable than the camouflaged type, and the absence of the old predators has allowed this advantage to be expressed.

The case of the Caribbean sugarbird also is suggestive. In most of the region the bird is yellow and gray. But on the island of Grenada the sugarbird population is largely black, with pockets of the normal type, and on Saint Vincent it is almost entirely black. It is tempting to conclude that we see there a species in various stages of adaptation to environmental conditions.

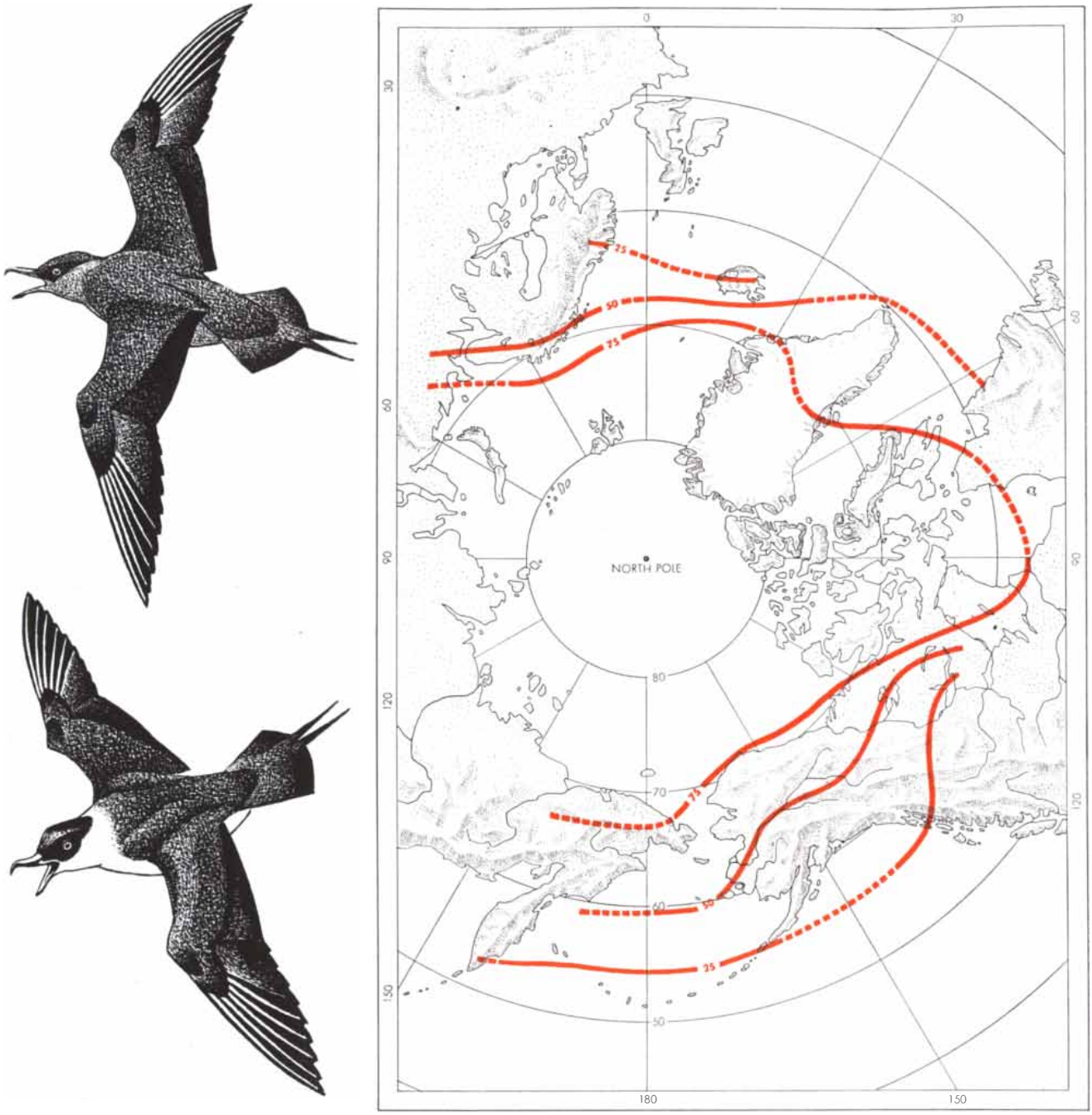
This kind of situation offers a beautiful opportunity to watch natural selection and evolution in action. The color phases of birds are sharply defined and easy to observe. They are controlled in

a simple way by a single gene or group of genes. The bird population probably responds swiftly to variations in environmental conditions—from place to place and from year to year. This means that the processes of selection can be followed simply by counting the frequencies of the various color types at different places and at different times.

We selected the guillemots for such a study. During the early 1930s I often visited the sea cliffs of the British Isles where sea birds breed in vast numbers, and I came to realize that the bridled and nonbridled phases of the common guillemot were an ideal subject for investigation. The guillemot is a comparatively large bird—about a foot high—and is easily identified. The bridled form, with its white eye-ring and line running back from the eye toward the nape, can be picked out from a considerable dis-



PERCENTAGE OF BRIDLED GUILLEMOTS in samples of guillemot colonies in the British Isles and Iceland is indicated by the numbers on this map. The black numbers give the percentage in 1938-39; the colored, the percentage in 1948-49. The percentage increases with latitude. In 10 years the proportion of bridled birds in most colonies decreased.



SKUA, like the guillemot a sea bird, has a dark phase (*upper left*) and a light phase (*lower left*). The percentage of the light phase, like that of the bridled guillemot, increases with latitude. The percentages are given by the contours in the map at right.

tance with binoculars. Huge colonies of the bird nest on the open cliff ledges. And last but not least, the wild, rocky headlands and islands where they nest are most attractive places to visit.

So when, in 1937, Julian Huxley suggested that I should organize a large-scale inquiry into the bridled guillemot, I was easily persuaded. He proposed that I enlist the members of the British Trust for Ornithology, who are mainly amateurs, in a cooperative endeavor, and most of them were only too willing to take part. Their job was simply to visit the cliff colonies and count the numbers of bridled and nonbridled guillemots.

I think that many people enjoyed themselves doing these counts. At any rate, sufficient enthusiasm was displayed to cover during 1938 and 1939 practically all the known breeding colonies of any size in Great Britain and many in other countries as well. For my own part I took great pleasure in my round tour of the northernmost part of Scotland, extending to the Orkney Islands. I found guillemots on cliffs of sandstone which glowed red in the setting sun, on cliffs of pink granite, of black basalt and even of chalk. Some of the colonies of these birds have to be seen to be believed. Often several thousand birds nest within a space only 50 to 100 yards long on a cliff face some 200 to 300 feet high. A guillemot's "nesting" consists in laying a single egg on the bare rock. The birds are so close together that a continual rain of droppings falls from their ledges. A mile or so of cliff populated at this density adds up to a most startling sight. Even more startling is the noise that assaults one's

ears. The birds "talk" constantly in a sort of muttering growl (*arrrrrr—arra-arra-arra*), and this roar from thousands of guillemot throats sounds very like a yard full of schoolchildren let out to play. I never hear the one without being irresistibly reminded of the other.

The results of that prewar survey were clear-cut. The frequency of the bridled character varied consistently with the latitude: at the southern end of the range, in Portugal, not a single spectacled guillemot was seen, but northward the proportion of bridled birds increased fairly regularly until it reached more than 50 per cent in Iceland. It was obvious that in some way the bridled trait, or something associated with it, conferred a considerable advantage in the northern part of the range, and that its absence was advantageous in the southern part. It also seemed probable that the selective advantages changed in a graded way in step with latitude.

Two or three interesting details in this geographical gradient are worth mentioning. The percentage of bridled birds does not increase *quite* evenly with latitude. For instance, in the range up the west coast from the southernmost part of England to the Clyde River in Scotland the proportion of bridled birds rises only from .5 per cent to about 2 per cent, but in the next colonies northward, in the Hebrides, it jumps to about 8 per cent. This is in accord with an analysis of geographical patterns by Huxley, which predicts such jumps where there is a succession of relatively isolated breeding groups. A second point of interest is that in Iceland the bridled phase suddenly declines. In Iceland the common guillemot is gradually replaced by a different species, called Brünnich's guillemot, as one goes northward. Curiously, as the common guillemot declines so does the percentage of its bridled members, until finally it is down to 10 per cent on the island of Grimsey north of Iceland. Still another interesting point is that in northwestern Europe the gradient of increase in bridling does not run strictly from south to north but rather from southeast to northwest: at a given latitude the bridle percentage is higher to the west than to the east. This slanting arrangement coincides with the geographical influence of the Gulf Stream on climate in western Europe.

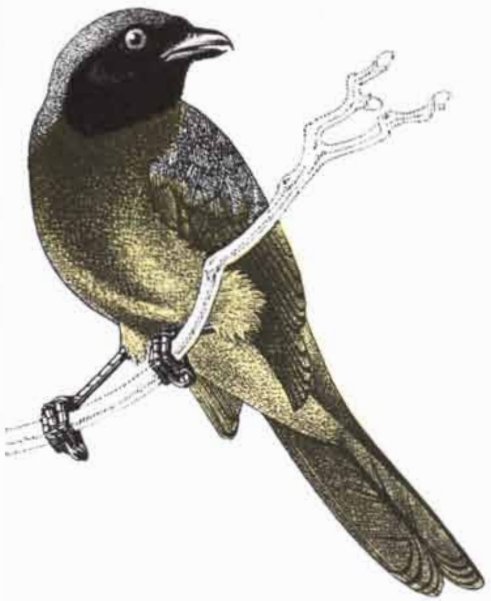
When we took stock of the results of that first survey, we felt we had collected the most complete and most extended picture of the geographical distribution of a genetic factor ever obtained. Now we faced the question: Was the situation a stable one or was an evolutionary change in progress? One possible interpretation was that the bridled gene was spreading south from a starting point near Iceland.

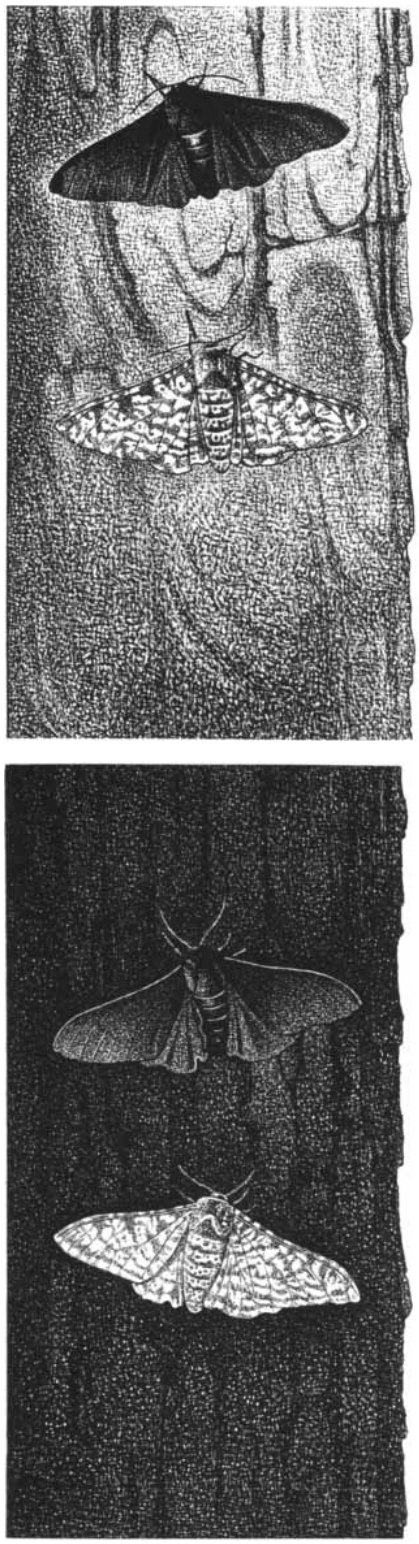
To settle the question we decided to repeat the survey 10 years later. When

SHRIKES of the genus *Chlorophoneus* have four color phases in West Africa. At upper left in these semischematic drawings

1948 arrived, circumstances threatened to thwart our plan: private motoring was strictly rationed and it looked unlikely that we could reach the more remote nesting places. But by spreading the survey over three seasons and carrying out a large part of it by myself, I was

is the buff phase; at upper right, the scarlet; at lower left, the yellow; at lower right, the black. These birds have other colors.





PEPPERED MOTH has two phases: normal and dark. In the upper drawing the two phases are shown on a relatively light tree trunk in the country; under these conditions the dark phase is the more visible to predators, and the light phase tends to survive. In the lower drawing the two phases are shown on a soot-darkened tree trunk in the city; in cities the dark mutant prevails because this form is fundamentally more viable in the absence of predators.

able to get a fairly adequate cross section of counts.

The results were something of a surprise. In every area (except one) where we found any significant change in counts, the percentage of bridled guillemots *decreased*. In Iceland, for example, it dropped from 29 per cent to 18 per cent; on the island of Saint Kilda, from 17 to 10. Only in one small area did the proportion increase. The counts were not altogether conclusive, but they did establish fairly clearly that there was no general rise in the frequency of the bridled trait—in short, that the gene responsible for it was not spreading.

We are therefore left with two possible conclusions: either (1) the bridled and nonbridled phases of the guillemot are in long-term balance and the changes in counts on the second survey represent only random fluctuations around an average, or (2) the bridled phase is declining in frequency because of a general change in the environment. We know that a climatic change is in fact under way. There is plenty of evidence that during the past century the temperature difference between the Equator and the Poles has decreased: the ice caps have been retreating, and many species of birds and animals have been extending their ranges northward, especially in western Europe. If the bridled gene is better adapted to the colder climates, as its distribution suggests, then we should expect the warming change to reduce its over-all frequency. We are planning a third survey in 1958-59, and this should tell us more definitely whether such a decline is really occurring.

In the meantime I have been trying to learn more about the population dynamics of the guillemots, partly with a view to determining how rapidly any real change in the gene's frequency could take place. I have pursued these studies with help from the University of Aberdeen zoologists along a stretch of precipitous coastline in northeastern Scotland. We have surveyed certain colonies there each year for eight years and are beginning to get some answers.

On mainland cliffs the guillemots generally nest on inaccessible ledges, out of reach of foxes and other predators. But on a shaft of rock just off the coast, easily reached by boat, we found an accessible sub-colony of about 200 guillemots which we had no difficulty in catching and banding with colored rings. With a cautious approach we were able to slip a noose hanging from a long bamboo pole over the head of a bird and thus capture it for marking. Unhappily the

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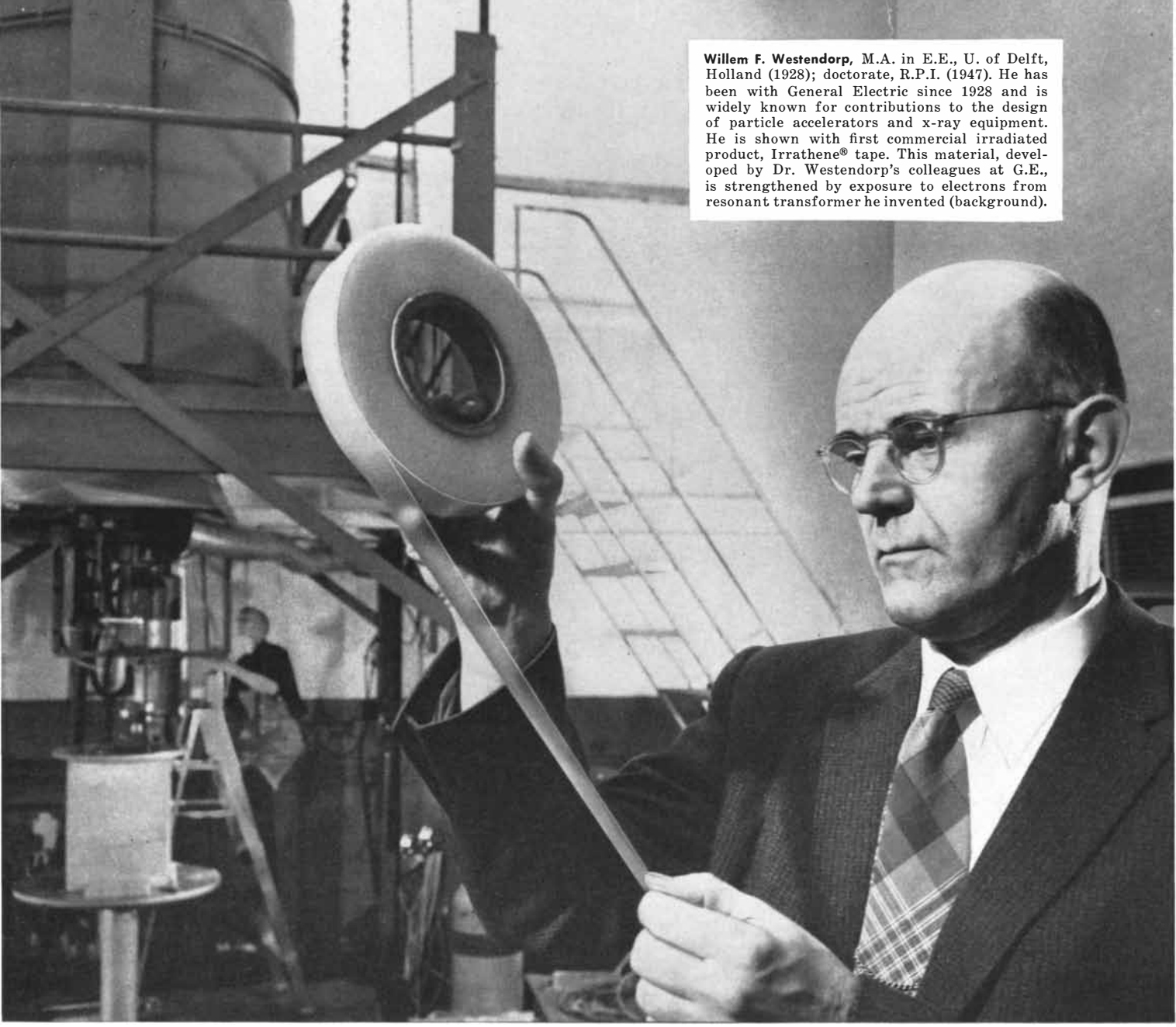
colored identifying bands faded after a couple of years, but they lasted long enough to give us most of the information we were seeking.

We learned, first, that guillemots move very little once they are established on a breeding site. The bird sticks to its own square foot of ledge, and the same individual turns up on the same ledge from one year to the next. No marked bird on the stack of rock off the coast moved over to the mainland quite close by. In short, the colonies are well isolated. Secondly, we found that the turnover of the population in a colony is slow. A guillemot, once it has survived to breeding age, has a long expectation of life. Young birds replace the older birds only slowly, for they suffer a heavy mortality during the early years before they have won a place on the ledge. The result is that any significant change in the ratio of bridled to nonbridled birds in a colony cannot take place very rapidly: over the eight years of our intensive study we found only random fluctuations in the ratio. This means that it will probably take several decades to see a real shift in the ratios.

Birds admittedly have many drawbacks as subjects for the study of evolution in progress. Their succession of generations is slow compared with that of invertebrates; many of them are difficult to acclimatize to captivity, where their inheritance might be studied conveniently. But, to look at the other side of the coin, birds are adaptable to a broad range of environmental differences, and so can give us a sweeping picture of geographical variation.

This kind of work also has another felicitous feature. A tremendous amount of amateur enthusiasm can be harnessed to it in a cooperative way. In the modern world the amateur naturalist no longer dominates the research scene as he did up to the last century. He no longer has abundant leisure, for one thing. But he still has unbounded zeal, and, in bits and pieces, can contribute what amounts in the aggregate to a great deal of time in field work. Amateur naturalists can, therefore, act as a tremendous extension of the eyes and ears of professional investigators—a function which they are usually only too glad to perform. The field of population genetics and of systematics in the broad sense is peculiarly susceptible to attack by the teamwork of professionals and amateurs. Supported by such a combination, the investigation of the patterns of life on our planet may become one of the most vigorous growing points in biology.



Willem F. Westendorp, M.A. in E.E., U. of Delft, Holland (1928); doctorate, R.P.I. (1947). He has been with General Electric since 1928 and is widely known for contributions to the design of particle accelerators and x-ray equipment. He is shown with first commercial irradiated product, Irrathene® tape. This material, developed by Dr. Westendorp's colleagues at G.E., is strengthened by exposure to electrons from resonant transformer he invented (background).

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When a child on a swing wants to "go higher," the easiest way for father to impart needed energy is through a series of gentle, properly timed pushes. Dr. Willem F. Westendorp of the General Electric Research Laboratory used a similar idea in creating the *resonant transformer,* a machine that increases voltages from 200 to as high as 4,000,000 in a series of low-frequency "pushes" from carefully tuned coils.

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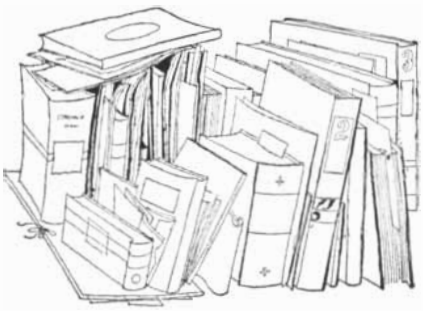


BOOKS

A new approach to a classical question: What is the logical basis of induction?

by J. Bronowski

FOUNDATIONS OF INDUCTIVE LOGIC, by Roy Harrod. Harcourt, Brace and Company ($7).

It is usual to distinguish between two methods of inference in science. One method is deduction: by this we conclude, for example, that if all three sides of a Euclidean triangle are equal, then each of its angles is 60 degrees. The other is induction: by this we reason, for example, that because the spectra of distant nebulae are shifted towards the red, therefore the universe is expanding.

There are several ways of characterizing the second form of argument which distinguish it from the first. We can say, cogently, that induction bases a general law on particular examples; it posits that spectra which have not been observed are also shifted towards the red. We can say something that is not quite the same, that induction assumes that the future will match the past; new observations, of the same or of other spectra, will continue to find them shifted towards the red. And we can say, more profoundly, that induction reasons backward, from effect to cause; because a universal expansion would shift all spectra towards the red, it argues that the shift is evidence for an expansion.

Science has flourished in the last 300 years because it has learned these inductive procedures, particularly the last. Francis Bacon foreshadowed its coming importance at the beginning of the 17th century, when he wrote that the method of science must be "to educe and form axioms from experience," and then "to deduce and derive new experiments from axioms"; there had been hints in even earlier writers. But the procedure was not fully understood until the end of the century, when Christian Huygens stated it precisely in his *Treatise on Light:* "Here principles are tested by the consequences derived from them."

I have said that science has flourished by using the procedures of induction, yet none of these procedures has any sanction in formal logic. For example, Isaac Newton as much as Huygens was a pioneer of the revolutionary procedure which argues from consequence to principle, from effect to cause. Yet Newton was aware of the weakness of such argument, and rightly criticized it on the ground that "I cannot think it effectual for determining truth, to examine the several ways by which phenomena may be explained, unless where there can be a perfect enumeration of all those ways."

It is in fact characteristic of all the inductive procedures that they allow us to draw several alternative conclusions, and that we have to choose between them. We are free to suspect that the spectra of some nebulae are not shifted, or to consider that all the shifts will disappear in the future, or above all to offer a different explanation for the shifts that we see now. Deduction is unique, but induction is not—there are always alternative inductions. For this reason deduction is certain, but induction is not—each of the alternative inductions can only be described as probable.

The criticism of one inductive procedure which I have quoted from Newton goes to the heart of the scientist's difficulty. The astronomer does not lie awake at night sweating with doubt whether the spectra of all nebulae shift towards the red and will go on doing so. He will not change his mind or trouble his head about this until the observations tell him he must—or until he hits on an explanation of the shift which would imply such differences between one nebula and another, or between one time and another. For the only induction which interests the practicing scientist is that which offers an explanation of the observations. Like Huygens, he wants to find the principles behind them, which are to give order and meaning to what he sees. And he does not accumulate observations for their own sake, but always to test such an inductive explanation.

It happens, however, that the most powerful attack on induction was not made professionally by a scientist, but was made on more general grounds by a historian and philosopher. He was David Hume, and this is what he wrote in 1739:

"All reasonings concerning cause and effect are founded on experience, and all reasonings from experience are founded on the supposition, that the course of nature will continue uniformly the same.

"We are determined by CUSTOM alone to suppose the future conformable to the past. When I see a billiard-ball moving towards another, my mind is immediately carry'd by habit to the usual effect, and anticipates my sight by conceiving the second ball in motion. There is nothing in these objects, abstractly considered, and independent of experience, which leads me to form any such conclusion: and even after I have had experience of many repeated effects of this kind, there is no argument which determines me to suppose, that the effect will be conformable to past experience."

This criticism is different in kind from Newton's. It is not content to point to the impossibility of listing all explanations before we choose one. Instead, it insists brutally that we had no business in the first place even to generalize. Our personal observation is only a sample of the total of human observations in all places and at all times, and we have no ground for the conviction that, because the time and place is ours, it must be a fair sample. Experience teaches us what to expect, but it cannot also guarantee that what it teaches will happen. Or to put the matter more formally: To seek in experience the ground, not for specific inductions, but for a general principle of induction, has since Hume been recognized to be a circular argument.

Of course the target for these strictures is not, at bottom, induction as a mode of reasoning. The target is experience as a source of knowledge. Hume's contention is that experience can strictly tell us only what we have experienced; the force of this would remain the same even if we were content to reason from experience by deductive steps only. For example, we may measure the angles of an equilateral triangle in nature and find them

to be each 60 degrees; yet we cannot strictly conclude that they will remain 60 degrees elsewhere or tomorrow, because we cannot be sure that the universe will remain Euclidean.

The lesson of Hume, then, is that we have no right to generalize our experience; and if we take this lesson to heart, we shall not dare to use the simplest procedures of induction. For example, we shall not trust in the persistence of any of the regularities which we have detected in nature, and all empirical science will at once become impossible. This situation was long felt to be a philosophical scandal; mathematicians such as Pierre Simon de Laplace and logicians such as John Stuart Mill tried hard in the last century to show that Hume was mistaken, and that there is a rigorous ground for induction in the accumulation of instances. Their attempts have not carried much conviction, chiefly because practicing scientists know that their useful inductions are as often wrong as right, yet are not reached in this way in either case. As a result philosophers have for some time shelved the puzzle of induction.

Roy Harrod, who now takes it up again, is not a philosopher by trade. He is an economist, and is best known for his life of the most famous of modern economists, John Maynard Keynes. Early in his career Keynes wrote a book on probability which is full of unorthodox and indeed untenable views, but which has since remained a constant stimulus to all those who work on the foundations of probability. Harrod knows Keynes's book well, and has in places been prompted by it. It is pleasant to find in him the confidence which buoyed Keynes, that the bases of human reasoning can be uncovered by the amateur philosopher as well as by the professional.

Harrod begins firmly from experience and nothing else; he refuses to make any prior assumptions about the nature of the world within which we act and whose laws we try to discover. He will not, for example, accept the assumption which underlay the method of Laplace, and which persists today in the work of Sir Harold Jeffreys and of Rudolf Carnap, that some laws are inherently more probable than others; in this I am sure he is right. "The greatest care has been taken," writes Harrod about his argument, "to make no presupposition about the character of the universe. This rule will be adhered to rigidly throughout."

For this reason Harrod also rejects the assumption that nature is uniform, on which Mill based his case for induction. Instead Harrod argues as follows. Suppose that we are exploring, over a period of time, something which is continuous. It may be, in Harrod's metaphor, a sustained sound or a repeated pattern. We can picture our exploration as a kind of journey along a line which remains straight and unbroken so long as what we meet goes on being continuous with what we have met. How should we act before each step along the way?

Hume said, in perfect skepticism: We have no reason to believe that every step will be like those we have already taken. Mill said, in perfect confidence: We have no reason to doubt that every step will be like those we have already taken.

Harrod is less uncompromising than either Hume or Mill. He refuses to generalize about every step. He asks us to confine the question to the next step; he advises us to make this step equal to some fixed fraction of the distance we have already come—equal, say, to a 10th of that distance.

Harrod's method of induction, then, is this. Before he sets out to explore an extension which he believes to be continuous, he makes up his mind that after the first step he will make each step a 10th of the distance he has already covered. This 10th is, at each step, the limit of his induction. He is willing to trust, at each step, that the continuity he has found so far will go on for another 10th of the distance he has come. He points out that by using this method he can after all be wrong only at the last step—and that he will have been right for 10 times as far as that.

This is an ingenious policy, and it is right in stressing that whatever we say about the world must be extrapolated from samples. But Harrod is mistaken if he believes that it makes "no presupposition about the character of the universe." Harrod has pictured all human exploration as a journey; if this picture is to be universal, then the journey must be not in space but in something more general and abstract—we can call it an experience-space. Harrod silently assumes that this abstract experience-space has the same properties as the Euclidean space in which we move physically. There is no warrant at all for this, and it makes his argument merely a crude analogy. The experience-space may have a geometry which quite distorts his succession of fractional steps. Or it may be fissured everywhere by discontinuities. It may be impossible in it to take the first step which Harrod needs without at once meeting a discontinuity.

Let me put this in another way. Harrod summarizes his argument "in popu-

lar words": "If we are crossing an expanse, but know not what part of it we have reached, we are unlikely to be on its extreme edge." But this supposes that the expanse is of the kind to which we are used: an island or a table top. It is, however, possible to construct an expanse which is not like this, and whose edge meanders close to every point on it. We cannot know that experience will not be an expanse of this kind.

It will now be clear that Harrod's vigorous book does use an underlying postulate about the universe, but that it is not so restrictive as Mill's postulate. Mill assumed that nature is uniform. Harrod assumes that nature is continuous —or more precisely, as mathematicians would say, that she is continuous "almost everywhere." This may seem a natural assumption; it may seem obvious that, if we examine the universe in small enough pieces, there will be continuity within them. But the Greeks thought it equally obvious that, if we examine the universe in small enough pieces, there will be discontinuity within them. Field theory is on Harrod's side and quantum theory is on the side of the Greeks: neither is complete without the other.

It would be ungracious to close these comments on this oddly discursive and stimulating book without asking what unwritten assumption about the universe a practicing scientist makes in place of Mill's or Harrod's. I believe that he assumes something less restrictive than either: that nature is not uniform or even continuous but merely lawful. The scientist's concern is to find laws, and the only inductions which interest him are those which yield new laws.

For this reason hardly any scientist is interested in those procedures of induction which are typified by Harrod's step-by-step journey, in which we go on finding facts—facts of the kind we already have. He does not demand justification of these daily procedures, any more than he demands a proof that the material world exists outside his own head. And when he is told that the soundness of these procedures cannot be proved, he is no more troubled than when he is told that solipsism cannot be disproved. The scientist accepts the behavior of facts on the same practical grounds that he accepts their existence.

The procedure which interests scientists is that by which we make an induction from the facts to find a law behind them. The central question in induction today is: Why do we prefer one law to another? The central interest of induction is in the interplay of laws. There is a coherence in the totality of

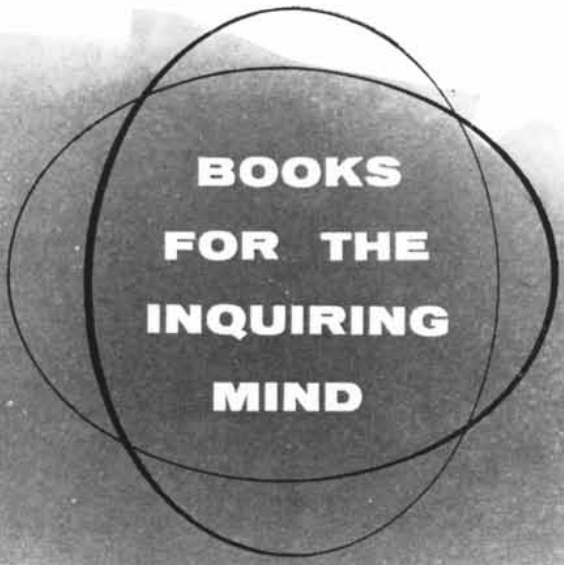
laws which grows out of their inner connections one with another. To find, as it were, a topological measure for these connections, to characterize the nexus of laws, and to show why one law fits into the totality of laws better than another—this is the central problem of induction for the philosopher of science today.

Short Reviews

RATTLESNAKES: THEIR HABITS, LIFE HISTORIES, AND INFLUENCE ON MANKIND. by Laurence M. Klauber. University of California Press ($17.50). Rattlesnakes are misjudged. They have long been the subject of wild fears and a feast for human credulity. Even the zoological names conferred on the various species, *e.g.*, *Crotalus horridus horridus* (the timber rattlesnake), are calculated to make us shiver. To be sure, rattlesnakes do not make ideal house pets. And they can be dangerous even when dead. But they are neither as large, nor as wily, nor as widespread, nor as deadly as common opinion—and even some "expert opinion"—would have us believe. These two volumes by an engineer who is a herpetologist by avocation, and who in 35 years has had experience with more than 12,000 rattlers in the field and laboratory, says everything on the subject that need ever be said—everything that an amateur or professional snake fancier or snake dreader would ever want to know. Klauber's superb work has 1,530 pages, 243 illustrations, 141 pages of bibliography and a 73-page index. The identification and classification of rattlesnakes, their physiology and psychology, their diet, their reproduction, the treatment and prevention of rattlesnake bite, the folklore and myth of rattlesnakes—these and many other topics are treated in massive detail. A thumbnail sketch of Klauber's findings regarding these unloved creatures should include the following. Rattlesnakes are pit vipers belonging to the genera *Crotalus* and *Sistrurus*. Some 30 species are known. They are found only in the Western Hemisphere and live in every state of the Union except Maine and Delaware. They also eschew the District of Columbia. All rattlers possess rattles. All are venomous, though there is a wide difference in the seriousness of their bites. All are rather heavy-bodied and have broad heads. They are of various colors and are marked by blotches or by crossbands along the back. The biggest known rattlesnake, *Crotalus adamanteus*, runs to eight feet in length; the smallest measured rattlesnakes are about six inches long It is not true that a rattler adds a new rattle every year (a new rattle grows whenever the snake sheds, which may be three or four times a year); that the rattles have 30 or 40 segments (six to eight segments are average); that rattlers *always* rattle before striking (sometimes they simply don't feel like it, or don't have time); that the purpose of the rattle is to mesmerize the prospective victim (it is used as a warning device). It is not even true that the rattles rattle: their sound is a dry, rasping, toneless buzz, and, in large snakes, a hiss. Rattlesnakes are not truly aggressive, nor hardy, nor clever, nor long-lived. They will run away whenever they can rather than fight a man. When it gets too hot, they must flee to the shade or else they die quickly; when it gets too cold, they must find shelter. Since they don't move very fast—three miles per hour at top speed—they are forever in danger, in a variable climate, of perishing before they can wriggle to their homes. Under suitable circumstances rattlers bite. The bites can be unpleasant and sometimes fatal. But except for those persons who are bitten the statistics are reassuring. Rattlesnake fatalities in the U. S. average less than 30 per year, which comes to about 3 per cent of those bitten. The treatment of bites has a long and mostly feckless history. Scarification, long practiced, is useless; so is cauterization, applying a split chicken or the saliva of a fasting man, eating onions, taking a slug of whisky or munching on a radish. No single therapeutic agent will do the job. Incision, suction, tourniquet and sedation, used together with a suitable antivenin, represent the best first-aid. Don't pick up a snake for at least an hour after you have killed it: the jaws are quite capable of snapping for that length of time even when the head has been separated from the body.

OSTEOLOGY OF THE REPTILES, by Alfred Sherwood Romer. The University of Chicago Press ($20). Professor Romer, the noted Harvard zoologist, summarizes in this massive work our present knowledge of the reptile skeleton, living and fossil, and presents a classification of the various reptile groups based on osteological characters. His book, though written afresh, is patterned on the classic 1925 study, bearing a similar title, by Samuel Wendell Williston. Illustrations and an extensive bibliography.

ANATOMY OF THE HONEY BEE, by R. E. Snodgrass. Cornell University Press. ($6). The life of the bee, as the au-



THE LIFE AND DEATH OF CELLS

Joseph G. Hoffman, *Professor of Biophysics, University of Buffalo; Director of Cancer Research, Roswell Park Memorial Institute, Buffalo.* For generations men have asked the question, "What is life?" and each has answered it in his own way. Here is modern science's answer in an inquiry into the basic component of life, the individual cell. Dr. Hoffman pays particular attention to cancer – how it is studied for clues to an understanding of life and how the latest advances in atomic research have affected its control. $4.50

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John R. Pierce, *Director of Research, Electrical Communication, Bell Telephone Laboratories.* "A subject about which he knows as much as anybody in the world . . . extremely illuminating, highly recommended," says L. A. Du Bridge, President, California Institute of Technology. Simply, lucidly and comprehensively presented, Mr. Pierce's book has all the wonder, the excitement, the challenge of this ever-growing field of activity. $5.00

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Erik Bergaust *and* **William Beller** • *Foreword by* **Prof. Hermann Oberth.** This first book about space satellites explains what they are, how they work, what we learn from them, how they will affect our future. The authors discuss such topics as rocket motors, launching programs, long-range weather prediction, life on Mars and Venus, space medicine, satelloids, genetic hazards, and many other topics relating to man's coming exploration of space. $3.95

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DOUBLEDAY

thor of this admirable book points out, is more intimately known than that of any other insect, and the anatomy of the bee "has long been a subject of correlated interest." In 1925 Dr. Snodgrass published his *Anatomy and Physiology of the Honeybee*, but much has been learned about insects since then, and the present work is almost entirely rewritten. Systematically, and in the detail demanded by students, the various aspects of the bee's anatomy are set forth: embryonic development; muscles, head, feeding organs, thorax, legs, wings, alimentary canal; the circulatory, nervous, respiratory and reproductive systems, endocrine organs and so on. Even a layman leafing the volume can gain appreciation of the marvelous architecture of this celebrated insect. Its compound eye, for example, with its cylindrical light receptors, is able to analyze how sunlight is polarized, and it is this capacity which enables the bee to navigate. When the bee returns to the hive, it performs a dance "the direction of which, relative to the perpendicular on the comb, gives to the bees following her the angle that the direction to the food source makes with the direction of the sun." If the outgoing bees correctly judge the proper angle of flight, they can find the feeding place. Equally absorbing are the discussions of the bee's mating habits, of its heart and blood supply, of habits of personal hygiene, of the design and movement of its wings. The many drawings are clear and useful.

THE BIRDS OF SCOTLAND, by Evelyn V. Baxter and Leonora Jeffrey Rintoul. Oliver and Boyd (3 pounds, 3 shillings). These two volumes cover the history, distribution and migration of all species of birds found in Scotland, from crows to partridges. The authors have restricted themselves to these three topics, excluding discussion of physical appearance and habits on the ground that such information is adequately covered in other books on British birds. Four introductory chapters comprise a description of Scotland, factors influencing Scottish bird life, the composition of the Scottish avifauna and migration. A number of handsome photographs and two color plates by George Lodge illustrate the work.

BIRDS OF ARABIA, by Colonel R. Meinertzhagen. Oliver and Boyd (4 pounds, 4 shillings). The author of this attractive and readable book is a distinguished British soldier, now retired, who devoted many years of his life to travel and the study of African

birds. He says in his preface that his is the first book on the birds of Arabia, that it "lays no claim to 'literature' " and is intended for ornithologists and "lovers of the desert." He gives a full and remarkably interesting account of crows and magpies, sparrows, pipits, finches and wagtails, zosterops, shrikes and bulbuls, babblers, nightingales, bee-eaters, hoopoes, doves, owls, hawks, grebe, cranes, crakes, button quails, ostriches, flamingoes, woodpeckers, kingfishers and dozens of other familiar and unfamiliar species of birds that inhabit or wander through not only the Arabian peninsula but the desert regions of Sinai, Palestine, Syria, Jordan and Iraq. Meinertzhagen is a careful observer, an original theorist, and a delightfully independent and prickly commentator. He spices discussions of geology, geography and climate with comments on politics. He spells Arabic place names as he pleases on the ground that, since the experts don't agree, his orthography is as good as theirs. He demolishes beliefs he does not like but does not hesitate to endorse beliefs that appeal to him, even though it has long been known they are without foundation. He is an engaging raconteur, and when he describes the habits of a bird, he never fails for an anecdote or detail which makes the species come to life for the reader. Allowing for its agreeable waywardness, this survey, richly illustrated with many color plates, is a valuable contribution to science and to the autobiographical literature of colorful men.

NATURAL HISTORY OF BIRDS, by Leonard W. Wing. The Ronald Press Company ($6.75). This guide to ornithology is addressed to students and amateurs. It is clearly written, has many illustrations and useful bibliographies, and touches upon a broad range of topics. They include the classification, anatomy and physiology of birds; their appearance, songs, courtship and nesting habits; their longevity, sex ratios, distribution and migration; how birds evolved; their ecological relations and social behavior; their method of flight; the enemies and the diseases to which birds are prey; the rise of bird protection; the economic relations of birds; bird study. A serviceable compendium.

NEW ZEALAND BIRDS, by W. R. B. Oliver. W. S. Heinman ($25). The second edition of this standard reference work, first published in 1930, has been revised and substantially enlarged. Dr. Oliver carefully describes each species and reports on its habits, migration,

ecology, economic value and other attributes. New Zealand possesses some of the strangest birds in the world. Among them are the fabled kiwi, which has its nostrils at the tip of its bill (it is unique in this respect), lays relatively enormous eggs, and looks altogether like a furry alembic. Also described are a dozen species of penguin, from the king to the white-flippered; the timid and curious-looking dabchick, with its button eyes; diving and stormy petrels; prions, shearwaters, albatrosses and mallemucks; frigate birds, shags, pelicans and boobies; pied oyster catchers, banded tuturiwhatus, knots and phalaropes (whose males have the humiliating assignment of sitting on the eggs); hakoakoas, weka-pongos, coots, spoonbills, tomtits, yellow-rumped Alpine riflemen, fantailed piwakawakas, black-faced cuckoo shrikes and diverse parakeets. A dozen color plates and hundreds of photographs.

MAN OF HIGH FIDELITY: EDWIN HOWARD ARMSTRONG, by Lawrence Lessing. J. B. Lippincott Company ($5). The late Major Armstrong was the inventor of frequency-modulated radio, and made other important contributions to the technology of wireless telegraphy and radio. He was a gifted, eccentric, independent, unhappy man who spent himself almost as much in fighting the great companies, whom he regarded as usurpers of his inventions, as in his researches. He made a fortune, but depleted it in his elaborate laboratories and in litigation. His last days were embittered and ended in tragedy. The author, who has had access to the great store of Armstrong's papers and has had the close cooperation of his family, presents a clear account of his work and argues his claims with deep feeling.

THE SUN, by Giorgio Abetti. The Macmillan Company ($12). The British astronomer J. B. Sidgwick has translated from the Italian a wholly revised edition of this excellent compendium, which gives a complete rundown of all aspects of modern solar knowledge: methods and instruments of observation, the physical constitution of the sun, sources of solar energy, the sun's radiation and temperature, solar-terrestrial relationships. There are many fine illustrations.

OPERATIONS RESEARCH FOR MANAGEMENT: VOL. II, edited by Joseph F. McCloskey and John M. Coppinger. The Johns Hopkins Press ($8). There are

collected in this volume case histories of applied operations research, discussions of new methods and papers on information handling in organized groups. Among the more ingenious analyses are those dealing with the traveling salesman problem, the revision of New York's subway-fare structure, operational gaming in industry, traffic delays at toll booths, queueing theory and cost concepts applied to inventory control, utilization of training aircraft.

SHIPS IN THE SKY, by John Toland. Henry Holt and Company ($4.95). This readable account of the great dirigibles is mainly a sequence of disasters. Dr. Solomon Andrews sailed safely over New York City in the 1860s in his Aereon, and little Santos-Dumont kept Paris enthralled for years put-putting about the sky in his wickerbasket suspended from a gasbag; but that was in the good old days. More recently almost every one of the grander ships came to a tragic end. Various zeppelins exploded; the *Akron* caught fire, split in two and fell into the Atlantic; the *Shenandoah* was ripped apart in line squalls over Ohio; the *Italia* crashed on polar ice; the *R-101* disintegrated over France; the second *Akron* drowned with 75 men off the New Jersey coast; the *Macon* plunged into the Pacific off San Francisco, with only two casualties; the *Hindenburg* came to its flaming Nibelung end at that most un-Nibelung spot, Lakehurst. Toland's descriptions are full of color and suspense. He makes it clear that most dirigibles failed because of carelessness or faulty construction. There is little doubt that a safe dirigible could be built if enough skill and money were spent on it. Whether such a dirigible should be built is another matter. The dirigible is perhaps a craft that deserves to be extinct.

SCIENTIFIC USES OF EARTH SATELLITES, edited by James A. Van Allen. The University of Michigan Press ($10). Thirty-three papers touching upon various phases of the satellite program. The topics include estimates of the satellite's orbit under the influence of perturbations caused by other heavenly bodies; the oblateness of the earth and atmospheric drag; methods of visual tracking; observation and tracking by electronic and optical instruments; instruments to be carried by the satellite; experiments for measuring temperature, meteor penetration and surface erosion of the aerial vehicle; the determination from the satellite of air density, meteorological conditions, the distribution of hydrogen

in space, ultraviolet radiations, cosmic rays, the earth's magnetic field and the structure of the ionosphere; measurements of interplanetary dust; electromagnetic propagation studies. Though these are technical papers, the subject so lights the imagination that even the layman will find himself poring over the discussions.

A Life of Sir William Ramsay, by Morris W. Travers. St. Martin's Press ($12.50). Sir William Ramsay, who died in 1916 at the age of 64, was one of the leading chemists of his time. With Lord Rayleigh he discovered argon and with Morris William Travers, his present biographer, neon, krypton and xenon. The element helium was first observed in 1868 in the sun's chromosphere by the French astronomer Pierre Jules César Janssen, but its independent and almost simultaneous discovery on earth was made by Ramsay and the Swedish chemist Per Theodor Cleve. Ramsay is also remembered for his remarkable researches on the atomic weight of radon, the heaviest of the inert gases. He won the Nobel prize in 1904. In this careful, sympathetic biography, which the author wrote between his 81st and 83rd birthdays, Ramsay's personal life and scientific career are fully set forth. Travers collected a great many of Ramsay's letters, and as a collaborator in many of his most important achievements is uniquely qualified to describe how they came about. The details of the chemical researches, though valuable, are not always easy to follow, except for the specialist, and while Travers scrupulously records the large and small events in his subject's life, there is not enough excitement and variety in the book to keep the reader engrossed. Moreover, one is struck by the fact that Ramsay was clever and skilled in his choice of assistants and collaborators, rather than profoundly original. The chief merit of the book is that it adds to the understanding of the complex, often illogical and haphazard circumstances of scientific discovery.

Bibliography of Russian Mathematics Books, by George E. Forsythe. Chelsea Publishing Company ($3.95). Under an Office of Naval Research grant Forsythe has made a list, both by author and subject, of all known Russian mathematical books published since 1930 "that a practicing mathematician might wish to consult, if he could read them." It is an impressive collection and shows, as Forsythe points out, that Soviet workers, besides producing

their own literature, follow ours much more closely than we do theirs; pretty soon this will result, he says, in most Soviet mathematicians "knowing more about the subject than most of us."

Notes

ELECTRONIC COMPUTERS, PRINCIPLES AND APPLICATIONS, edited by T. E. Ivall. Philosophical Library ($10). Articles selected from the British magazine *Wireless World* describing the structure, function and uses of different types of computers.

CULTURE, LANGUAGE, AND PERSONALITY, edited by David G. Mandelbaum. University of California Press ($1.50). For this stimulating paperback the editor has assembled nine essays on various anthropological topics written by the late Edward Sapir, who made pioneer contributions to the study of language as a cultural or social product.

SOCIAL CHARACTERISTICS OF URBAN AND RURAL COMMUNITIES, 1950, by Otis Dudley Duncan and Albert J. Reiss, Jr. John Wiley & Sons, Inc. ($6.50). Based on the 1950 census, this monograph shows the relationship between such community characteristics as size, location, growth and stability on the one hand, and population age, sex, race nativity, movement, family-status composition and economic activities on the other.

IN SEARCH OF ADAM, by Herbert Wendt. Houghton Mifflin Company ($6.50). This book by a German science-journalist is another of the popular surveys of "man's quest for the truth about his earliest ancestors."

THEORY OF APPROXIMATION, by N. I. Achieser. Frederick Ungar Publishing Co. ($8.50). An English translation of a Russian work based on lectures given at the University of Kharkov by a leading contributor to this branch of mathematics.

RHEOLOGY: THEORY AND APPLICATIONS, edited by Frederick R. Eirich. Academic Press Inc. ($20). The first volume of a substantial cooperative handbook on the science of the deformation and flow of solids and liquids.

CALDER HALL, by Kenneth Jay. Harcourt, Brace & Company ($3). A clearly written account of a historic structure—the first nuclear power station in the world. Illustrations.

report on an experiment...

OR: SOME SOLACE FOR VIEWERS WITH ALARM

Two years ago, The Library of Science was founded—frankly as an experiment. Like many good experiments, it was based on a hunch—a hunch that the American scientist was *not,* as many critics were charging, a narrow-gauge specialist who read nothing but "the journal."

Our experimental procedure was simple: we would offer this scientist a variety of stimulating, rigorous books, many of which might be outside his own specialty but which would serve to broaden his knowledge and satisfy his interest in scientific areas other than his own and in science as a whole.

When we decided to go ahead, journal editorials were deploring the scientist's overspecialization but calling it inevitable. Scientists themselves were pointing to the impossibility of "keeping up with the literature." And even the employment-ad pictures showed happy scientists with test tube (professional) or fishing rod (recreational) in hand—never a book.

But now that our data are in, they seem to offer a fairly flat contradiction to the viewers with alarm. The American scientist is not, according to our information, headed for a specialist's perdition, and he does—more than occasionally—read something in fields of science other than his own.

When we offered Louis De Broglie's *Physics and Microphysics,* for example, it was warmly received by geologists and biostatisticians as well as by physicists and philosophers of science. Polya's *Mathematics and Plausible Reasoning* appealed as strongly to anthropologists and chemists as to mathematicians. Dobzhansky's *Evolution, Genetics and Man* was already well known to the biologists among our membership, but it gave large numbers of our physicists, mathematicians and engineers an adult introduction to genetics.

By the end of the first year, membership in The Library of Science stood at a gratifying 10,000. Today—a year later—it has reached an astonishing 29,500. At professional meetings, in research centers and elsewhere, these members tell us how pleased they are to have significant books of all fields brought to their attention. But our relationship with our members is by no means a unilateral one. Far from being passive, they know very definitely what they want—and frequently they are willing to tell us. We, in fact, have derived a great deal of knowledge and pleasure from their enthusiastic "Why don't you get us a book on such-and-such?" or "Have you ever thought of republishing so-and-so?"

This kind of two-way participation will, we hope, benefit the entire membership. In two or three months, for example, we plan to re-issue *Natural Magick,* a scientific treatise by one J. Baptista Porta, first published in 1658. We were infected with this idea by an enthusiastic historian at the Smithsonian Institution, and we are reasonably convinced that many other members will share our delight in discovering Signor Porta's magnum opus.

Other Selections that have been stimulated by members and their friends are *The Roots of Scientific Thought: A Cultural Perspective,* which is scheduled for early Fall, and a two-volume history of atomism, which will be coming along next Spring.

The statistical probability is fairly high that you or some associate of yours is one of our 29,500 members. But if this report is the first you have seen of The Library of Science, perhaps the invitation on the facing page will also be of interest to you.

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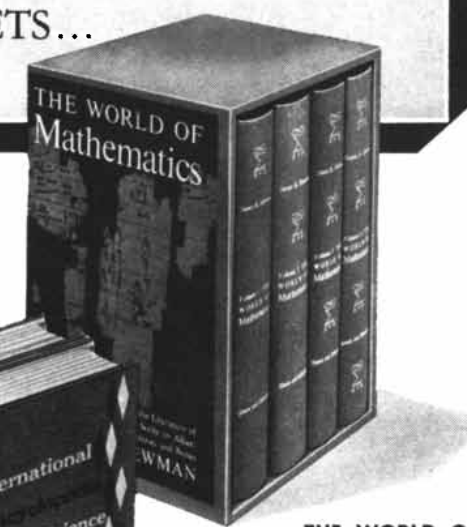

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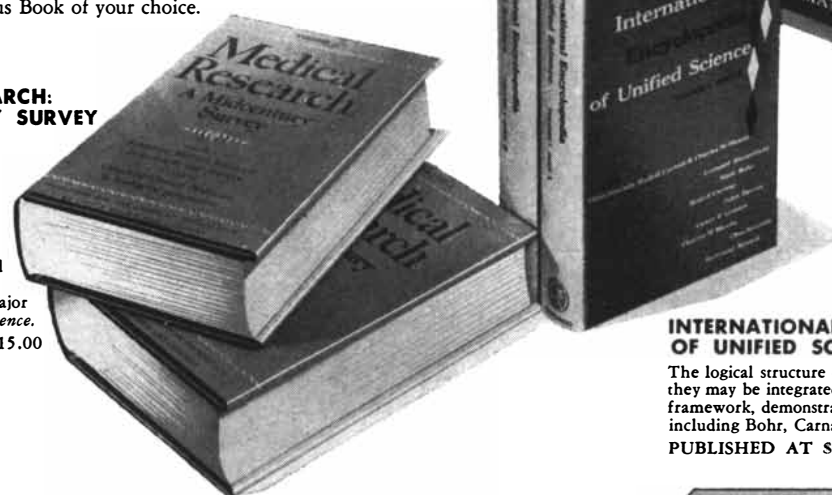

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MATHEMATICAL GAMES

About the remarkable similarity between the Icosian Game and the Tower of Hanoi

by Martin Gardner

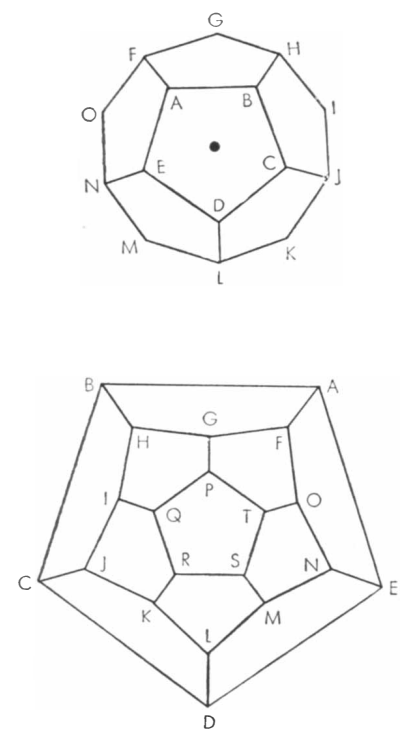
To a mathematician few experiences are more exciting than the discovery that two seemingly unrelated mathematical structures are really closely linked. Recently D. W. Crowe of the University of British Columbia made such a discovery concerning two popular 19th-century puzzles: the "Icosian Game" and the "Tower of Hanoi." We shall first describe each puzzle and then show the startling manner in which they are related.

The Icosian Game was invented in the 1850s by the illustrious Irish mathematician William Rowan Hamilton. It was intended to illustrate a curious type of calculus which he had devised and which was similar in many ways to his famous theory of quaternions (the forerunner of modern vector analysis). The calculus could be applied to a number of unusual path-tracing problems on the surfaces of the five Platonic solids, particularly the icosahedron and dodecahedron. Hamilton called it the Icosian calculus, though the game was actually played on the edges of a dodecahedron. In 1859 Hamilton sold the game to a dealer in London for 25 pounds; it was then marketed in several forms in England and on the Continent. This was the only money Hamilton ever received directly, his biographer tells us, for a discovery or publication.

Hamilton suggested a variety of puzzles and games that could be played on the dodecahedron, but the basic puzzle is as follows. Start at any corner on the solid (Hamilton labeled each corner with the name of a large city); then by traveling along the edges make a complete "trip around the world," visiting each vertex once and only once, and return to the starting corner. In other words, the path must form a closed circuit along the edges, passing once through each vertex.

If we imagine that the surface of a dodecahedron is made of rubber, we can puncture it and stretch it open until it lies in a plane. The edges of the surface will now comprise the network shown in the lower illustration on this page. This network is topologically identical with the network formed by the edges of the solid dodecahedron, and of course it is much more convenient to handle than the actual solid. The reader may enjoy tackling the "round trip" problem on this network, using counters to mark each vertex as it is visited.

On a dodecahedron with unmarked vertices there are only two Hamiltonian circuits that are different in form, one a mirror image of the other. But if the corners are labeled, and we consider each route "different" if it passes through the 20 vertices in a different order, there are 30 separate circuits, not counting reverse runs of these same sequences. Similar Hamiltonian paths can be found on the other four Platonic solids and on



DODECAHEDRON (*top*) is punctured (*dot*) and stretched flat (*bottom*). The flat network, which is not in scale with the solid, is topologically identical with its edges.

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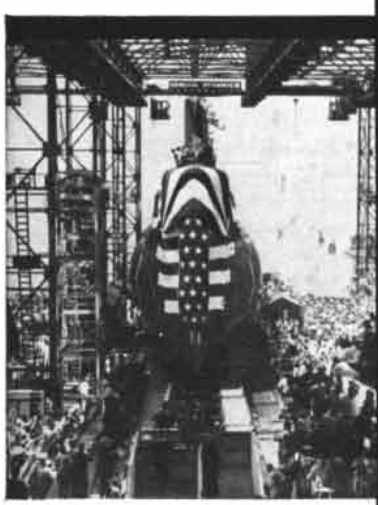

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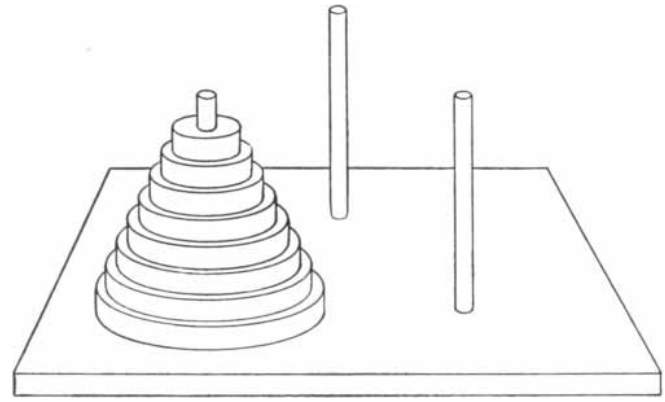


TOWER OF HANOI consists of eight disks, the largest of which is at the bottom and the smallest at the top. The rules for rebuilding the tower on another peg are given in the text.

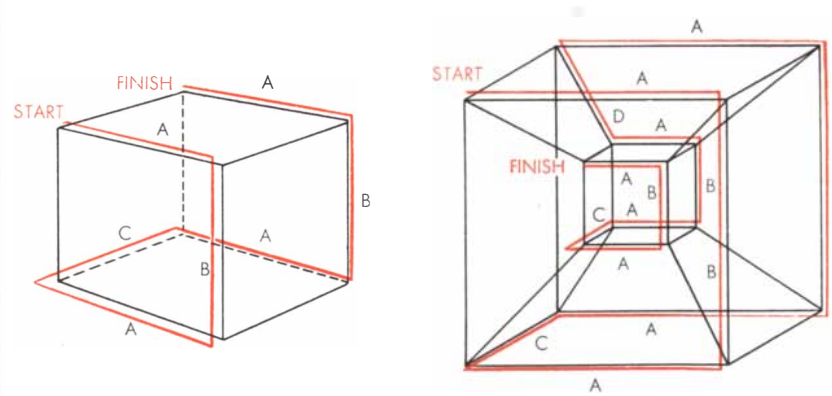
many, but not all, semiregular polyhedrons.

The familiar Tower of Hanoi was invented by the French mathematician Edouard Lucas and sold as a toy in 1883. The illustration at the top of this page depicts the toy as it is usually made. The problem is to transfer the tower of eight disks to either of the two vacant pegs in the fewest possible moves, moving one disk at a time and never placing a disk on top of a smaller one.

It is not hard to prove that there is a solution regardless of how many disks are in the tower, and that the minimum number of moves required is expressed by the formula $2^n - 1$ (n being the number of disks). Thus three disks can be transferred in seven moves, four in 15, five in 31 and so on. The original description of the toy called it a simplified version of a mythical "Tower of Brahma" in a temple in the Indian city of Benares. This tower, the description read, consists of 64 disks of gold, now in the process of being transferred by the temple priests. Before they complete their task, it was said, the temple will crumble into dust and the world will vanish in a clap of thunder. The disappearance of the world may be questioned, but there is little doubt about the crumbling of the temple. The formula $2^{64} - 1$ yields the 20-digit number 18,446,744,073,709,551,615. Assuming that the priests worked night and day, moving one disk every second, it would take them many thousands of millions of years to finish the job.

(The forementioned number, by the way, is not a prime, but if we increase the number of disks to 89, 107 or 127, the number of moves required to transfer them in each case *is* a prime. They are examples of the so-called Mersenne numbers: primes having the form of $2^n - 1$. Lucas himself was the first man to verify that $2^{127} - 1$ was a prime. This Gargantuan 39-digit number was the largest known prime until five years ago, when a large electronic computer was used to find five higher Mersenne primes, the largest being $2^{2281} - 1$.)

A Tower of Hanoi puzzle is easily made by cutting eight cardboard squares of graduated sizes (or using playing



HAMILTONIAN PATH is traced along the edges of a cube at left. The cube has the coordinates A, B and C; the path follows them in the order ABACABA. At right a Hamiltonian path is traced along the edges of a four-dimensional cube projected in three dimensions. This cube has the coordinates A, B, C and D; the path follows them ABACABADABACABA. This corresponds to the order of transferring four disks in the Tower of Hanoi.

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cards from the ace to the eight) and moving them among three spots on a piece of paper. If the spots form a triangle, the following simple procedure will solve the puzzle for any number of "disks." Transfer the smallest disk on every other play, always moving it around the triangle in the same direction. On the remaining plays, make the only transfer possible that does not involve the smallest disk. (It is interesting to note that, if the disks are numbered serially, the even disks circle the triangle in one direction and the odd disks in the opposite direction.)

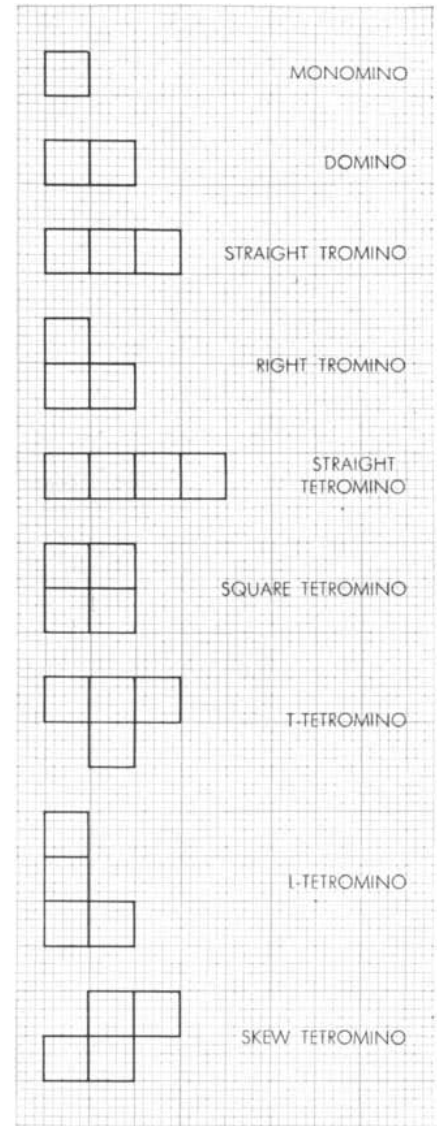
How is this puzzle related to Hamilton's game? To explain the connection we must first consider a tower of three disks only, labeling the disks, from top to bottom, A, B and C. If we follow the procedure given above, we solve the puzzle by moving the disks in the following order: ABACABA.

Let us now label with A, B and C the three coordinates of a regular hexahedron, commonly called a cube [*see illustration at left at the bottom of page 156*]. If we trace a path along the edges of the cube, choosing the coordinates in the order ABACABA, the path will form a Hamiltonian circuit! Crowe saw that this could be generalized as follows: the order of transferring n disks in the Tower of Hanoi puzzle corresponds exactly to the order of coordinates in tracing a Hamiltonian path on a cube of n dimensions.

An additional illustration will make this clear. Although we cannot make a model of a four-dimensional cube (called a hypercube or tesserace), we can project the network of its edges in the three-dimensional model depicted at right at the bottom of page 156. This network is topologically identical to the network of edges on a hypercube. We label its coordinates A, B, C and D, the D coordinate being represented by the diagonal lines.

The order for transferring a tower of four disks is ABACABADABACABA. When we traverse the hypercube model, making our turns correspond to this sequence, we find ourselves tracing a Hamiltonian path. By the same token five disks transfer in an order corresponding to a Hamiltonian circuit on a five-dimensional cube.

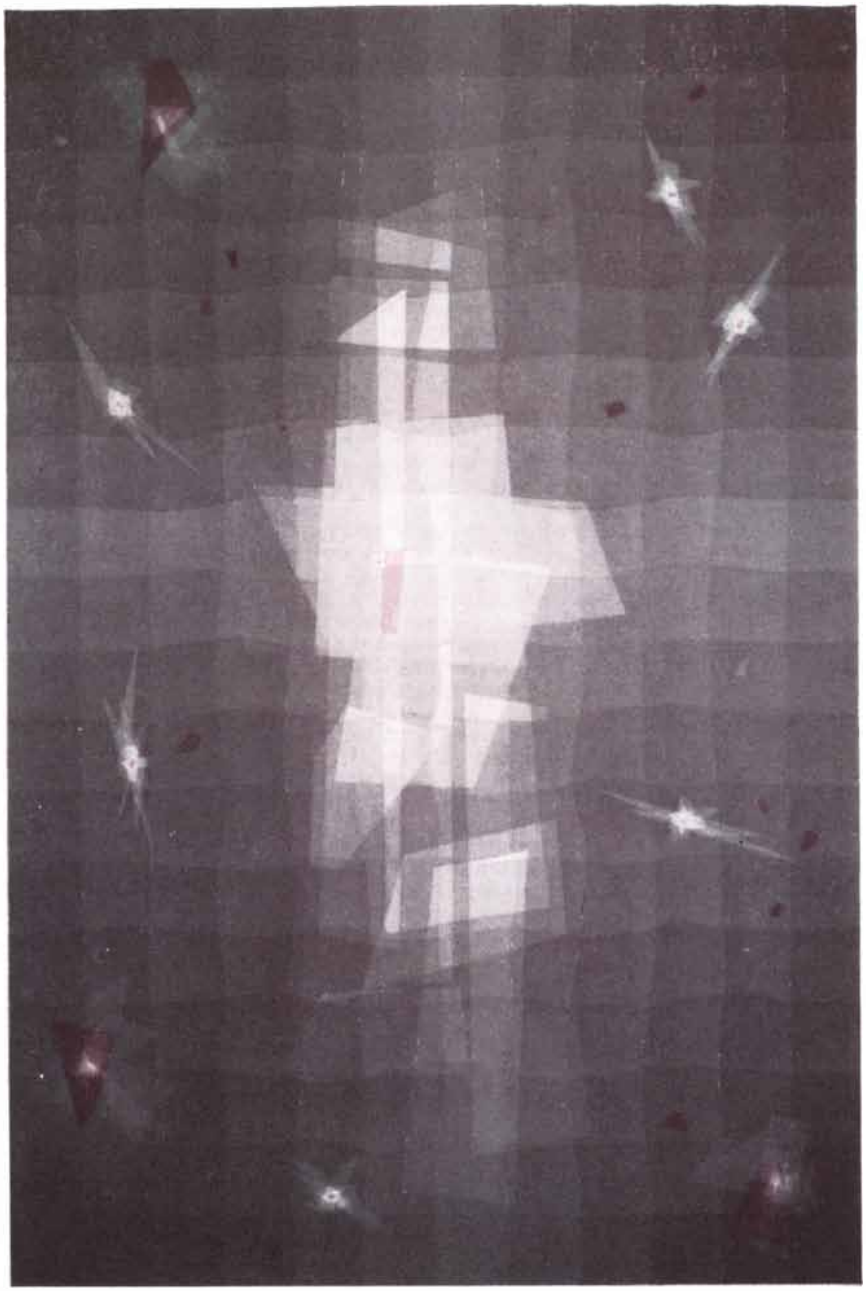
The problem of the dominoes and the checkerboard (among the "brain teasers" in this department for February) prompted Octave Levenspiel of Bucknell University to call my attention to a remarkable article by S. W. Golomb in *American Mathematical Monthly* for December, 1954. This article takes up an astonishing variety of theorems, all dealing with the placing of "polyominoes" of various sizes and shapes [*see illustration on this page*] on an eight-by-eight checkerboard.



SUPER-DOMINOES are used in a game of which the object is to fill an eight-by-eight checkerboard. The figures made up of more than two squares are polyominoes.

For example, Golomb proves (by a clever system of coloring the board) that it is impossible to cover completely with 21 trominoes a board missing a corner square. On the other hand, a board with one square missing at *any* point, *can* be covered by 21 right trominoes. It also is possible to cover a nonmutilated board with 16 tetrominoes, provided they are all of the same species, the only exception being the skew tetromino, which will not even cover a single edge of the checkerboard.

There are exactly 12 distinct types of



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Atomic Radiation for Rocket Testing

by Alfred Cohen

Assistant Project Engineer in the Instrumentation Section of the RMI Test Department, Mr. Cohen is investigating new concepts for acquiring, reducing and evaluating test data. After graduating in mechanical engineering from City College of New York, he worked as a civilian test engineer for the Navy. Mr. Cohen came to Reaction Motors in 1954 as a Test Department Instrumentation Engineer.

Although the rocket engine in theory is an extremely simple powerplant, its development is a highly critical art. Successful operation of an engine depends upon the solution of many unique problems and the accurate measurement of unusual variables. One of the problems we encountered at RMI was the measurement of the corrosive effects of a new high energy rocket propellant, a problem we solved through the use of atomic radiation.

In determining the corrosive effects of propellants, it is essential that the sensing element employed does not come into direct contact with the propellant being tested. The propellant would rapidly damage or destroy most measuring equipment. In addition, the tolerance of the tests does not permit additional contamination from other foreign bodies.

We approached the problem on the basis that the density variation of the propellant could be the measure of its degree of corrosion upon the component materials with which it had been in contact . . . and the denser the material being tested, the less radiation would pass through it. We decided, therefore, to use the penetrating power of radiation as the tool to measure density variation.

To conduct the tests, a radioactive source and a detector for radiation were located so that the propellant being measured lay in a container between the two. The radioactive source emits gamma rays which penetrate through the propellant and its container. That part of the radiation that gets through the propellant and its container strikes the detector.

The detector contains a filling gas which is forcibly ionized when bombarded by atomic radiation. The energy of ionization is converted directly into electrical energy. Thus, an increase in the density of the propellant reduces the radiation field intensity at the detector, and results in a decreased generated signal.

However, accurate measurement of this energy is difficult because the generated signal is very low (in the magnitude of 1×10^{-13} amperes). To overcome this, an instrumentation system was specially developed to transmit, amplify and record this data.

The signal is transmitted to the amplifier by a special shielded cable that eliminates the effects of noise and other disturbances. Data is recorded by a Null system of measurement, using a ten-inch strip chart recorder. The recorder is calibrated to give full deflection for a density change equivalent to one tenth of a pound per cubic foot.

As a result of the data acquired by this test program, the research scientists have been able to improve the propellants to a point where they are both safe and highy desirable for use as rocket fuels.

This project is typical of one of the ways in which RMI Test Department supports the applied research, development and production projects associated with advanced rocket powerplants. All projects pass through this department, from the evaluation of components and fuels to the static "hot testing" of the entire engine system for an aircraft or missile before delivery.

The Test Department is staffed by a team of specialists highly qualified in mechanics, electronics, chemistry, and instrumentation. This team is constantly working to provide the most accurate possible test results and also to develop new equipment and methods that will allow for even more accurate information in the future. And—because this team is constantly expanding—we are always anxious to talk with top-rated engineers and technicians who are interested in test work.

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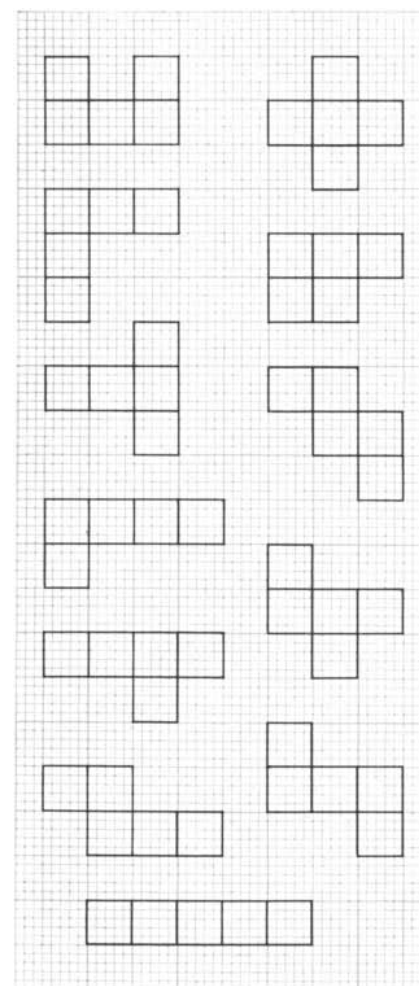
If you desire one or more reprints of Mr. Cohen's article, or would like to receive further information about employment at RMI, write to our Information Services Coordinator. Reaction Motors, Inc., 90 Ford Road, Denville, N. J.

pentominoes [*illustration on this page*]. Is it possible to place these 12, together with one square tetromino, on a checkerboard so that all squares are covered? Happily the answer is yes, and Golomb gives one elegant solution wherein the square tetromino is exactly in the center of the board!

If the reader will cut the 12 pentominoes and one square tetromino from cardboard (a sheet of graph paper rubber-cemented to the cardboard will simplify the task), he will find it no easy problem to fit the 13 pieces together to make an eight-by-eight checkerboard with the square piece in the center. It is not necessary, by the way, to turn over any of the pieces. The solution will be published in this department for next month.

Is it possible to form with these same pieces a checkerboard that has the square at one corner? I know of no such solution, but if any reader can discover one (here it is permitted to turn over the pieces), its receipt will be welcome.



PENTOMINOES, of which there are 12, may be placed together with one square tetromino so that they cover the checkerboard.

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5

THE AMATEUR SCIENTIST

Experiments which show that the earth functions as an electrostatic machine

One sunny morning last fall a jolt of electricity knocked Fred Ellis, an Ohio radio ham, from the roof of his barn. Fortunately Ellis landed on a stack of straw and lived to tell the tale. "I started to hook a ground wire to a 50-foot antenna tower on the roof," he writes, "when a fat spark jumped from the metal tower to my hand and knocked me off balance. Although the weather was hot and dry there had been no breeze of any consequence for several days. Hence the charge could not have been generated by wind friction. How do you account for it?" In Minneapolis a steeplejack was badly burned earlier in the year when a similar spark jumped from the base of a flagpole and touched off a nearby pile of gasoline-soaked rags. Again the accident occurred on a clear, still day. A television viewer on a Pennsylvania farm, plagued for months by a strange electrical disturbance which occasionally obscured his picture, finally cured the difficulty when he detected small sparks jumping from the sheet-metal cupola on his house. The trouble was ended by grounding the cupola. In all three cases the explanation has to do with the sometimes-overlooked fact that the earth is, among other things, the negative electrode of a huge electrical generator of the Van de Graaff type. Many details of this natural generator await explanation; if you enjoy electrostatic experiments, here is a ready-made project and a machine that goes with it.

Nature's generator works on the same basic principle as the man-made Van de Graaff machine but differs remarkably in its geometry and details of construction. The conventional Van de Graaff employs a pair of spherical electrodes, held apart by a cylindrical insulating column and charged by the action of a motor-driven belt. The arrangement resembles a big dumbbell. The belt "pumps" electrons out of one sphere and deposits them in the other. As the pumping action continues, an electric field builds up between the spheres. The voltage is limited only by the curvature of the collectors and the insulating properties of the column, belt and surrounding atmosphere. In nature's design, on the other hand, the parts of the generator take the form of concentric spheres. The earth, which is the negative electrode, is at the center. It is surrounded by a hollow sphere of insulating material: the lower atmosphere. The insulator is in turn surrounded by the positive electrode: the ionosphere. A spherical pattern of thunderstorms within the insulator functions as the charging belt. The machine's effectiveness as a generator of high voltage leaves something to be desired because the atmosphere is a relatively poor insulator: its resistance amounts to only 200 ohms. Yet thunderstorms do an astonishingly good job of keeping the electrodes charged.

Lightning, the counterpart of the man-made machine's corona points, carries current amounting to thousands of amperes. On the average 100 strokes of lightning hit the earth every second. You can hear the resulting electromagnetic debris at any hour by hooking a long antenna to the input of an audio-frequency amplifying system and turning up the volume [see "The Amateur Scientist"; SCIENTIFIC AMERICAN, January, 1956]. It makes a sharp, buzzing sound. The energy output of the 2,000 to 6,000 thunderstorms in progress at any one time is sufficient to maintain an average potential of 360,000 volts between the earth and the ionosphere. This despite a leakage of current through the atmosphere of 1,800 amperes! The intensity of the field diminishes with height, but near the surface it amounts to about 100 volts per yard of altitude. Accordingly we walk around with our heads in air some 200 volts positive with respect to the ground at our feet [see "The Earth's Electricity," by James E. McDonald; SCIENTIFIC AMERICAN, April, 1953].

Given sufficient time, conductors insulated from the ground pick up the potential of the surrounding air. A negatively charged body attracts positive ions from the air until its negative charge is neutralized. Conversely, a positively charged body attracts negative ions. The time required for a body to reach electrical equilibrium with the surrounding air depends largely on its size and the concentration of ions naturally present in air. The amount of electricity that a body can accumulate—its capacity for holding charge—is also proportional to its size. Ellis's antenna tower was so big, and had lost so much negative charge to the surrounding air, that he was knocked off balance by the swarm of returning electrons. Had he touched a small object, say a metal ventilator or several hundred feet of wire, the current would doubtless have been so small he would not have felt it.

Several methods of measuring the intensity of the earth's field are based on the fact that conductors can reach electrical equilibrium with the surrounding air. These methods lend themselves to an interesting series of experiments. In principle the measurement is simple. You merely place a test structure (a few feet of wire will do) at a given height above the ground, insulate it from the earth, wait until it reaches electrical equilibrium with the air, and connect a voltmeter of appropriate sensitivity between the test structure and the earth. The meter reading is divided by the height in feet; the result is the field intensity in volts per foot. The field intensity varies considerably with location, topography, the hour of day and the state of the weather. Readings made at the top of mountains or steep hills average much higher than those made at sea or in prairie country. Conversely, observations made in valleys average somewhat lower. Usually the charge of the earth is negative, but under the trailing edge of a thunderstorm it is often positive. Here potential differences of 3,000 volts per foot have been recorded. The intensity of the earth's electrical field also

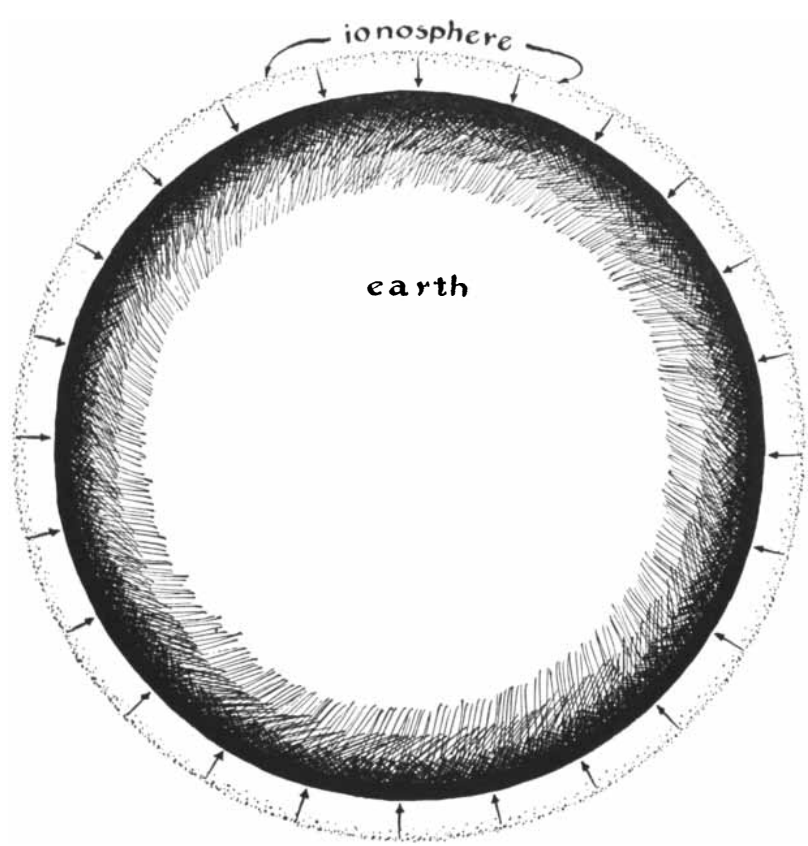
varies during the day; this appears to be a consequence of the uneven distribution of the earth's land area. The number of thunderstorms reaches a peak when the continents of the Western Hemisphere are turned toward the sun; at that time Europe and Africa have just absorbed their daily quota of solar heat. This explanation, like many others concerning the generation and distribution of the earth's electric field, has not been tacked down as neatly as physical meteorologists would wish. More observations of the daily population of thunderstorms, together with corresponding information on the variation in field intensity, are needed.

Although the measurement of field intensity is simple in principle, it is made difficult in practice by the fact that considerable time may be required for a conductor to pick up charge from the surrounding air. Lord Kelvin devised the first method of speeding up the process. He insulated a metal tank from the ground, filled it with water and arranged matters so that water would flow from a spray nozzle at the bottom, where the charge density is greatest per unit area. He called the arrangement a "water-dropper." The surface of each drop, immediately before it is detached from the stream, is an extension of the surface of the tank. Accordingly the potential difference between the drop and the air is equal to that between the tank and the air. When the drop is detached, it carries charge away. The process continues until equilibrium is established between the tank and the air. The test conductor need not consist solely of the tank. A relatively small water-dropper can be used for charging a test structure of any desired size. Garden sprays of the type which operate on compressed air supplied by a hand pump will charge a 30-yard length of wire in about 20 seconds. Fine spray is preferred to large drops because the higher ratio of droplet surface to volume not only conserves water but speeds the charging process.

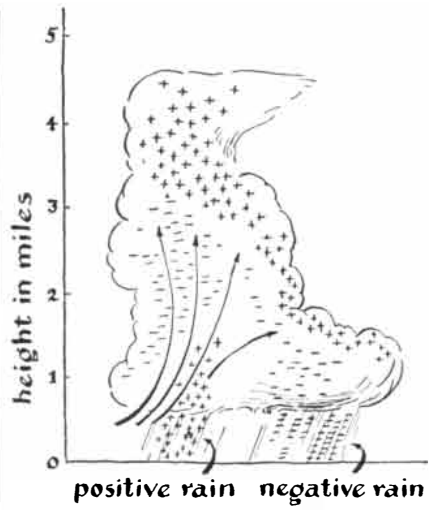
The charging time can also be reduced by enriching the concentration of ions in the vicinity of the test structure. For example, a wire 10 to 15 feet long with a glass insulator at each end is suspended a yard or so above the ground between a pair of posts. A short length of the wire is then wrapped in string or paper that has been soaked in inflammable lead nitrate. When the string or paper is ignited, the flame produces ions in the vicinity of the wire; in a few seconds the potential of the wire will reach that of the ambient air. A torch waved in the vicinity of the wire will accomplish the same result but at some cost in terms of convenience. Where it is desirable to monitor the field continuously over long periods, radioactive materials may be called into service. A film of polonium electrolytically deposited on a wire will emit alpha particles which strongly ionize the surrounding air.

The practical measurement of field intensity is further complicated by the necessity of using measuring instruments of extreme sensitivity. Test conductors of reasonable size store little energy at low voltages—at most a small fraction of a watt. If a substantial part of that little is consumed in driving the pointer of the measuring instrument, the accuracy of the reading will suffer. Lord Kelvin measured the potential of his water-dropper with a quadrant electrometer. This instrument consists of a metal vane suspended by a fine wire inside a metal structure which resembles a pillbox cut into four sectors. All the sectors are insulated from the ground, and sectors diametrically opposed to each other are wired together. The two pairs of sectors are then charged in opposite polarity by a battery, and the vane is connected to the test structure under measurement. A small mirror cemented to the wire from which the vane is suspended serves as a pointer; a spot of light reflected from the mirror moves as the mirror turns. The vane moves in response to the electrostatic attraction and repulsion between its charge and that of the sectors. In the finest quadrant electrometers the wire supporting the vane is replaced by a quartz fiber which has been made a conductor by depositing a film of gold on it. When the vane is charged, it draws almost no current; yet the device is extremely sensitive to changes in voltage. Amateurs who go in for instrument-making will find the construction of such an electrometer a challenging and rewarding enterprise.

Most modern electrometers are built around vacuum tubes of the screen-grid type. The basic circuit is simple. Bias voltage is connected between the cathode and grid of the tube through a high resistance. A microammeter is inserted into the plate lead; an ordinary battery supplies both screen-grid and plate voltage. The test structure is connected to the grid and the cathode is grounded. The intensity of the earth's field determines the charge on the grid and hence the strength of the plate current. The device is calibrated by connecting a



Principal components of nature's Van de Graaff generator



Distribution of charge in a thunderstorm

source of known voltage to the grid and noting the resulting deflection of the microammeter.

A number of precautions must be observed or the grid will draw an intolerable amount of current. Some current, for example, is contributed by positive ions which are ejected by the cathode and strike the grid. Another source of current is gas atoms ionized by electrons accelerated between the grid and plate. In addition, some of these electrons strike the plate with enough energy to produce soft X-rays, which in turn dislodge electrons from the grid. Light falling on the grid also ejects electrons from it. Finally, grid current tends to leak along the surface of the bulb.

A number of techniques have been developed for reducing these currents. The production of positive ions can be reduced by operating the cathode at subnormal temperature. The grid can in effect be shielded by charging the screen grid to a higher positive potential (15 volts) than the plate (6 volts). This has the effect of repelling positive ions ejected by the cathode. Reduced plate voltage prevents electrons from acquiring enough energy for ionizing the residual gas in the tube and lowers the production of X-rays. Photoelectrons are eliminated by enclosing the tube assembly in a light-tight box. Surface leakage is reduced by washing the glass envelope with alcohol and dipping the area surrounding the terminal of the control grid in ceresin wax. In applications demanding maximum sensitivity air is evacuated from the light-tight box.

By meeting these circuit requirements and using a tube of special design, such as the General Electric FP-54, it is possible to detect currents of 60 electrons per second. Other special electrometer tubes include the Victoreen 5803 and Raytheon 5886. The RCA 954 and 959 and the Western Electric 259-B types may also be used in all but the most exacting electrometer applications. For maximum sensitivity the grid must be tied to the cathode through a resistance on the order of 100,000 megohms. Such resistors are manufactured by the S. S. White Company, Victoreen and the International Resistance Company.

A third method of measuring the earth's field intensity eliminates the need for highly sensitive instruments by employing a device called a "field mill," which in effect transforms electrostatic charge into alternating current. Alternating current from the mill is amplified electronically and rectified. The output drives low-sensitivity direct-current ammeters, recorders and so on as desired. In effect, the field mill is comprised of a motor-driven variable capacitor which is connected in series with the capacitor represented by test structure, the earth's surface and the intervening air. As the capacity of the variable capacitor increases, current flows into it from the test structure. When the current of the variable capacitor decreases, current returns to the test structure. The frequency is made high in relation to the time required for the test structure to assume electrical equilibrium with the surrounding air. Hence the test structure remains substantially at the ambient potential, and energy lost through the weak oscillating current is not significant. Output from the mill is provided by voltage de-

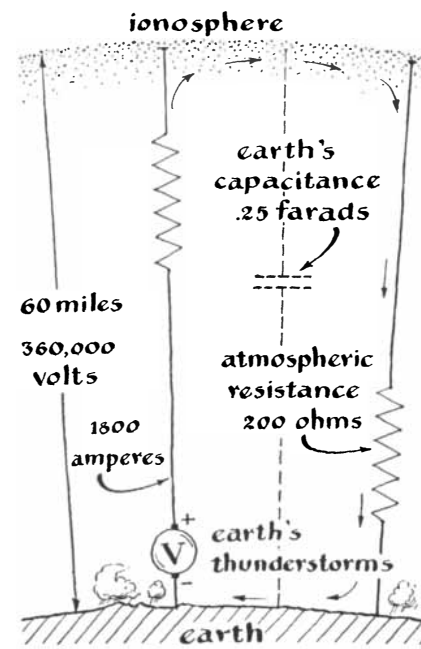


Diagram of the earth's electric circuit

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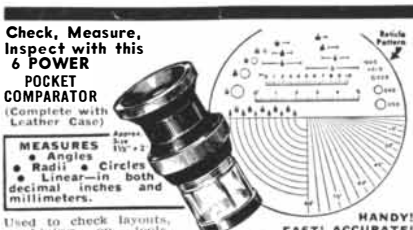

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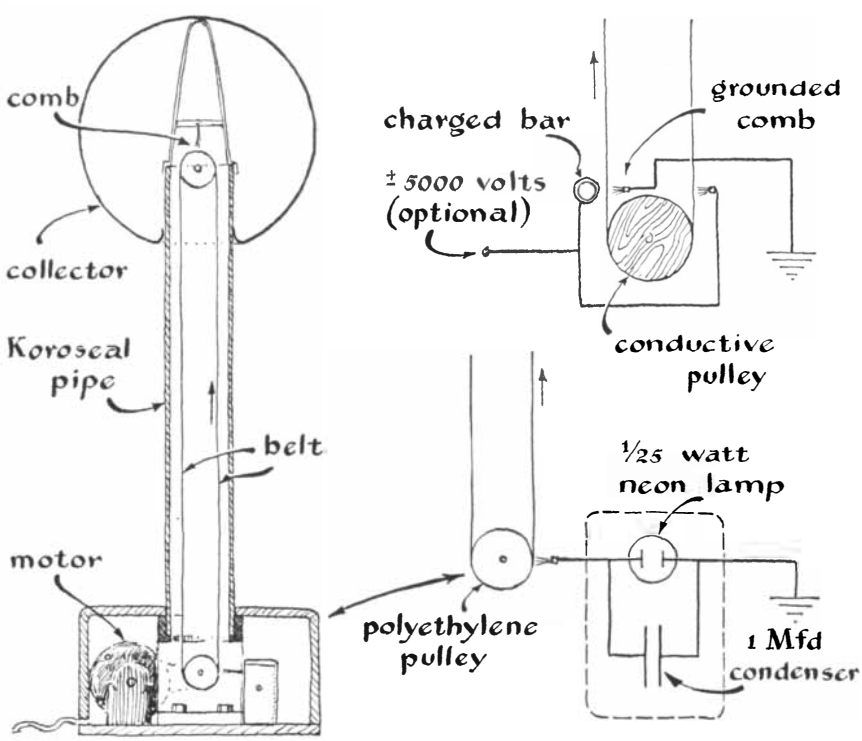
veloped across a megohm resistor inserted between the variable capacitor and the test structure.

As usually constructed, the mill takes the form of a capacitor with three plates, two fixed and the third motor-driven. One plate is a shallow cylinder closed at the bottom and open at the top. The other two plates form the lid of the cylinder. Each of these plates looks rather like a two-bladed paddle; it consists of opposing quadrants joined at the apex. One of them is mounted flush with the open end of the cylinder, but is insulated from it. This plate covers two quadrants of the cylinder, leaving two quadrants open. The open quadrants are closed by the other plate, which is mounted directly above them. This last plate is keyed to the end of a shaft which extends through the assembly to the motor, fastened to the bottom of the box. When the shaft rotates, the blades of the plate alternately cover and expose the fixed plates. The rotating assembly is mounted on insulators and grounded through the megohm resistor across which the output voltage is developed. The alternating-current output is rectified by a synchronous reversing switch, or commutator, keyed to the opposite end of the motor shaft. By rectifying the output synchronously, both field polarity and intensity can be observed. The mill is calibrated by comparison with a known voltage. It is both rugged and portable. Special designs have been developed for use in aircraft, and have contributed significantly in recent years to this phase of meteorological research.

Franklin B. Lee, a chemical engineer and faculty member of the Erie County Technical Institute in Buffalo, N. Y., has built a number of small Van de Graaff machines and passes along the results of his experiments to amateurs who prefer to work with generators less bulky than the earth. "Two important pieces of information for the designer of Van de Graaff machines," he writes, "are, first, approximately 50 square inches of belt per second passing over the pulleys will produce one microampere of current; second, the maximum potential developed by the machine will be equal to 70,000 times the smallest radius of curvature of the collector in inches. Thus a perfect sphere 12 inches in diameter will have a theoretical limiting potential of 420,000 volts. Holes made in the sphere to admit the belt assembly alter the pattern of the field and reduce the theoretical maximum. The most effective compromise with the ideal shape for a practical collector is a spheroid slightly flattened at the bottom, with minimum radius of curvature located at a reasonable distance from the insulator to dis-



Van de Graaff generator with internal belt and external excitation

MISSILE SYSTEMS ELECTRONICS

Activities at Lockheed Missile Systems Division laboratories in Palo Alto cover virtually every field of electronics related to missile systems. Inquiries are invited from those who desire to perform research and development of a most advanced nature.

Here staff members discuss a laboratory model of an airborne component of a guidance system. Left to right: Dr. R. J. Burke, telemetering; E. A. Blasi, antennas; K. T. Larkin, radar and command guidance; Dr. S. B. Batdorf, electronic division head; Dr. H. H. Leifer, solid state; S. Janken, product engineering.

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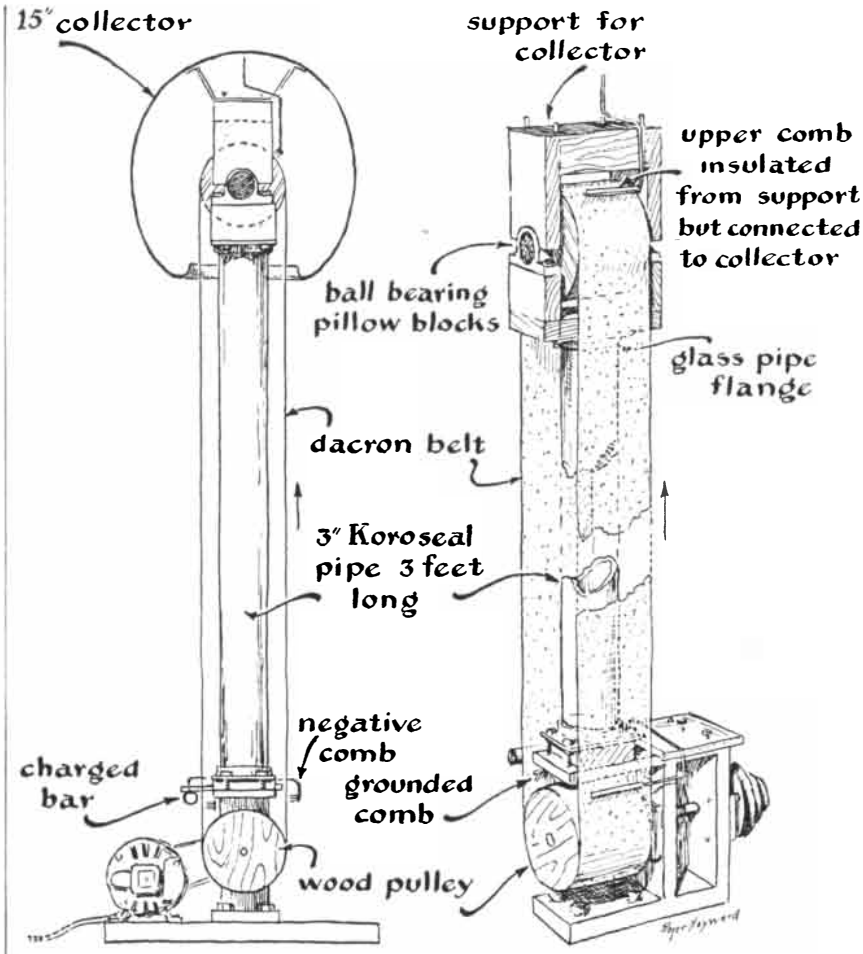

Van de Graaff generator with external belt and internal excitation

courage sparking along the insulator surface [see "The Amateur Scientist"; SCIENTIFIC AMERICAN, April, 1955].

"The designer's choice of maximum voltage determines the size of the collector. To realize a large fraction of the theoretical limiting potential, the collector must be at least two or three diameters removed from other metallic parts. The distance should be greater if sharp-edged metal parts are present, and may be somewhat less if all parts are covered by a rounded metal shield of large radius of curvature. The opening which admits the belt to the collector ought not to be much larger than half the diameter of the collector and should be smoothly curved inward, using a generous radius of curvature.

"Although a high polish adds to the attractiveness of the collector, it is not essential. Minor surface imperfections, if well rounded, limit the maximum voltage only slightly. Sharp edges or burrs must be ground down. Lint and dust particles will reduce the voltage to 40 per cent of the theoretical maximum if they protrude from the surface as much as 1 per cent of the radius. Unpolished commercial aluminum spinnings, free of lint and dust, will collect about 85 per cent of the theoretical maximum. A high polish will increase the voltage another 1 per cent. The concentration of charge around the hole through which the belt enters accounts for the remaining 14 per cent, a quantity which varies, of course, with the size of the hole and its distance from other conductors.

"The hemispheres from which my collectors have been assembled were procured from a local metal-spinner who, if not too busy, will turn them out for $4.50 each, a reasonable price considering the fact that he pays $2 for the 14-gauge blanks. I had to furnish the wooden die on which the parts were spun. They would otherwise have cost on the order of $25. Incidentally, I will be glad to supply any number of 12-inch hemispheres at cost plus postage plus 75 cents per pair for handling, boxing and so on.

"Selection of the desired current output determines the size of the belt and the speed at which it must run. Meet-

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			0-2	2-3	4-15	0-2	2-3	4-15	1-2	2-3	4-15	1-2	2-3	4-15
• ***SYSTEMS*** *(Integration of theory, equipments and environment to create and optimize major electronic concepts.)*	**AVIATION ELECTRONICS • CONTROLS**		W	W	W C	W	W	W C	W	W	W C			
	DIGITAL DATA HANDLING DEVICES	M C		M C	M C		C	C		C	C			
	MISSILE WEAPONS SYSTEMS • RADAR	M W	W	M W X C	M W X C	W	M W C	M W C	W	M W X C	M W X C			
	INERTIAL NAVIGATION			W C	W C		W C	W C		W C	W C			
	COMMUNICATIONS		C	C N	C N	C	C				C N			
• ***DESIGN • DEVELOPMENT*** **MISSILE WEAPONS SYSTEMS**—Planning and Design—Radar—Fire Control—Servomechanisms—Computers		C M	W C M X	W C M X	W C M X	W C M	W C M	W C M X	W C M	W C M X	W C M X			
AVIATION ELECTRONICS—Radar—Computers—Servomechanisms—Shock and Vibration—Circuitry—Remote Control—Heat Transfer—Sub-Miniaturization—Automatic Flight—Automation—Transistorization—Infrared—Airborne TV		W C	W C X	W C X	W C X	W C	W C X	W C X	W C X	W C X	W C X			
RADAR—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control—Information Handling—Displays		M C	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X			
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GAS, POWER AND PHOTO TUBES—Photosensitive Devices—Ceramic to Metal Sealing—UHF and VHF—Super Power			L	L	L	L	L	L	L	L	L	L	L	
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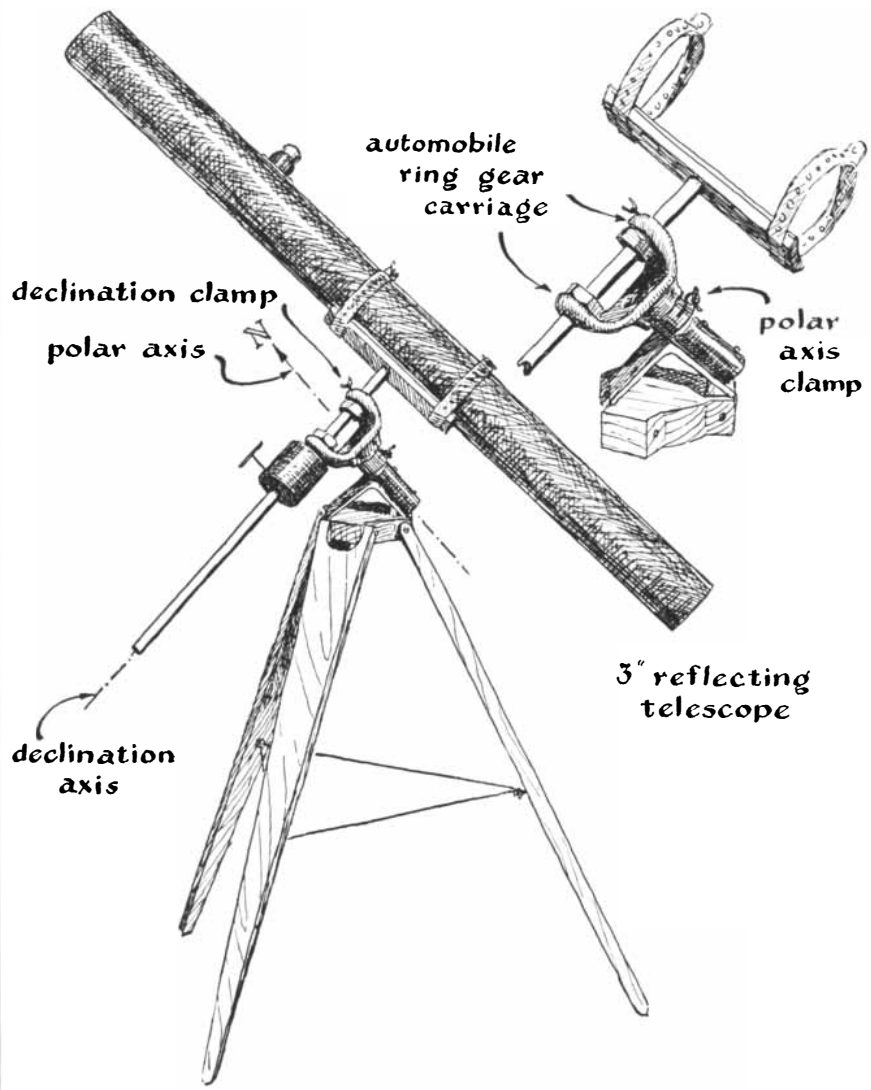
ing this specification is not so simple as it might seem offhand, because the properties of the materials used for the belt and its driving assembly enforce speed limits on both the belt and the shaft bearings. For maximum current one should in theory use the highest possible belt speed. But there are disadvantages in running belts faster than about 100 feet per second. Higher speeds aggravate the tendency of belts to fray at the edges and to come apart at the splices. At high speeds, particularly in the case of small pulleys, extreme tension must be maintained; this leads to bearing problems. Lubrication difficulties limit the shaft speed of sleeve bearings to about 5,000 revolutions per minute. The noise level of ball bearings becomes annoying above this speed unless special steps are taken to minimize it. At belt speeds above 100 feet per second appreciable amounts of power are lost through air friction. Finally, part of the charge appears to be 'blown' off the belt at excessive speeds—a phenomenon which I do not wish to be called on to explain.

"Belts may be made of almost any insulating material: paper, cloth, rubber, plastic and so on. Rubber, because of its poor resistance to ozone, has a limited life, but with used inner tubes costing so little the inducement to improve on it is slight. Rayon, nylon, Dacron and cloth (made into belts with acetone cement) are almost as good. Incidentally, when these materials are substituted for rubber, the position of the corona-collecting combs must be shifted. Cloth belts are more durable than rubber, are quieter and require less



A simple equatorial mounting for a small telescope

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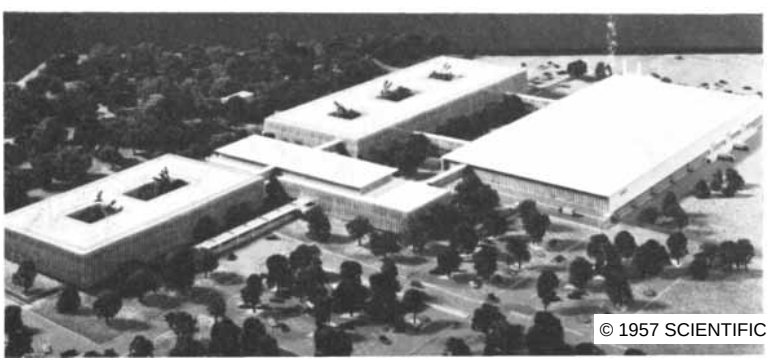
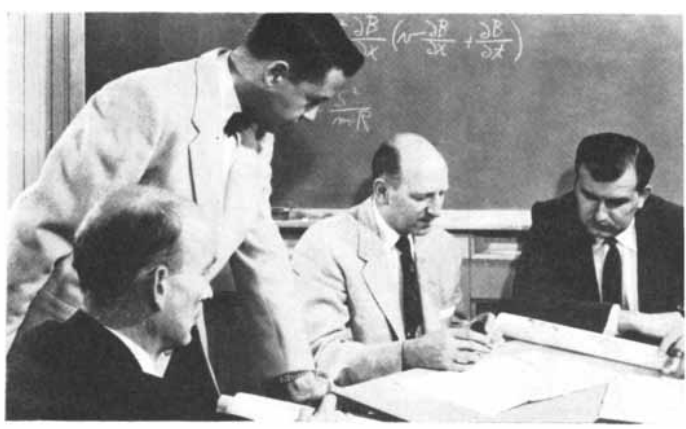
Lloyd P. Smith

Pictured below is our new Research Center now under construction in Wilmington, Massachusetts. Scheduled for completion in early 1958, this ultra-modern laboratory will house the scientific and technical staff of the Avco Research and Advanced Development Division.



Dr. Lloyd P. Smith



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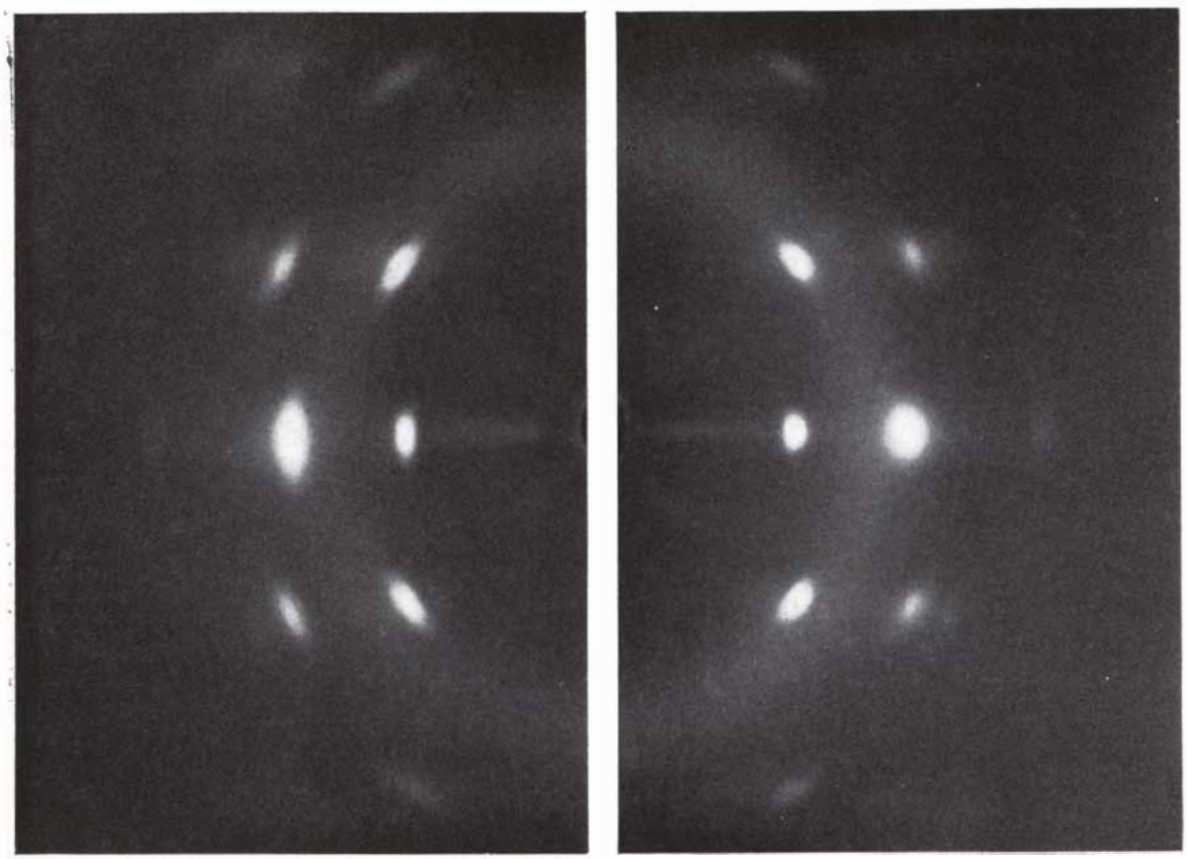
driving power, but tend to fray at the edges. This is easily remedied by a coat of lacquer. All things considered, I find that belts of neoprene joined with a diagonal splice are a good compromise.

"The upper pulley must be made of a material which is a good electrical conductor, such as wood or Bakelite. Surprised? At such voltages these materials are very good conductors for the small currents involved. Scrap plywood may be glued together to make a highly satisfactory wooden pulley. The lower pulley should also be electrically conducting if a separate 5,000 to 10,000-volt d.c. power supply is used for spraying charge onto the belt. If the machine is to be self-excited (that is, if the belt is to be energized by friction), the lower pulley should either be coated with or constructed of a material of extremely high resistivity. A 1/32-inch thickness of polyethylene makes a splendid covering for small wooden pulleys. The pulleys should be turned with a slight crown, the edge making a snug fit with the inside of the polyethylene tube. The tube may be made by cutting the ends off a round squeeze bottle. The tube is simply pushed over the wooden core. The choice of pulley and belt material for self-excited machines determines the polarity of the collector charge. A rubber belt running on a lower pulley of polyethylene or polystyrene will usually pump electrons from the collector and hence charge it positively.

"The belts may run on either the inside or the outside of the insulating support. Economy, simplicity and high currents favor running them on the outside. Appearance and neatness of construction require them to be on the inside. The former arrangement permits the use of a small, relatively inexpensive insulator with low current leakage and minimum deterioration due to corona discharge (the source of ozone). It also permits use of the widest belt possible for a given opening in the collector. Problems arising from unequal potentials throughout the insulator are similarly minimized. All hygroscopic or fibrous materials should be avoided in the selection of the insulating column because they invite leakage through the moisture which forms on the surface. The material must also be selected with an eye to its mechanical properties: strength, stiffness and toughness. Finally, it should be readily available at a reasonable price. Tubing of polyester glass-fiber laminate or polyvinyl chloride meets these requirements and is available in standard pipe sizes. In the three-inch (diameter) size, it costs $2.60

GIANT MOLECULES



These two photographs compare the x-ray diffraction patterns of natural rubber (*left*) and a new synthetic rubber produced by the Firestone Tire and Rubber Company (*right*). As the patterns suggest, the new man-made high polymer successfully duplicates the structure of the polymer synthesized by the *Hevea* tree.

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per foot. Polyvinyl chloride is the less hygroscopic of the two and may be flanged or formed to other contours by heating it to its softening point in hot paraffin.

"Combs or corona points for applying charge to the belt may be contrived in great variety. Often a common pin or a single phonograph needle can be as effective as the most elaborate comb. A tuft of wire, bound at one end and sheared like a broom at the other, makes a satisfactory comb, as does a small rectangle of wire screening. Care must be taken to avoid spraying areas of the belt with unwanted charge. This may happen if charges are permitted to mix on the front and back of the belt near the pulleys. The problem is met by mounting the combs on fixtures which provide easy adjustment over a wide range of positions, and by selecting comb sizes which restrict the areas that are sprayed with charge."

The simple Newtonian telescope that is shown on page 166 is submitted by W. Gorrell, Jr., of Buffalo, Wyo. A local school, having purchased a telescope kit and made a three-inch mirror, was stumped for an adequate mounting. On appeal, Gorrell solved the problem by a visit to a local automobile junkyard plus a few evenings of labor. The gadget he picked up in the junkyard should interest any amateur on the verge of assembling a small equatorial mounting.

The lucky find is a "ring-gear carriage," a component of the transmission assembly in most pre-automatic-shift cars. "The holes through the yoke end," Gorrell writes, "are aligned precisely and make a snug fit with a .75-inch shaft. The bottom of the part is faced off. Both the outside and inside are turned. The shoulder and the top surface are nicely faced. I used only one of the inside bores (the smaller one), for which I turned a piece of pipe to fit. A brass collar on the pipe takes the downward thrust of the instrument.

"The ring-gear carriage turns in a short length of pipe, which is welded to an angle-iron base as shown. The 45-degree angle of the base is close enough to that of our latitude (44 degrees, 21 minutes) so that a slight tilt of the tripod compensates for the difference.

"Since the entire rig weighs only a few pounds and the center of the yoke is the center of balance between the 'scope and the counterweight, the instrument can be lifted off the tripod—yoke, counterweight and all—and reassembled without touching a single screw or clamp."

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BIBLIOGRAPHY

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

VANISHING CULTURES

THE ABORIGINES OF TASMANIA. H. Ling Roth. Kegan Paul, Trench, Trübner & Co., Limited, 1890.

BLACK WAR: THE EXTERMINATION OF THE TASMANIAN ABORIGINES. C. Turnbull. F. W. Cheshire Pty., Ltd., 1949.

THE KÁFIRS OF THE HINDU-KUSH. Sir George Scott Robertson. Lawrence & Bullen, Ltd., 1896.

THE MYSTERY OF EASTER ISLAND. Mrs. Scoresby Routledge. Sifton, Praed & Co. Ltd., 1919.

RESEARCH ON SOUTHEAST ASIA: PROBLEMS AND SUGGESTIONS. Robert von Heine-Geldern in *American Anthropologist*, Vol. 48, No. 2, pages 149-175; 1946.

AN S.O.S. OF ETHNOLOGY. Robert Heine-Geldern in *Actes du IV^e Congrès International des Sciences Anthropologiques et Ethnologiques*, Vol. 3, pages 261-272; 1956.

THE SHORTEST RADIO WAVES

ELECTRIC WAVES. Heinrich Hertz. Macmillan and Co., 1900.

FURTHER EXTENSION OF MICROWAVE SPECTROSCOPY IN THE SUBMILLIMETER WAVE REGION. Monroe Cowan and Walter Gordy in *The Physical Review*, Vol. 104, No. 2, pages 551-552; October 15, 1956.

MICROWAVE SPECTROSCOPY. Walter Gordy in *Reviews of Modern Physics*, Vol. 20, No. 4, pages 668-717; October, 1948.

MICROWAVE SPECTROSCOPY IN THE REGION FROM TWO TO THREE MILLIMETERS. O. R. Gilliam, Charles M. Johnson and Walter Gordy in *The Physical Review*, Vol. 78, No. 2, pages 140-144; April 15, 1950.

MILLIMETER AND SUBMILLIMETER WAVE SPECTROSCOPY. Charles A. Burrus and Walter Gordy in *The Physical Review*, Vol. 101, No. 2, pages 599-602; January 15, 1956.

ONE TO TWO MILLIMETER WAVE SPECTROSCOPY: I. William C. King and Walter Gordy in *The Physical Review*, Vol. 90, No. 2, pages 319-320; April 15, 1953.

ONE TO TWO MILLIMETER WAVE SPECTROSCOPY: IV. EXPERIMENTAL METH-

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ods and Results for OCS, CH_3F, and H_2O. William C. King and Walter Gordy in *The Physical Review*, Vol. 93, No. 3, pages 407-412; February 1, 1954.

Short Electric Waves. E. F. Nichols and J. D. Tear in *The Physical Review*, Vol. 21, No. 6, pages 587-610; June,1923.

Submillimeter Wave Spectroscopy. Charles A. Burrus and Walter Gordy in *The Physical Review*, Vol. 93, No. 4, pages 897-898; February 15, 1954.

THE RETICULAR FORMATION

Brain Mechanisms and Consciousness. J. F. Delafresnaye. Blackwell Scientific Publications, 1954.

Brain Stem Reticular Formation and Activation of the EEG. G. Moruzzi and H. W. Magoun in *Electroencephalography and Clinical Neurophysiology*, Vol. 1, No. 4, pages 455-473; November, 1949.

Patterns of Organization in the Central Nervous System. Edited by Philip Bard. The Williams & Wilkins Company, 1952.

Spasticity: The Stretch-Reflex and Extrapyramidal Systems. H. W. Magoun and Ruth Rhines. Charles C. Thomas, 1947.

THE HEART

Physiology in Health and Disease. Carl J. Wiggers. Lea & Febiger, 1949.

The Motion of the Heart: The Story of Cardiovascular Research. Blake Cabot. Harper & Brothers, 1954.

"NICOLAS BOURBAKI"

A Contribution to the Mathematical Theory of Big Game Hunting. H. Pétard in *The American Mathematical Monthly*, Vol. 45, No. 7, pages 446-447; 1938.

Eléments de Mathématique. N. Bourbaki. Hermann & Cie., 1939. Foundations of Mathematics for the Working Mathematician. N. Bourbaki in *The Journal of Symbolic Logic*, Vol. 14, No. 1, pages 1-8; March, 1949.

DIFFUSION IN METALS

Atom Movements. American Society for Metals, 1951.

Diffusion in Metals. Albert G. Guy in *Elements of Physical Metallurgy*. Addison-Wesley Press, Inc., 1951.

Diffusion in and through Solids.

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Richard M. Barrer. Cambridge University Press, 1951.

THE DYING OAKS

THE CURRENT STATUS OF OAK WILT IN THE UNITED STATES. George H. Hepting in *Forest Science,* Vol. 1, No. 2, pages 95-103; June, 1955.

INSECT TRANSMISSION OF OAK WILT. Frederick F. Jewell in *Phytopathology,* Vol. 46, No. 5, pages 244-256; May, 1956.

A STUDY IN THE EVOLUTION OF BIRDS

CHANGE IN STATUS OF THE BRIDLED GUILLEMOT AFTER TEN YEARS. H. N. Southern in *Proceedings of the Zoological Society of London,* Vol. 121, pages 657-671; 1951.

THE GENETICAL THEORY OF NATURAL SELECTION. R. A. Fisher. Oxford University Press, 1930.

GENETICS AND THE ORIGIN OF SPECIES. Theodosius Dobzhansky. Third edition. Columbia University Press, 1951.

MORPHISM AND EVOLUTION. Julian Huxley in *Heredity,* Vol. 9, Part 1, pages 1-52; April, 1955.

POLYMORPHISM. E. B. Ford in *Biological Reviews of the Cambridge Philosophical Society,* Vol. 20, No. 2, pages 73-88; April, 1945.

THE THEORY OF ADAPTIVE POLYMORPHISM. A. J. Cain and P. M. Sheppard in *The American Naturalist,* Vol. 88, No. 842, pages 321-326; 1954.

MATHEMATICAL GAMES

CHECKER BOARDS AND POLYOMINOES. S. W. Golomb in *The American Mathematical Monthly,* Vol. 61, No. 10, pages 675-682; December, 1954.

THE N-DIMENSIONAL CUBE AND THE TOWER OF HANOI. D. W. Crowe in *The American Mathematical Monthly,* Vol. 63, No. 1, pages 29-30; January, 1956.

THE AMATEUR SCIENTIST

AMATEUR TELESCOPE MAKING: BOOK I. Edited by Albert G. Ingalls. Scientific American, Inc., 1951.

ELECTRONICS: EXPERIMENTAL TECHNIQUES. William C. Elmore and Matthew Sands. McGraw-Hill Book Company, 1949.

PHYSICAL METEOROLOGY. John Clark Johnson. The Technology Press and John Wiley & Sons, Inc., 1954.

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