SCIENTIFIC AMERICAN

EXPERIMENT IN ANTHROPOLOGY

FIFTY CENTS

January 1957

The sun that never sets

FOR YEARS, movie makers have relied on the powerful carbon arc to light their motion picture studio sets. It gives them brilliant, man-made "sunlight" for use when and where it is needed.

Recently, Union Carbide—a pioneer in carbon-arc lighting—perfected a new yellow flame carbon arc for use in color photography. It gives off a perfectly balanced light which brings out true colors on today's sensitive film. This development has been recognized by the award of an "Oscar," symbol of highest achievement in the motion picture industry.

But the carbon arc is not limited to studio lighting alone. Its intense beam is also used to project the tiny picture on the film to the breathtaking realism and depth you see on theatre screens.

Many more uses of this amazing light have been developed—duplicating the effect of sunlight on new paint and textile colors . . . or analyzing the basic composition of a great many different materials. The scientists of Union Carbide will continue their research efforts to find new and better ways to make carbon serve all of us.

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THE PLENTIFUL RARE EARTHS

some facts about a clubby clan of elements that are rare in name only

a report by LINDSAY

We got to thinking the other day that perhaps a lot of industry folks are passing up a diamond-studded opportunity because they believe the rare earths are unavailable in commercial tonnages. Nothing could be farther from the truth. Rare earths are *not* rare! Commercial salts of the rare earths are available, right now, for prompt shipment in quantities from a gram to a carload.

That the rare earths are so plentiful is due, in large part, to Lindsay. During the last 50 years, Lindsay has developed the extraction and separation of rare earths to a high degree.

New equipment and processes are now in operation at Lindsay's West Chicago plant and are producing greater quantities of these versatile materials in higher purities than before.

FROM 57 THROUGH 71—Some chemists call rare earths Lanthanides, Lanthanons or the Lanthanum Series. Actually they are not earths, but trivalent metals, a rather amazing family of elements . . . atomic numbers 57 through 71. They are grouped together because they are always found together, with thorium and yttrium, in ores such as monazite, and all have closely related properties. While rare earths are technically metals, Lindsay produces them in chemical salt forms—individually or in combinations.

ATOMIC NUMBER	ELEMENT
39	Yttrium
57	Lanthanum
58	Cerium
59	Praseodymium
60	Neodymium
62	Samarium
63	Europium
64	Gadolinium
65	Terbium
66	Dysprosium
67	Holmium
68	Erbium
69	Thulium
70	Ytterbium
71	Lutetium
90	Thorium

SOME USES FOR RARE EARTHS

LANTHANUM—As lanthanum oxide in a high refractive optical glass, particularly for aerial cameras and other instruments.

CERIUM—Glass polishing. Scavenger in explosives production. Radiation protection glass for atomic reactors. Opacifier for porcelain. Oxidizing catalysts in organic preparations. Ultraviolet light absorber.

MIXED RARE EARTHS—Misch metal for lighter flints and alloy uses. Motion sickness medication. Cores of arc carbon electrodes. Aluminum and magnesium alloys.

PRASEODYMIUM & NEODYMIUM—Dichroic colorants for ceramic glazes and glass. Used in better grade sun glasses. They do not lower light permeability and index of refraction when used as colorant or decolorizer. Ceramic capacitors.

The rare earths are becoming increasingly important in the production of steel and steel alloys. Small quantities added to the metal in the ladle result in a strong, fine-grained steel. Steel thus treated has great resistance to low temperature oxidation and corrosion. Stainless varieties have better hot and cold workability. Silicon and electrical grade steels have better electrical qualities.

Rare earths added to cast iron act as powerful deoxidizers and help remove sulfur from the molten metal. They are responsible for cast iron that is resistant to scaling at higher temperatures and to certain corrosive atmospheres. In malleable metals, they act as a carbide stabilizer.

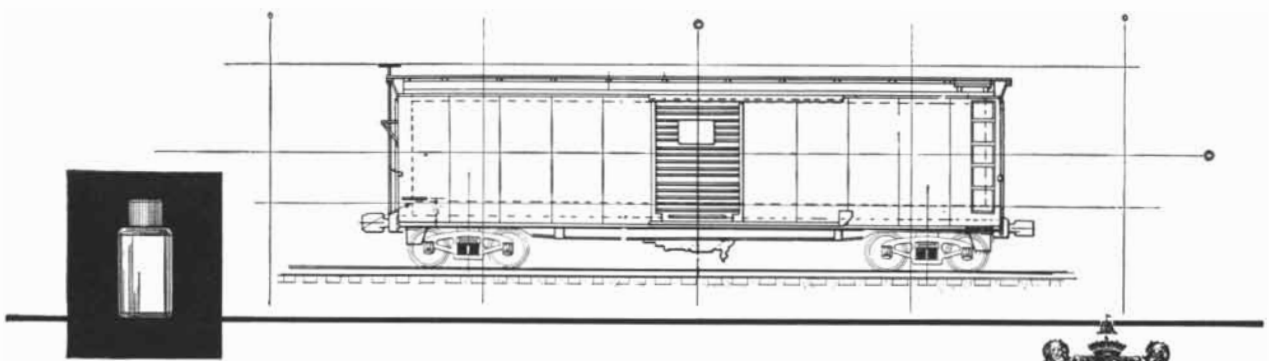
Magnesium-rare earth-zirconium alloys have excellent casting qualities and mechanical properties that make them ideal for important light-weight stressed components of aircraft engines.

Other rare earth compounds are used extensively for waterproofing, mildewproofing, weighting and dyeing of fabrics and compounding printing inks and phosphors.

LIKE AN ICEBERG—You might compare uses for the rare earths to an iceberg. What you see is only a small part of what lies undiscovered under the surface. In all probability, there is a real place for one or more of the rare earths in your operations. New uses—and profitable ones, too—are being discovered constantly. These versatile elements offer so much promise in so many different ways they merit your investigation.

To industries interested in the rare earths, we offer detailed technological data compiled over the years by our research staff. We will also furnish samples for experimentation.

And please remember . . . the rare earths are *plentiful*. Lindsay can supply you with quantities from a gram to a carload.



PLEASE ADDRESS INQUIRIES TO LINDSAY CHEMICAL COMPANY

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Established 1845 **SCIENTIFIC AMERICAN** January, 1957 Volume 196 Number 1

ARTICLES

DEPARTMENTS

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THE COVER

The photograph on the cover shows the people of Hacienda Vicos, an ancient estate in Peru, in front of their church during the *fiesta* of *La Virgen de las Mercedes* (Our Lady of Mercies). The Vicosinos are the subject of a current experiment in applied anthropology (*see page 37*).

THE ILLUSTRATIONS

Cover photograph by John Collier

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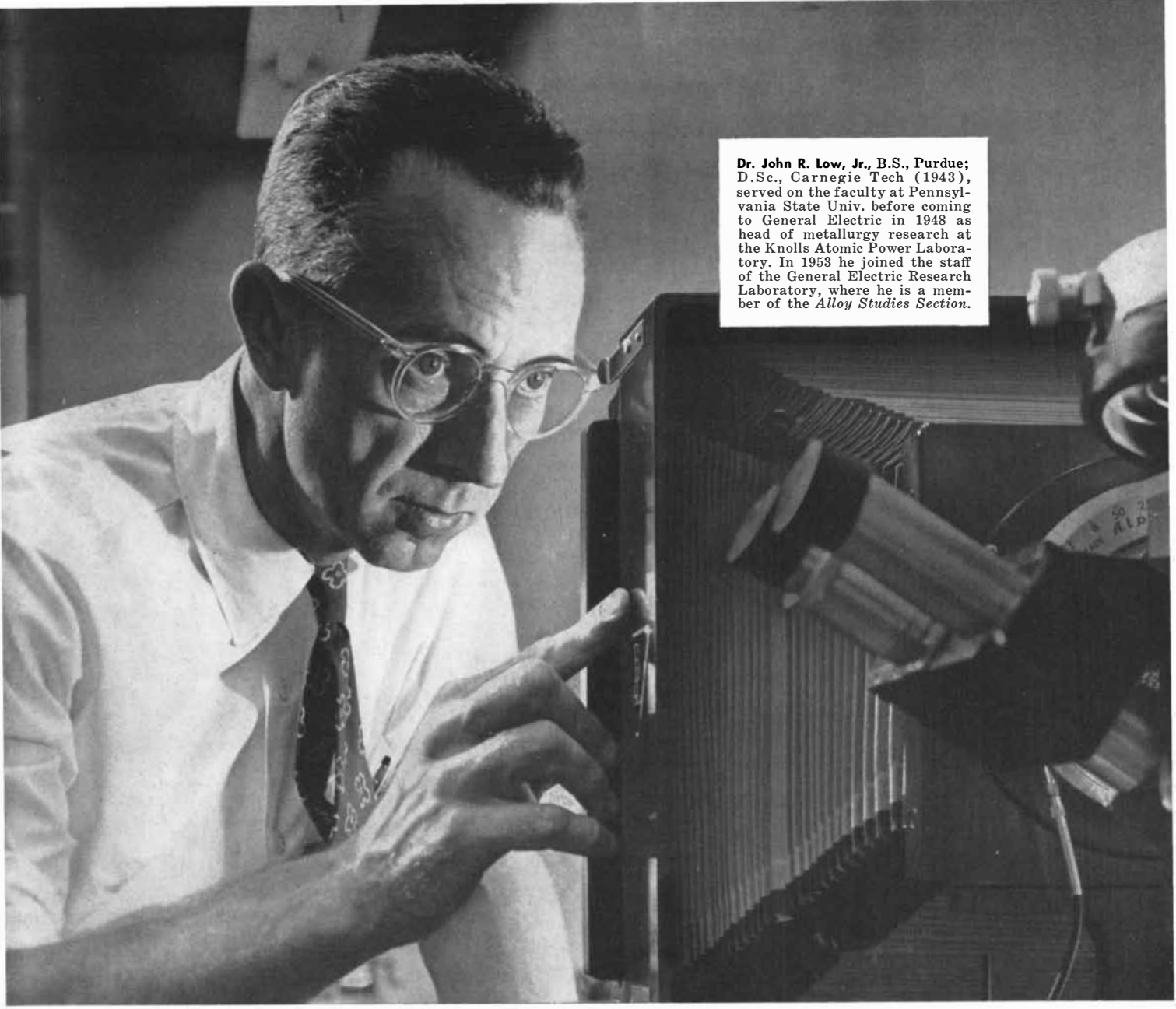

Dr. John R. Low, Jr., B.S., Purdue; D.Sc., Carnegie Tech (1943), served on the faculty at Pennsylvania State Univ. before coming to General Electric in 1948 as head of metallurgy research at the Knolls Atomic Power Laboratory. In 1953 he joined the staff of the General Electric Research Laboratory, where he is a member of the *Alloy Studies Section.*

Searching for safer metals

Dr. J. R. Low, Jr., of the General Electric Research Laboratory, provides theories to explain the fracture of materials

A history of wintertime tragedies involving broken ships, collapsed bridges, and ruptured pipelines testifies to the importance of understanding why metals break as they do. Dr. J. R. Low, Jr., of the General Electric Research Laboratory, began his attack on the problem of *low-temperature fracture* by looking for the very first evidences of cracks in a stressed-metal sample. He found that tiny breaks — microcracks — actually are present in the grains of the metal well before catastrophic failure occurs.

Recently, Dr. Low has been able to assemble the known facts about fracture into a consistent theory and thus has provided a mathematical relationship between the grain size and the brittleness of metals.

Dr. Low's work is being applied to making better and safer *metals* — and also to the development of *ceramics,* where a reduction in brittleness at both high and low temperatures could mean a revolution in materials for tomorrow.

At General Electric, such research is motivated by a belief that providing scientists with the tools, the incentives, and the freedom to seek out new knowledge is the first step toward progress for everyone.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Imaginative minds and skilled hands created these 5 "ideas" for industry and you

More than 50 years ago, General Mills launched its first research program. Since then many startling achievements have emerged from our laboratories into industry and home. These achievements are changing production practices, improving man's environment. Not content with yesterday's performance, the five divisions of the General Mills Industrial Group are reaching still further into the unknown, hoping to serve industry and you still better. The following examples are representative of recent products and processes resulting from this research.

1/ Jets Fly Faster With Sludge-Free Fuel. Today's improved petroleum fuels and lubricating oils are partly the result of General Mills versatile fatty nitrogen products. They are added to jet and diesel fuels, fuel oil, and gasoline to prevent darkening and sludge, to actually stop formation of sludge precursors. The fatty amines and quaternaries protect metals from corrosion by depositing a molecular film on its surface, find widespread use in refinery operations, crude oil production, transportation, storage. New booklet tells more, explains other exciting uses.

Chemical Division, Kankakee, Ill.

2/Millions of Mops Using Cellulose Sponge. Why? They're more sanitary, more absorbent, easier to use. Several million units of O-Cel-O cellulose sponge are used yearly by mop manufacturers to make high quality mops for home and industry. O-Cel-O makes a specialized product with extremely high water absorption, outstanding resistance to chemicals. If you have industrial uses for cellulose sponge requiring these or other specialized properties, get in touch with . . .

O-Cel-O Division, Buffalo, N.Y.

3/Golden Beans Keep Paint White. Soybeans gave paint makers new opportunities when General Mills introduced *Alkalite*. This alkali refined soybean oil is exceptionally light colored; heat bleaching makes it even lighter. A neutral oil, *Alkalite* has unusual non-yellowing properties, is used to make and maintain lightest colored finishes—to improve color and gloss retention, elasticity, toughness, durability in alkyd resin finishes. Send for facts about other soybean products too.

Soybean Division, Minneapolis

4/Can Today's Metals Carry Man to the Moon? General Mills' Dr. Gottfried Wehner says, "No." Metals must be improved to cope with heat, other obstacles. Here he checks "sputtering" of metal under simulated conditions in outer space. This is one phase of multi-faceted research in theoretical and developmental physics, findings from which are translated regularly into applications for industrial and military use today. Booklet shows engineering, manufacturing facilities.

Mechanical Division, Minneapolis

5/New Foods, New Markets on the Horizon. Food processors are finding greener fields these days with *Pro-80 Vital Gluten*, General Mills' 80% protein. Low cost, high grade wheat protein, it enriches staple and newly created foods to satisfy growing numbers of health and diet conscious consumers. Mixed with other ingredients during processing, *Pro-80* is bland, compatible with other foods, adds no taste or odor, hydrates rapidly, blends smoothly. Booklet tells of markets, uses.

Special Commodities Division, Minneapolis

WANT MORE INFORMATION?

Facts about these or other General Mills Industrial Group products and services can be had by writing Mr. C. H. Bell, President, General Mills, 1202 General Mills Building, Minneapolis 1, Minnesota

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General Mills

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LETTERS

Sirs:

The article on fuels by Eugene Ayres in your issue of October, 1956, was of great interest to me, both as a petroleum geologist and also as the person cited by the author as the source of the data on which he bases his predictions for the future. Mr. Ayres makes his point well that the age of fossil fuels is a transient one, and that forecasts as to its probable length are difficult to compute with accuracy. However, it does seem to me that he is unnecessarily pessimistic in his conclusions.

Soundly based evidence indicates that, as of the beginning of 1956, the world's proved and probable reserves of crude oil and petroleum gas liquids stand in the neighborhood of 300 billion barrels. The estimates of ultimate total oil resources mentioned by Mr. Ayres were not made on the basis of arbitrary averages but rather after careful study of each basin's geology, based on worldwide experience and analysis of the relation between oil occurrence and basin-type architecture, as well as many other pertinent geologic and engineering facts. Scientific knowledge and practical experience give great promise that the present proved reserves of oil might be increased six, seven, or even more times—putting our oil supply more in the range of upwards of two trillion barrels, in contrast to the 1,280 billion barrels quoted in the article.

It would seem that the article also

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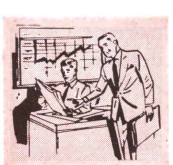

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seriously underestimates other vast potential sources of petroleum. For example, several hundred billion barrels of liquid petroleum may ultimately be recovered from shale-oil deposits in the western U. S. alone; perhaps as much as 300 billion barrels of oil occur in the tar sands of western Canada and comparably large amounts occur in other countries; extensive deposits of lignite and subbituminous coal in the western and other parts of the U. S. and Canada could be economically recovered in liquid form or hydrogenated to yield more than a trillion barrels of petroleum. The techniques for such recovery have been worked out and are not in the theoretical stage. Moreover, we should also take into account the factor of improved recovery of the oil we do find—experience here leading us to believe that we should be able to raise this figure before long by some 50 per cent. All these considerations persuade many petroleum geologists—myself included—that the age of fossil fuels, although limited, has a greater span than the article implies.

More important to the point at issue, however, is whether or not we approach our resources with the attitude that they are wasting substances and, once gone, would leave mankind to do without. To be sure, we owe it to posterity to conserve our resources. The best conservation of all, as experience has proven, is not hoarding but the concept that the human mind is the key to abundance and has been able to adapt or change seemingly useless materials into resources of great worth or, indeed, create what is needed to fill human want. So long as man's mind is at work I do not think we need to fear any shortage of energy—a point which Mr. Ayres ably makes in passing and the one which I urge upon your readers as the most significant in his interesting work.

LEWIS G. WEEKS

Standard Oil Company
New York, N. Y.

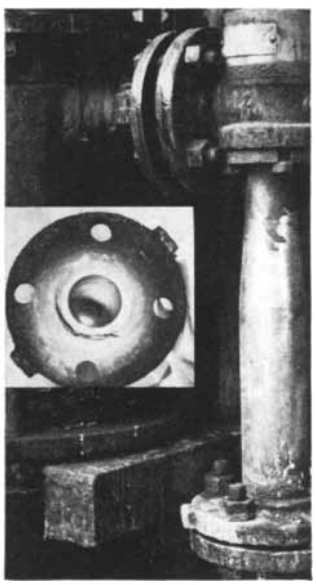
Sirs:

I am interested to note that the figures in Lewis G. Weeks's letter are somewhat more pessimistic in regard to ultimate petroleum reserves than the figures used as a basis for predictions in my article. I have great respect for Dr. Weeks's judgment in these matters.

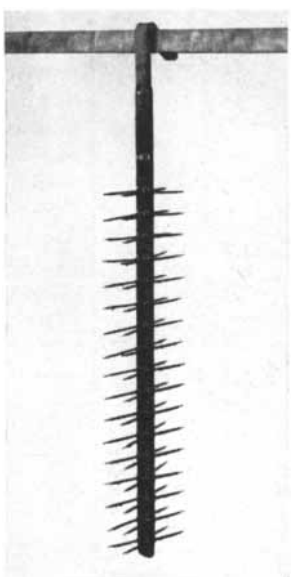
He states that "soundly based evidence indicates that as of the beginning of 1956, the world's proved and probable reserves of crude oil and petroleum gas

MALLORY·SHARON

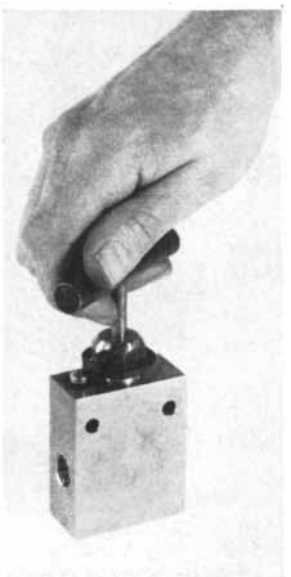
reports on **TITANIUM**



Titanium bore of steam jet ejector installed at DuPont shows no corrosion despite exposure to hydrochloric acid and high velocity steam. Previously, bore of different material had to be replaced frequently. Compare titanium bore to cast-iron flange.



Use of titanium in an anodizing rack has increased useful life from forty-five hours to one year. The sulphuric acid electrolyte used in anodizing operations quickly attacked the material previously used. Made by R. W. Renton Co.



Valve made of titanium for handling corrosive materials. Titanium is now much easier to fabricate than it was even a year ago. Thus piping, tubing, and complicated fittings are now available. Made by Autoclave Engineers, Inc.

Where use of Titanium piping is indicated, it can mean fewer shutdowns, contribute to safer operation. These Ladish Seamless Butt Welding Fittings, by Ladish Co., show versatility in fabrication of variety of fittings . . . elbow, tee, cap, and reducer.

Where **TITANIUM** *stops corrosion*

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New booklet lists available data on titanium's corrosion-resistant properties, shows typical applications, and includes corrosion data charts covering behavior with many common acids and industrial chemicals. For free copy write Mallory-Sharon Titanium Corporation, Dept. C-1, Niles, Ohio.

• Titanium offers outstanding resistance to many common corrosive media, including some of the most troublesome industrial chemicals — nitric acid, moist chlorine, chlorinated organic or inorganic compounds, etc. Titanium is not susceptible to stress corrosion, and resists pitting attacks in solutions which affect other metals.

Use of this new metal can end costly shutdowns, replacements, and hazards from corroded parts. Wherever corrosion presents a tough problem, we suggest you investigate titanium. Write and tell us the nature of your corrosion problem—our service engineering group can furnish technical data, and will propose a plan for economical evaluation.

MALLORY-SHARON TITANIUM CORPORATION, NILES, OHIO

MALLORY Ti SHARON

liquids stand in the neighborhood of 300 billion barrels." The figure I used was 1,367 billion barrels—more than four times as much.

He points out that "scientific knowledge and practical experience give great promise that the present proved reserves of oil might be increased six, seven, or even more times. . . ." The present proved reserves of oil are about 160 billion barrels. I assume, too optimistically perhaps, the probability that this may be increased about 8.5 times. Two trillion barrels, by the way, would represent an increase of 12.5 times which might, of course, be possible, but this must be regarded now as more of a hope than a prediction.

He mentions that "several hundred billion barrels of liquid petroleum may ultimately be recovered from shale-oil deposits in the western U. S. alone. . . ." I mention that "if we could exploit our entire oil-shale resource, we could reckon it as equivalent to 1,000 billion barrels of petroleum," and I have ventured to suggest how this might conceivably be achieved.

He mentions that "perhaps as much as 300 billion barrels of oil occur in the tar sands of western Canada. . . ." I use the same figure.

He calls attention to our extensive deposits of lignite and subbituminous coal. I point out that less than 2 per cent of this coal can be mined economically. The other 98 per cent is deep and scattered.

If Dr. Weeks should make projections based upon the figures in his letter for the world's probable reserves of petroleum he would set the dates of production peaks quite a bit earlier than I did. Of course any projections of this sort assume normal increases in demand. It is possible that the present Middle East situation could bring the peak of production in the U. S. closer than 1965 while postponing the peak of production in the rest of the world beyond 1980.

I heartily agree with Dr. Weeks that as long as man's mind is at work we do not need to fear any shortage of energy. To keep man's mind working at an effective pitch requires a realization of the serious technical and economic problems that lie ahead.

EUGENE AYRES

South Wellfleet, Mass.

Sirs:

In the November, 1956, issue of *Scientific American* (page 68) there appeared a brief item describing some re-

Wanted: Pioneers for man's last frontier

Help us build power for the conquest of space:

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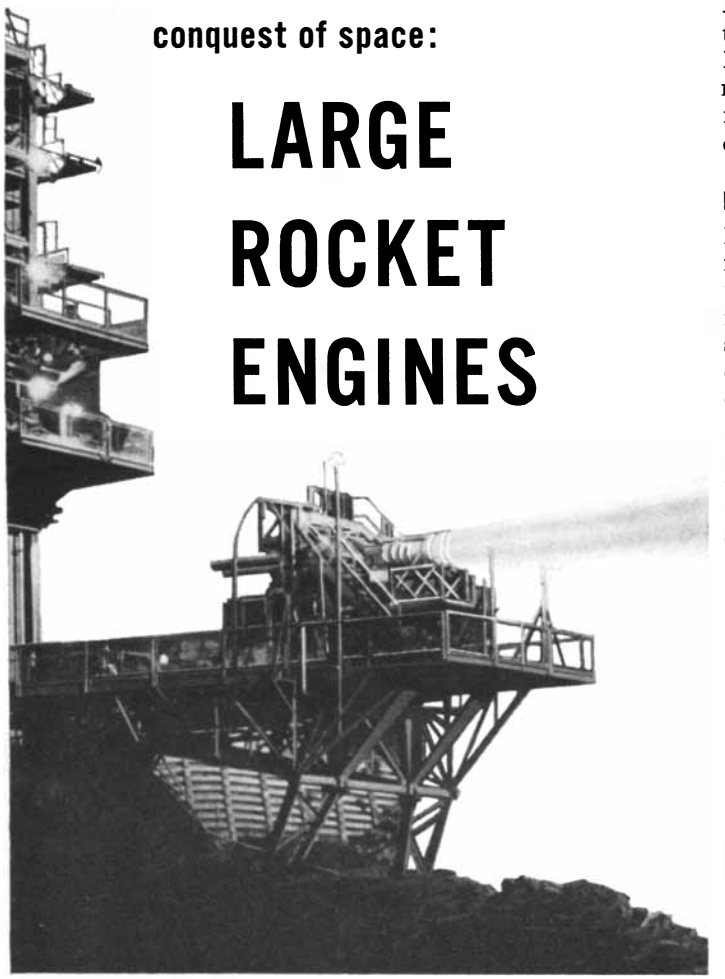

WILLIAM J. CECKA, JR., 35, aeronautical engineer, (Univ. of Minn. '43), was called from North American by the Air Force for experimental rocket work in 1944. On his return, he progressed rapidly: 1948, supervisory test job; 1950, group engineer, operations; 1953 engineering group leader; 1955, section chief of engineering test. Using our refund plan, he has his M.Sc. in sight.

GEORGE P. SUTTON, in the 13 brilliant years since receiving his MSME, Cal Tech, has made rocketry a way of life. His reputation is world wide. His book *Rocket Propulsion Elements* is recognized as the standard text on the subject. Still active academically, but no bookworm, he takes time off occasionally to study the laws of motion at some of the world's better ski resorts.

Tomorrow's count down already fills the air at ROCKETDYNE's 1,600-acre Field Test Laboratory in the Santa Susana Mountains near Los Angeles. For this is the free world's largest workshop for rocket engineering—the great new industry that is now attracting many of the finest scientific and engineering minds in the country.

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search being conducted at the National Bureau of Standards on the stabilization of free radicals at low temperatures. The statement in that necessarily brief news item that "the storage technique was developed . . . at the National Bureau of Standards" overlooks the important prior contributions of others to this rapidly developing new field.

I attempted to review and to summarize the work in this field at a Symposium on Unstable Chemical Species held by the New York Academy of Sciences in March, 1956. The papers presented at this symposium will soon be published in monograph form by the Academy. In my paper I pointed out that these studies on the production and stabilization of free radicals at low temperatures have been a long-developing effort, and that much of the recent work has been done independently and simultaneously in a number of laboratories. Many of the laboratories undertaking these studies did so without the knowledge that others were attempting similar or related investigations. Moreover, most of the laboratories have used a different set of experimental techniques, and have had different interests in undertaking these experiments. It is therefore incorrect to ascribe the entire development of the method to any one investigator or laboratory.

I would appreciate your bringing this point of view to the attention of your readers.

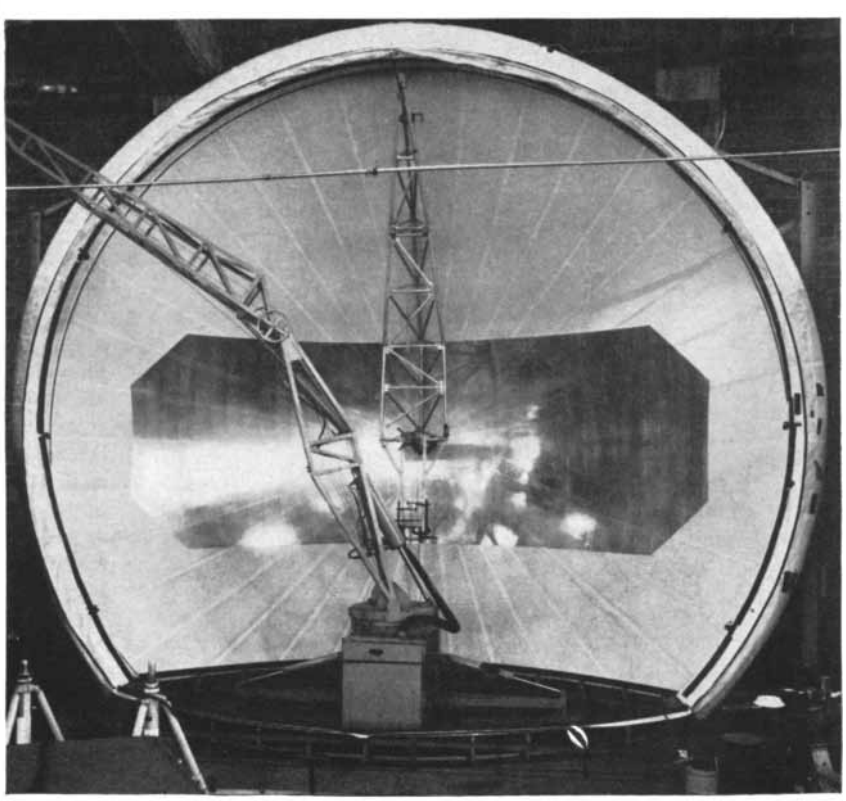
H. P. BROIDA

National Bureau of Standards
U. S. Department of Commerce
Washington, D. C.

Sirs:

In my recent article on pneumatic buildings [SCIENTIFIC AMERICAN, June, 1956], military security requirements prevented describing a most intriguing development of pneumatic construction. This development was recently declassified and the information can now be shared with your readers.

The item is an inflated radar antenna. This antenna, called a paraballoon, is made of Fiberglas cloth partly coated with a thin metal layer which forms the reflector. The enclosed photograph [*below*] shows this reflector in place on one side of the paraballoon which is mounted in a wall fixture. The space behind the cloth is sealed and a slight vacuum is applied to shape the surface. Two sections such as the one pictured are fastened together to form a paraballoon. The complete unit is supported by a rubber tire pressurized to about 10



A thin metal radar antenna mounted on a balloon of Fiberglas cloth

FYI
FOR YOUR INFORMATION

Allied Chemical

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

- *injection molding*
- *liquid fluorine*
- *phthalonitrile*

Injection Molding

The problem perplexing our white-coated friend in the picture above is the polyethylene basket in his hand. Or rather the half-a-basket, which is *really* his problem.

His trouble stems from the flow properties of high molecular weight polyethylene, a critical factor in large household goods—as our photograph and many injection molders will attest.

One solution: using low viscosity A-C polyethylene in the mix. A-C polyethylene, when correctly combined with the proper polyethylene molding resin, gives better control of flow and permits reduced pressures when filling large-cavity or intricate molds.

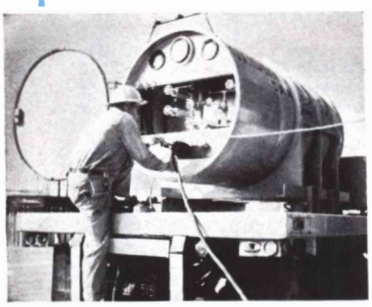
An added dividend in using this new polymer is better appearance. Color dispersion is improved, and the use of polished molds gives a high gloss finish.

Other appealing notes are increased production and decreased costs through faster cycle time.

A-C is an Allied Chemical trademark

Injection molders with questions about low viscosity A-C polyethylene can get the answers by checking the coupon.

Liquid Fluorine



A giant "thermos bottle"—designed to keep cool our most reactive element—is paving the way to large-scale use of fluorine.

Normally a gas, fluorine is handled and transported safely in liquid form for the first time in tanks newly developed by General Chemical Division. So carefully engineered are the tank transports that a shipment could be delayed for several weeks during hot weather in the middle of a desert without replacing the nitrogen.

Permitting this advance in industrial fluorine technology is a unique triple tank system. The fluorine in the inner tank is kept in a liquid state by a layer of liquid nitrogen in the second which cools the fluorine below its boiling point. The space between the second and third tanks serves as an insulating shield for the nitrogen.

General Chemical, one of the world's largest commercial producers of fluorine and hydrofluoric acid, has a new technical bulletin available covering the handling of both gaseous and liquid fluorine.

Phthalonitrile

If you remember how your blue automobile used to discolor some years ago, then you appreciate today's brilliant, permanent blue pigments—such as phthalocyanines.

Phthalocyanine blue and green pigments can now be made advantageously from phthalonitrile, an intermediate to be available in commercial quantities for the first time when Barrett Division begins large-scale production at Edgewater, N. J. late this summer.

Phthalonitrile (ortho-benzodinitrile) can also be the progenitor of many new chemicals. Its formula — $C_6H_4(CN)_2$ — with two reactive ortho-positioned nitrile groups, shows its usefulness in organic synthesis.

Information Service
ALLIED CHEMICAL
61 Broadway, New York 6, N. Y.
Please send me the following material:

- ☐ Information on injection molding
- ☐ Information on fluorine handling
- ☐ Phthalonitrile data sheet

Name_____
Company_____
Address_____
_____
Position_____
Remarks_____

pounds per square inch which runs around the rim joining the two halves of the paraballoon. Slight air pressure (.02 p.s.i.) is also maintained in the paraballoon proper during operation to retain the paraboloidal shape built into the unit during fabrication. Final adjustments are made by letting out cemented seams between strips while the cloth is mounted on the wall fixture.

In actual use the paraballoon is mounted inside a pressurized radome which protects it from the weather and allows it to rotate with minimum power. A quarter-horsepower motor can rotate a radome-enclosed 30-foot paraballoon at 6 revolutions per minute.

The paraballoon offers important advantages over metal reflectors. It is considerably lighter (1,700 pounds for a 30-foot unit) and can be handled and transported easily. Time of erection is negligible—a few men can do the job in an hour. It can be built to closer tolerances (1/16 inch over the whole 30-foot disk) and will hold its dimensions despite changes in ambient temperature. It requires no structural supports, thus avoiding shadow areas and breakup of the wave pattern. Fifty-foot reflectors have been designed, and there is no basic reason why antennas two or three times larger than that cannot be built in the same way.

This research development of Cornell Aeronautical Laboratory, Inc., sponsored by Westinghouse Electric Corp., Baltimore, Md., makes a substantial contribution—that of precision—to the virtues of pneumatic construction, thus increasing considerably the potential usefulness of this method of construction.

MURRAY KAMRASS

Systems Research Department
Cornell Aeronautical Laboratory, Inc.
Buffalo, N. Y.

ERRATA

The three pictures on page 81 of "The Gene," by Norman H. Horowitz [SCIENTIFIC AMERICAN, October, 1956] were incorrectly labeled. The top picture shows Erich Tschermak; the middle picture, Hugo De Vries; the bottom picture, Carl Correns. The ratio at the bottom of the third column on page 82 should be 9:3:3:1 rather than 6:3:3:1.

WHITE ALICE

The largest forward propagation tropospheric scatter system yet conceived is now in partial operation. Telephone service for the major portion of Alaska, in much of which no such service now exists, will be provided by the huge "White Alice" system.

Its 132 channels will furnish ample facilities both for civilian telephones and for military communications in an area larger than Texas, California, New York, Illinois, Delaware, and Tennessee combined. REL designed and manufactured all the tropospheric radio equipment for White Alice, including 10 and 1 kilowatt klystron amplifiers, driver exciters, dual diversity receivers, and radio test equipment.

More kilowatt miles of Tropo equipment by REL is in use and in production than that of all other companies combined.

REL **Radio Engineering Laboratories·Inc.**

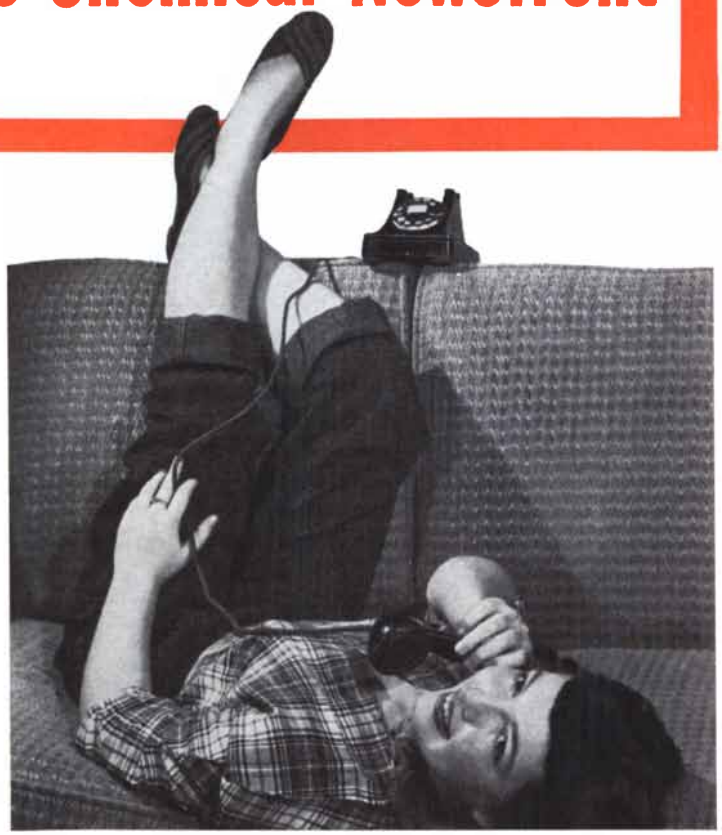
36-40 37th St · Long Island City 1, N Y

STillwell 6-2100·Teletype: NY 4-2816

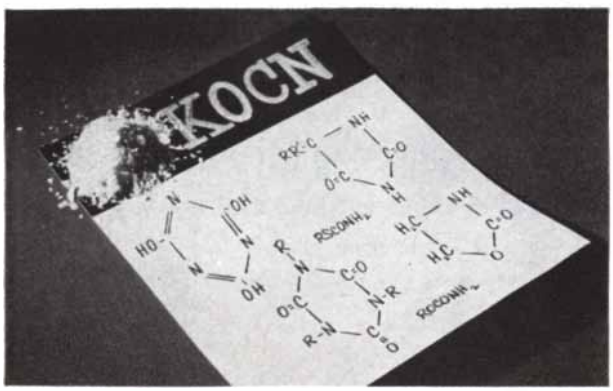
Canadian representative: AHEARN & SOPER CO • BOX 715 • OTTAWA

Creative careers at REL await a few exceptional engineers. Address resumes to James W. Kelly, Personnel Director.

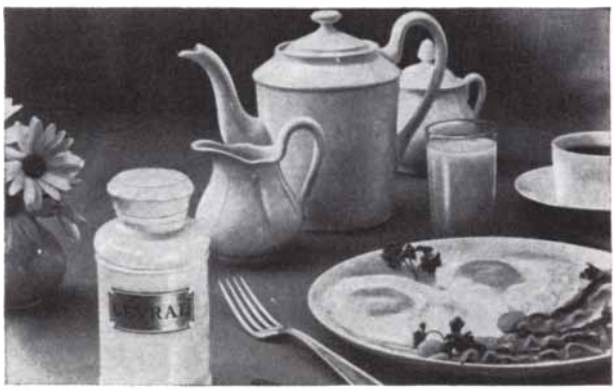
Life on the Chemical Newsfront



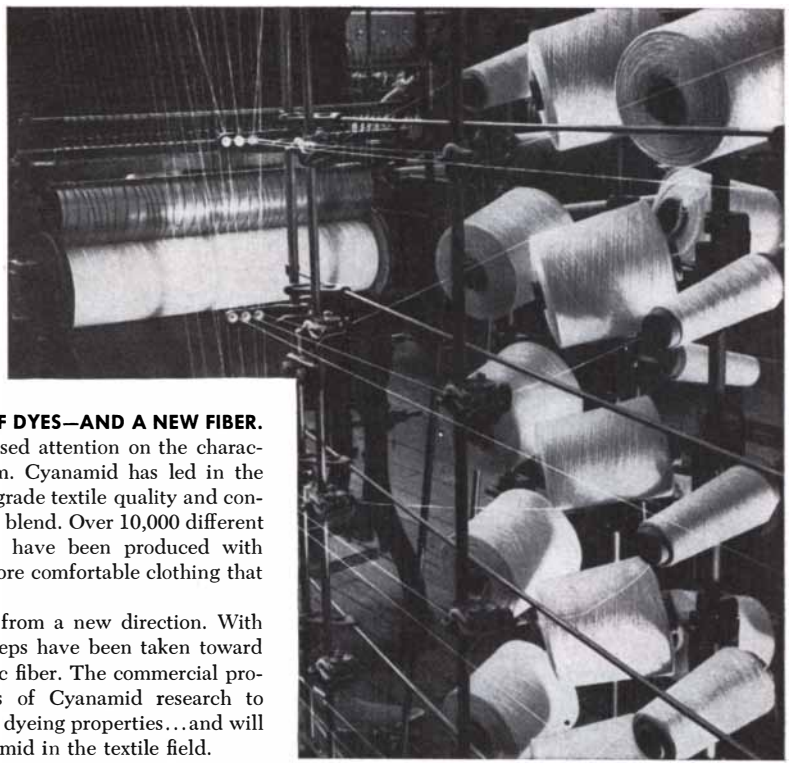
SOFTER, MORE COMFORTABLE DENIMS have made possible a style trend toward the use of this fabric for casual wear. This is only one application of Cyanamid's No-Odorol® sulfonated oil which softens and gives a full, smooth, well-lubricated hand to cotton, rayon and synthetic fabrics of various constructions. With the advent of the rubber-belt shrinking process, vegetable-base softeners are replacing mineral-base products to prevent damage to the rubber belts. No-Odorol has high resistance to discoloration and odor development, and may be used along with most commonly used textile finishes. In addition to imparting softer feel to off-the-loom fabrics, and a soft absorbency to toweling, it lubricates knitting yarns, and aids the sewing and cutting of piece goods. **(Organic Chemicals Division)**



AN OLD-TIMER IS REBORN on a commercial scale. It's Potassium Cyanate, which was used in 1828 by Dr. F. Wohler in his historic preparation of urea...the first synthesis of an "organic" chemical. Synthetic organic chemistry has become a giant industry, but Potassium Cyanate has just recently made its debut as a chemical of commercial importance. Cyanamid now produces large quantities at a price permitting application in a wide range of agricultural, pharmaceutical and industrial products. Among the initial reaction products of Potassium Cyanate are isocyanates, substituted ureas, hydantoins, triazines and many other intriguing heterocyclics and acyclics. **(New Product Development Department)**



VITAMINS JOIN CREAM AND SUGAR on the dinner table, thanks to a new packaging development of Cyanamid's Lederle Laboratories Division. Recognizing the widespread use of vitamin-mineral supplements as "preventive maintenance," Lederle now packages Gevral® geriatric vitamin-mineral capsules in attractive apothecary-style jars which can find a permanent place on the dining table. Their ready convenience aids greatly in maintaining adequate levels of vital chemicals in the diets of adults and children. Research has shown that some vitamins act as "triggers" for others and a general supplement type, such as Gevral, is desirable even when deficiencies are suspected to be specific. **(Lederle Laboratories Division)**



CYANAMID . . .

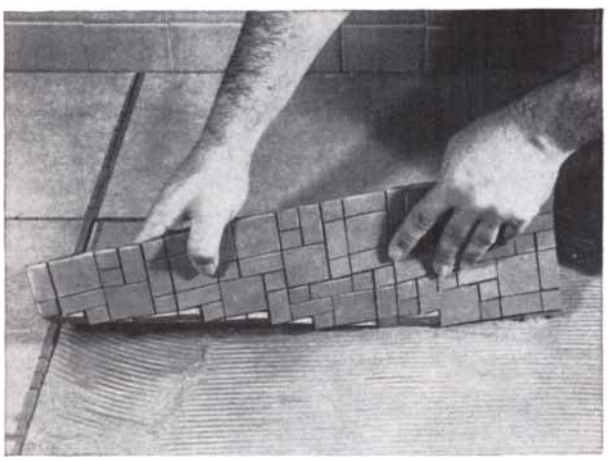
AND THE TEXTILE INDUSTRY

10,000 DIFFERENT TEXTILE FINISHES—A HOST OF DYES—AND A NEW FIBER. The increasing importance of synthetics has focussed attention on the characteristics of all fibers and fabrics made from them. Cyanamid has led in the development of chemicals, resins and dyes that upgrade textile quality and contribute to the beauty of virtually every fiber or fiber blend. Over 10,000 different textile finishes and an untold number of colors have been produced with Cyanamid products. Consumers benefit through more comfortable clothing that looks better and wears better.

Cyanamid is now entering the textile industry from a new direction. With the announcement of the new Fibers Division, steps have been taken toward the production and marketing of CRESLAN® acrylic fiber. The commercial production of CRESLAN will climax over 10 years of Cyanamid research to produce an acrylic fiber with superior physical and dyeing properties . . . and will inaugurate an expanded area of interest by Cyanamid in the textile field.

BETTER TEXTILE FINISHES are produced with a new Cyanamid textile resin. AEROTEX* Resin EU, an ethylene urea-formaldehyde resin, is applicable to a wide range of fabrics, providing exceptional protection against chlorine retention. Excellent fabric stabilization and high wrinkle recovery contribute to the "minimum care" properties of treated textiles. The physical and chemical stability, low free formaldehyde content and controlled minimum color of AEROTEX Resin EU are all important plus values in mill application. It is compatible with most finishing agents. (Textile Resin Department)

*Trademark



ALL TILE IS "GREEN," UNTIL FIRING . . . and the pressed or extruded "green" ceramic clay has virtually no strength . . . is easily damaged. Binders are added to the ceramic mix to improve the prefiring characteristics. Cyanamid's new HYFORM® Wax Emulsions add remarkably to green strength, greatly reducing breakage during production and permitting a greater latitude of forming operations. Other properties imparted by HYFORM emulsions are greater plasticity during pressing or extrusion, and improved lubrication in mold release. (Industrial Chemicals Division)

CYANAMID

AMERICAN CYANAMID COMPANY

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Helping America Make Better Use of its Resources

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

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JANUARY, 1907: "Capt. Roald Amundsen has returned from his Arctic expedition. The most important aim of this daring Norwegian, *viz.*, to locate the Magnetic North Pole, has been realized. It is situated 30 degrees south of the geographical North Pole, toward Canada, in the neighborhood of the meridian 100 degrees west of Greenwich."

"The meeting this past week of the American Association for the Advancement of Science is believed to have been the largest gathering of American scientists that has ever convened. Among the several thousand interesting exhibits we mention an ingenious rotating apparatus to show the movement of intestines and stomach during digestion, prepared from X-ray photographs of a small animal that was fed a solution of bismuth; an ingenious and novel gyroscope, perplexing indeed to explain; and casts showing cancer in successive stages of cure by radium. The most important of the meetings was a symposium on the biological control of sex. The consensus of opinion was that there is no known means of controlling the sex of offspring. In the geology section Dr. George N. Rice showed that the old notion of alternating regions of ocean and continent leading to a belief in some lost Atlantis has given place to the knowledge that the present continental areas are in fact primeval. In the chemical section Prof. Bertram B. Boltwood and Prof. Ernest Rutherford read papers on the origin of radium. Both men agree that there are probably many steps in the evolution of radium, beginning with uranium; one of these steps is actinium."

"If the promises which are held out by the inventors of metallic filament lamps are fulfilled we may soon witness the passing of the carbon filament bulb. Although the Nernst lamp, on which great hopes were based because it requires only half as much current as the carbon filament, has proved too costly, and the osmium lamp has been found wanting

(Left to right) Dr. John Bardeen*, Dr. William Shockley* and Dr. Walter H. Brattain, shown at Bell Telephone Laboratories in 1948 with apparatus used in the early investigations which led to the invention of the transistor.

Bell Telephone Laboratories Salutes Three New Nobel Prize Winners

Drs. John Bardeen, Walter H. Brattain and William Shockley are honored for accomplishments at the Laboratories

The 1956 Nobel Prize in Physics has been awarded to the three inventors of the transistor, for "investigations on semiconductors and the discovery of the transistor effect."

They made their revolutionary contribution to electronics while working at Bell Telephone Laboratories in Murray Hill, N. J. Discovery of the transistor was announced in 1948. Bell Laboratories is proud to have been able to provide the environment for this great achievement.

This is the second Nobel Prize awarded to Bell Telephone Laboratories scientists. In 1937 Dr. C. J. Davisson shared a Nobel Prize for his discovery of electron diffraction.

Such achievements reflect honor on all the scientists and engineers who work at Bell Telephone Laboratories. These men, doing research and development in a wide variety of fields, are contributing every day to the improvement of communications in America.

**Dr. Bardeen is now with the University of Illinois, and Dr. Shockley is with the Shockley Semiconductor Laboratory of Beckman Instruments, Inc., Calif.*

Bell Telephone Laboratories

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

for the same reason, the tantalum and tungsten lamps seem the most likely successors of the standard incandescent lamp."

"In the past 12 months wireless telegraphy has maintained its hold on the interest of the public because of a number of interesting conditions. Early in the year Reginald A. Fessenden and Lee De Forest made extensive essays to give us cableless telegraphy; but their experiments, like those previously made by Marconi, were futile insofar as transoceanic work is concerned, and the submarine cable still holds its own. Among those who are engaged in wireless telegraphy over land—and this includes not only numerous operating companies but the armies and navies of the world as well—the lack of transmission selectivity has brought about a state of affairs that borders on chaos; for only one or two stations in the active zone—and this often means a radius of 1,000 miles—can send at the same time. In this connection Valdemar Poulsen has recently exhibited his newly developed selective wireless telegraph, which he believes, and which we all hope, will be commercially selective instead of theoretically selective, as has been the case of its predecessors. Should the new system ring true, then the past year will go down in the history of wireless as the most progressive since the beginning of the art."

"At the recent Aero Club show, the Wright brothers exhibited a 30-horsepower aeroplane motor designed and built for their new and larger machine which, with one man aboard, they are confident of driving for a distance of 500 miles at an average speed of 50 miles an hour. With mechanical aeroplane flight an accomplished fact, we may look for a diversion of interest and effort from the dirigible balloon to the aeroplane proper. Its field of usefulness will be found chiefly in military service, but in all probability its chief development ultimately will be in the field of sport, where it should enjoy a popularity equal to that of the automobile."

SCIENTIFIC AMERICAN

JANUARY, 1857: "The Rev. Dr. Livingstone has recently returned to England from an African adventure of the most dangerous and thrilling character. He has traced by himself the course of the great river Zambesi, in eastern

U. S. Air Force Photo

Designed basically for night photographic work, the Martin RB-57 is employed by USAF TAC, powered by two Wright J-65 jet engines.

WADC'S WEAPONS GUIDANCE LABORATORY GIVES ACCURACY TO AIR FORCE BOMBS, MISSILES AND AIRCRAFT

The Weapons Guidance Laboratory at the Air Research and Development Command's Wright Air Development Center performs applied research and development of all Air Force weapons guidance equipment.

Included under this broad category are airborne bombing systems and equipment, weapon defense systems, offensive fire control systems, missile guidance equipment, electronic jamming systems, chaff systems, navigation systems, manual navigation aids and special test equipment peculiar to the requirements of the weapons guidance systems or equipment. In addition, all components of the foregoing are the province of this laboratory. The facilities available for these studies include various gun ranges, temperature and altitude chambers and other specialized test and evaluation installations.

Weapons Guidance is one of the laboratories that form the Wright Air Development Center. WADC, in turn, is the largest Center under the Air Research and Development Command. At its location at Wright-Patterson Air Force Base, Ohio, upward of 10,000 military and civilian workers are engaged in research, development and testing of aircraft, guided missiles and all types of associated flight and ground equipment.

Africa, extending 2,000 miles. This immense stream, whose discovery is the great fruit of the journey, is an enigma without parallel, for only a small portion of its waters ever reach the sea. Like the Abyssinian Nile, it falls through a basaltic cleft, near the middle of its course, which reduces its breadth from 1,000 to only 20 yards. Above these falls it spreads out periodically into a great sea filling hundreds of lateral channels. During his unprecedented march, alone among savages to whom a white face was a miracle, Dr. Livingstone was compelled to struggle through indescribable hardships. The hostility of the natives he conquered by his intimate knowledge of their character and the Bechuana tongue, to which theirs is related. He waded rivers and slept in the sponge and ooze of marshes, being often so drenched as to be compelled to turn his armpit into a watch pocket. He has brought back memoranda of the latitudes and longitudes of a multitude of cities, towns, rivers and mountains, which will go far to fill up the unknown regions in our atlases. Toward the interior he found the country more fertile and populous. Lions were numerous, being worshiped by many tribes as receptacles for the departed souls of their chiefs. The natives also worshiped idols, believed in transmigrated existence after death, and performed religious ceremonies in groves and woods. They were less ferocious and suspicious than the seaboard tribes, had a tradition of the Deluge, and had more settled governments. Some of them practiced inoculation and used quinine, and all were eager for trade. He has described a Quaker-like tribe, on the river Zanga, who never fight and never have consumption, scrofula, hydrophobia, cholera, smallpox or measles. Dr. Livingstone is nearly forty years old. His face is furrowed by hardship and thirsty fevers, and black with exposure to a burning sun. His left arm is crushed and rendered nearly helpless from the attack of a lion. His discoveries, in their character and commercial value, have been declared superior to any since the discovery of the Cape of Good Hope by Vasco da Gama. But greater than any commercial value is the lesson which they teach—that all obstacles yield to a resolute man."

"During the recent holidays, small balloons made of goldbeater's parchment colored red and filled with hydrogen gas have been delightful gift toys to the infantile world of Paris."

AL Stainless Steels
for the Process Industries

VARIOUS TYPES—Generally speaking, stainless steels are divided into three groups: chromium, chromium nickel, and chromium-manganese-low nickel steels. Their corrosion resistance, hardenability, tensile strength, etc., varies with the proportion of chromium, nickel and other alloying elements each type contains.

The chromium stainless grades are divided into two types: martensitic steels, which are hardenable; and ferritic non-hardenable steels. Both types are magnetic. The chromium nickel and chromium-manganese-low nickel stainless grades are austenitic steels, hardenable only by coldworking, and are non-magnetic.

The principal chromium stainless steels of chemical industry significance are Types 410, 431 and 440A martensitic grades, and Types 405, 430, 442 and 446 ferritic steels. Chromium nickel austenitic steels of principal importance are Types 302, 304, 316, 317, 347, 309 and 310. In the more recently developed chromium-manganese-low nickel austenitic group, Type 202 has physical and mechanical properties closely approximating those of Type 302—with the advantage of much lower nickel content and more ready availability in times of nickel shortage.

PRINCIPAL GRADES—Industry has called for quite an extensive range of chemical and physical properties in stainless steels. To meet these requirements, types have been developed which are best suited for a particular application: such as Types 316 and 317 for extra corrosion resistance, Types 309 and 310 for extra high temperature service, etc. Knowledge of these stainless steel qualities is essential for engineers and designers to create a product that will best do the work for which it was intended. Complete data on AL Stainless Steels is available in the various publications listed below.

Of all the stainless steels, the grades most used in the chemical and allied industries are Types 304, 316, 317 and 347 chromium nickel steels. The first three grades are also available in extra low carbon varieties to meet extreme conditions of fabrication or service which might carry the threat of intergranular corrosion. Designated Types 304L, 316L and 317L, these low carbon stainless steels are practically immune to carbide precipitation in the as-welded condition. Like Type 347, they permit the field-welding and stress-relieving of material of any thickness, for example, without the hazard of intergranular corrosion.

REGULARLY SUPPLIED FORMS—Allegheny Ludlum Steel Corporation is in position to furnish the various grades of stainless steel in all of the commercial forms required by fabricators of these metals. These include:

- Plates, including formed heads
- Sheets, either coiled or straight cut lengths
- Strip, either coiled or straight cut lengths
- Bars, rounds . . . flats . . . hexagons . . . octagons . . . squares or special shapes
- Billets, for forging or upsetting
- Angles
- Wire
- Tubing, seamless or welded
- Castings and smooth-hammered Forgings
- Extrusions
- Clad stainless

Information as to size ranges and mill tolerances are available in literature devoted to detailed discussions of AL Stainless Steels.

SPECIAL REQUIREMENTS—When selecting a grade of corrosion and heat resisting steel for a given application, it should always be borne in mind that laboratory tests, however carefully performed, can be expected at best to be only indicative of field performance. Variations in actual service conditions are so wide that a special study of the case at hand may be necessary at times. To that end, Allegheny Ludlum engineers and technical men are available for consultation on unusual problems involving stainless applications.

FABRICATION—AL Stainless Steels may be easily fabricated by any of the usual processes—welding, drawing, blanking, machining, spinning, forging, riveting, shearing, soldering, etc. In some instances, however, care must be exercised in handling of the material to preserve its corrosion or heat resisting properties. No one should undertake to fabricate any of the stainless steels without a full understanding of these handling procedures. Proper processing is fully discussed in Allegheny Ludlum literature—available on request.

RESISTANCE TO ATTACK—There is a wide range of conditions under which AL Stainless Steels operate in resisting corrosive attack at normal and elevated temperatures. Detailed information regarding their resistance to various media, heat resistance and strength will be sent upon request. See the publication list below.

STAINLESS CLAD STEEL—Allegheny Ludlum Stainless Clad is available commercially in the following commodities:

- Double Clad—Stainless both surfaces with carbon steel core. In plates, sheets and strip.
- Single Clad—Stainless one side only; plates only 3/16" and heavier.

Special clad materials on application.

PUBLICATIONS AVAILABLE

The following list of technical and service literature is freely available on request; just ask for the bulletins which contain the type of information you need.

Blue Sheets—An individual Blue Sheet, containing certified laboratory data on physical and chemical properties, etc. is available on each grade of AL Stainless Steel.

Fabrication of Stainless Steels—Contains valuable data for your shop men on various methods of handling, forming and finishing stainless steel.

AL Stainless Steel in Chemical Processing—36 pages on various applications, advantages, etc. of stainless in the chemical industry.

Stainless Steel Handbook—A case-bound book of 124 pages, containing complete data leading to the proper selection and fabrication, etc. of the correct grade of stainless for each application.

● Write to *Allegheny Ludlum Steel Corporation, Oliver Bldg., Pittsburgh 22, Pa.*

ADDRESS DEPT. NO. SC-85

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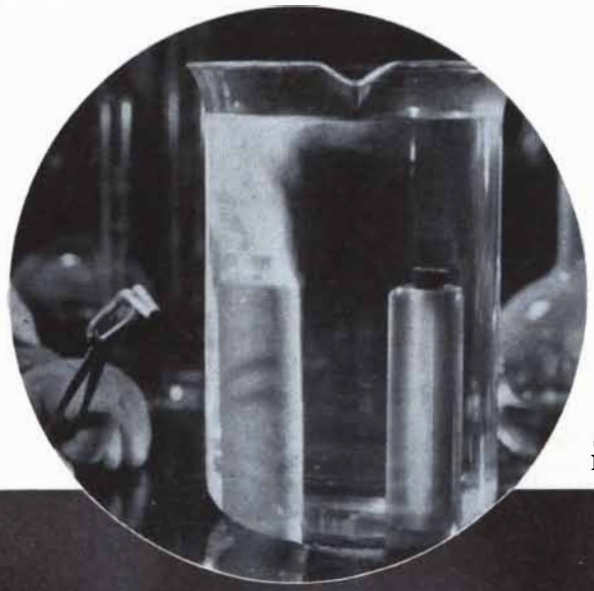
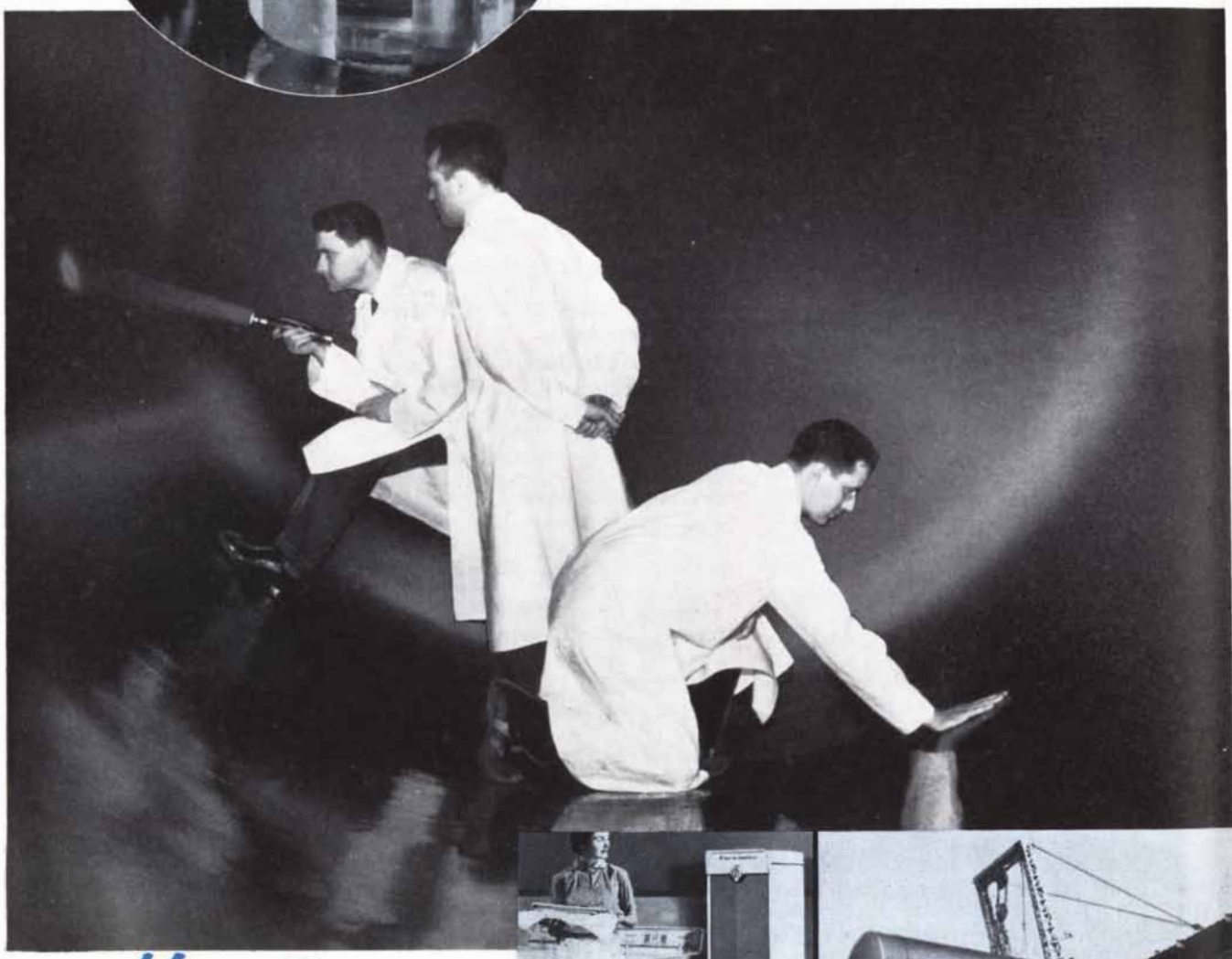


(Left) Comparative test by acid. (Below) Physical inspection of glass-lined tanks.



Here's Proof

of performance by the world's largest manufacturer of glass-protected steel products...for home, farm and industry

PERMAGLAS water heaters . . . set new standards of life expectancy in tank linings.

PERMAGLAS beer storage tanks . . . guard product flavor, purity and uniformity.

products, and tomorrow's product problems

YOU CONSIDERED

protected steel?

Glass coating may be the answer to improving your product's chemical and physical properties — whether that product is the size of a 2-penny nail or a 25,000 gallon storage tank!

Here are the properties

Chemical

In order to create the custom-glasses that today protect steel against various kinds of chemical action — A. O. Smith developed and tested more than 3000 glass formulations.

A. O. Smith can protect steel with glass . . . to withstand all inorganic acids except hydrofluoric — with corrosion-resistance actually improving as acid concentration is increased. No organic acid has yet been found that will break down A. O. Smith's specially developed glass formulations. And even though the silica element of glass is soluble in alkali—A. O. Smith can produce glass coatings to stand off alkali conditions up to pH of 12 at boiling temperature.

The highly corrosive characteristics of water fail to faze A. O. Smith glass coatings . . . proved in actual service by more than 3,000,000 home water heaters.

Physical

A. O. Smith glass coatings provide a fusion bond that is both chemical and mechanical — to 10,000 psi. The glass cannot be separated from the steel until the yield point of the metal has been exceeded. Also, special coating techniques promote high dielectric strength . . . outstanding non-stick and anti-abrasive qualities.

Up to now 500° F. is peak operating temperature for chemical-resistant glasses, but A. O. Smith has successfully developed ceramic formulations for protecting base metals at far higher temperatures. For other types of service, ceramic coatings can protect carbon steels at up to 1250° F. . . . stainless steels at up to 1500° F.

NOW AVAILABLE FOR YOU...
the research and production facilities of A. O. Smith. Write for full information on a specific problem, or ask for free booklet, "THE STORY OF GLASS-PROTECTED STEEL."

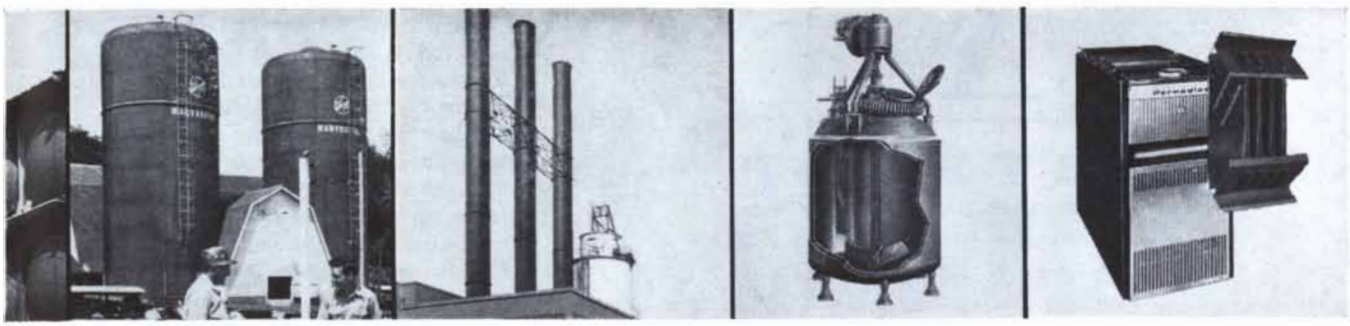
Through research A.O. Smith *. . . a better way*

A.O.Smith
CORPORATION

MILWAUKEE 1, WISCONSIN

12 plants in New Jersey, Pennsylvania, Ohio, Illinois, Wisconsin, Texas and California

International Division: Milwaukee 1, Wisconsin



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

PERMAGLAS smokestacks . . answer industry's need for longer smokestack life . . . economically.

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

PERMAGLAS home heating and cooling . . . ceramic-coated heat exchangers prevent oxidation and condensate corrosion.

THE AUTHORS

JOHN and MARY COLLIER ("An Experiment in Applied Anthropology") have pioneered in using the camera as a tool in the social sciences. They went to Peru to photograph the Vicos experiment, described in their article, as part of a long-term project in which they have been building a photoarchive of Cornell University's far-flung anthropological studies. John Collier acquired his interest in anthropology from his father, John Collier, Sr., long-time U. S. Commissioner of Indian Affairs. The son's career as a documentary photographer began in the Dust Bowl years of the 1930s recording rural conditions for the Farm Security Administration. During World War II he made photosurveys of oil development in Alaska and South America for the Standard Oil Company of New Jersey. After living among the Indians of Colombia he produced an ethnographic book, *The Awakening Valley*, in collaboration with the anthropologist Aníbal Buitrón. The Colliers spent a year at Vicos, documenting the "base line" of Indian culture at the beginning of the experiment. Among other things this involved photographing all the walls of every eighth house on the hacienda, an operation which will be repeated at intervals to record the visible effects of social and technological change in the community. Mary Collier is a Vassar graduate who assists her husband both as a writer and as a photographer. They are now preparing two books for publication, one on the Peru project and another entitled *Documentary Photography for Social Science*. They are accompanied on their expeditions by their three small children.

JEROME B. WIESNER ("New Methods of Radio Transmission") is professor of communications engineering at the Massachusetts Institute of Technology and directs its Research Laboratory of Electronics. Born in Detroit, he graduated from the University of Michigan in 1937, then took his M.A. and was associate director of the University's broadcasting service. In 1940 he became chief engineer to the Library of Congress, where he was concerned with recording. During the war he served at the M.I.T. Radiation Laboratory and at Los Alamos; he returned to M.I.T. in 1946, and completed a Michigan doctorate in 1950. Wiesner's chief interests in the field of communications engineering are

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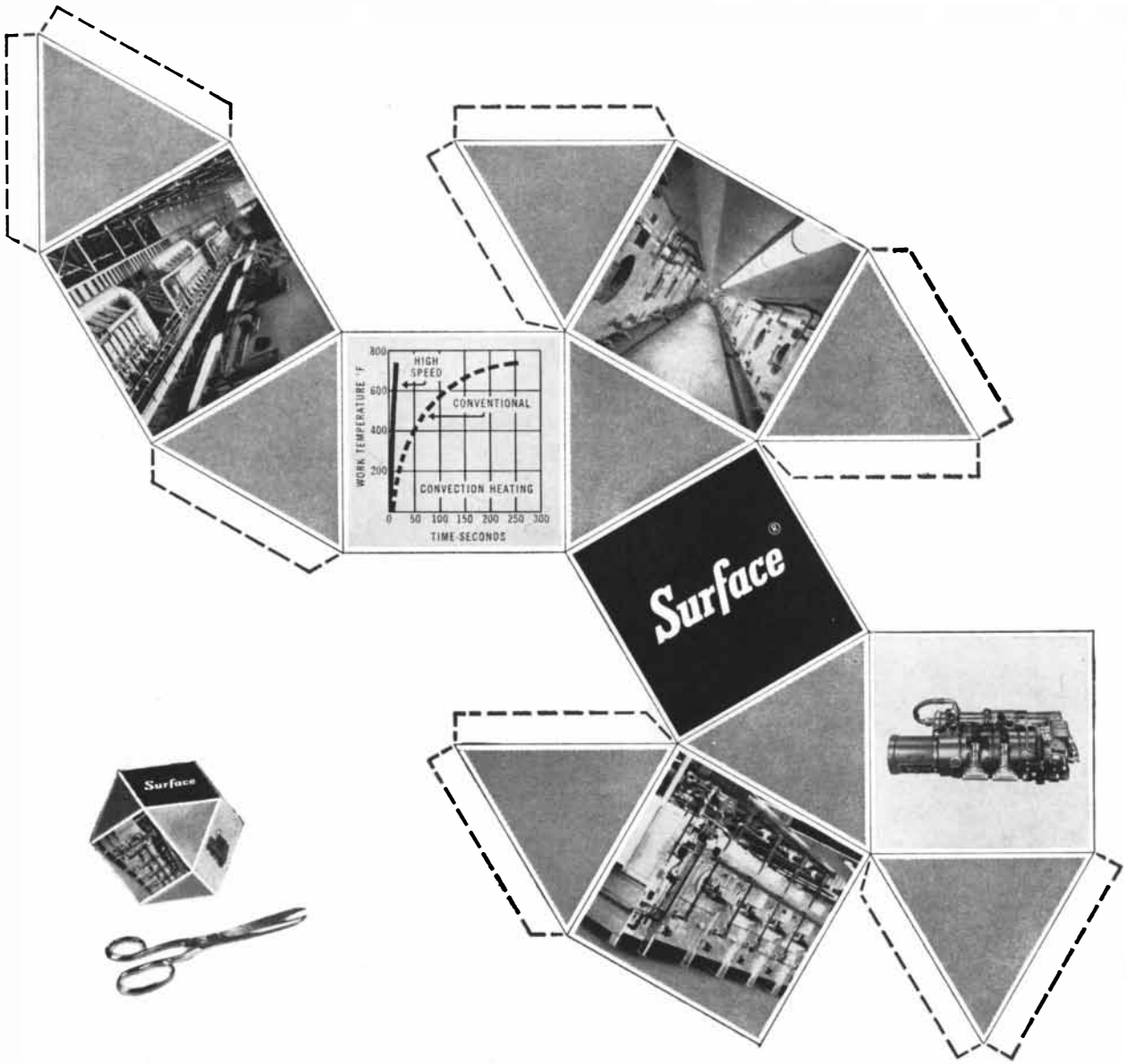
information theory and information processing. He is a member of the Army Scientific Advisory Panel and a consultant of the Department of Defense and was one of those who did the pioneering work on scatter communication and proposed the DEW system.

WOODBURN HERON ("The Pathology of Boredom") has recently been appointed assistant professor of psychology at McGill University. He was born in Jamaica, B.W.I., in 1926 and received his undergraduate and graduate training at McGill, where at the suggestion of the psychologist D. O. Hebb he became one of the first to work on the problem of perceptual isolation.

HENRY K. BEECHER ("Anesthesia") is Henry Isaiah Dorr Professor of Anesthesia at Harvard University and anesthetist-in-chief at Massachusetts General Hospital in Boston. A leading authority in his field, he has written two books and more than 150 articles, has lectured on his subject in Colombia, Italy, Switzerland, Great Britain and the U.S.S.R., has served on many national committees and been awarded the Legion of Merit and the Légion d'Honneur. Anesthesiology entered late into Beecher's career. After receiving his bachelor's and master's degrees at the University of Kansas, he earned an M.D. from Harvard in 1932 and proceeded to Massachusetts General Hospital as a resident in surgery. This enlightened institution, he found, shared Alfred North Whitehead's view that it was a crime to swamp with routine duties the minds of young men in their most creative period. The Hospital sent him to Denmark for a year of study under the late Nobel laureate August Krogh. In Denmark Beecher developed a love of research which led him to give up surgical practice and explore the neglected subject of anesthesia.

ROBERT E. MARSHAK ("Pions") is Harris Professor of Physics and chairman of his department at the University of Rochester. He is intimately associated with the discovery of the pi meson; he predicted its existence in his two-meson theory, which he set forth in 1947 when only the mu meson had been found. Marshak was born in New York City and attended Columbia University as a Pulitzer Scholar, graduating at the age of 19. At 22 he took a Ph.D. in theoretical physics under Hans Bethe at Cornell University and joined Victor F. Weisskopf at Rochester. During the war he worked for the Manhattan District. Marshak edits *Interscience Tracts in*



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Physics and Astronomy and has written a book on meson physics and contributed articles to SCIENTIFIC AMERICAN.

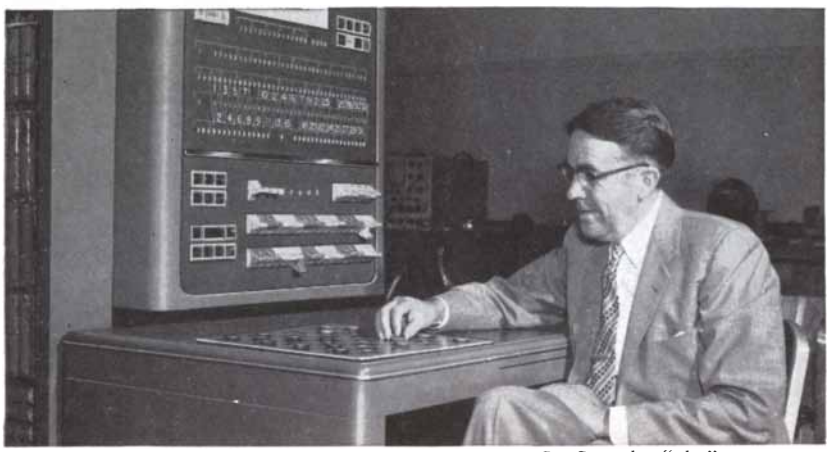
ERIC PONDER ("The Red Blood Cell") is research investigator and attending physician at Nassau Hospital in Mineola, Long Island. He was born at Darjeeling, India, in 1898, graduated in medicine at the University of Edinburgh, and became an associate of Sir Edward Sharpey-Schafer, the physiologist who invented the Schafer method of artificial respiration. After several years as a lecturer at Edinburgh he came to the U. S. as professor of physiology at New York University. Later he directed the Biological Laboratory at Cold Spring Harbor, N.Y. He has been a U. S. citizen since 1940. Ponder has written some 250 research papers, most of them on red blood cells.

EDMUND L. VAN DEUSEN ("Chemical Milling") is a technical writer for an instrument company in southern California. He was born at Weihsien, China, in 1923, the son of missionary parents. He went to Pennsylvania State University, became a captain in the Corps of Engineers during World War II and continued his engineering studies afterward. Van Deusen was a staff writer for *Fortune* from 1953 to 1956. One of his pieces won a Benjamin Franklin Award citation. This article, on the disappearance of lone inventors, he says was partly autobiographical, as he is the author of an application now pending in the Patent Office.

SHERMAN A. MINTON, JR., ("Snakebite") is associate professor of microbiology at the Indiana University School of Medicine, where he received his M.D. in 1942. His father is the recently retired Justice Minton of the U. S. Supreme Court. Born and raised in the hill country of southern Indiana, young Minton acquired an interest in reptiles and similar creatures. "Officially," he says, "I suppose I should be classified as a medical man with a strong interest in zoology and natural history. I might just as well be considered a naturalist who drifted into the field of medicine." He has studied a wide variety of subjects, including arthropod-borne virus diseases, snake poisoning and the taxonomy of North American amphibians and reptiles. Since his wife is an enthusiastic collector of minerals and gem stones and his eldest daughter (aged 11) is an aspiring archaeologist, it is understandable that the Minton family devotes most of its spare moments to field trips.

putting IDEAS *to work—research at* IBM

- **Checkers with a Purpose: unique programming of an IBM 704 scientific computer for logical decisions, anticipating a multitude of variables.**
- **Molded Wiring: how to hold electrical conductors on a non-conductor material.**



Dr. Samuel at "play"

Checkers with a Purpose

Through the years, many people have been intrigued by the possibility of constructing game-playing machines, particularly chess and checkers—including L. Torrès y Quévedos in 1914, and more recently Mr. C. Strachey of England. Now Dr. A. L. Samuel of IBM has programmed the IBM 704 computer so that it is able to play a surprisingly satisfactory and even challenging checker game.

Dr. Samuel's program includes the basic rules of checkers and an equation which enables the computer to assign a white versus black merit rating to any possible arrangement of pieces on the checkerboard. A further element of the program instructs the computer to consider all possible moves and responses for a given situation, *and to repeat this procedure to include from four to twenty moves in advance*. The storage or memory units of the computer retain the merit rating of each option and thus enable the computer to select the "best" move and signal its selection to the operator. The next logical step will be to modify the program so that the computer will profit from its mistakes. The modified program would enable the computer to adjust the coefficients of its merit equation in the light of past experience and thus, in a sense, "learn" to play a better game.

The design of a checker-playing program is, of course, of no importance per se. It is important, however, as part of a study of the decision-making ability of a modern computer. The game of checkers is a greatly simplified mathematical model of many real-life situations. It is useful in preliminary investigations because it requires logical decisions, offers a multitude of variations, and yet is free from extraneous and complicating features of real-life problems.

Molded Wiring

Because of the advanced nature of IBM equipment, standard electronic components frequently must be designed or redesigned to suit critical reliability requirements. This has been found to be true in the case of printed wiring panels.

In the past, production panels have been limited to flat patterns on laminated surfaces. However, a new process for printed wiring fabrication, developed by IBM's Dick Bell, Poughkeepsie Plastics Laboratory Manager, eliminates such limitations and thereby affords the design flexibility necessary to the development of future IBM equipment.

Mr. Bell's process allows the use of any moldable plastic for the support of flush electrical conductors, and permits fabrication in almost any shape desired. It eliminates the use of standard adhesives for the bonding of conductor to plastic, thus allowing higher temperatures in fabrication and machining operations not possible where adhesives have been used.

Fundamentally, the process involves the coating of a .003″ thick metal foil plate with a single-particle thickness of copper powder, which is fused to the foil under high-temperature sintering. Plastic can then be molded to the plate, to be held mechanically secure by the thousands of sphere-shaped copper powder particles.

A typical application of a molded flush circuit is illustrated below. Wire brushes are pulled over the smooth surface of this component, thus allowing proper electrical and mechanical performance. The process also provides for metallic inserts and molded holes, eliminating costly drilling. Mr. Bell points out that day by day, as this process is being put into production, new methods for improvement in fabrication are coming to light.

For a complete technical description of this process, you may obtain Mr. Bell's technical report, "A Molded Flush Circuit Process," which was presented at The Society of the Plastics Industry meeting in New York on June 14, 1956. Request IBM Bulletin 500.

Molded circuit with a shape

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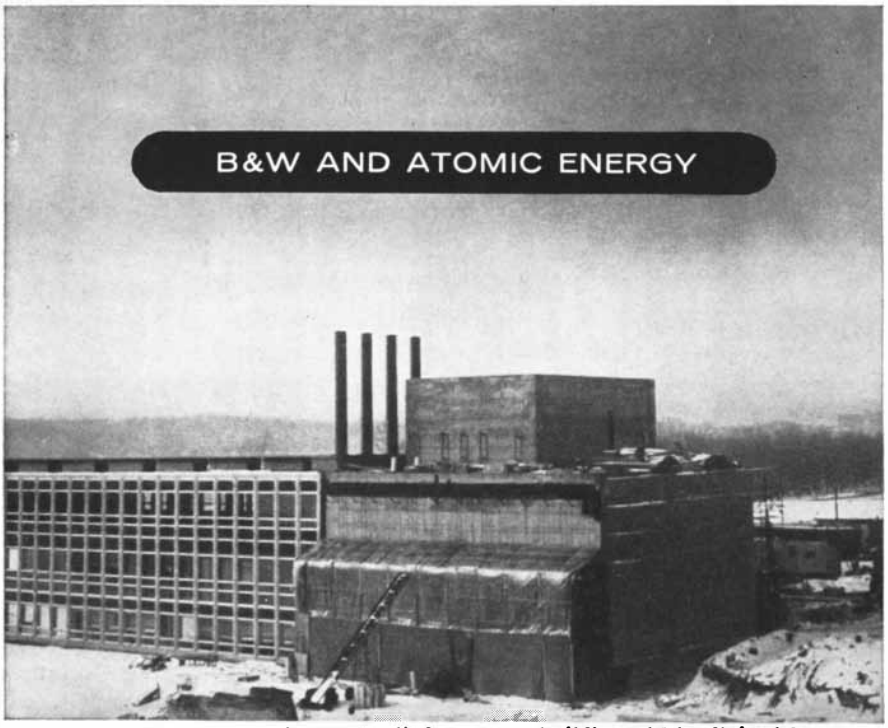
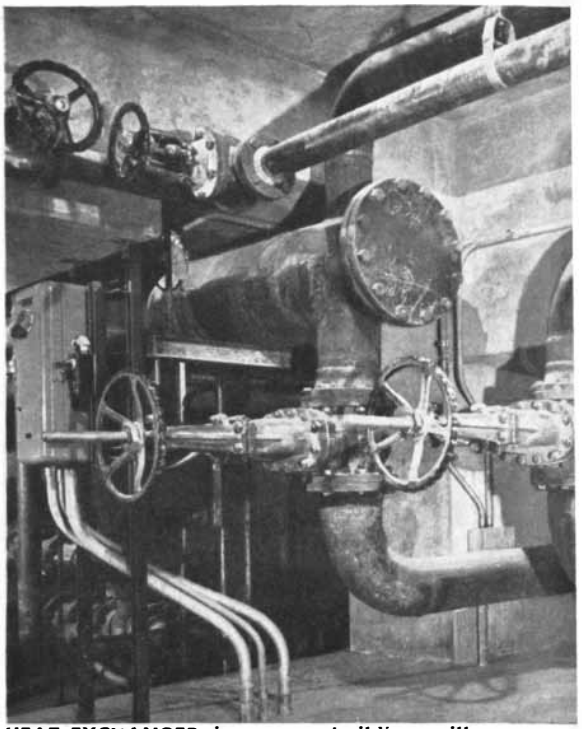


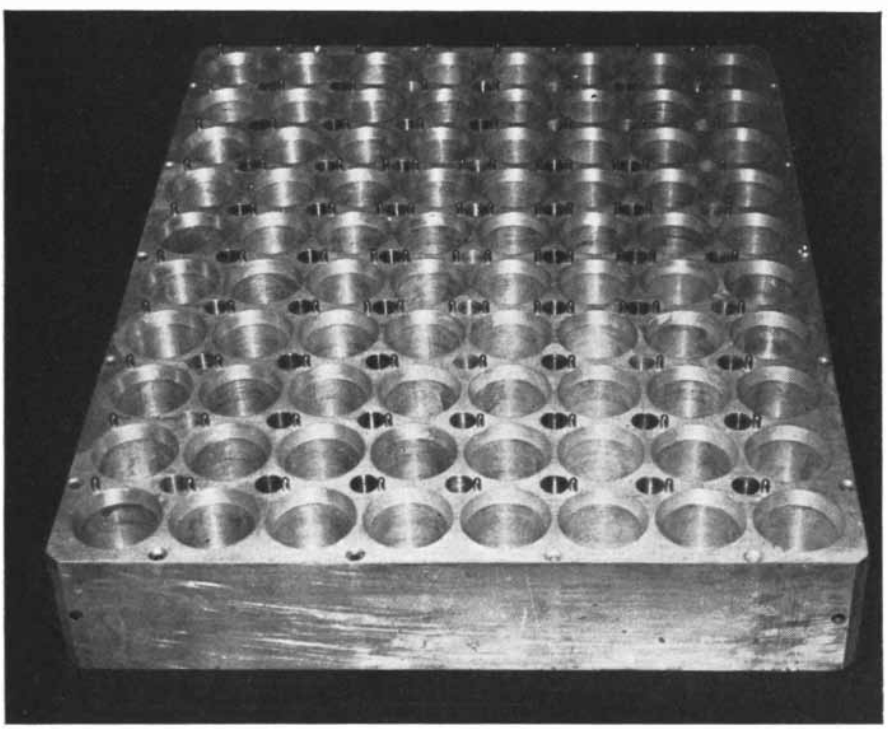
FINISHING touches are applied to reactor building which adjoins laboratory. Doors and building dampers are fitted with gaskets to provide a tight seal when closed.



HEAT EXCHANGER in reactor building will remove one megawatt of heat by forced circulation.

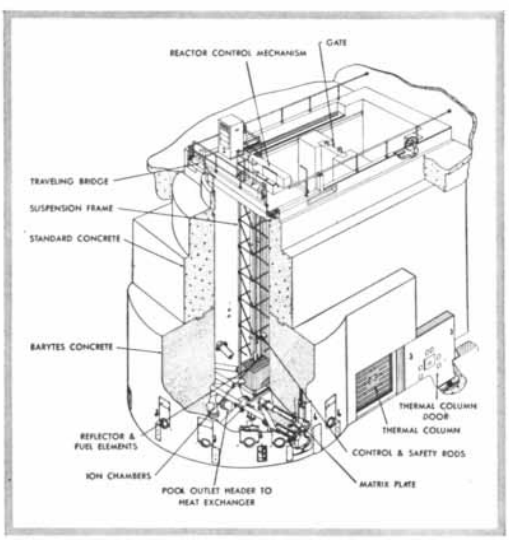
UNIVERSITY OF MICHIGAN LABORATORY ATTACKS

B&W Reactor Putting

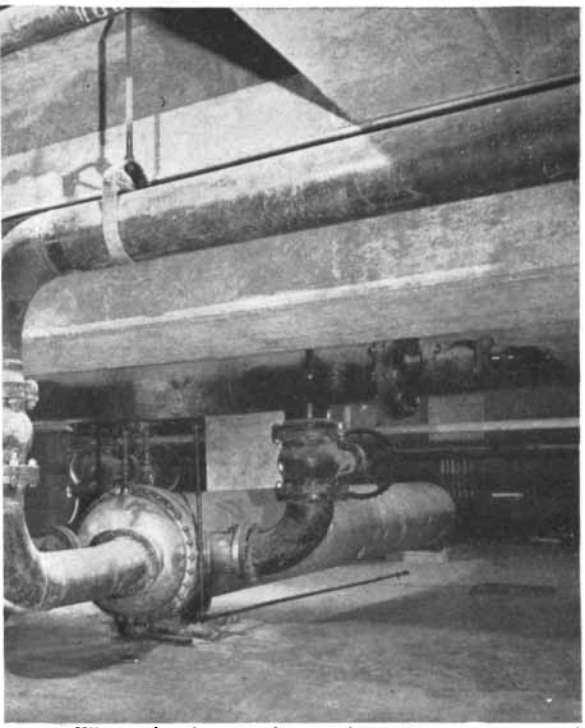


GRID PLATE has 80 different locations for fuel and graphite reflector elements, permitting many different core arrangements. Grid plugs for unused holes prevent the coolant from by-passing the fuel elements.

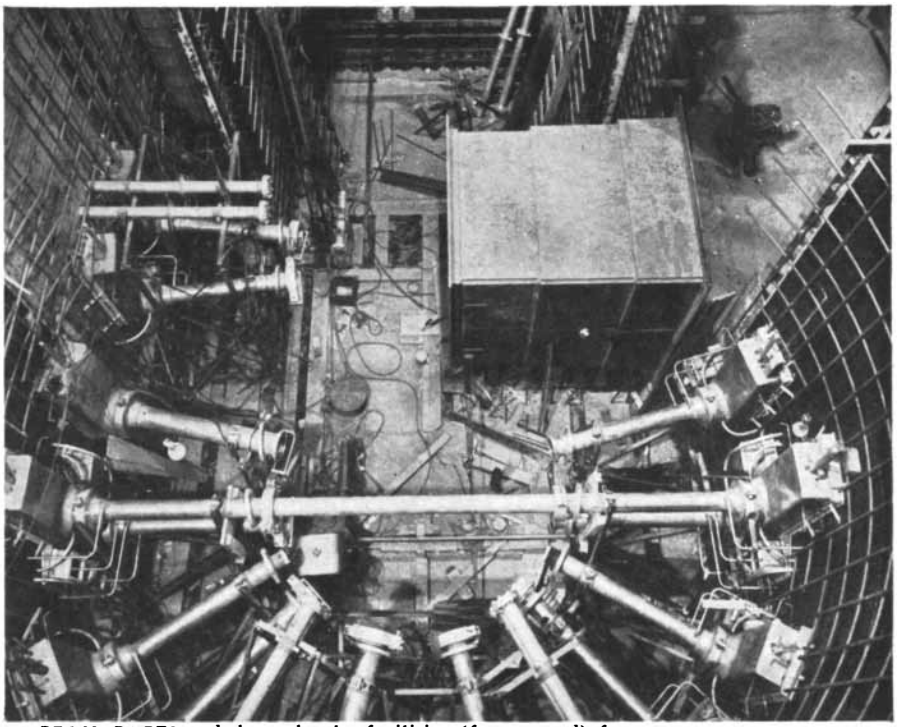
The Ford Nuclear Reactor provides an intense source of neutron and gamma radiation for basic medical, biological, chemical, physical, and engineering research and prac-



DETAILS of construction of the B&W Swimming Pool Type Reactor at the University of Michigan are shown in the cutaway drawing.



Water is drawn down through core, pumped through heat exchanger, and then returned to pool.

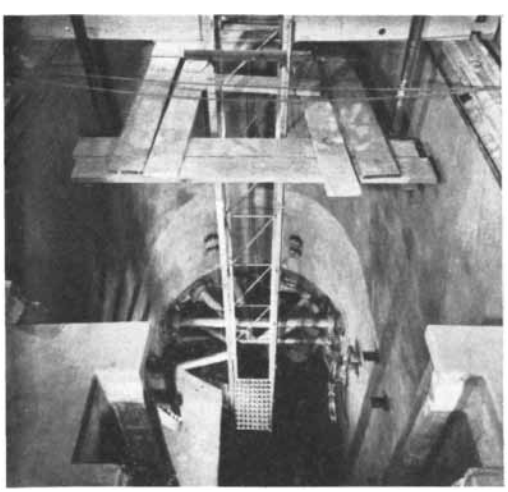


BEAM PORTS and through-tube facilities (foreground) focus on reactor core full-power operating position. Thermal column (upper right) is stacked with graphite blocks to slow down entering neutrons to thermal velocities.

BASIC RESEARCH PROBLEM WITH . . .

Neutrons to Work

tical training in nuclear technology for both engineers and scientists. It will also supply some of the radioactive isotopes for the many studies now employing tracer techniques.



GRID PLATE is in position to support fuel and reflector elements in rounded end of pool. Concrete channels in foreground are for pool gate which is raised by crane to permit passage of suspension frame.

In this design the basic pool-type reactor concept was adapted by B&W engineers to the special needs of the University of Michigan. The equipment components were fabricated and installed by B&W.

FROM THE BEGINNING of atomic energy, at Chicago, Oak Ridge and Hanford, to the application of nuclear energy to steam generation, like the new Consolidated Edison plant soon to rise at Indian Point, B&W has had an important and responsible role in the field of atomic energy. It continues to maintain its leadership by backing its long experience in related fields with a continuing, independent research and development program that studies the implications and the uses of a whole new world of energy.

FOR NEARLY 100 YEARS, B&W has been intimately identified with power generation, corrosion research, heat transfer problems, high temperature metallurgy, steam technology, and fabrication of heavy pressure vessels. The introduction of atomic energy found B&W engineers particularly equipped to cope with the problems posed in this new field. It was, in effect, an extension of familiar problems which they were called upon to answer.

Whether it is a research reactor to fit a research budget or a complete nuclear steam generation plant, with a single responsibility from fuel element to turbine throttle, consult The Babcock & Wilcox Company, Atomic Energy Division, 161 East 42nd Street, New York 17, New York.

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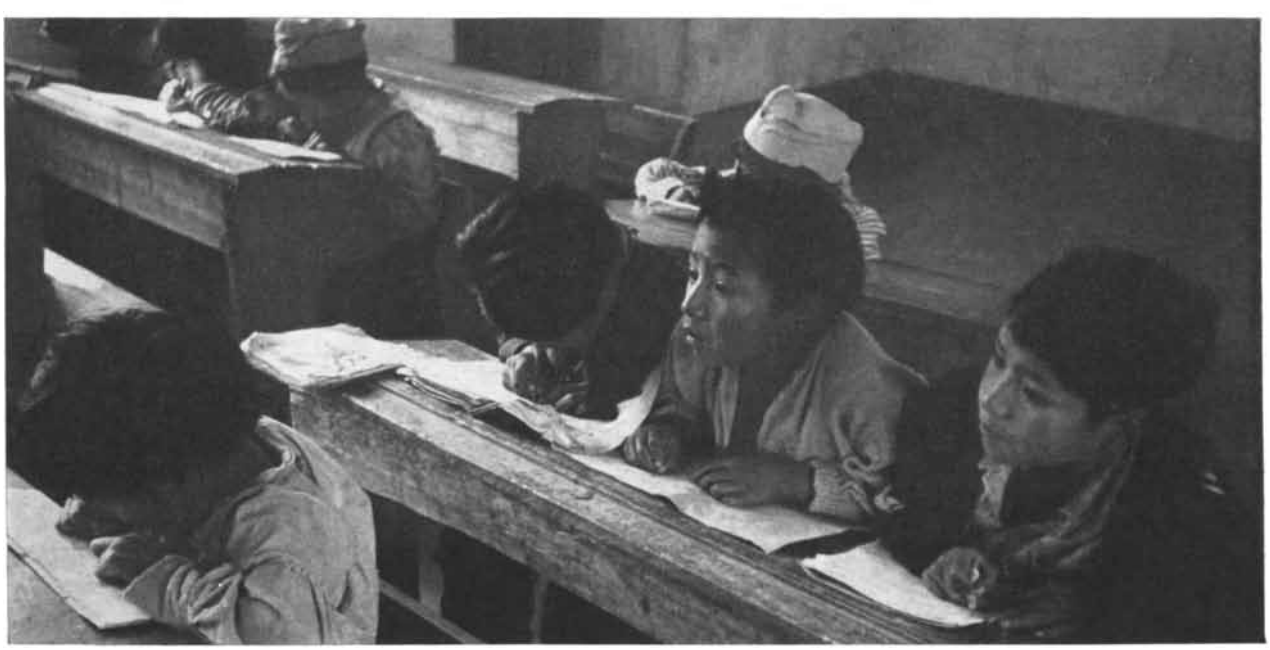
An Experiment in Applied Anthropology

How can the social sciences enable a poverty-stricken people to improve its condition? U. S. and Peruvian anthropologists seek the answer at Hacienda Vicos, an ancient estate in Peru

by John and Mary Collier

In a beautiful mountain valley in the high Andes of Peru, inhabited by some 380 families of Indians, an eventful social experiment has been under way during the past five years. It is an experiment in "applied anthropology." Under the guidance of scientists a "backward" population has been stirred to break away from the hopeless traditions of centuries and raise itself to a more abundant life. The way in which this has been accomplished makes the experiment significant for millions of people in the underdeveloped areas of the world.

In the decade since World War II the U. S. has found itself assuming, partly from necessity and partly as a matter of wise long-range policy, responsibility for aid to peoples all around the globe—in the Pacific, in Asia, in Europe, in Africa, in South America. This experience has made plain that aid raises problems which reach beyond money and technology. There is the problem of persuading a backward people to accept not only technological innovations but also the



CHILDREN OF VICOS copy sentences in Spanish from a blackboard in the new school built by the Vicosinos themselves. Before the Cornell-Peru Project was inaugurated, 98 per cent of the Vicosinos were illiterate. Most spoke only the Indian language Quechua.

economic and social changes made necessary by these innovations. Even more important, there is the problem of giving help without making them dependent. Benevolence all too often defeats its basic purpose by destroying a people's self-reliance.

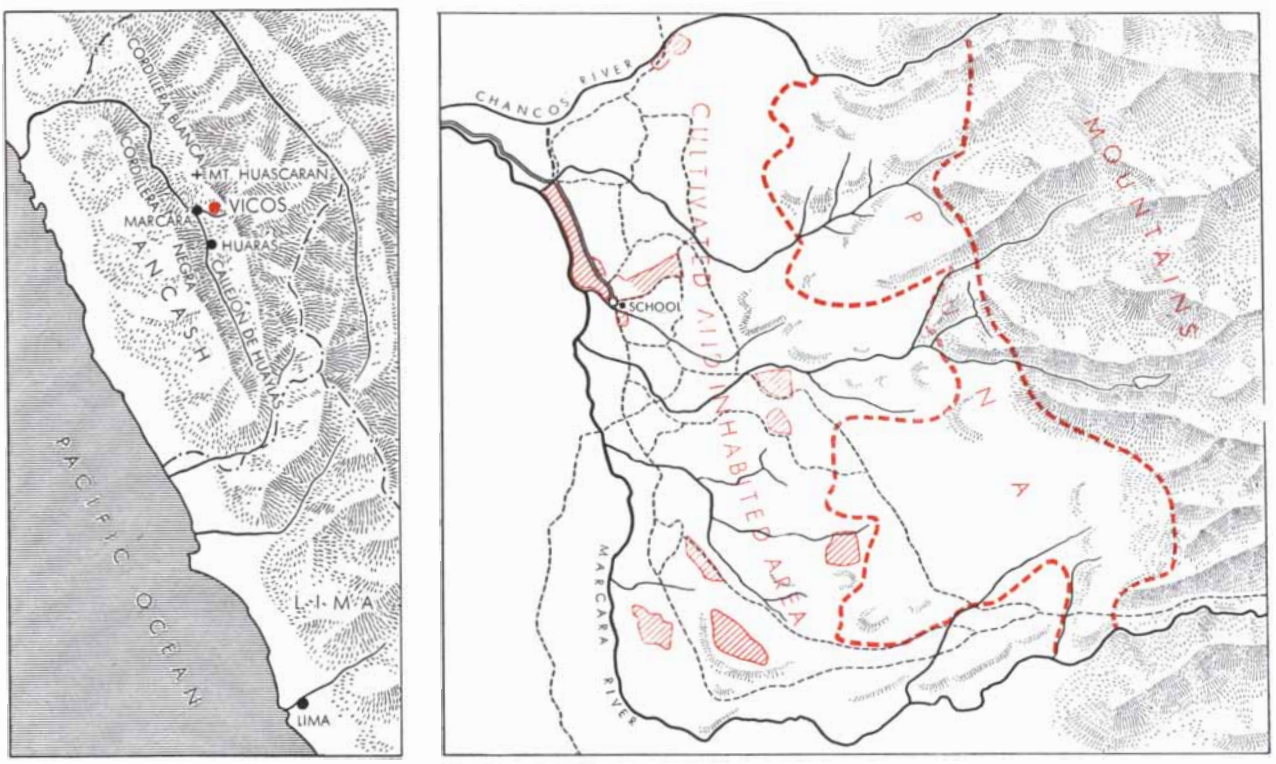
It was these considerations that prompted a group of social scientists to undertake their experiment in applied anthropology in the Peruvian valley. Their aim was to learn how an impoverished population might be stimulated to lift its standard of living by its own efforts and within the framework of its own culture. The scientists undertook to acquire a thorough understanding of the people's customs and traditions and then to assist the community as "participating interventionists."

The originator of the project was Allan R. Holmberg of Cornell University, an anthropologist who had studied Indian groups in Peru for the Smithsonian Institution and later in association with the University of San Marcos. Holmberg enlisted his Peruvian colleagues and students in a search for a laboratory in which to study how a backward group would respond to the introduction of modern technological change. On a field trip with his students Holmberg found an ideal community for such a program. It was an ancient estate, called Hacienda Vicos, on the upper slopes of a long, narrow valley paralleling Peru's highest mountain range, the Cordillera Blanca. The hacienda was in decay, its lands eroded, its more than 2,000 Indians living in hunger and disease. Holmberg conceived the bold idea of renting the hacienda and operating it in the conventional way, but under a scientific group instead of the usual private patron. With a grant of funds from the Carnegie Corporation of New York, the Cornell department of sociology and anthropology rented the hacienda from the Peruvian Government and launched a five-year experiment, known as the Cornell-Peru Project, in cooperation with Peruvian scientists and government agencies.

Hacienda Vicos is an estate of some 35,000 acres at an altitude of from 9,000 to 12,000 feet in a valley called the Callejón de Huaylas. Its history goes back to the Spanish Conquest. Legend says that nearly 400 years ago its then owner, a very wealthy Spanish woman, on her deathbed gave the hacienda, complete with its Indians, to a hospital in Lima. Whether or not this story is true, Hacienda Vicos has been in public custody since the early 17th century, first under Spanish authorities and later under the Peruvian national government. For hundreds of years the estate, with its lands and peonage system intact, has passed from one lessee to another, recently by public auction to the highest bidder.

The hacienda system, established by the Spanish conquerors, is maintained by rigid traditions which even the patron is often powerless to change radically. The Indians who live on a hacienda are its serfs, and the owner or lessee is their lord—their benefactor and exploiter. One member of each serf household must work for the hacienda three days a week without pay. In return the Indians are allowed to farm a few acres of land, drink water from the streams, gather faggots for their fires and graze their animals in allotted pastures. They turn to the patron for assistance and advice in times of trouble and leave every important decision in his hands. Within the hacienda they attend chapel, bury their dead, celebrate their fiestas and remain bound for generation after generation.

The Cornell-Peru staff's decision to operate the hacienda under the traditional rules was the core of their anthropological approach. They wished to avoid disrupting the community or creating confusion and anxiety. Their pur-



VICOS IS LOCATED 200 miles north of Lima (*map at left*). The hacienda lies in a high valley called the Callejón de Huaylas (*map at right*). Its cultivated area is hatched in color. The broken line marks off the puna, a bleak plateau between valley and mountains.

pose was to acquire a full understanding of the Indians and their problems in the customary pattern of their lives, to persuade them to improve their farming methods, to plow back the higher returns into a better life for the community and eventually to lead the Indians to a free and self-reliant life. The change would develop from the bottom up, not be imposed from the top.

Peru is a land of the Indian. Its leaders have long been aware that the country is held back by the traditional prejudices and fetters of its Indian masses, and they therefore welcomed the anthropologists' project, hoping, with the scientists, that it would be a practical demonstration of wide benefit. The Cornell-Peru experiment received enthusiastic cooperation from the country's universities, scientists, educators and authorities in agriculture and public health.

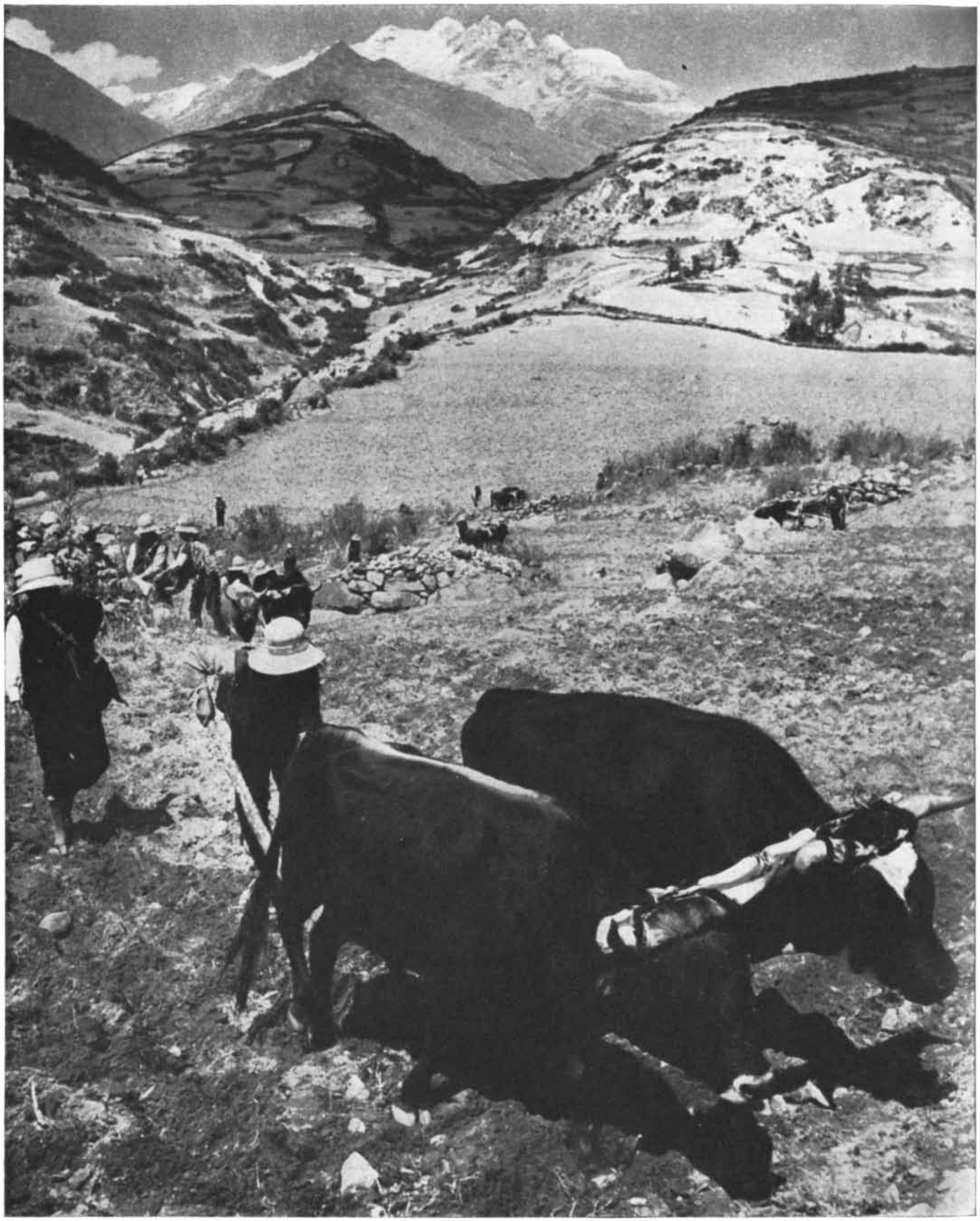
At Vicos the anthropologists found a clear epitome of Peru's problems. Its Indians were almost completely illiterate: only 2 per cent could read or write, and most spoke only the Indian language Quechua. Hunger was their chronic condition, and drinking almost their only recreation. Epidemics brought death to nearly every home. They were little better than slaves, despised by their neighbors. Between the hacienda Indians and the *mestizos* (mixed Spanish-Indian breeds) of surrounding communities there was strong hostility. *Mestizos* look down on Indians, considering them biologically inferior; the Indians are submissive but fear and distrust the *mestizos*. Nevertheless, the Project scientists had to hire *mestizos* for skilled work on the hacienda, and they took advantage of this necessity to study the relationship between the groups. They were confident that cooperation would eventually improve the relationship. The Project even kept on the administrator who had been in charge of the hacienda for several years under the former lessee.

The first task was to increase the food crop. Most of the Vicosinos were living at a level of bare subsistence. A blight had hit the potato fields in the two preceding years, and the corn crop also had failed. Food was so scarce and costly that the Indians were eating the seed grain, digging up seed potatoes as soon as they were planted, selling their cattle to buy food and stealing as much of the hacienda crop as they could.

The Project staff had an agricultural survey made and took steps to rebuild the potato culture. It obtained blight-resistant potato seed, fertilizer and insec-

VICOS HOME has a circular wall and a conical thatched roof. Some two thirds of the Vicosinos live in such houses. The rest dwell in rectangular adobe structures with tile roofs.

POOR FAMILY OF VICOS regards its world with fear and distrust. The first task of the Project was to convince the Vicosinos that its program was not some kind of deception.



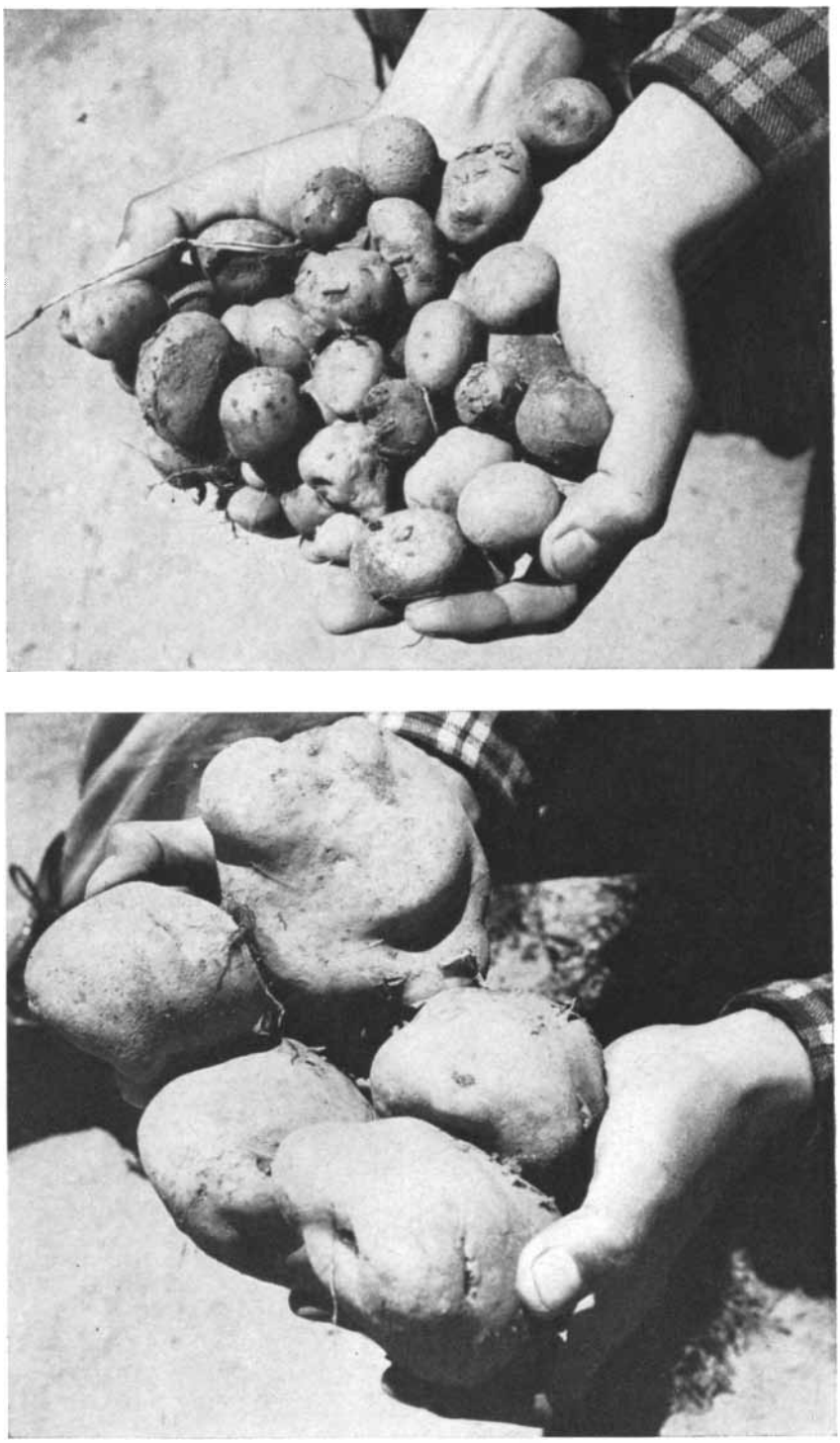
CORN IS PLANTED in a high field. The hacienda's 35,000 acres lie between 9,000 and 12,000 feet. Oxen were introduced into Peru 400 years ago by the Spaniards. Today about 20 per cent of the farmers of the hacienda own animals. The rest borrow or rent them.

ticides from agricultural experiment stations, and then offered them to the Indians at cost.

Few came to buy. Days passed and the Indians paid no attention to the announcement. Recognizing that most of the Indians could not pay for the seed even if they had wanted to, the Project then worked out a credit plan. It proposed to advance the seed, fertilizer and insecticide on a crop-sharing arrangement—half of the crop to the hacienda, half to the farmer.

This plan was first presented to a meeting of the *mayorales*, the Indian leaders of the community who served as foremen in directing the work of the other peons. The *mayorales* listened, and shook their heads. They declared the plan would never work. But it became plain that the leaders were hostile to the proposal because vested interests were at stake. They feared that improvement of the prospects of the other peons would undermine their own favored position.

Notwithstanding this discouraging opposition by the leaders, the Project staff decided to offer the plan directly to the community as a whole. At the peons' weekly meeting (the *mando*) for assignment of the week's work, the scientists described their proposal. It evoked excited discussion among the peons. They appeared to approve it at first, but after one of the *mayorales* spoke against it, the approval seemed to cool. Only nine of the 125 peons present came forward to sign up for the plan at the end of the meeting. Later 22 more did so privately. But a majority of the community hung back, and active opposition grew. Rumors, perhaps initiated by landowners and *mestizos* in the area, spread among the distrustful and suspicious peons. Why had the *gringos* come to the valley? What were their reasons for offering help to the Indians? The *mestizos* whispered that the fair-appearing scheme surely hid some plan to cheat and exploit the peons. One rumor went so far as to suggest that the Americans had come to Vicos to fatten the Indians on potatoes and then boil down their bodies for oil for American machinery! The credulity that accepted such lurid tales was fed by the Indians' fear of change—of what the unknown might bring.



POTATOES at the top are of the kind grown at the Hacienda Vicos before the Cornell-Peru Project. Those at the bottom resulted from seed and methods recommended by the Project.

Mario Vásquez and other Peruvian scientists in the Project worked hard to allay the Indians' fears. Vásquez visited scores of Indians in their homes and in the fields and signed up nine more peons to participate in the program. But of the total of 40 who agreed to take part, only 17 actually took the seed and entered into the farming project when the planting season began. Most of these were the poorest of the poor; against the disapproval of their wives in some instances they decided to take the chance to save themselves from starvation and improve their position.

The participating Indians were required to carry out to the letter instructions from Peruvian Government agricultural specialists. They had to disinfect the seed potatoes and the land, to plant the seed at 18-inch intervals in rows three feet apart, to apply guano as fertilizer, to spray insecticides at set times and to remove blossoms from the

OLD AND NEW SCHOOL BUILDINGS of the hacienda are shown in these photographs. Before the Cornell-Peru Project eight children were taught on a porch which served as the schoolhouse (*top*). The new school (*bottom*) has eight teachers and some 200 pupils.

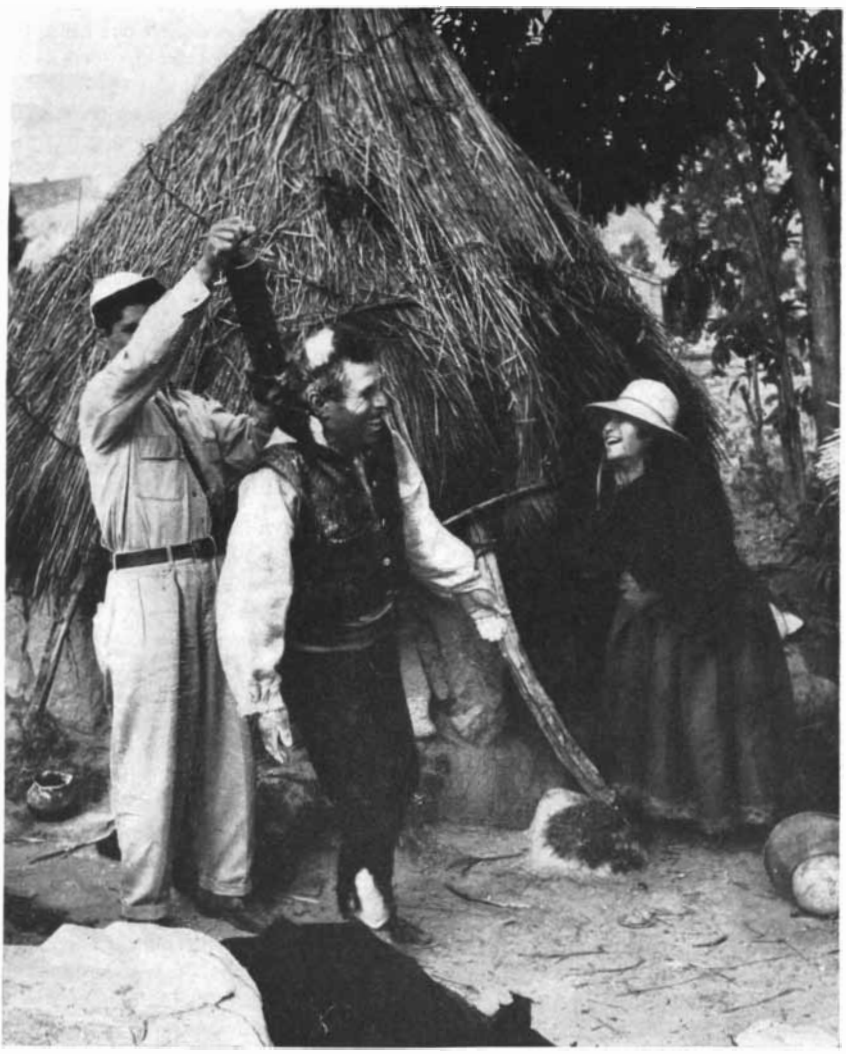
plants. They were instructed in techniques of cultivation, irrigation and so on.

Besides supervising every step of the cultivation—the fumigating, the planting, the harvesting—the Project staff also kept a careful watch on the farmers' working relations and social behavior. By doing so, they were able to forestall small frictions and points of resistance that often defeat a whole program. For example, at one point the staff employed a young, intelligent Vicosino as a supervisor. Their close observation at once disclosed that this was a mistake. Taking orders from a young member of their own group hurt the vanity of the older Indians; they preferred to be directed by outsiders. This delicate pride was illustrated by another incident. A peon whose plots had somehow been overlooked during a routine inspection of the participating fields turned up at the hacienda highly agitated. He complained: "If you don't pay as much attention to my field as you do to the others, people will think it is because my field isn't being cultivated correctly and that you are displeased!" Incidents such as these demonstrated how important it is to enlist the perceptions and skills of social science (applied anthropology) in any aid program among a proud and sensitive people.

Throughout this first season the other Vicosinos felt sorry for the 17 Indians who had been foolish enough to be taken in by the Project. They would surely lose everything, and have thrown away their season's labor. But at harvest time the nonparticipants were taken aback. The 17 participants harvested more than double the usual crop of potatoes. Each of them divided his crop into two piles, one to be taken by the Project, the other to be kept by himself. The Project staff then invited the farmer to take his choice of the piles. The Indians were deeply impressed. This was something foreign to their experience: the *gringos* did not cheat; they kept their word!

The following season 87 Indians, including one of the *mayorales* who had opposed the program, took advantage of the seed. Even some of the *mestizos* asked to be included in the experiment. By the third year 135 Indians took part, and they accounted for nearly 80 per cent of the total potato crop raised on Hacienda Vicos. In that year some of the Indians bought the seed and other materials on credit, instead of sharecropping. All but one of the borrowers paid his debt in full at harvest time. Consequently the sharecropping system was dropped entirely in 1955. The In-

CLINIC conducted by the Peruvian Government is attended by Vicosinos. Its physicians visit critically sick patients in their homes. The clinic also serves nearby town of Marcará.



DDT is dusted on the house and bodies of a Vicos family in another program administered by the Peruvian Government. The insect which is the main target of these efforts is the louse.

dians proved in that season that they were sufficiently skilled in the new farming techniques to take the full risk and responsibility of buying the seed and to realize a yield adequate to support themselves at a higher level than they had known.

Economic reforms sowed their own seeds of social reform. For example, the hacienda Indians had constantly stolen cattle from one another and fought over the ownership of animals. The Project staff suggested that they brand their cattle. The Indian leaders showed no enthusiasm for this, but when one of them observed bitterly that the wealthiest had built their herds by rustling, the owner of the largest herd began to brand his cattle to prove his innocence. The other Indian families followed his example, and cattle rustling stopped.

Along with the rehabilitation of their agriculture, the Indians also began to rehabilitate the collapsing ruins of the hacienda. Under the direction of skilled craftsmen they rebuilt their crumbling dwellings, erected storage buildings for the crops and soon were able to turn to the construction of a school.

Although school attendance is theoretically compulsory in Peru, fewer than 5 per cent of the eligible children in Vicos were enrolled, and these came only sporadically. As Vásquez observed, even these few Vicosino families treated schooling like their forced labor for the patron: so long as one child of a household was in school, it didn't matter whether the child who sat on the school bench on Monday was the same child who had sat there Friday. School was kept in an open porch, where a woman instructor tried to teach about eight children of assorted ages something of reading, writing and arithmetic in Spanish, a language almost totally foreign to most of the Quechua-speaking Vicosinos.

Soon after the Project began in 1951, the Indians were invited to a meeting to discuss the possibility of a new school. They agreed to provide all the labor, and the Project offered to buy needed materials. Plans were drawn for a modern schoolhouse, and ground was broken in May, 1952. The Indians made thousands of adobes (clay bricks), quarried great piles of rock for the foundations and felled tall eucalyptus trees to make the doors, window frames and roof beams. The only materials that had to be purchased were glass for the windows, lime for the plaster, cement for the floor and tiles for the roof. Although much of the building project was at first quite beyond the Indians' limited skills, the work was accomplished, under the direction of the contractor and a few *mestizo* craftsmen. In 1953 the first unit of six classrooms was opened, and the following year saw the completion of a second unit with three more classrooms, a spacious auditorium, a dining room and kitchen for the hot-lunch program. Later living quarters for teachers were built.

The Peruvian educational authorities, who operate the school, have staffed it with eight teachers, and more than 200 children are now enrolled. Most of these are boys, who receive vocational instruction, including carpentry and agriculture. A small group of girls attends a technically separate primary school in the same building.

This beautiful school has become a symbol. It has given new confidence to the community, for the building is notably finer than any other rural school of the region. And it has inspired the Indians with the pride of achievement. Visitors have come even from Lima to see the modern school the Vicosinos have built with their own hands.

Hacienda Vicos has seen a third major improvement—its first health program. With the cooperation of the Cornell-Peru Project, the regional Peruvian public health agency has set up a clinic which serves not only the hacienda but also the neighboring *mestizo* town of Marcará. Twice a week a truck, supplied by the United Nations International Children's Emergency Fund, arrives at Vicos with a doctor and nurses and public health specialists. Though their program is chiefly concerned with child and maternal welfare, the clinic at Vicos gives attention to all, dispensing medicine and advice on the full range of ailments from itches to tuberculosis. The doctors visit critically ill patients in their homes, though this sometimes means an hour's ride on horseback on the rocky mountain trails. The clinic gives a thorough physical examination to all the children attending the school. It keeps careful medical records which supply an invaluable body of data for studying the health of Peruvian Indians. The clinic is gradually educating the Indians to combat their ailments with modern medicine rather than with native religious methods or magic.

Along with the basic projects—food, education, health—there have been special programs, one of which deserves particular mention. All young Peruvian men who have not served in the army are required to attend military drill every Sunday for a two-year period. The Cornell-Peru Project arranged for the young Vicosinos to be drilled at the hacienda (instead of walking to Marcará five miles away), and it has used this occasion to provide classes for them in Spanish, reading, writing and arithmetic. Two years ago the Indians of Vicos, marching in sandals with wooden guns and wooden bayonets, won a citation at the annual military review of their province.

Foremost among all the purposes of the Project has been a calculated endeavor to develop the Indians' self-reliance and change their own image of themselves—an image of serfs destined to poverty and endless unrewarding work. The Project ended tyrannical exploitation of the Indians, not only by the hacienda but also by outside employers. The peons no longer are sent out to work without pay in mines or factories. No longer do neighboring communities come to the hacienda to conscript crews for construction of bridges and public buildings. The weekly meetings of the *mayorales* and of the peons have been turned into discussion sessions at which both the foremen and the peons can air their grievances and take part in decisions. The goal of the entire program is to enable the Vicosinos themselves to continue their progress toward a higher level of living when the Project staff withdraws from the community.

Beyond all this, the Project's broader concern has been to develop a body of scientific experience which will serve to establish equations for work in other underdeveloped areas—in Peru itself and in the world at large. In the Vicos research U. S. scientists have teamed up with scientists of Peru. Indeed, a great part of the detailed research has been carried out by Holmberg's Peruvian student and assistant Mario Vásquez. He lived with an Indian family on the hacienda and was largely responsible for dispelling distrust and enlisting the Indians' cooperation. As a research project the Vicos experiment has also attracted dozens of other students from the University of San Marcos and from Cornell and other universities.

Perhaps the biggest single lesson the Project has demonstrated is that, by working within the existing structure of a society, with sufficient understanding of both its limitations and its potentialities, it is possible to accomplish basic social changes without a staggering budget or swarms of personnel. The anthropologists at Hacienda Vicos have shown that in the field of social reform, understanding may be a far more important tool than money or power.

MAYORALES, or foremen, of Vicos argue with the administrator of the hacienda at their weekly meeting. The administrator (*hatless man at left*) is Enrique Luna, who is employed by the Cornell-Peru Project. The Project encourages *mayorales* to express opinions.

STOLEN COW is discussed at another meeting between Luna and the Vicos *mayorales*. At left is Héctor Martinez, student of anthropology at the University of San Marcos in Lima. At right is William Blanchard, field director of the Project. The meeting is recorded.

NEW METHODS OF RADIO TRANSMISSION

A part of the energy in a beam of radio waves is scattered in all directions by small irregularities in the atmosphere. This energy is now used in long-distance radio communication

by Jerome B. Wiesner

Radio communication is in the midst of one of the most exciting developments in its history. A major breakthrough has been achieved in the transmission of high frequencies—the frequencies used for shortwave radio broadcasting, television and many kinds of civil and military communication. The high-frequency end of the radio spectrum holds a wealth of communication channels which could enormously expand man's use of radio, but it has been subject to a frustrating limitation: very short range. Until half a dozen years ago it was generally believed that in the nature of things ultrahigh-frequency radio transmission must be restricted to the line of sight, and its effective range on our round planet would therefore always be limited to the horizon. A new discovery in the past six years, however, has swept away this restriction. It has already been put to use in the U. S. defense establishment's Distant Early Warning (DEW) system, whose radars now span long distances in the Arctic regions. And among the harbingers of what is to come, television will soon cross a sea via a link now being built between Key West and Havana.

The discovery making such transmission possible is known as "scatter communication." Precisely how it works is a matter of dispute, but the methods are sufficiently well understood to be used with high reliability. There are, in fact, two methods. In one the radio waves are reflected back from the troposphere, the lowest layer of our atmosphere; in the other, from the ionosphere, the high electrified mantle of our atmosphere.

Long-wave radio signals travel around the earth by two routes which are now fairly common knowledge. One

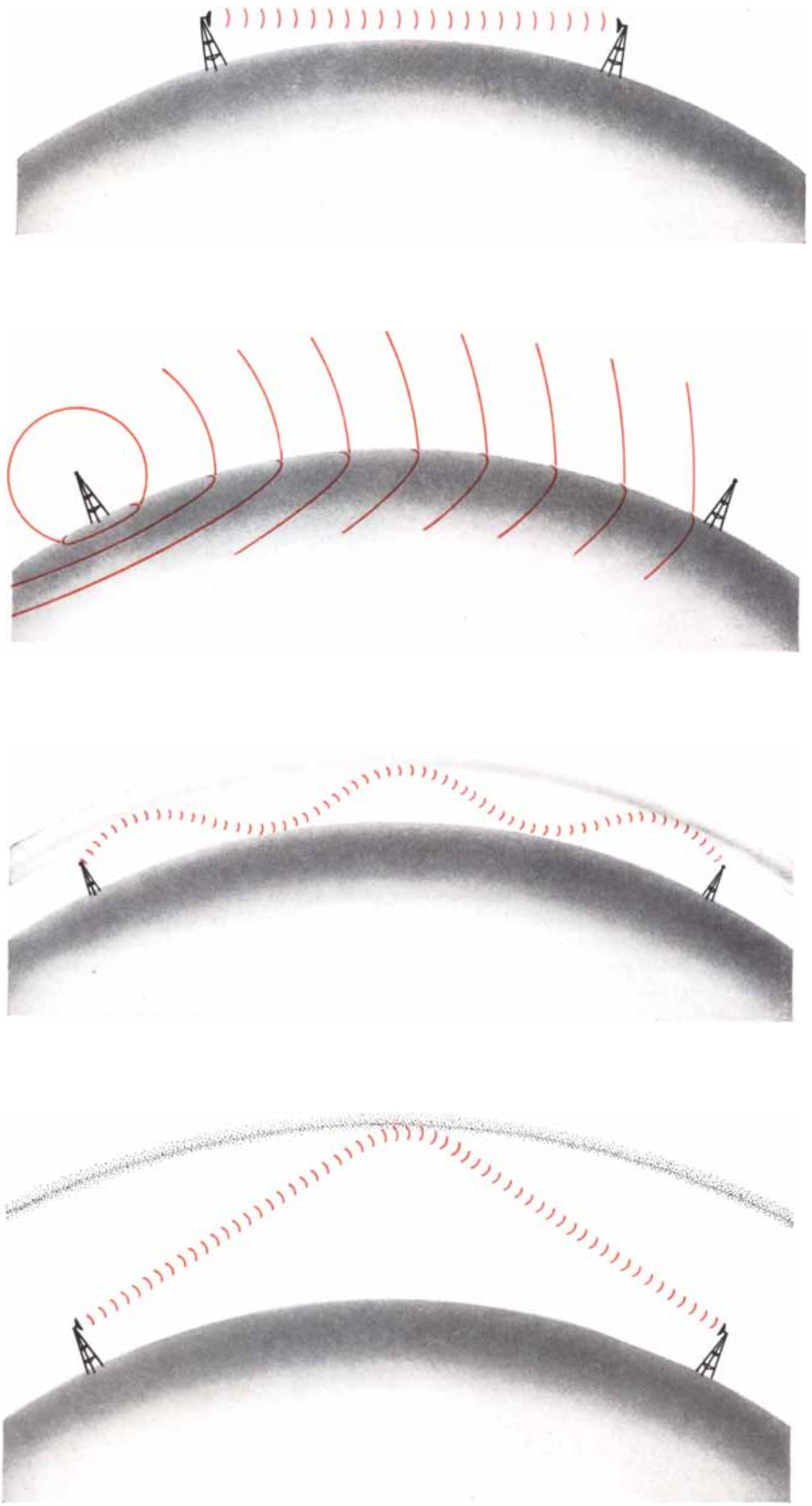
SCATTERED ENERGY from a radio beam comes off at all points in a manner similar to that shown for a single point in this diagram. The scattered waves are strongest in the direction nearest to that of the beam, and grow weaker as they point away from this direction. A receiving antenna (*right*) located within the scattering pattern "sees" the beam just as the eye sees a searchlight beam.

route is along the ground. A radio-transmitting antenna sets up oscillating electrical currents in the ground nearby; they reradiate oscillations at the same frequency which thus spread over the ground. Unfortunately the energy of high-frequency waves is soon dissipated and they do not travel far. Low-frequency waves go farther, because the slower oscillations use less energy, but their range also is limited.

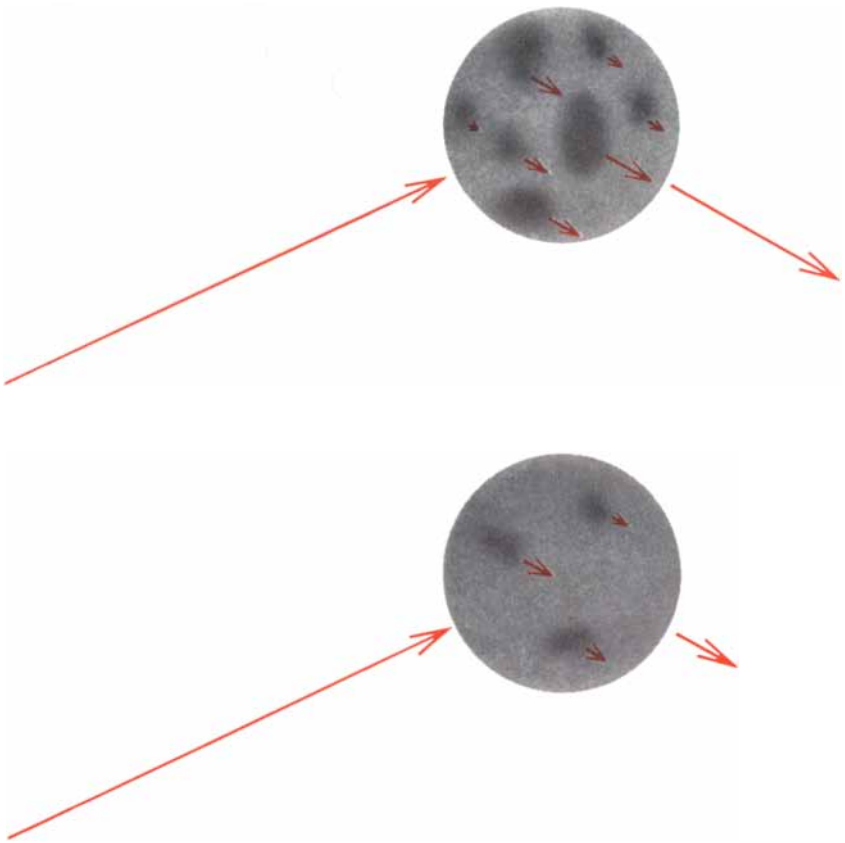
In the air, the second route of transmission, the waves encounter only slight resistance. Most of their energy would soar into outer space, however, were it not for the ionosphere. Its electrified layers, whose electrons are set oscillating by the electric field of the radio wave, bend radio waves back to the earth when they strike the ionosphere at an oblique angle [*see bottom diagram at right*]. But the amount of bending depends on the frequency of the wave. High-frequency waves have comparatively little effect upon the ionospheric electrons and are themselves little affected, so that their refraction is small. Waves of frequencies higher than about 30 megacycles (30 million cycles per second) pass right through the ionosphere. This is why short waves do not ordinarily bounce back and travel around the curvature of the earth.

And yet even in the early days of high-frequency radio (in the 1930s) investigators noted that short waves were sometimes unaccountably propagated far beyond the horizon. In 1932 Guglielmo Marconi in a paper to the Royal Institution of Great Britain perspicaciously observed: "In regard to the limited range of propagation of the microwaves, the last word has not yet been said. It has already been shown that they can round a portion of the earth's curvature, to distances greater than had been expected, and I cannot help reminding you that at the very moment when I first succeeded in proving that electric waves could be sent across the Atlantic Ocean in 1901, distinguished mathematicians were of the opinion that the distance of communications, by means of electric waves, would be limited to a distance of 165 miles."

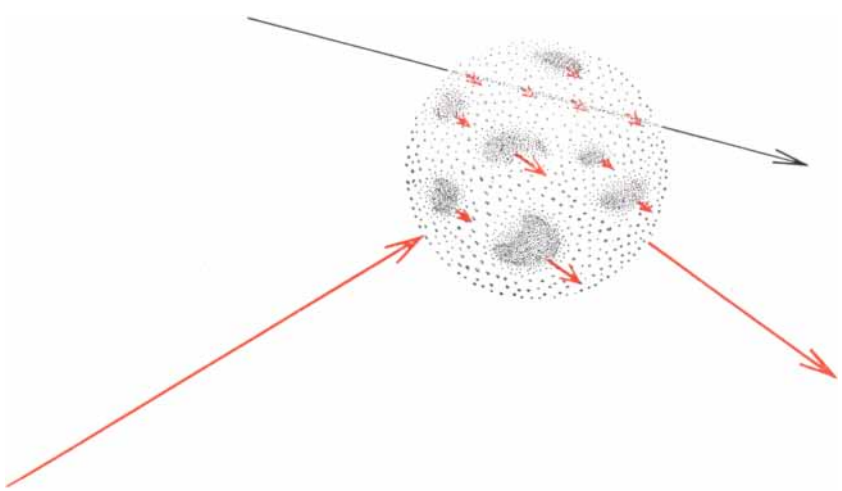
Marconi himself succeeded in transmitting microwaves nearly 200 miles, and somewhat later Harold Zahl and his colleagues at the U. S. Army Signal Corps Laboratories propagated them for approximately the same distance. Unfortunately not much attention was paid to these experiments at the time. During World War II the U. S. Navy was embarrassed to learn that the Japanese had



OLDER TRANSMISSION METHODS are illustrated in this series of diagrams. Line-of-sight system (*top*) is used for short radio waves, which travel in straight lines. Longer waves produce currents in the earth, and a "ground wave" carries the transmitted energy over the horizon (*second from top*). A layer of moisture in the air occasionally produces a "duct" in which waves can travel by multiple reflection between the layer and the ground (*third from top*). Ducts are short-lived and cannot be used for regular transmission. The ionosphere reflects long waves, and is used in long-distance transmission (*bottom*).



TROPOSPHERIC SCATTERING is caused by small-scale variations in the density of the air. The diagrams above show a given volume of air at two different times, and illustrate the fact that as the irregularities change, the energy scattered in a particular direction changes also. The long arrows at left represent the incoming energy in the beam from the transmitter. Small arrows in the shaded circles represent energy scattered in one direction by each region of high density. Arrows at right of the circles represent total energy scattered in this direction. The actual mechanism is more complex than this, since scattering takes place from each irregularity, no matter whether its density is higher or lower than average.



IONOSPHERIC SCATTERING is caused by variations in the density of the free electrons in the ionosphere. In addition to the usual turbulent irregularities, a given region often contains a sharp line of high electron density left by a meteor (*black arrow*). These lines contribute substantially to the amount of energy which is scattered in certain directions.

been eavesdropping on its short-wave fleet communications in the Pacific from hundreds of miles away. After the war anomalous reception of high-frequency signals at long distances became more and more common. Occasionally television viewers were startled to see telecasts from far distant stations appear fleetingly on their screens.

Radio physicists supposed that these accidental transmissions were due to layers or concentrations of water vapor in the atmosphere, whose surfaces act as ducts guiding radio waves around the earth's curvature. But it became clear that the long-distance transmissions occurred much too frequently to be explained by such meteorological happenstances. Indeed, the characteristic sudden, fading signals from distant transmitters were an almost constant occurrence.

A number of experimenters began to look into the matter, notably I. A. Gerks of the Collins Radio Company and J. H. Chisholm of the Lincoln Laboratory at the Massachusetts Institute of Technology in the U. S. and E. C. S. Megaw of the British Admiralty's research laboratories. My attention was first drawn to the subject in 1950 when I visited Megaw in his laboratory in England. He had begun an experiment to investigate propagation of radar signals over the North Sea. With his sensitive equipment he was consistently getting signals from beyond the horizon day after day, even when he was certain that water-vapor ducting could not be responsible. Moreover, there was a measurable pattern of signal reception. On the average the signals received were a million times stronger than theory predicted. They showed rapid and wide fluctuations, fading and increasing from moment to moment. There were also daily and seasonal variations in the median value of the signal strength. The signals usually were stronger in warm weather than in cold and in moist conditions than in dry.

Quite evidently the atmosphere—within the tropospheric layer in which we live—played tricks with radio microwaves. A theory was soon proposed by H. G. Booker and W. E. Gordon of Cornell University, who gave it a mathematical formulation. The theory is that high-frequency radio waves are scattered by pockets of inhomogeneity produced by turbulence in the atmosphere. These are "blobs" of air whose dielectric constant differs from the average. When such a blob is larger in di-

ameter than the wavelength of the radio wave, it acts like a lens and focuses the radio energy in the forward direction [*see upper diagram on opposite page*]. Radio signals scattered toward a receiver by a great many blobs will be strong enough to be detected.

A familiar form of the scatter phenomenon is exemplified by a searchlight beam in the sky. If the atmosphere were perfectly empty and homogeneous, the beam would be invisible. It is the scattering of the light by dust particles and inhomogeneities in the path of the searchlight beam that makes it visible to an observer on the ground. In the radio case we can illustrate the situation by a model consisting of a highly directive transmitting antenna beamed to a certain locality in the sky and a directional receiving antenna aimed at the same locality [*see diagram on page 46*]. The receiver will pick up radio waves scattered toward it by inhomogeneities in the area where the fields of the two antennas intersect, and thus a path for transmission of signals from the transmitter to the receiver is established.

This interpretation of how signals are transmitted is disputed and is not conclusively confirmed by the experiments, but most investigators accept the scatter theory and I personally believe that it gives the best explanation of the observations so far.

The directed receiving antenna intercepts only a small part of the radio energy sent out by the transmitter. Consequently to make use of the scatter phenomenon for effective transmission we must employ high-power transmitters and sensitive receivers with very large antennas. With such equipment it has been found possible to transmit high-frequency signals reliably over distances up to 300 or 400 miles. The method I have been discussing—reflection from the troposphere—works well for frequencies from 100 to 10,000 megacycles.

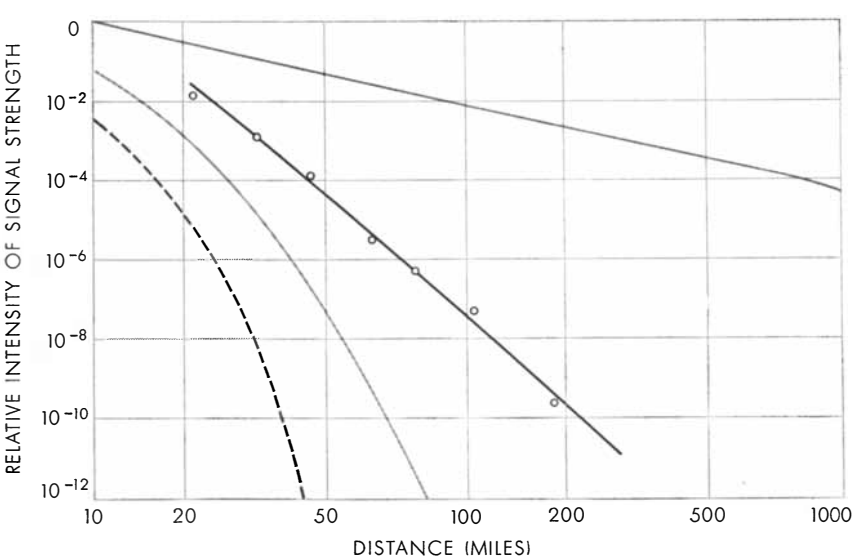
Naturally the first applications of the method have been made to span long sea distances and uninhabited areas, particularly in the Arctic regions, where ordinary transmission by way of the ionosphere is notoriously poor. The military DEW system was developed largely by workers at the Bell Telephone Laboratories and the M. I. T. Lincoln Laboratory. The same groups have also set up an experimental system which has transmitted a television picture for a distance of 188 miles. The American Telephone and Telegraph Company and the International Telephone and Telegraph Corporation are now jointly building the commercial high-frequency radio link between Key West and Havana; it will be capable of handling either telephone or television signals.

In inhabited land regions, where high-frequency signals are at present transmitted to distant points by way of a network of relay towers, the value of the scatter method must be measured by its relative cost. A single scatter station is far more costly, in the expense of equipment and in power consumption, than a single line-of-sight station. A typical scatter system designed to transmit 64 telephone messages at a time for a distance of 200 miles would use a 10,000-watt transmitter and 60-foot antennas, whereas a 30-mile line-of-sight transmitter with the same message capacity needs less than one watt of power and only 10-foot antennas. A string of relay stations of the latter type covering 200 miles may cost less than the one scatter station. But the relay system's advantage in cost of equipment is offset by the fact that sites have to be prepared for the several stations and they must be supplied with power and manned by permanent staffs.

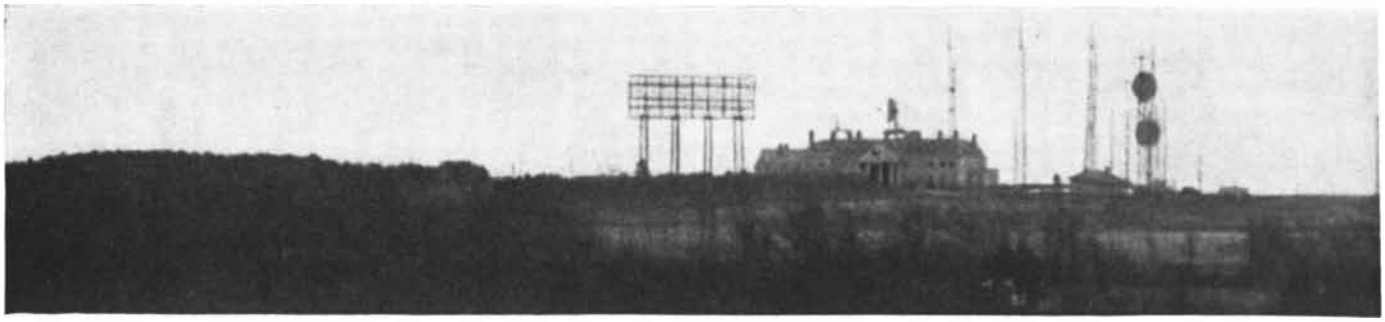
Now we come to the second method of scatter propagation that I mentioned at the beginning of this article. It depends on inhomogeneities in the reflecting medium, as the first method does. But the medium in this case is the ionosphere, instead of the troposphere. The inhomogeneities in the ionosphere that serve to scatter radio energy are concentrated blobs of electrons (or "holes" relatively free of electrons).

The possibility of using the ionosphere for scatter propagation was first suggested by Lloyd V. Berkner in the fall of 1950. We were working together in a group which had been given a special assignment by the Voice of America—namely, to improve its technical facilities for transmitting broadcasts from the U. S. to Europe. We considered trying to use the tropospheric scatter method to cross the Atlantic, but since it seemed to require a chain of relay stations at intervals of about 200 miles across the Greenland icecap and other remote areas, it was not a very attractive solution. Berkner suggested that if signals could somehow be reflected from the high ionosphere, they might be transmitted for much greater distances than 200 miles. Calculations by Edward M. Purcell of Harvard University and Booker of Cornell indicated that signals scattered from the ionosphere might indeed be detected at distances as great as 1,100 miles. This belief was reinforced by experimental evidence supplied by Dana K. Bailey of the National Bureau of Standards.

An experiment was made with a modified Navy transmitter located at Cedar



PROPAGATION CURVES show how the strength of a radio signal would fall off with increasing distance from the transmitter, under various actual and theoretical conditions. Dark gray line at top gives the decrease along the line of sight, which follows the inverse square law. Light gray and broken curves show (for 500 megacycle and 4,000 megacycle waves respectively) how signal strength will decrease over the horizon, according to older theories which take no account of scattering. Solid black line is drawn through experimental points which give variation of strength with distance for a signal of 3,000 megacycles.

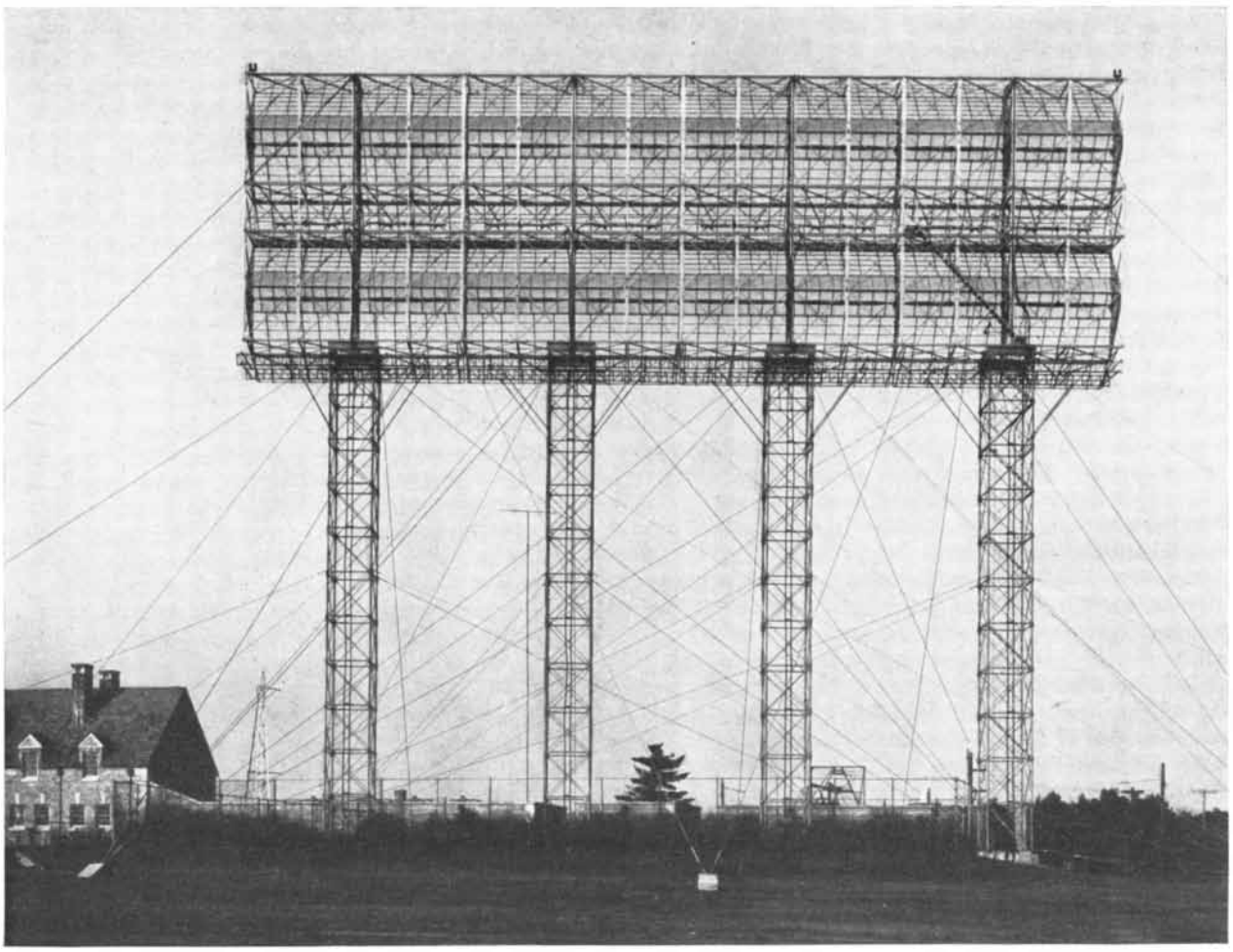


The Round Hill Field Station of the Lincoln Laboratory, at South Dartmouth,

Rapids, Iowa, and beamed toward an experimental station of the National Bureau of Standards in Sterling, Va., 700 miles away. The transmitter operated at a frequency of 50 megacycles—much higher than the critical frequency at which transmission beyond the horizon normally fails. But when it was turned on for the first time in February, 1951, the signal was immediately detected by the receiver in Sterling.

The received signal showed the rapid fading characteristic of scatter propagation, but it also had an extremely interesting and unexpected feature. Every few minutes it suddenly jumped sharply in intensity, and along with this came whistles of descending pitch which lasted for several seconds. The cause was not difficult to guess: these events were due to meteors whose ionization trails crossed the junction area where the fields of the transmitter and the receiver overlapped.

These meteor bursts present troublesome problems in the design of scatter-communication equipment, but it is also possible to take advantage of them. They reflect signals so effectively that they greatly reduce the transmission power requirement. The Canadian Government has recently announced a military communication system, called Janet,



CORNER REFLECTOR ANTENNA, which consists of 16 open-work "corners" in two rows of eight, is seen from the rear. The structure is 130 feet high. It was used to test ionospheric scatter communication between Cedar Rapids, Iowa, and Round Hill.

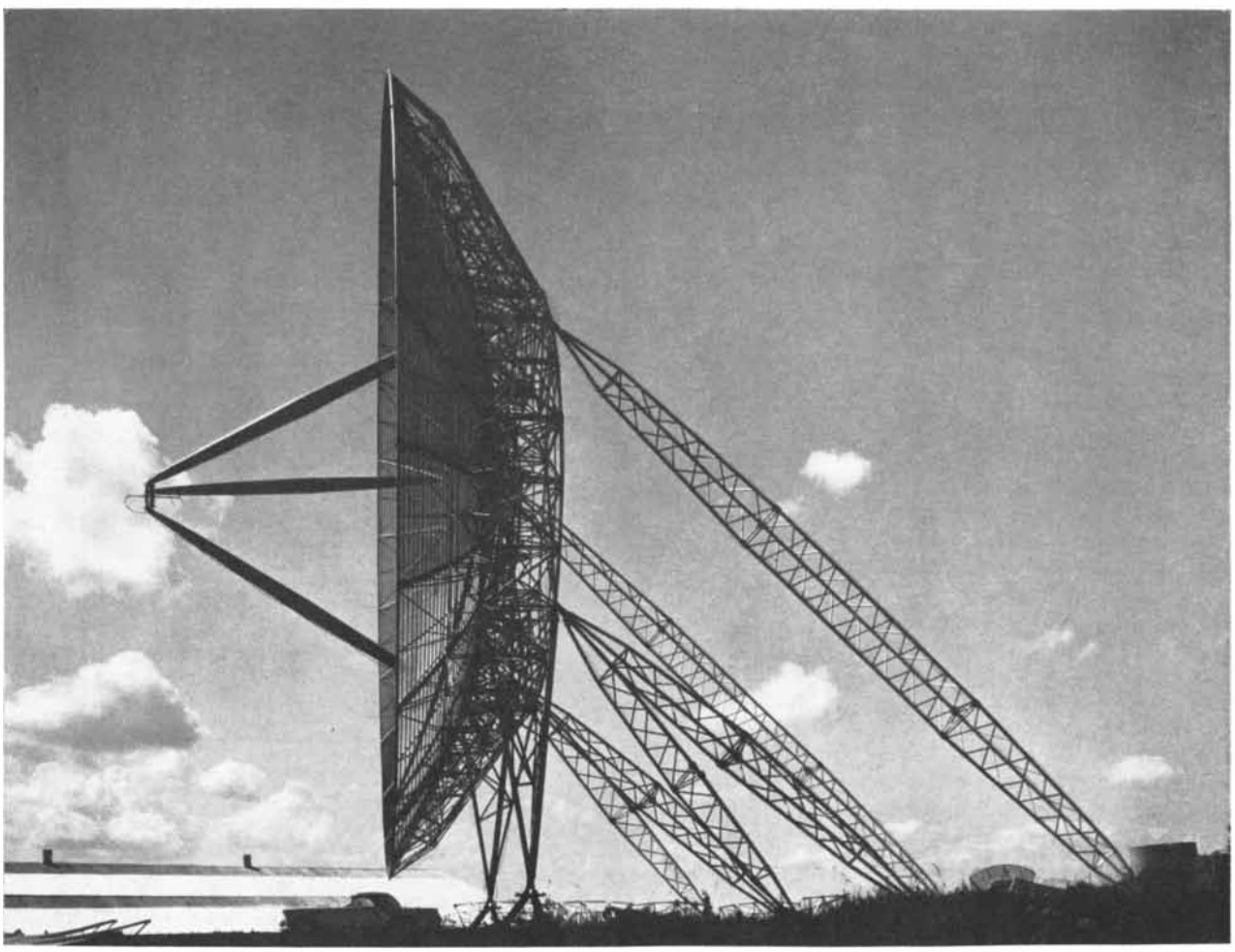
Mass., is one of the chief centers of research on scatter communication

which is designed to use the brief meteor bursts for teletype communication.

The effectiveness of ionospheric scattering is greater in daytime than at night and varies with the seasons, but its basic level is sufficient to permit the design of highly reliable transmitting systems. At night the transmitter may have to use many kilowatts of power; during the day a few hundred watts may suffice. A virtue of the scatter system is that it functions well in periods of great sunspot activity, when normal radio communications are seriously disturbed.

The range of frequencies for which the ionospheric scatter method is useful is from 30 to approximately 70 megacycles. Most systems designed to date have operated between 30 and 50 megacycles.

The Radio Propagation Engineering Laboratory of the National Bureau of Standards and the Lincoln Laboratory have pioneered the development of these systems. The operational installations have been made by a number of firms which have entered the field. The U. S. Air Force, the pioneer user of both scatter techniques, has used ionospheric scatter teletype relays extensively in its world-wide communication network. The ionospheric method gives high-frequency radio an effective and reliable range of 600 to 1,200 miles.



PARABOLOIDAL ANTENNA is used for tropospheric scatter communication over distances of 600 miles. It is 60 feet in diameter. The big dish is a reflector which converts into a parallel beam the energy received from a small antenna pointing at its center.

The Pathology of Boredom

Aviators sometimes suffer hallucinations during long, monotonous flights. The phenomenon is illuminated by a general examination of the effect of prolonged exposure to a monotonous environment

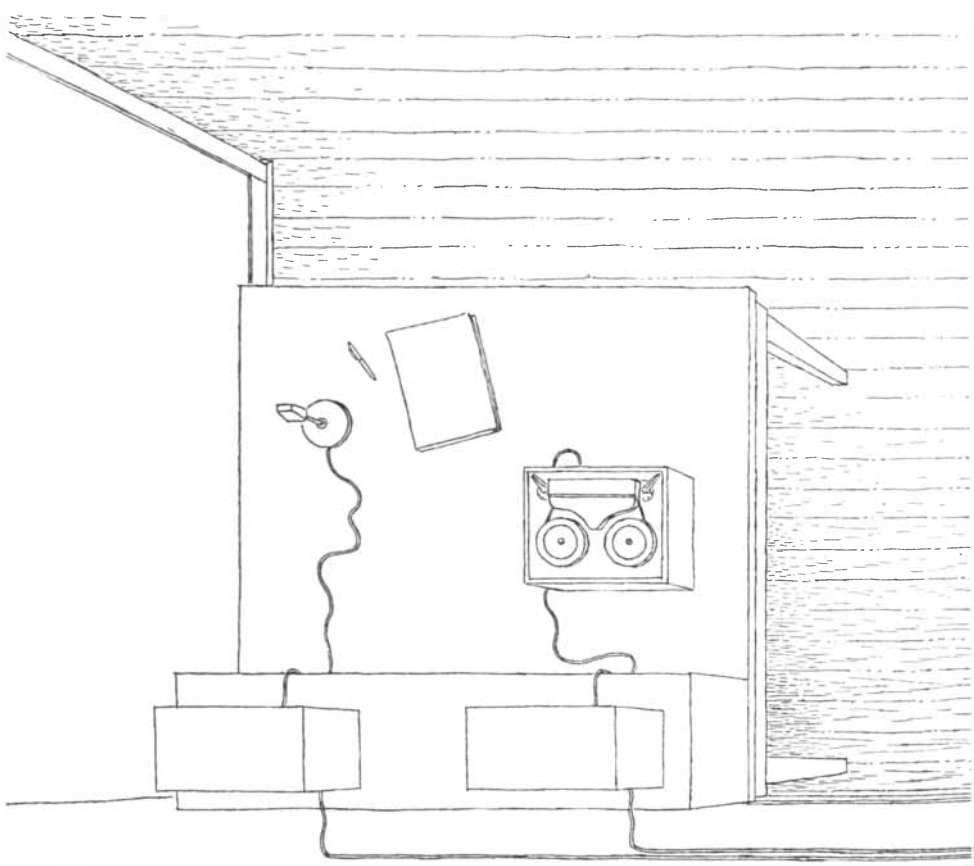
by Woodburn Heron

If you shake the surface on which a snail is resting, it withdraws into its shell. If you shake it repeatedly, the snail after a while fails to react. In the same way a sea anemone which is disturbed by a drop of water falling on the water surface above it ceases to be disturbed if drops continue to fall; a bird stops flying away from a rustling motion if the motion is steadily repeated. Most organisms stop responding to a stimulus repeated over and over again (unless the response is reinforced by reward or avoidance of punishment). Indeed, the higher organisms actively avoid a completely monotonous environment. A rat in a maze will use different routes to food, if they are available, rather than the same one all the time. It will tend to avoid areas in which it has spent considerable time and to explore the less familiar areas.

Monotony is an important and enduring human problem. Persons who have to work for long periods at repetitive tasks often complain of being bored and dissatisfied with their jobs, and frequently their performance declines. During the last war N. H. Mackworth of England made a series of researches for the Royal Air Force to find out why radar operators on antisubmarine patrol sometimes failed to detect U-boats. The operators usually worked in isolation, watching a radar screen hour after hour. Mackworth set up a comparable laboratory situation, requiring subjects to watch a pointer moving around a graduated dial and to press a button whenever the pointer made a double jump. The subjects' efficiency declined in the surprisingly short time of half an hour. As a result of this and other research the radar operators' tour of duty was shortened.

In this age of semi-automation, when not only military personnel but also many industrial workers have little to do but keep a constant watch on instruments, the problem of human behavior in monotonous situations is becoming acute. In 1951 the McGill University psychologist D. O. Hebb obtained a grant from the Defence Research Board of Canada to make a systematic study of the effects of exposure for prolonged periods to a rigidly monotonous environment. Hebb's collaborators in the project were B. K. Doane, T. H. Scott, W. H. Bexton and the writer of this article.

The aim of the project was to obtain basic information on how human beings would react in situations where



EXPERIMENTAL CUBICLE constructed at McGill University in Montreal to study the effects of perceptual isolation is at the right in this semischematic drawing from above. The subject lies on a bed 24 hours a day, with time out for meals and going to the bathroom. The room is always lighted. The visual perception of the subject is restricted by a translu-

nothing at all was happening. The purpose was not to cut individuals off from any sensory stimulation whatever, but to remove all patterned or perceptual stimulation, so far as we could arrange it.

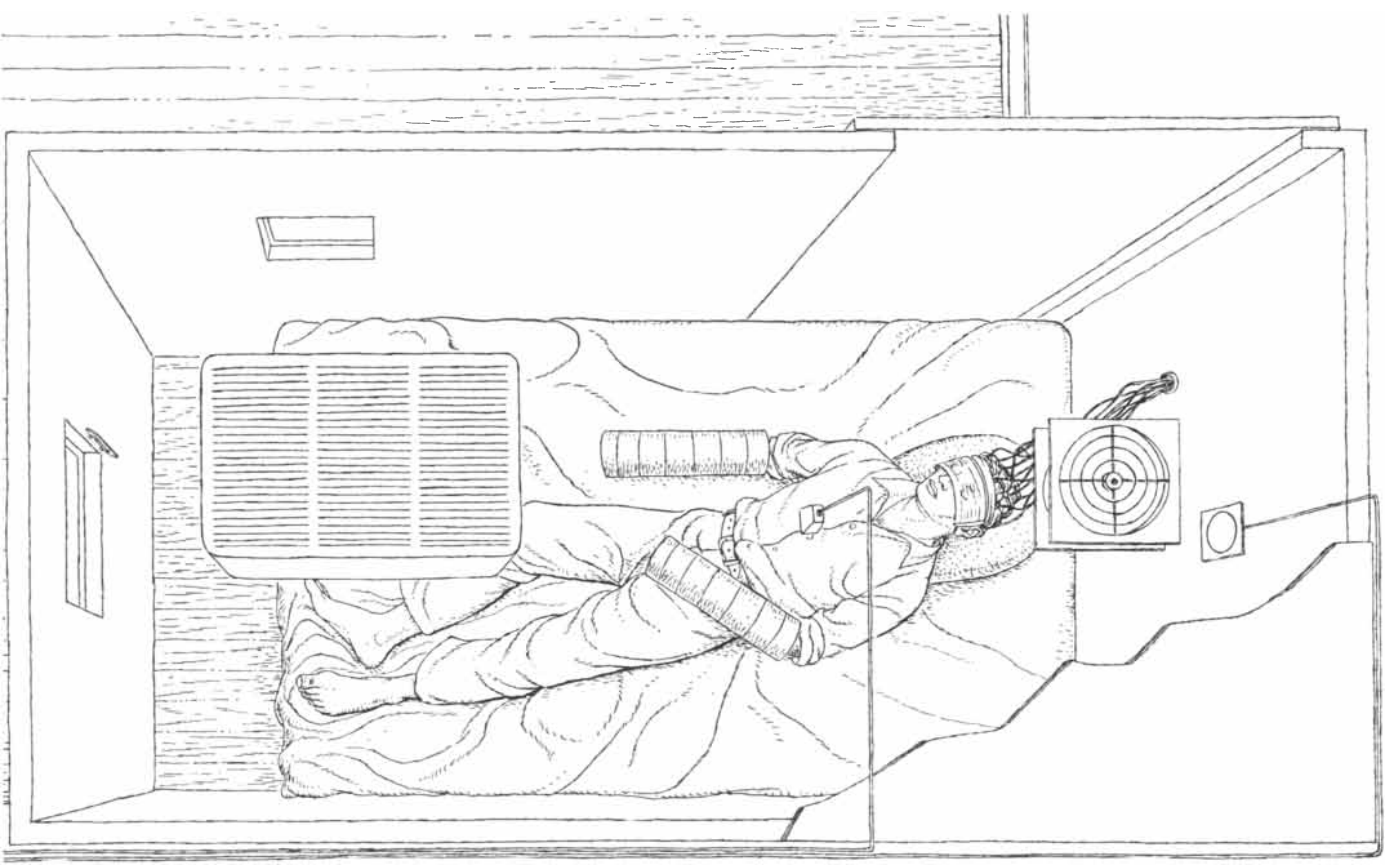
The subjects were male college students, paid $20 a day to participate. They lay on a comfortable bed in a lighted cubicle 24 hours a day for as long as they cared to stay, with time out only for meals (which they usually ate sitting on the edge of the bed) and going to the toilet. They wore translucent plastic visors which transmitted diffuse light but prevented pattern vision. Cotton gloves and cardboard cuffs extending beyond the fingertips restricted perception by touch. Their auditory perception was limited by a U-shaped foam rubber pillow on which their heads lay and by a continuous hum of air-conditioning equipment which masked small sounds.

When we started the research we were not at all sure what aspects of behavior it would be most profitable to investigate. Accordingly we began with a preliminary run in which we merely observed the subjects' behavior and interviewed them afterward. Most of these subjects had planned to think about their work: some intended to review their studies, some to plan term papers, and one thought that he would organize a lecture he had to deliver. Nearly all of them reported that the most striking thing about the experience was that they were unable to think clearly about anything for any length of time and that their thought processes seemed to be affected in other ways. We therefore decided that the first thing to do was to test effects on mental performance.

We used three main methods of investigating this. One was a battery of oral tests involving simple arithmetic, anagrams, word association and so on. This battery was given before the experiment, at 12, 24 and 48 hours during the isolation and finally three days afterward. Another battery of tests, given two days before and immediately after the isolation period, included copying a design with blocks, speed of copying a prose paragraph, substituting symbols for numbers, picking out what was odd in each of a series of pictures (for instance, one picture showed a man in a canoe using a broom instead of a paddle) and recognizing patterns embedded in a complex background. The third test used a recording of a talk arguing for the reality of ghosts, poltergeists and other supernatural phenomena. It was played to each subject during his isolation. We examined the individual's attitude toward supernatural phenomena before he entered isolation and after he had emerged.

On almost every test the subjects' performance was impaired by their isolation in the monotonous environment (and was poorer than that of a control group of students). The isolation experience also tended to make the subjects susceptible to the argument for the existence of supernatural phenomena. Some of them reported that for several days after the experiment they were afraid that they were going to see ghosts.

As the subjects lay in isolation, cut off from stimulation, the content of their thought gradually changed. At first



cent plastic visor; his auditory perception, by a U-shaped pillow covering his ears and by the noise of an air conditioner and a fan (*ceiling of cubicle*). In the experiment depicted here a flat pillow is used to leave room for the wires attached to the subject's scalp, which are connected to an electroencephalograph in an adjacent room. The subject's sense of touch is restricted by cotton gloves and long cardboard cuffs. The experimenter and the subject can communicate by means of a system of microphones and loud speakers.

they tended to think about their studies, about the experiment, about their personal problems. After a while they began to reminisce about past incidents, their families, their friends and so on. To pass the time some tried to remember in detail a motion picture they had seen; others thought about traveling from one familiar place to another and would try to imagine all the events of the journey; some counted numbers steadily into the thousands. (Incidentally, such experiences are commonly reported by persons who have been in solitary confinement for long periods.) Eventually some subjects reached a state in which it took too much effort to concentrate, and they became "content to let the mind drift," as one subject put it. Others said: "My mind just became full of sounds and colors, and I could not control it"; "I just ran out of things to think of"; "I couldn't think of anything to think about." Several subjects experienced "blank periods" when they did not seem to be thinking at all.

Not surprisingly, the subjects became markedly irritable as time went on and often expressed their irritation. Yet they also had spells when they were easily amused. In the interview afterward many of the subjects expressed surprise that their feelings could have oscillated so much, and that they could have behaved in such a childish way. They also said that they seemed to lose their "sense of perspective" while in the cubicle, and some subjects mentioned that at times they felt that the experimenters were against them, and were trying to make things exceptionally tough for them.

The subjects reported something else to which we at first paid no particular attention, but which was to emerge as the most striking result of the experiments. Many of them, after long isolation, began to see "images." One man repeatedly saw a vision of a rock shaded by a tree; another kept on seeing pictures of babies and could not get rid of them. Several subjects seemed to be "having dreams" while they were awake. Not until one of the experimenters himself went through the isolation experience for a long period did we realize the power and strangeness of the phenomenon. His report, and a review of the literature on other experiments in monotony, made clear that the experimental situation induced hallucinations.

The visual phenomena were similar to those experienced after taking the intoxicating drug of the mescal plant (mescal buttons), which is a ceremonial practice of some Indian tribes in the Southwest. They have also been reported in experiments in which subjects were exposed for long periods to blank visual fields or flickering light.

Our subjects' hallucinations usually began with simple forms. They might start to "see" dots of light, lines or simple geometrical patterns. Then the visions became more complex, with abstract patterns repeated like a design on wallpaper, or recognizable figures, such as rows of little yellow men with black caps on and their mouths open. Finally there were integrated scenes: *e.g.*, a procession of squirrels with sacks over their shoulders marching "purposefully" across the visual field, prehistoric animals walking about in a jungle, processions of eyeglasses marching down a street. These scenes were frequently distorted, and were described as being like animated movie cartoons. Usually the subjects were at first surprised and amused by these phenomena, looked forward eagerly to see what was going to happen next and found that the "pictures" alleviated their boredom. But after a while the pictures became disturbing, and so vivid that they interfered with sleep. Some of the subjects complained that their eyes became tired from "focusing" on the pictures. They found sometimes that they could even scan the "scene," taking in new parts as they moved their eyes, as if they were looking at real pictures.

The subjects had little control over the content of the hallucinations. Some kept seeing the same type of picture no matter how hard they tried to change it. One man could see nothing but dogs, another nothing but eyeglasses of various types, and so on. Some subjects were able to realize visions of objects suggested by the experimenter, but not always in the way they were instructed. One man, trying to "get" a pen, saw first an inkblot on a white tablecloth, then a pencil, then a green horse, finally a pen.

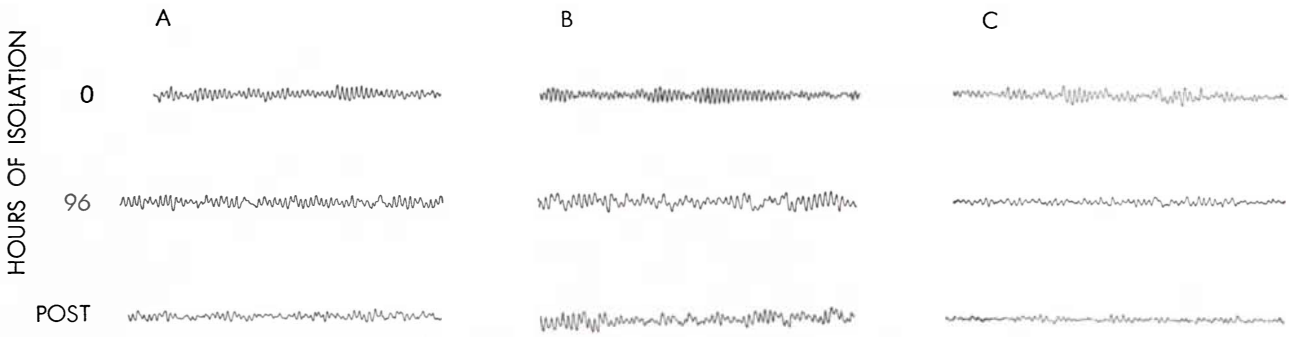
The hallucinations were not confined to vision. Occasionally a subject heard people in the "scene" talking, and one man repeatedly heard a music box playing. Another saw the sun rising over a church and heard a choir singing "in full stereophonic sound." Several subjects reported sensations of movement or touch. One had a feeling of being hit in the arm by pellets fired from a miniature rocket ship he saw; another, reaching out to touch a doorknob in his vision, felt an electric shock. Some subjects reported that they felt as if another body were lying beside them in the cubicle; in one case the two bodies overlapped, partly occupying the same space. Some reported feelings of "otherness" or "bodily strangeness"; trying to describe their sensations, they said, "my mind seemed to be a ball of cotton wool floating above my body," or "something seemed to be sucking my mind out through my eyes."

After emerging from isolation, our subjects frequently reported that "things looked curved," "near things looked large and far things looked small," "things seemed to move," and so on. We therefore made some systematic tests of their visual perception. The most striking finding was that when subjects emerged after several days of isolation, the whole room appeared to be in motion. In addition there was a tendency for surfaces to appear curved, and for objects to appear to be changing their size and shape. Asked to match a disk that was handed to them to one in a row of disks of various sizes 12 feet away, the subjects consistently chose a larger disk than did control subjects.

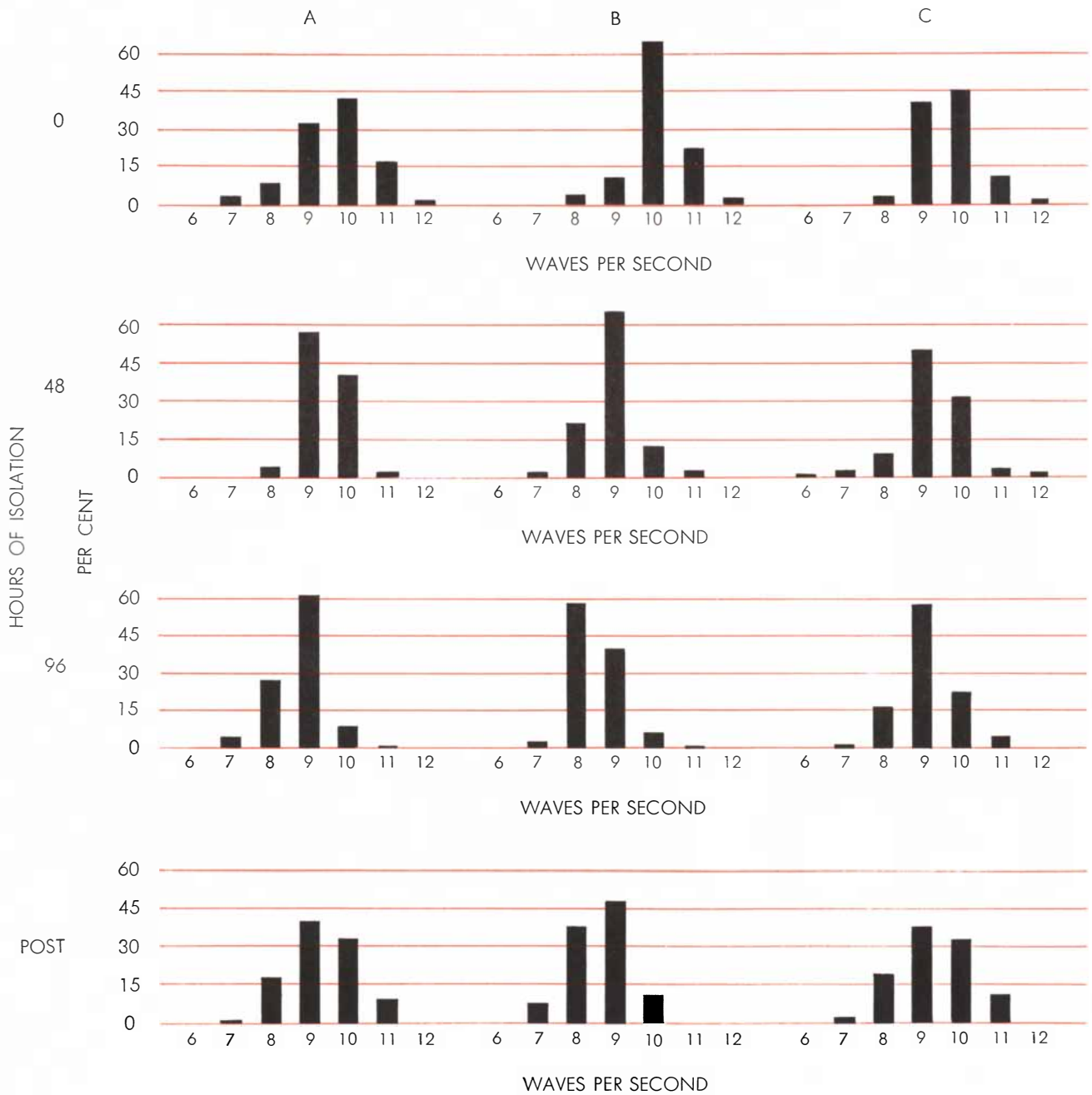
We recorded changes in the electrical activity of the brain in these subjects by means of electroencephalograms made before, during and after the isolation period. There was a tendency for some slow waves, which are normally present in sleep but not when an adult is awake, to appear after a period of isolation. In addition, the frequencies in the region of the principal brain rhythm slowed down [*see charts on opposite page*].

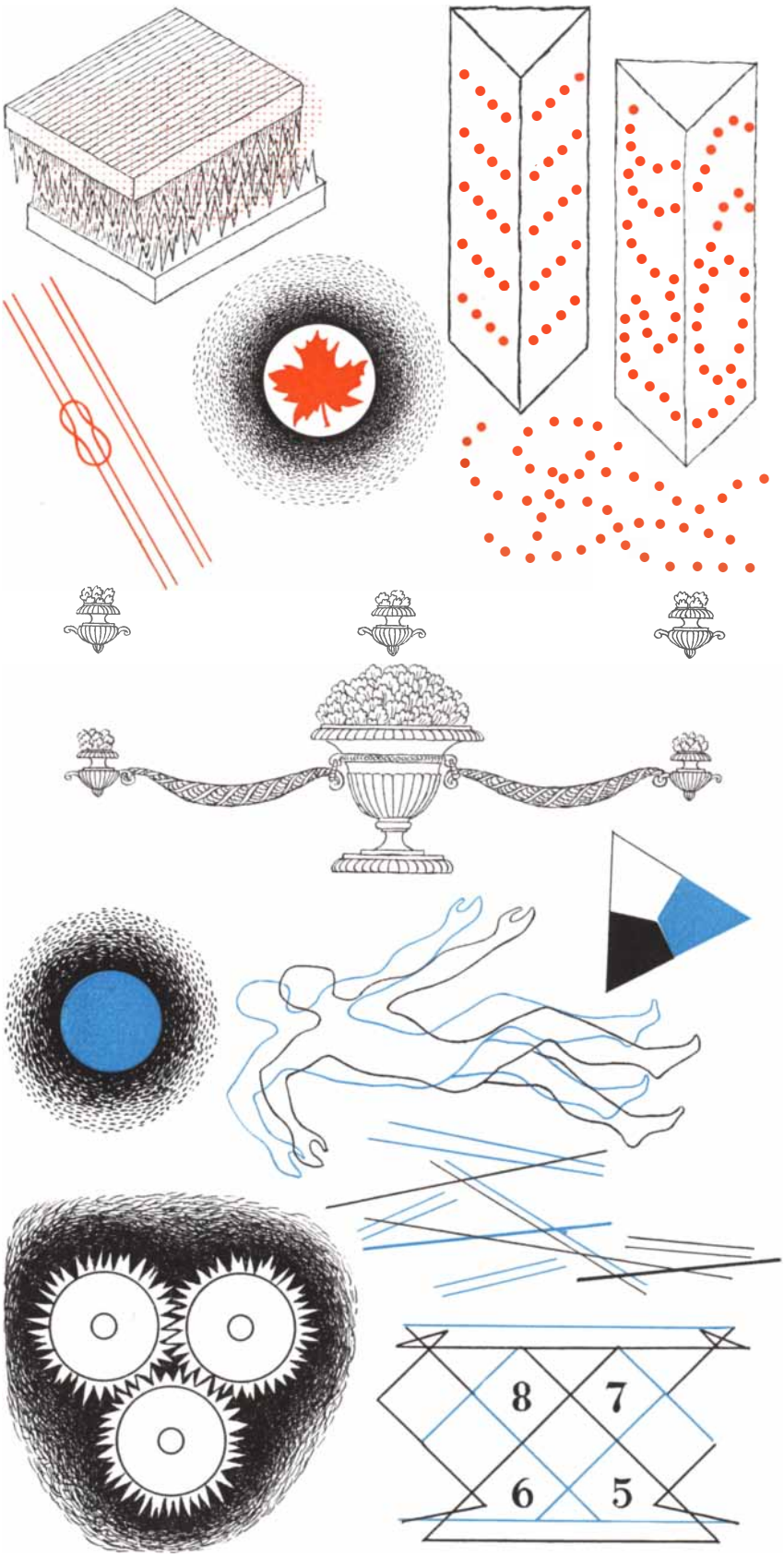
The overt behavior of the subjects during the experiment was, of course, carefully recorded. Most of the subjects went to sleep fairly soon after they had been placed in the cubicle. After waking they showed increasing signs of restlessness. This restlessness was not continuous but came in more and more intense spells, which were described as being very unpleasant. The subjects appeared eager for stimulation, and would talk to themselves, whistle, sing or recite poetry. When they came out for meals, they tended to be garrulous and attempted to draw the experimenters into conversation. In moving about, as when they were led to the toilet, they appeared dazed and confused, and had increasing difficulty in finding their way about the washroom.

As an outgrowth of the general experiment, we have begun some tests to find out the effects of restriction of just one sense. We tested six subjects who wore the frosted visors constantly but who otherwise were allowed to pursue



BRAIN WAVES from the occipital region of three subjects of the McGill University experiments (*above*) showed some change after 96 hours of isolation and three hours after the subject had emerged from isolation (POST). Similar changes in three other subjects are reflected in the bar charts (*bottom*). Below each bar is the number of waves counted in each one-second interval over a period of 300 seconds. The height of each bar is the percentage of all the waves during that period. Thus it indicates wave frequencies.





HALLUCINATIONS of isolated subjects are depicted. The drawings are based on descriptions by the subjects during the experiment and on sketches made after isolation period.

comparatively "normal" activities. Unfortunately the results of this experiment are not "pure," because the restriction of vision greatly restricted their movements and opportunity for other stimulation. These subjects developed visual hallucinations and also experienced some disorders of visual perception when the visors were removed.

Prolonged exposure to a monotonous environment, then, has definitely deleterious effects. The individual's thinking is impaired; he shows childish emotional responses; his visual perception becomes disturbed; he suffers from hallucinations; his brain-wave pattern changes. These findings are in line with recent studies of the brain, especially of the reticular formation in the midbrain [see "Pleasure Centers in the Brain," by James Olds; SCIENTIFIC AMERICAN, October, 1956]. In some way the reticular formation regulates the brain's activity. The recent studies indicate that normal functioning of the brain depends on a continuing arousal reaction generated in the reticular formation, which in turn depends on constant sensory bombardment. It appears that, aside from their specific functions, sensory stimuli have the general function of maintaining this arousal, and they rapidly lose their power to do so if they are restricted to the monotonously repeated stimulation of an unchanging environment. Under these circumstances the activity of the cortex may be impaired so that the brain behaves abnormally.

The results of our experiments seem to throw light on a number of practical problems. For instance, studies in France and at Harvard University have indicated that hallucinations are fairly common among long-distance truck drivers. After many hours on the road they may begin to see apparitions such as giant red spiders on the windshield and nonexistent animals running across the road, which frequently cause accidents. Similar phenomena have been reported by aviators on long flights: Charles Lindbergh described some in his autobiography. It is not improbable that some unexplained airplane and railroad accidents have been occasioned by effects of prolonged monotonous stimulation.

A changing sensory environment seems essential for human beings. Without it, the brain ceases to function in an adequate way, and abnormalities of behavior develop. In fact, as Christopher Burney observed in his remarkable account of his stay in solitary confinement: "Variety is not the spice of life; it is the very stuff of it."

Kodak reports to laboratories on:

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Actually a bargain

A month or two ago "Eastman Organic Chemicals, List No. 40" appeared and was sent or offered to all who feel a need for a list of some 3500 organic compounds available from a single source. Even as the type was being set, additions were being made. A few of these we were able to incorporate in a last-minute supplementary list. Let us, for fun, examine the most costly of these items, *2,4-Dimethylbenzoic Acid* (Eastman 7262) at $3.55 for one gram.

This is actually a bargain. Anybody who has use for more than one gram of it knows a secret that we don't know. We are speaking, then, not of $1600 per pound but of the sum of $3.55. $3.55 is less than it costs a chemist's employer to have him walk down to the library, fire up his pipe, exchange a few observations on school district politics with a colleague, and consult a few books which help him decide to get hold of some really pure m-xylene (where?), treat it with acetyl chloride in the presence of ferric chloride to convert to 2,4-dimethylacetophenone (assume he realizes that aluminum chloride suggested in some of the books sends the methyl groups skittering around the ring), and finally convert the acetyl substituent to a carboxyl by splitting it with sodium hypochlorite in a haloform reaction. For $3.55 we not only do all this but stand prepared to defend the thesis that *2,4-Dimethylbenzoic* Acid is what was in the bottle when we sealed it.

If this makes sense and you haven't as yet received your copy of "Eastman Organic Chemicals, List No. 40," write Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

S. O. 1177

We have outdone ourselves. We have made a sheet film that is approximately four times as fast as *Kodak Royal Pan Film* when both films are forced equally in the developer. Photography has scarcely had time in two years to adjust itself to the broader potentialities opened to it by *Royal Pan* and its roll film counterpart, *Kodak Tri-X Film*. These films had confounded 20 years of common photographic knowledge about the limits of fast film with respect to exposure time, lighting requirements, and the lens aperture requirements that determine depth of field. Now new and stronger superlatives must be found. Four times as fast as *Royal Pan!*

The new film does not have an official name yet. It is temporarily designated *Kodak Sheet Film S.O. 1177*, the "S.O." standing for the special order which your dealer places for two- to three-week delivery. Limited quantities only are being manufactured so that improvements and modifications, if any, can be effected quickly. News photographers who have tried this film out for us have reported back exposure index figures that some of our people regard as impossibly high by an order of magnitude. So we guess until there is an official determination we had better not mention a figure.

The exposure index is the parameter representing the film in the function that connects light level to the shutter and diaphragm setting on the camera. Well-meaning zealots have taken to quoting index figures as a measure of triumph over luminous insufficiency, forgetting that the index was devised as a guide to an arbitrary ideal, not a record of what you have gotten away with under certain conditions.

Still, what do you think of this shot made on *S.O. 1177* at 1/25 second, *f*/5.6 by the light of nothing more than the ordinary cigarette lighter with which wives light their husbands' cigarettes?

If you had one

If you had a little *Kodak Contour Projector, Model 8*, like this around the lab, you would like it. If you have frequent occasion to measure dimensions, angles, or configurations of relatively small objects, "you" could mean you. You lay them down on the glass stage and get a magnified shadow image of their contours on the circular screen. Depending on the lens used, you have a choice of six magnifications from 10× to 100×. You can have a chart over the screen as a guide. Alternatively, you can use the measuring stage for two inches of crosswise movement or one inch of movement the other way and read both of these displacements against a reference line on the screen to ±.0001″. With the rotatable protractor ring around the screen, angles can be read to 5′.

In factory inspection departments this projector is usually set up horizontally on a work bench, with a special fixture to hold the part being inspected. Now, the same micrometers that go on the $9,250 model, the measuring stage, and the protractor ring generalize the instrument for the laboratory.

This could use as little as $835 of budget money (if you wanted no accessories and could snitch a Kodak Contour Projection Ektar Lens from some other department). On the other hand, if the man who drops in just to tell you about the mechanical and optical quality of this instrument signs you up for the full lineup of features and lenses, you could spend $2,967.50. To summon him, write Eastman Kodak Company, Military and Special Products Sales, Rochester 4, N. Y.

Prices quoted are subject to change without notice.

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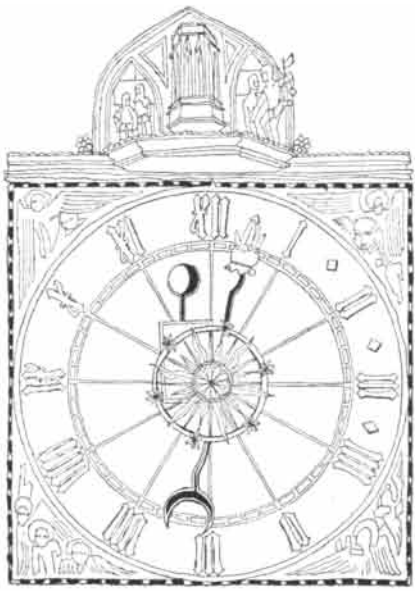
This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

SCIENCE AND



Federal Science Budget

The Federal Government will spend $2.7 billion on scientific research and development in 1957, according to a survey by the National Science Foundation. Eight government agencies will receive nearly 99 per cent of the total, most of it earmarked for applied research and plant facilities. Basic research will get 9 per cent of the research dollar, a one-third increase over 1956. All told the budget represents a 12 per cent increase over 1956 and 19 per cent over 1955.

The lion's share ($1.9 billion) will go to the Department of Defense. Next in order are the Atomic Energy Commission ($529 million), the Department of Health, Education and Welfare ($110 million) and the Department of Agriculture ($103 million). The four other government agencies receiving research grants are the National Advisory Committee for Aeronautics ($80 million), the Department of the Interior ($44 million), the Department of Commerce ($24 million) and the National Science Foundation ($43 million). NSF will invest $18 million in the satellite project.

Research, Education and Taxes

A change in the tax law to encourage private support of research and higher education was proposed last month by Paul E. Klopsteg, associate director of the National Science Foundation. Unless gifts from individuals to colleges and universities increase substantially, said Klopsteg in an article in *Science*, these institutions will have to depend increasingly on subsidies from the government for their maintenance.

Under the current tax law contributions are much more expensive to persons in lower tax brackets than to those with very high incomes. If a taxpayer's highest surtax bracket is 20 per cent, every dollar of a charitable gift represents 80 cents he might have kept for himself, even though he can deduct the gift from his gross income, while in the 90 per cent bracket a dollar gift costs the taxpayer only 10 cents.

Klopsteg suggested that contributions be credited against the tax itself rather than against taxable income, up to some maximum percentage. The plan, he says, would give many millions of citizens "an opportunity that they are now virtually denied: to participate effectively in truly democratic support of education and other public enterprises." At the same time, it would "solve the deeply rooted problems of education for the long term." The proposal was advanced by Klopsteg personally, not as a policy of the NSF.

Paradise of 1984?

"Science is steadily increasing our power to influence, change, mold—in a word, control—human behavior," says B. F. Skinner, professor of psychology at Harvard University. In a series of lectures, articles and books he has argued for a "behavioral technology" which would operate to a set of specifications such as: "Let men be happy, informed, skillful, well-behaved and productive."

This vision has called forth considerable debate among psychologists and other commentators. At the Chicago meeting of the American Psychological Association last fall Skinner debated behavior control with Carl R. Rogers, a psychotherapist and professor of psychology at the University of Chicago. Their discussion was published in a recent issue of *Science*.

Whether we admit it or not (and we usually don't), Skinner says, society has always engaged in some control of behavior, promoting some kinds and discouraging others by systems of reinforcements and punishments. He proposes that as more is learned about the causes and reinforcements of behavior, this knowledge be used to achieve a "far

THE CITIZEN

better world" in which every student effortlessly learns everything in the syllabus, in which "people are wise and good without trying, without 'having to be,' without 'choosing to be.'"

Acknowledging that there are "very real dangers" in control, Skinner argues that this is no reason to turn away from the potential benefits: "All men control and are controlled. The question of government in the broadest possible sense is not how freedom is to be preserved but what kinds of control are to be used and to what ends."

Rogers agrees that the capacity to predict and control behavior is developing rapidly. But he does not believe the consequent dangers can be easily dismissed. "Who will be controlled? Who will exercise control? What type of control will be exercised? Most important of all, to what end or what purpose, or in the pursuit of what value, will the control be exercised? . . . To hope that the power which is being made available by the behavioral sciences will be exercised by the scientists, or by a benevolent group, seems to me a hope little supported by either recent or distant history. . . . If behavioral scientists are concerned solely with advancing their science, it seems most probable that they will serve the purposes of whatever individual or group has the power. . . . I would hate to see Skinner become 'well-behaved' as that term would be defined for him by behavioral scientists. . . . The most awful fate I can imagine for him would be to have him constantly 'happy.' It is the fact that he is very unhappy about many things which makes me prize him. . . .

"If we choose some particular goal or series of goals for human beings and then set out on a large scale to control human behavior to the end of achieving those goals, we are locked in the rigidity of our initial choice, because such a scientific endeavor can never transcend itself to select new goals. Only subjective human persons can do that. . . . I would remark that colossal rigidity, whether in dinosaurs or dictatorships, has a very poor record of evolutionary survival."

The growing power to control behavior, says Rogers, should be exercised only to make people "self-directing, less rigid . . . better organized and integrated," to supply conditions which make

for "creativity and the process by which knowledge becomes self-transcending."

In rebuttal Skinner accuses Rogers of wanting to "solve the problem of our power by renouncing it." He argues that individuals can never become truly self-directing, because they are actually under the control of environmental forces.

"If we are worthy of our democratic heritage," says Skinner, "we shall, of course, be ready to resist any tyrannical use of science for immediate or selfish purposes. But if we value the achievements and goals of democracy we must not refuse to apply science to the design and construction of cultural patterns, even though we may then find ourselves in some sense in the position of controllers. Fear of control, generalized beyond any warrant, has led to a misinterpretation of valid practices and the blind rejection of intelligent planning for a better way of life."

Venezuelan Brain Center

In a mountain jungle near Caracas, Venezuela is building one of the largest and most expensive neurological centers in the world. It will cost more than $50 million. Twenty-six buildings, constituting a "pilot unit," have already been finished and fully equipped. The projected Institute for Neurology and Brain Research will also have a 200-bed hospital, a neurotropic virus research unit, a large radiation laboratory equipped with a nuclear reactor for medical research, and buildings for biochemistry, biomathematics and experimental neuropharmacology.

Teen-Agers in Africa

A recent survey of teen-agers in Africa shows that, given a free choice, almost half the boys would like to be birds and almost half the girls would like to be boys. The study was carried out by Hortense Powdermaker of Queens College, best known for her anthropological study of the Hollywood culture.

Miss Powdermaker did her new research among school children in a copper-mining community in Northern Rhodesia. The youngsters were largely Westernized, aiming to be clerks, mechanics, nurses and teachers. The boys felt closely identified with white people, admired European living standards and cleanliness, and did not think themselves badly treated. On the other hand, the youngsters disapproved some of the European values. They felt that Europeans were cold and inhospitable even to one another: two thirds of the African

RCA color TV tubes aluminized on Stokes high-production system

First continuous production installation for aluminizing color TV tube face plates is now operating at RCA's Lancaster, Pa., tube plant, using Stokes automatic in-line system.

Application to this unique tube design demonstrates the versatility of Stokes aluminizing systems. They are adaptable to all TV tube designs, for black and white and color, now being used or developed in the industry. They are engineered to provide high output and flexibility to meet changes in production rates and tube sizes.

Systems can be made up of single-tube units, as shown here, or of the exclusive Stokes twin-tube units that aluminize two tubes at a time on each cart. The combination of Stokes high-speed "Ring-Jet" vapor pumps and mechanical forepumps gives rapid evacuation, short cycles and fast production. A complete range of capacities and prices is available.

Specialists in high vacuum engineering and automatic production techniques for more than 30 years, Stokes engineers are well qualified to produce economical, efficient systems for your high vacuum production problems. Write or call Stokes today for a consultation and for literature applicable to your specific field of interest.

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children were convinced that the Europeans made their house guests pay a fee.

In their fantasies of an ideal existence the African teen-agers reverted to native values. Two thirds of the boys would have preferred to be an animal or some other part of nature—usually a bird. The reasons given were that they associated kindness and goodness with the animals. One boy wanted to be a swallow because "a bird is helpful to people." A girl wanted to be a tree because "trees are very generous to many creatures."

The girls were more conservative than the boys, felt more remote from European life and were more apt to feel badly treated by the whites. In their fantasies about a quarter of them would have chosen the life of a bird, but a much larger number preferred that of an African male. This reflected their resentment of their inferior status as women.

Miss Powdermaker found no indication that the conflict between European and African value systems in the minds of these boys and girls produced any inner turmoil. Europeans, no less than Africans, she observes, have "a remarkable facility for rationalizing logically incompatible positions."

Better Magnets

A new material which promises stronger, smaller, more versatile magnets than any now available has been developed by physicists of the General Electric Company. It is composed of submicroscopic cigar-shaped particles of iron, lined up parallel to one another and pressed together in a matrix of a nonmagnetic substance. They represent an alignment of magnetic "domains," suggested by basic research in magnetism [see "Magnetic Materials," by Richard M. Bozorth; SCIENTIFIC AMERICAN, January, 1955].

The superior magnetic properties of such a material have been suspected for some time, but no one was able to make particles of the right size and shape. Now T. O. Paine and a group of colleagues at the G.E. measurements laboratory have found a way to do it. They adapted a century-old electrolytic process in which iron is electroplated into a cathode of a liquid metal such as mercury. By proper choice of the cathode material, electroplating solution, current, temperature and so on, they have made particles less than a millionth of an inch in diameter and two to 10 or more times as long.

Each particle is so small that it consists of no more than a single domain. It therefore retains magnetization more

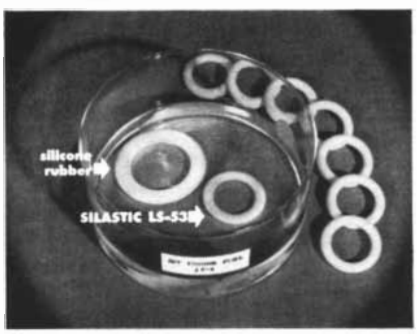
DOW CORNING

SILICONE NEWS

New Silicones Solve Old Problems

- New fluorosilicone rubber resists jet fuels, solvents, heat and cold
- Silicone-glass laminates superior to light metal for high temperature use
- Invisible silicone surface for glass containers speeds bottling, packing

FLUOROSILICONE RUBBER — is a new kind of heat and cold resistant rubber developed by Dow Corning research chemists in conjunction with the Materials Laboratory of Wright Air Development Center. Identified as Silastic LS-53*, it stays rubbery at temperatures from —80 to 400 F . . . but most remarkable feature is its outstanding resistance to the fuels, oils and solvents that limit the use of ordinary rubbers.

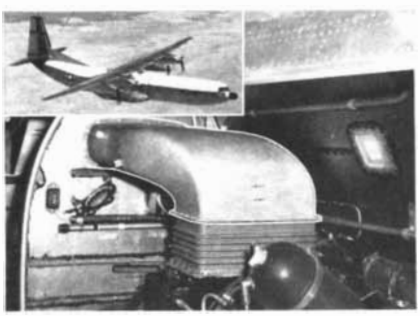


As illustrated, O-rings made of Silastic LS-53 swell only 20% when immersed in an aromatic jet engine fuel while those made of the best general purpose silicone rubbers swell over 200%. Presently limited to use in essential Air Force applications, new fluorosilicone rubber should help solve many problems for commercial aircraft, chemical, petroleum and automotive industries . . . wherever rubber parts are exposed to oils, solvents and extreme temperatures.
*T.M. REG. U.S. PAT. OFF. No. 40

"WHAT'S A SILICONE?" — is answered in a documentary movie available free of charge for showings to industrial management, production and engineering audiences. In full color and sound, this informative 16 mm film shows silicones in action . . . helping designers, improving products, solving production and maintenance problems. No. 41

WHERE THE SPOT'S HOT — a growing number of designers and materials engineers are specifying silicone-glass laminates in place of metal parts. Here's why: laminates made with glass cloth and Dow Corning silicone resins retain a higher strength-to-weight ratio at "hot" temperatures than many light metals; another reason—large and complicated pieces are easier to shape—simple plaster forms replace dies required to fabricate metal parts.

Typical application: Ducts used in the heating and air conditioning system of the C-133, a giant military turboprop transport now in production at Douglas' Long Beach Division. Tests prove the silicone-glass laminate ducts withstand jarring punishment, like engine backfiring, that might split stainless steel ducts. Many other promising commercial applications now in development. No. 42



NO MORE JAM-UPS — A durable, invisible "silicone surface" for glass bottles and jars permits food packers and volume bottlers like Pepsi-Cola to get greater output from filling equipment. Treated bottles have better "slip", so there is less wedging and jamming on filling lines. The Dow Corning silicone surface also provides greater resistance to bruising and scratching . . . thus, line breakage is sharply reduced; appearance and life of all types of glass containers is improved. Applied to exterior of new containers by glass manufacturers, the silicone surface is available at little or no extra cost. No. 43

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stubbornly than do larger pieces. The particles are suspended in a nonmagnetic material such as a plastic or glass and are then lined up in a magnetic field and compressed to the desired density.

The G.E. group has turned out experimental particle magnets which are about as strong as any made from conventional alloys. Paine thinks he can do twice as well or better.

Slow-Fast Reactor

An experimental nuclear reactor which combines the advantages of two radically different designs has been developed at Argonne National Laboratory. Its designers call it the slow-fast or half-fast reactor.

A fast reactor with enriched uranium fuel and no moderator is surrounded by a slow or thermal reactor whose fuel rods are immersed in a water moderator. Each section by itself is below critical size and will not sustain a chain reaction, but together they do. The chain reaction can be controlled simply by controlling the thermal section. This means that the fast section is free to breed new fuel and yet is easy to control. The experimental version is officially named Zero Power Reactor No. V (ZPR-V). Its designers, headed by Bernard I. Spinrad, believe that the principle can be successfully applied to a power reactor.

National Radio Observatory

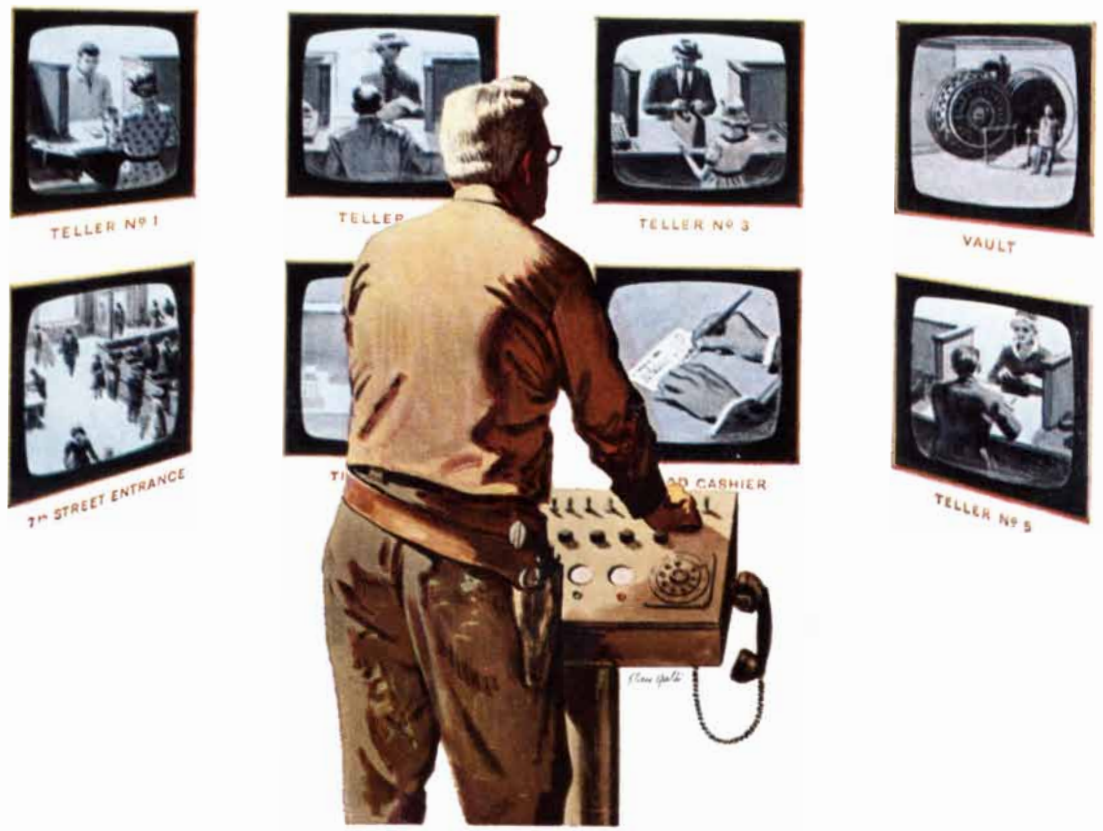
The National Science Foundation has appointed Associated Universities, Inc., to build and operate its 140-foot radio telescope at Green Bank, W. Va. [see "A National Radio Observatory," by Bart J. Bok; SCIENTIFIC AMERICAN, October, 1956].

A.U.I. is a cooperative organization of nine Eastern universities. Among other things, it operates the Brookhaven National Laboratory for the Atomic Energy Commission. It has already devoted two years to determining the site and the nature of the equipment to be used at the new radio observatory, which the National Science Foundation hopes will give the U. S. leadership in the field of radio astronomy. A.U.I. will have $4 million to spend on the project for the first year.

Radiation and Human Cells

How much radiation does it take to kill human cells? Estimates have ranged from 100 to 100,000 roentgens. Theodore T. Puck and Philip I. Marcus, biophysicists at the University of Colo-

CREATING A NEW WORLD WITH ELECTRONICS



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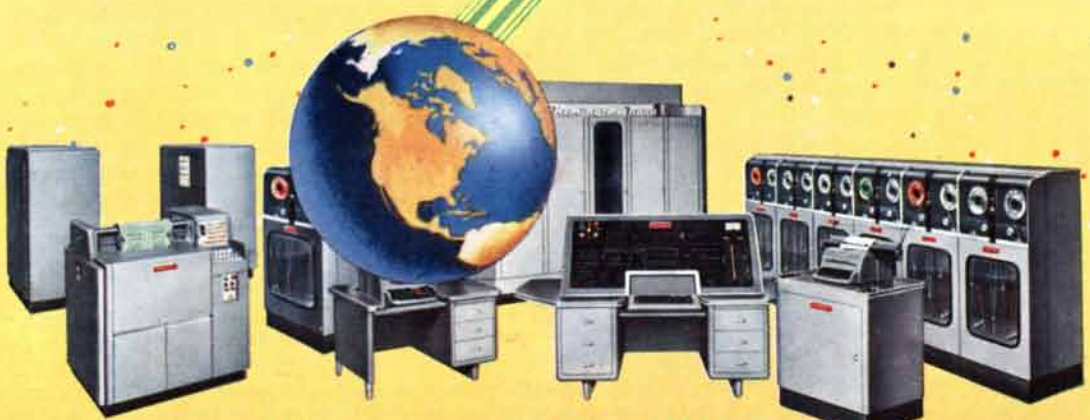

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rado, have now found a definite answer: the first 75 roentgens have comparatively little effect, but beyond this level each additional dose of 96 roentgens reduces the number of survivors by 63 per cent. Exposure to 500 roentgens kills 99 per cent of the cells. This means that human cells are tens to hundreds of times more sensitive to radiation than the cells of microorganisms.

The measurements were made possible by a new technique which Puck and his colleagues have developed for growing colonies from individual human cells in tissue culture. A cell was considered killed by X-rays when it failed to grow into such a colony. At low levels of radiation the effect did not express itself until after several generations—"killed" cells went through half a dozen divisions before petering out. Puck and Marcus interpret this to mean that the radiation damage is genetic, possibly involving the disruption of a chromosome. They point out that the ability of damaged cells to multiply for a time may explain the delay of radiation disease.

Tranquilizer

In the past year and a half prescription sales of the tranquilizing drug meprobamate, better known as Miltown and Equanil, have jumped to the rate of $32.5 million a year. More than a billion tablets have been sold, and the monthly production of 50 tons falls far short of the demand. Some California druggists herald each new shipment with colored window streamers reading, "Yes, we have Miltown today!"

In view of this widespread use the New York Academy of Sciences recently convened experts to discuss the drug. Reporting on a two-year study of 1,100 Air Force personnel and their families, Captain Noah M. Dixon of the Orlando Air Force Base in Florida reported that meprobamate had been effective in treating airsickness, insomnia and emotional instability. A Boston surgeon, Timothy A. Lamphier, said the drug had "excellent" effect in reducing postsurgical depression and anxiety and shortening the patient's convalescence. Leon A. Greenberg of Yale University said that tests conducted by his group at the Laboratory of Applied Biodynamics had shown that meprobamate can be "highly recommended" for the relief of insomnia, anxiety, tremors and depression in alcoholics who do not require hospitalization. Most of the physicians at the conference agreed that the drug was safe and not habit-forming.

But in *The Journal of the American*

Medical Association two California physicians, Henry T. Friedman and Willard L. Marmelzat, have reported 10 cases of severe reaction to meprobamate. They said there has been an "extreme paucity of pharmacological and clinical reports on this compound." A Seattle physician, Frederick Lemere, reported in the *Archives of Neurology and Psychiatry* that meprobamate can be habit-forming in a small percentage of cases. Lemere found typical symptoms of addiction, including a psychological craving for the drug, a buildup of tolerance, requiring increasing doses to achieve the same effect, and severe reactions when the drug is suddenly removed. Several patients under the influence of six or more tablets a day showed all the usual signs of intoxication.

Doctors will soon have more comprehensive evidence. William S. Middleton, chief medical director of the Veterans Administration, has announced plans for a nationwide testing and evaluation of the new tranquilizing drugs in 37 V.A. hospitals.

Professional Gamesmanship

Scientists on university faculties, overwhelmed by teaching duties, unfinished research projects and the necessity to publish, may often wonder whether there is not an easier way to advance their careers. According to Frank N. Young and Sears Crowell of Indiana University, there is. In a paper in the *Bulletin* of the American Institute of Biological Sciences they suggest how well-known principles of gamesmanship can help a professor to get along.

Academic worth is now universally measured by volume of publication, but "most deans apparently read only the titles; others simply count." Therefore the scientist should contribute only to journals which publish separate abstracts, taking "great care" to make a last-minute change in title so that the abstract and the paper bear different names. Reprints should be bound in heavy covers "in case weighing may be resorted to."

"To maintain a really rigid production schedule," a professor should get his name on the publications of his graduate students, preferably as senior author.

A final suggestion is to begin a series. This need not start with Number I. "A title such as 'Studies on the Regeneration of Cytochrome X in the Decapitated Chick. XXV' is in itself a thing of beauty to add to your bibliography. The addition of 'Further' to the title seems to us redundant, however."

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ANESTHESIA

The modern physician commands an imposing array of techniques for the suppression of pain. After 150 years a prime frontier in the study of anesthetics remains their effects on the mind

by Henry K. Beecher

A gray granite building in Boston—the oldest building of the Massachusetts General Hospital—is famous as a good example of the work of the early 19th-century architect Charles Bulfinch. But it is likely to be remembered long after Bulfinch is forgotten, for it contains in its attic one of the most celebrated rooms in the world. It was there that anesthesia had its first public demonstration. A small inscription on the wall announces that it was "from this room that this discovery spread throughout the civilized world and a new era began. . . ."

Anesthesia has considerably widened its scope since William T. G. Morton ushered in the new era on October 16, 1846, by administering ether to a patient about to go under the knife. Today the anesthetist can take away consciousness or obliterate feeling locally, stop spontaneous breathing and care for the body's oxygen needs by artificial means, paralyze the body and relax the muscles, control the blood flow and reduce the blood pressure to a low level to prevent bleeding, even largely suspend the body's need for oxygen by cooling. In short, he controls the vital functions of sensation, of consciousness, of respiration, of circulation, of neuromuscular action and of metabolism—and all of this he does under the adverse circumstances of preceding disease and present surgery. (It is a curious thing that it is technically easier to take away consciousness, with its vast consequences, than it is to take out a lung.)

Pain was doubtless the first reason for the development of the physician, and it remains one of his principal interests. Much of medicine is still concerned with the treatment of symptoms, and of these the most important is pain. Biologists too have a compelling interest in pain—its anatomical machinery and the whys and wherefores of its coming and going. Indeed, pain and anesthesia have a broad philosophical interest. As the physiologist R. S. Lillie said 40 years ago: "The problem of the general nature of anesthesia is in fact inseparable from the wider problem of the nature and conditions of irritability in general." It may be fair to say that the key to understanding life itself lies in this question of the irritability of tissue—what factors promote or block the response of a cell to a stimulus.

In medicine anesthesia has played a crucial part in the development of surgery and pharmacology. The debt of the surgeon—and, of course, the patient—to anesthesia could not be put better than it was by the great English physician and medical historian Sir Clifford Allbutt: "When I was a boy, surgeons operating upon the quick were pitted one against the other like runners on time. He was the best surgeon, both for patient and onlooker, who broke the three-minute record in an amputation or a lithotomy. . . . The obvious boon of immunity from pain, precious as it was, when we look beyond the individual, was less than the boon of time. With anesthetics ended slapdash surgery. Anesthetics gave time for the theories of Pasteur and Lister to be adopted in practice."

Anesthesia also ushered in the modern era of treatment of disease with drugs. Moreover the anesthetic drugs themselves have become powerful tools for studying the functioning of the body, especially of the mind in its many states—normal and disordered. It is to this aspect of the subject that I shall give particular attention in this article.

For a decade our laboratory at the Massachusetts General Hospital has been making an attack on a previously unexplored facet of the problem of anesthesia. Pharmacologists, as neat housekeepers, put the drugs acting on the central nervous system in several separate categories. They like to speak of sedatives, of hypnotics (sleep-producing drugs), of analgesics (pain-relieving drugs), of ego depressants (popularly known as "truth serums") and of anesthetic agents (used in surgery). But we have been interested to study these states as successive stages of what seems to us to be one continuous process. In fact, a single drug, given in increasing doses, may produce all five states. For example, a barbiturate in a small dose acts as a sedative, and then as the dose is increased it becomes a sleep-producing drug, then a pain-relieving agent, then an ego depressant and finally a general anesthetic.

The Anesthetic State

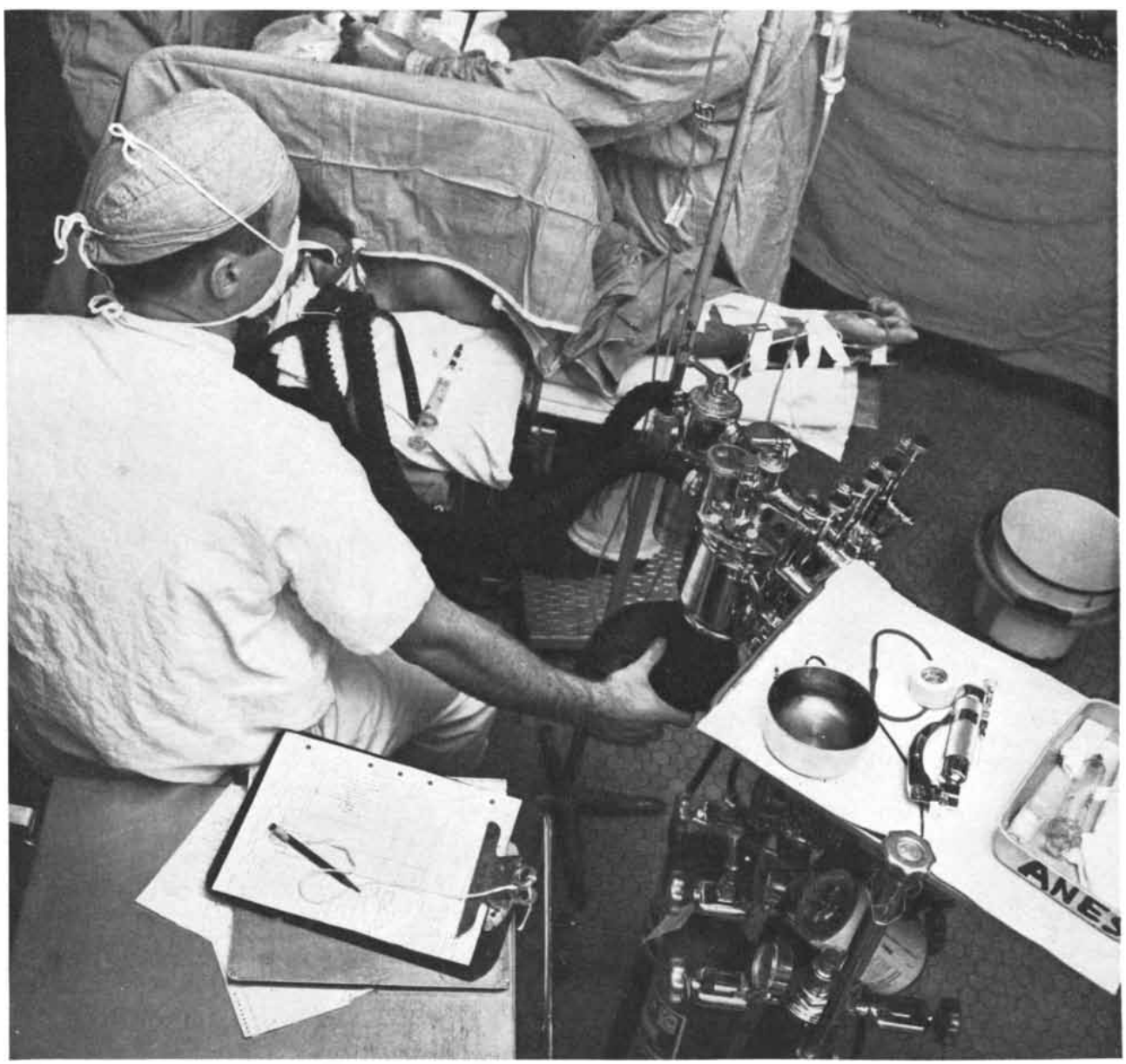
Anesthesia is a condition in which the body's normal responses to stimuli are temporarily depressed. The reversibility of this process is one of its outstanding characteristics. It has many points in common with sleep. These suggest that the state of anesthesia is not altogether a grossly abnormal condition.

The same state may, however, be produced both by relatively harmless and by harmful agents. An example of the latter is carbon dioxide. It interferes with essential life processes. Carbon dioxide acts first as an excitant, then as a depressant. When a person inhales air containing 3 per cent of carbon dioxide (normally room air has only .03 per cent) he begins to breathe heavily, and his ability to do hard work is reduced. When the percentage rises to 4, he breathes more rapidly, pumps a heavier flow of blood and shows this by a pound-

ing pulse. With an intake of 6 per cent carbon dioxide he develops a headache, becomes confused and has dilated blood vessels, a flushed skin and a rise of blood pressure. If the level of carbon dioxide in the air increases beyond 6 per cent (say to 30 per cent), he not only loses consciousness but the heart fails (in a manner very like that in asphyxiation by hanging), the blood pressure suddenly drops and the heart and respiration stop at about the same time. It is true that rather deep anesthesia can be produced by 30 per cent carbon dioxide. But at what cost!

Just how the body goes to sleep—what physiological and chemical process causes it to lose feeling or consciousness—is still an almost wholly unsolved mystery. The interest in anesthesia goes back to antiquity, but the history of deliberate experiment on it is comparatively short.

Many great names in science are associated with the subject in one way or another. Among them is Joseph Priestley, who in 1772 discovered nitrous oxide (the "laughing gas" of the dentist). Priestley did not realize the gas had anesthetic properties: they were first discovered by the chemist Humphry Davy in 1799. In the course of some remarkable experiments he carried out on himself at the age of 20 (including the production of headaches by the rapid drinking of a bottle of wine, to which, he said, he was unaccustomed) Davy found that deep draughts of nitrous oxide had a pain-relieving effect. He suggested in an account of his research published in 1800 that nitrous oxide might be of use in surgery, but unfortunately this suggestion was neglected for decades. Davy also described fantastic semiwaking dreams—a finding which in more recent times has become the foun-



ANESTHETIST administers a mixture of nitrous oxide and oxygen to a patient during an abdominal operation at Massachusetts General Hospital. The muscles of the patient have been relaxed with a drug similar to curare. The anesthetist controls the breathing of the patient by squeezing the rubber bag. On the chart in the foreground he records blood pressure, pulse and respiration.

dation for probing the subconscious levels of the mind with drugs.

In 1818 an anonymously published note, usually attributed to the physicist Michael Faraday, reported that effects similar to those of nitrous oxide could be produced by ether. This announcement had ludicrous rather than scientific results, for people began to inhale ether as a diversion.

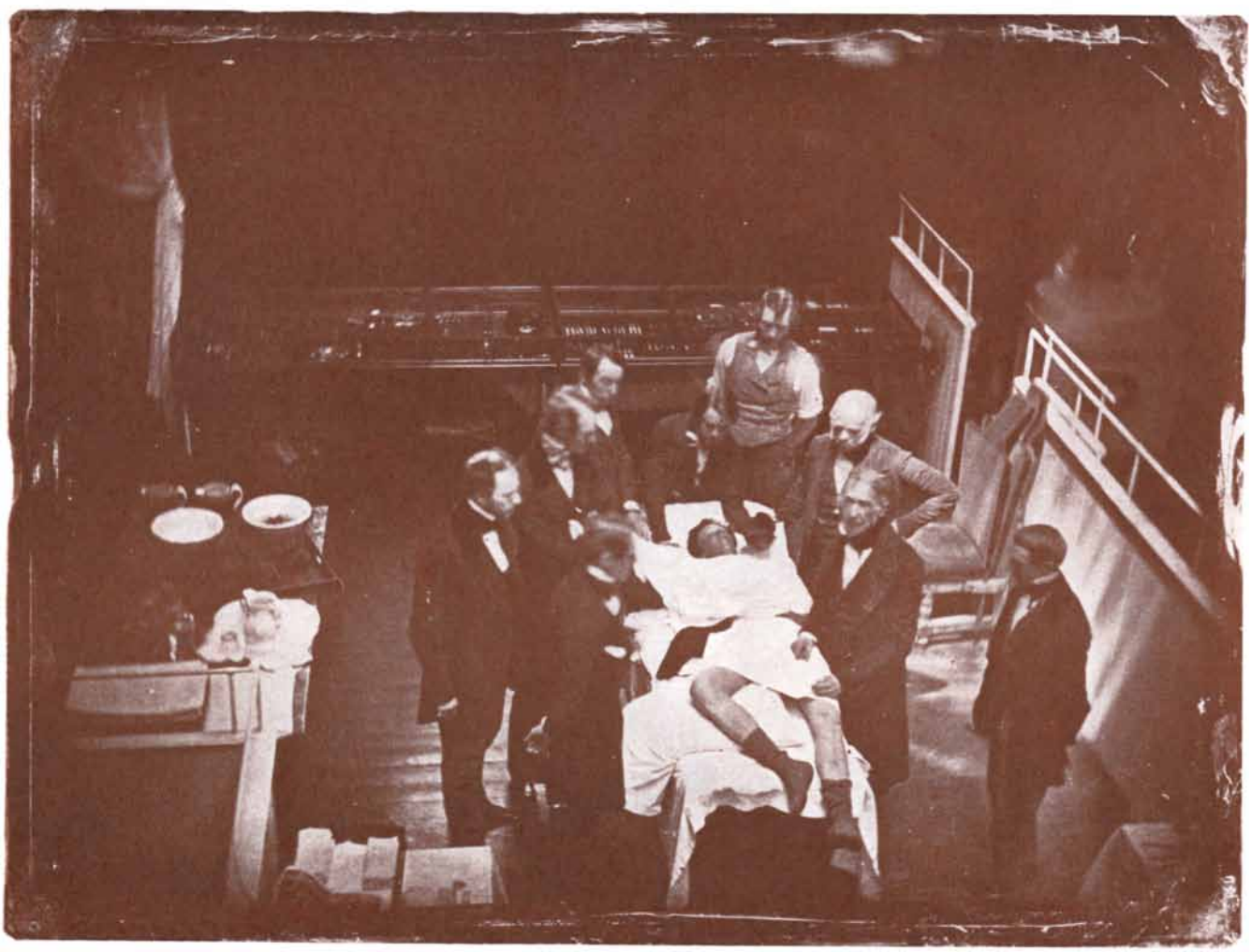
The Early Experiments

The story of the invention of surgical anesthesia is a long and bitter one, marked by frustrated careers, wrangling in the courts, heartbreak, madness and suicide. Without doubt the first to set out deliberately to dull the pain of a surgical procedure by the inhalation of a gas was Henry Hickman of England, who in 1823 carried out experiments on animals. Hickman's reports made no impression at the time. He was ignored by the Royal Society and, ironically enough, by Davy, who was then president of the Society.

It is probable that the first operation on a human being under anesthesia was performed in January, 1842, by a surgeon named Clarke, using ether, at Rochester, N. Y. Two months later Crawford W. Long carried out a more celebrated anesthetic operation in Jefferson, Ga. In December, 1844, the Hartford, Conn., dentist Horace Wells did his best to popularize nitrous oxide anesthesia by submitting himself to a tooth extraction. But it was the public demonstration by Morton in Boston on October 16, 1846, that really launched the use of anesthesia in surgical practice. In spite of the slow communication of those days, within six months after his demonstration the number of surgical operations in some London hospitals had more than doubled.

In the century since the beginning of anesthesia, many new agents have been discovered or synthesized, but it is a curious fact that ether, the first to be used, remains the most widely useful. If anesthetists had to give up all anesthetics but one, they would probably choose ether. It can produce deep anesthesia; it relaxes the muscles; a rich concentration of oxygen can be given to the patient with it; it does not poison a healthy heart in the doses used; its intake is automatically stopped by respiratory depression when the depth of anesthesia becomes dangerously great, and it can be administered with comparative safety by a novice as well as by an expert. Its main drawbacks are that it is inflammable and that it is apt to produce considerable nausea.

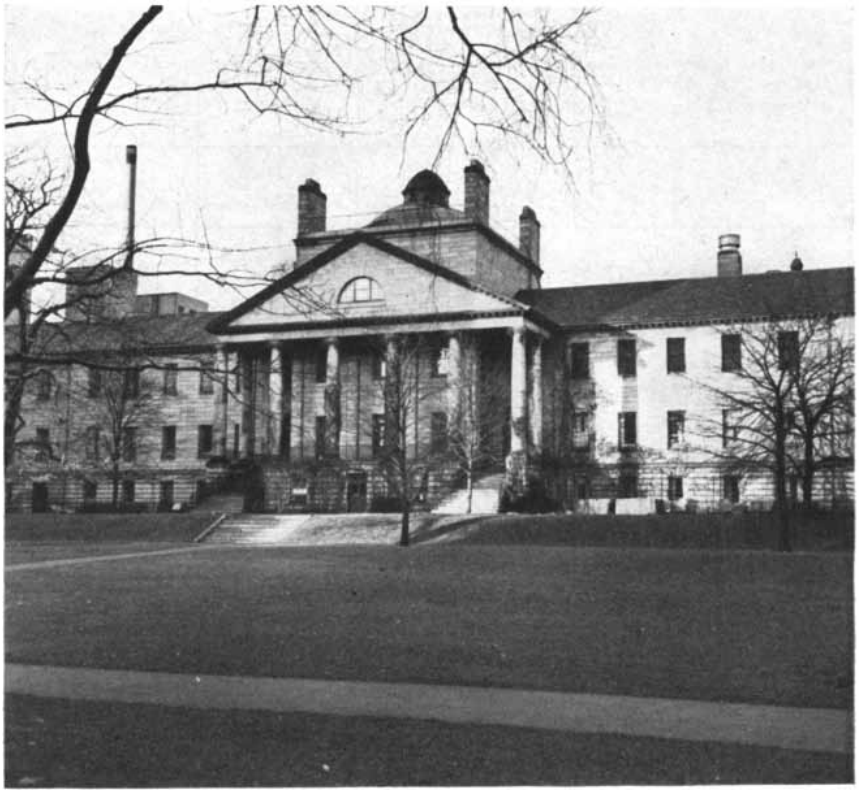
The discovery of the revolutionary benefits of anesthesia of course led to a vast amount of experimentation and development. By trial and error it was discovered that anesthetics could be administered by various routes: by breathing, by injection into the bloodstream or into tissues, by instillation into the lower



ETHER ANESTHESIA was first publicly demonstrated on October 16, 1846, at Massachusetts General Hospital. In this daguerreotype, the demonstration is reenacted sometime before 1853. William T. G. Morton, who presided at the demonstration, was not present.

intestinal tract, by introduction through the rectum. Local anesthetics, such as cocaine, were discovered; procaine (Novocaine) was synthesized. The advantages of combinations of anesthetics were exploited. It was found that anesthetic states could be produced by hypnosis and certain uses of electricity. And under the guidance of the great brain surgeon Harvey Cushing and his distinguished surgical colleague Amory Codman the condition of the patient under anesthesia was accurately determined by certain physical indicators, particularly the quality and rate of the pulse.

Basic researches in physiology and in physics contributed to development of anesthetic techniques. Twenty years ago Arthur Guedel of the University of Wisconsin devised a standard system for identifying the level of ether anesthesia. A crucially important basis for scientific development of inhalation anesthesia was laid by the great work of the Yale physiologist Howard W. Haggard on the kinetics of gas transport. He demonstrated the practical significance in this field of Dalton's law of partial pressure, bringing out the critical effect of the concentration of a component gas in a mixture of gases.



DEMONSTRATION WAS PERFORMED in this granite building, the oldest of Massachusetts General. The "ether dome" is below the cupola above the entrance of the building.

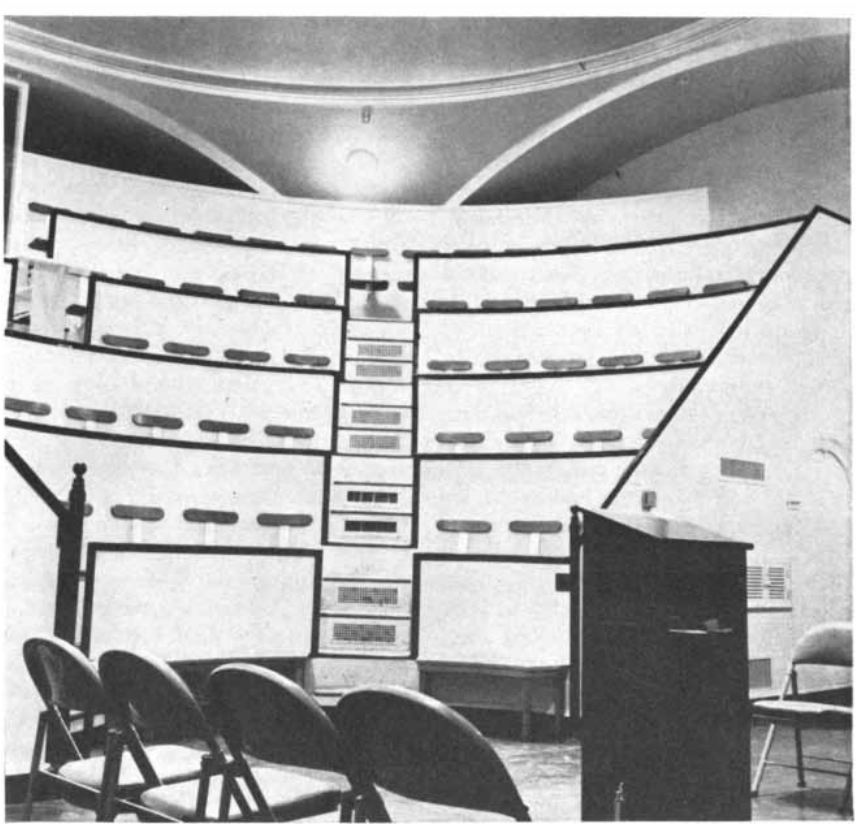
Anesthetic Agents

Let us take a look at some of the modern anesthetic agents that have followed in the train of ether and nitrous oxide.

Ethylene was discovered to have anesthetic powers after it was found to be responsible for the mysterious death of flowering carnations in certain Chicago greenhouses. Ethylene (a component of illuminating gas) has remarkably low solubility in the blood: it is much less soluble than ether or chloroform. This insolubility, coupled with anesthetic potency, makes for exceedingly rapid induction of surgical anesthesia. Because ethylene does not interfere with the body's sugar metabolism, it is useful in providing anesthesia for individuals with uncontrolled diabetes. But its advantages are purchased at the price of fearful explosiveness. It is remarkable that none of the early experimenters blew himself up with this explosive agent.

Another comparatively new inhalation anesthetic is divinyl ether—a deliberately synthesized combination of ethylene and ether. It acts more rapidly than ether, but it may produce liver damage under some circumstances. Carefully administered, it may be used, especially for children, when rapid anesthesia is desirable.

Cyclopropane, introduced in the early



DEMONSTRATION WAS OBSERVED in this small theater. The original seats occupied by the observers are in the background. The furniture in the foreground is modern.

EFFECTS	NITROUS OXIDE	ETHYLENE	CYCLOPROPANE	ETHYL ETHER	VINYL ETHER	ETHYL CHLORIDE	CHLOROFORM
ARRHYTHMIAS	OCCASIONAL	RARE	FREQUENT	OCCASIONAL	OCCASIONAL	FREQUENT	FREQUENT
MYOCARDIUM	NORMAL	NORMAL	MODERATE DEPRESSION	NORMAL	NORMAL	DEPRESSION	DEPRESSION
BLOOD PRESSURE	NORMAL	NORMAL	OCCASIONAL RISE	NORMAL	LATE DROP	LATE DROP	EARLY DROP
PULMONARY IRRITATION	NONE	NONE	NONE	++	++	NONE	+
CURARIFORM EFFECT	NONE	NONE	NONE	++	++	NONE	+
LIVER FUNCTION	NORMAL	NORMAL	NORMAL	NORMAL	MODERATE DEPRESSION	DEPRESSION	DEPRESSION
KIDNEY FUNCTION	NORMAL	NORMAL	NORMAL	NORMAL	LATE DAMAGE	NORMAL	LATE DAMAGE
BLEEDING TIME	NORMAL	SLIGHT INCREASE	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
HYPOXIC DANGER	+++	++	NONE	NONE	NONE	NONE	NONE

EFFECTS OF INHALATION ANESTHETICS are compared. Arrhythmia is any variation in the normal rhythm of the heart. The myocardium is the muscular part of the heart wall. The curariform effect is the paralysis of skeletal muscle. The hypoxic danger refers to hypoxia: the reduction of the level of oxygen in the body. The plus signs compare the intensity of certain effects.

1930s, has become a widely used agent. Like ethylene, it is highly insoluble in the blood and therefore has a very rapid action. It is more potent than ethylene or nitrous oxide, producing deeper levels of anesthesia. It also gives better muscle relaxation. Moreover, a higher percentage of oxygen can be used with it. It has two major defects: a terrible explosibility and a tendency to produce an irritability of the heart, which may be followed by serious consequences.

The first effective agent developed for local anesthesia by injection was cocaine, introduced toward the end of the 19th century. Natives of Peru had known for centuries that the pain of trephining operations on the skull could be relieved by chewing the leaves of the coca plant and then spitting on the wound. In 1884 at the Roosevelt Hospital in New York, William Stewart Halsted, who was later to become the great surgeon of his age at the Johns Hopkins Hospital, successfully blocked nerve trunks with injections of cocaine. The modern development of block anesthesia for specific portions of the body came from this important work.

The chemists began to take the cocaine molecule apart to see which of its components accounted for its anesthetic effects, and this led to the synthesis in 1904 of Novocaine. Since then workers have created other local anesthetic agents which are longer lasting and which can anesthetize tissues when painted on the surface. But they bring new difficulties onto the scene. As the molecule gets heavier, it becomes more and more toxic. The game has been, of course, to increase the strength more than the toxicity. Very helpful have been the discoveries that the toxicity of local anesthetic agents can be reduced greatly by adding a little adrenalin or by giving the patient barbiturates beforehand.

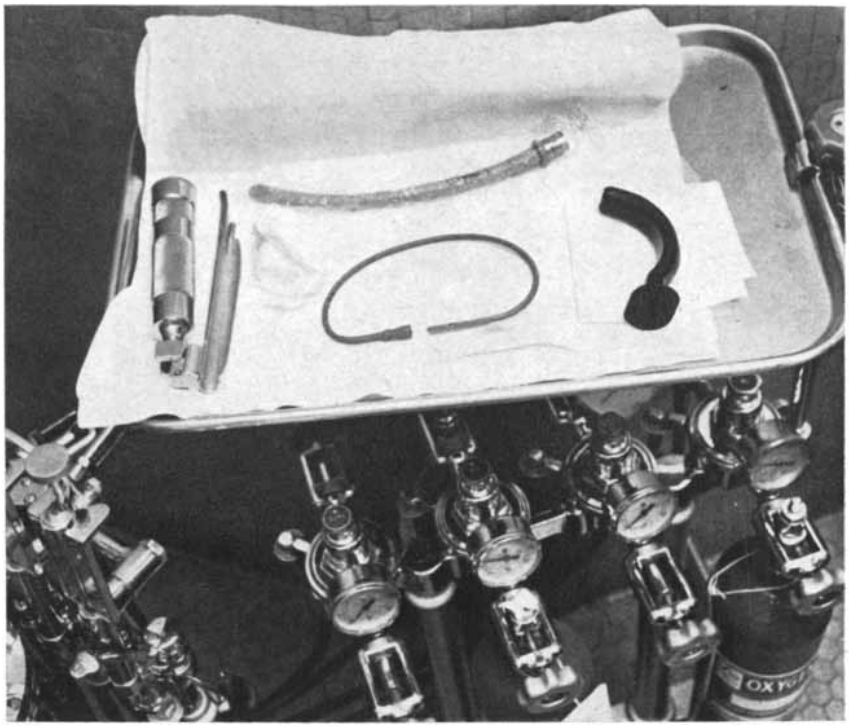
Another great advance at the turn of the century was the discovery of spinal anesthesia. A local anesthetic agent is injected into the fluid surrounding the spinal cord. It is absorbed by the cord and presumably adsorbed on the nerve cells. One of the effective present methods is injection of the drug by means of a catheter placed in the spinal canal.

South America originated not only coca juice but also the important class of anesthetics known as the muscle-relaxing agents. As everyone knows who reads the Sunday supplements of the newspapers, certain South American Indians for centuries have tipped their arrows with curare to paralyze their prey, whether animal or human. Sir Walter Raleigh introduced curare into Europe in 1595, and the great French physiologist Claude Bernard studied it in the latter part of the 19th century. Curare was used in our Civil War to treat the muscle spasms of tetanus. Modern interest in the drug as an anesthetic agent began in the 1930s and early 1940s, when it was introduced in surgery. The principal action of curare and similar agents is to block the junction between nerve and muscle. They thereby paralyze skeletal muscles and check respiration. But they also have effects within the brain and on the circulatory system, which need fuller exploration.

The great hope is that eventually it will be possible to use these relaxing agents to produce a degree of muscular inactivity permitting the most profound surgical exploration while the patient is under only light general anesthesia. Undoubtedly the procedure will increase in safety as well as in effectiveness. This development constitutes a real revolu-

tion in the field of anesthesia, for it promises to make major surgery feasible under a very light and relatively safe form of sleep.

During the past 100 years there have been many unquestionably authentic accounts of surgical operations successfully performed under hypnosis. It is unfortunate that something of a stigma has always been attached to hypnotism. The reality of the hypnotic state is indisputable. There can be no question that hypnosis may produce a genuine state of anesthesia, in which pain is abolished and the patient maintains a normal, steady pulse rate even under surgery. Indeed it has long been clear, and has recently been documented by evidence in our laboratory and elsewhere, that the feeling of pain depends in large part on the psychic state. Every small boy (or professional boxer) who engages in a fist fight knows that during the excitement of the fight he is likely to feel no pain. Suffering appears to arise from two components—the primary sensation and the psychic processing of that sensation. Many pain-relieving drugs apparently act on the psychic processing, and hypnosis clearly must. Hypnotic anesthesia deserves systematic and precise study.



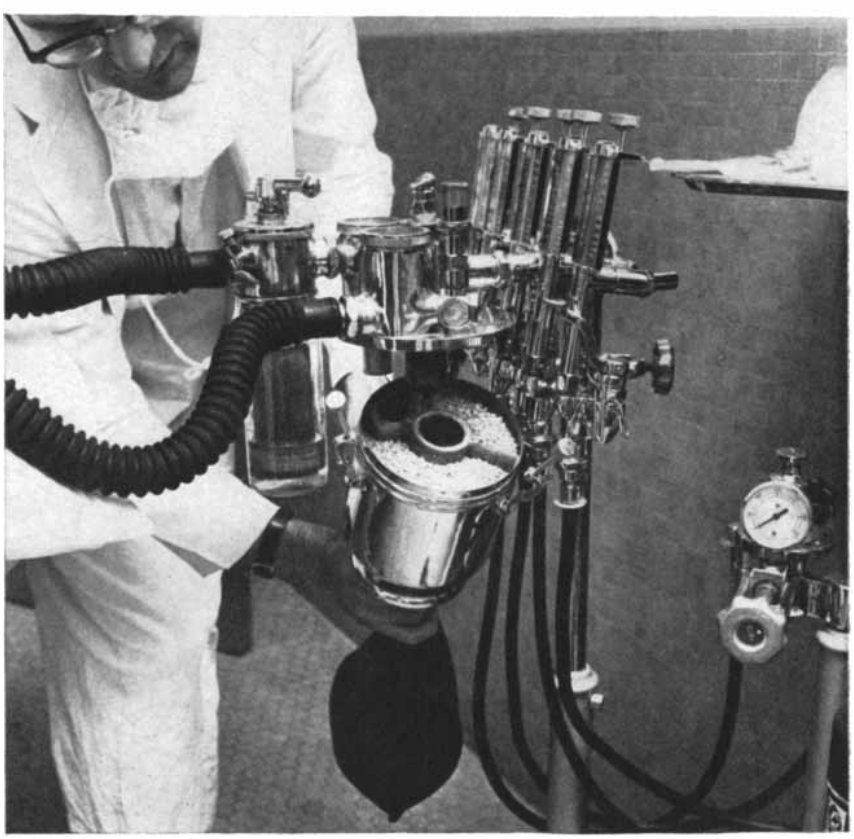
INSTRUMENTS used during the inhalation anesthesia are laid out before the anesthetic procedure depicted in the next two pages. At the left is a laryngoscope to examine the throat passage. At the top and right are tubes that are inserted into the throat to assure the free passage of air. In the middle is a narrow suction catheter to remove fluid from the mouth.

How Do Anesthetics Act?

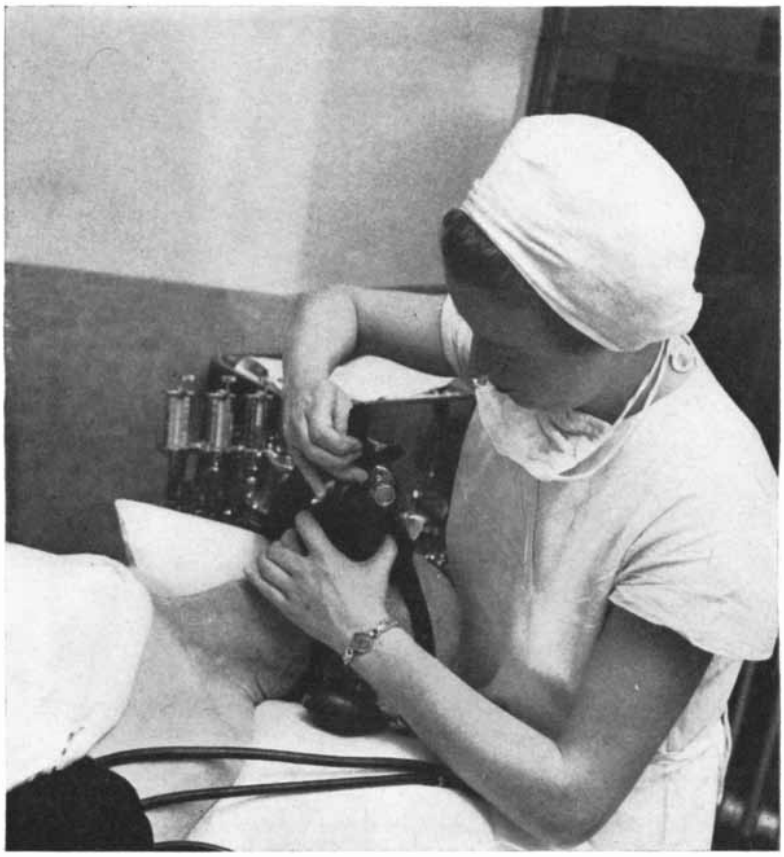
Like much of medicine, anesthesia is still an empirical art. A disease whose cause is not understood has to be treated on the basis of its symptoms, but once physicians learn the cause, their treatment usually becomes enormously more effective. So will it be with anesthesia. Once we understand the mechanism of the anesthetic process, it will become a far more precise tool than it is at present.

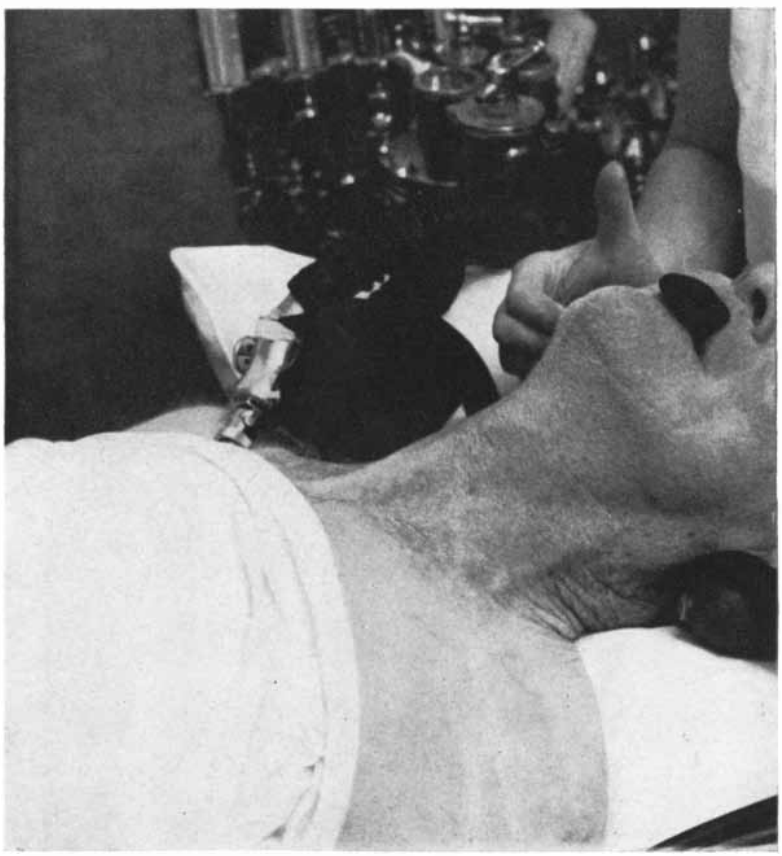
It must be said straight out that we know very little about how anesthetic agents act. Concerning their effects on the central nervous system we cannot even form a theory. Investigators of their action have been obliged to start at a simpler level, studying their chemical and physical effects on lower animals or on cells. There have been some beginnings of an attempt to describe their action at this level, and I shall mention two or three theories.

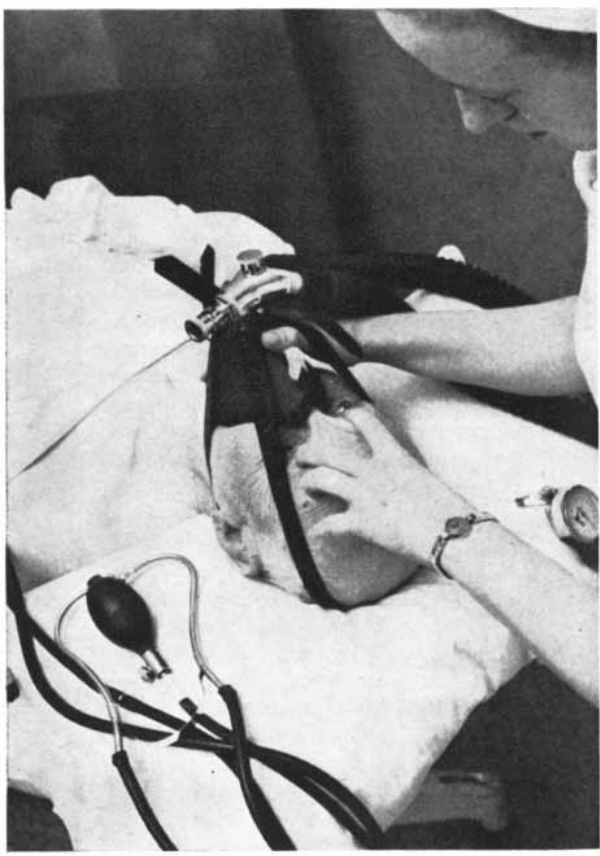
A German chemist, Hans Meyer, and a Swiss plant physiologist, E. Overton, independently discovered that the chief characteristic of many effective anesthetic substances was their relative solubility in lipoid (fatty) substances. In experiments on polliwogs they demonstrated that the greater the solubility of a substance in fat, the greater its anes-



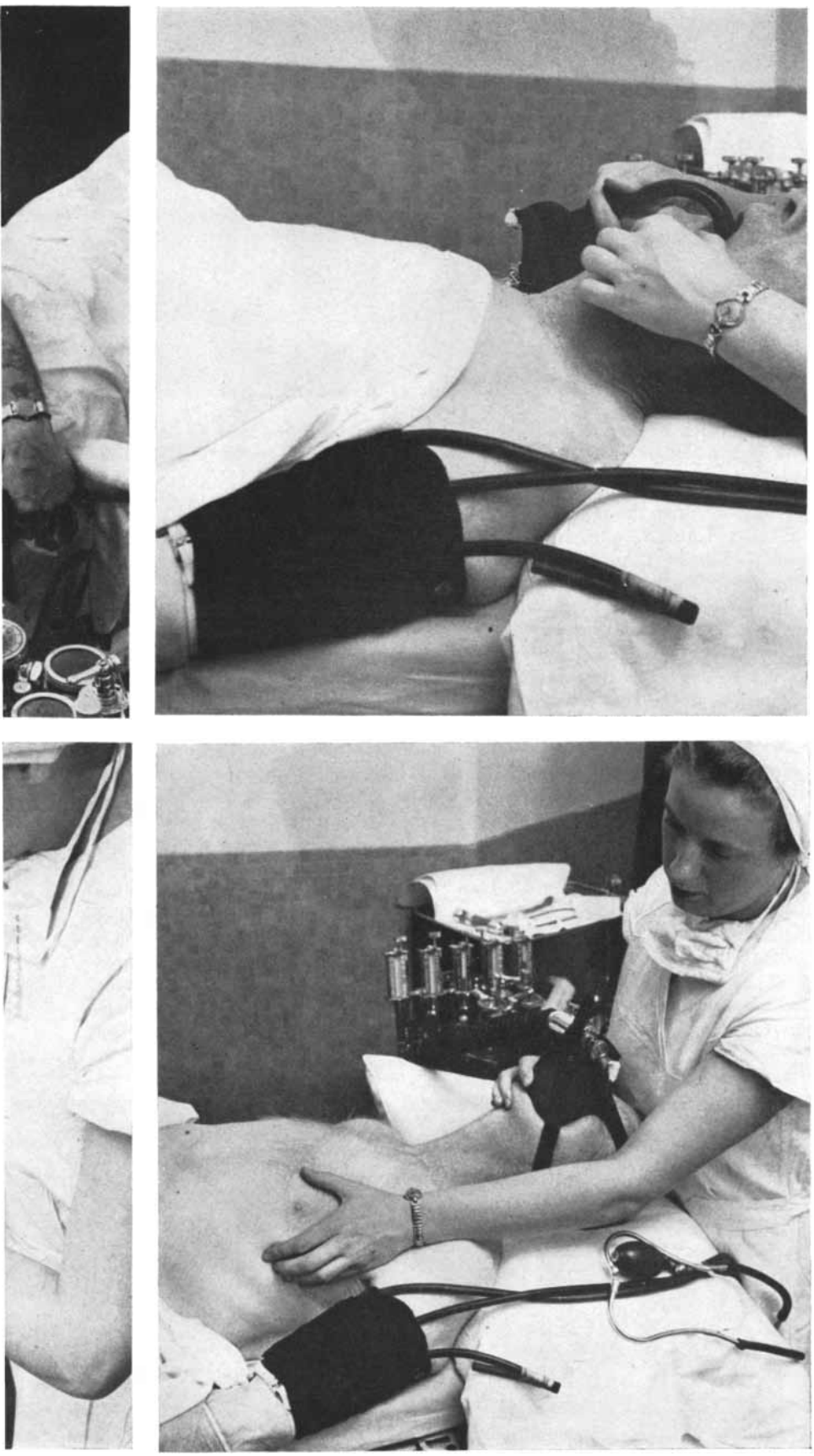
CANISTER of soda lime is inserted into anesthetic apparatus before the same procedure. The function of the soda lime is to absorb carbon dioxide in the closed cycle of the machine.







INHALATION ANESTHESIA is demonstrated during another abdominal operation at Massachusetts General. The anesthetic is a mixture of nitrous oxide, oxygen and ether. In the first picture the anesthetist straps the mask of the anesthetic apparatus over the face of the patient. In the second picture the anesthetic apparatus is turned on. In the third and fourth pictures, when the patient is



under light anesthesia, a tube is inserted into the pharynx to keep the breathing passage open. In the fifth and sixth, after the mask has been strapped on again, the anesthetist examines the eyes and the chest to estimate the depth of anesthesia.

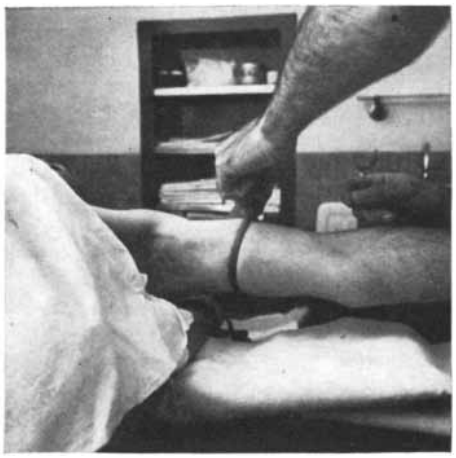
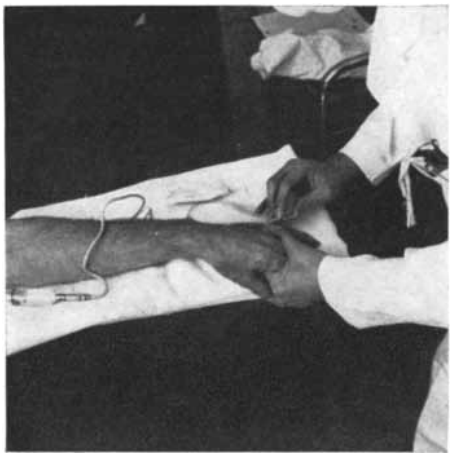
thetic power. From this Meyer developed the theory that the effectiveness of an anesthetic agent depends on its preferential solubility in fat, as compared with water, and that such a substance must exert its effect most markedly in nerve cells, in which lipoid substances predominate. The difficulty with this theory is that not all anesthetic agents have high solubility in fat. It may be that fat solubility explains the means of transport of anesthetic agents in the body rather than their action as anesthetics.

Another general theory, to which a number of workers have contributed, is that an anesthetic agent exerts its main action at the surface of a cell, either by interfering with the cell's uptake of oxygen or by reducing the permeability of the cell wall to substances responsible for normal stimulation of the cell.

But none of these theories actually explains the anesthetic process. As the famous Scottish pharmacologist Arthur R. Cushny remarked: "After the anesthetics have penetrated into the brain cell (or perhaps the environment of the brain cell), the effects depend on some other quality which is still unknown."

Anesthesia and the Patient

Notwithstanding the lack of basic understanding of the process, anesthetists have been able to refine their art and to advance with other developments in medicine. One important area is the matter of medication before anesthesia and surgery. The proper goal here is to take away the patient's anxiety and to present him on the morning of operation well rested from a good night's sleep, serene and comfortable and confident. For many years an attempt was made to achieve this state by the use of morphine, sometimes in very large doses. This practice goes back to 1850, when Lorenzo Bruno of Turin mentioned using the "injection of morphine an hour before surgery . . . to lessen psychic trauma." In the U. S. morphine was early advocated by W. W. Greene of the University of Maine medical school, who believed that it was helpful "in anticipating all pain, preventing shock, shortening the anesthetic influence and in preventing delirium and nausea." Actually recent studies in our laboratory have demonstrated that in most normal individuals morphine is comparatively ineffective in producing a state of euphoria, and that there is really little or no basis for its use before anesthesia unless the patient about to be operated on is in


INTRAVENOUS ANESTHESIA is used during an operation to remove a tumor inside the nose. In the first picture the arm of the patient is tied off to raise the veins in the hand. In the second picture a needle is inserted into a vein. In the third the anes-

pain, which few are immediately prior to surgery. It was found that the barbiturates, for example, are more effective for creating a serene state before surgery, and they do not produce the nausea and depression of respiration that sometimes accompany the administration of morphine.

Atropine (Belladonna) makes anesthesia and surgery safer by drying the mouth and throat and reducing secretions that may obstruct the air passages. It also minimizes unfavorable reflex action through the large vagus nerves. And so rational preanesthetic medication for individuals not in pain can now be based on the use of barbiturates in conjunction with atropine or scopolamine.

Over the centuries the various cavities of the body were invaded by the surgeon one by one, but the chest remained inviolate until comparatively recent years. It could not be entered until means were found to maintain the vital functions of the lungs and heart. In the 16th century Andreas Vesalius thrust a tube into the windpipe of a sow and kept it breathing while he demonstrated the anatomy of the animal's respiratory system. In 1667 Robert Hooke performed a similar experiment on a dog before the Royal Society of London. In the 19th century the famous Glasgow surgeon Sir William Macewen carried out operations in which he passed tubes into the windpipe through the mouth by his exquisite sense of touch. Over the years various sorts of complicated apparatus for forcing air into and out of the lungs during operations were tried and abandoned. The modern type of closed system, supplying oxygen to the lungs and removing carbon dioxide, was first suggested in 1915 by the pharmacologist Dennis Jackson, then at the Washington University School of Medicine in St. Louis. His suggestion led to the development of a practicable apparatus which administered oxygen under positive pressure to prevent collapse of the lungs. At the present time various mechanical lungs are in use for chest surgery.

The heart itself, the last of the cavities of the body to be breached by the surgeon, can now be operated upon. Various forms of "artificial hearts" have been constructed which operate outside the body to oxygenate the blood and remove carbon dioxide. This allows the surgeon to enter the empty heart and do with relative deliberation whatever task he finds necessary there.

Another approach to this problem has been to reduce the metabolic needs of the body, especially the oxygen uptake, by cooling. Profound cooling so slows the tissues' oxygen consumption that the blood in the veins still contains nearly as much oxygen as that in the arteries. But



SPINAL ANESTHESIA is used during the removal of the prostate gland. In the first picture the instruments are arrayed under sterile conditions. In the second the back of the patient is painted with iodine and then with alcohol. In the third the point at which the

thetic (sodium thiopental) is injected through a rubber tube. In the fourth oxygen is administered. In the fifth a muscle-relaxing drug (succinylcholine) is injected. In the sixth a topical anesthetic is sprayed on the trachea before inserting a tube for breathing.

cooling of the body presents its problems. If carried below certain limits, it increases the irritability of the heart and may lead to complications difficult to overcome.

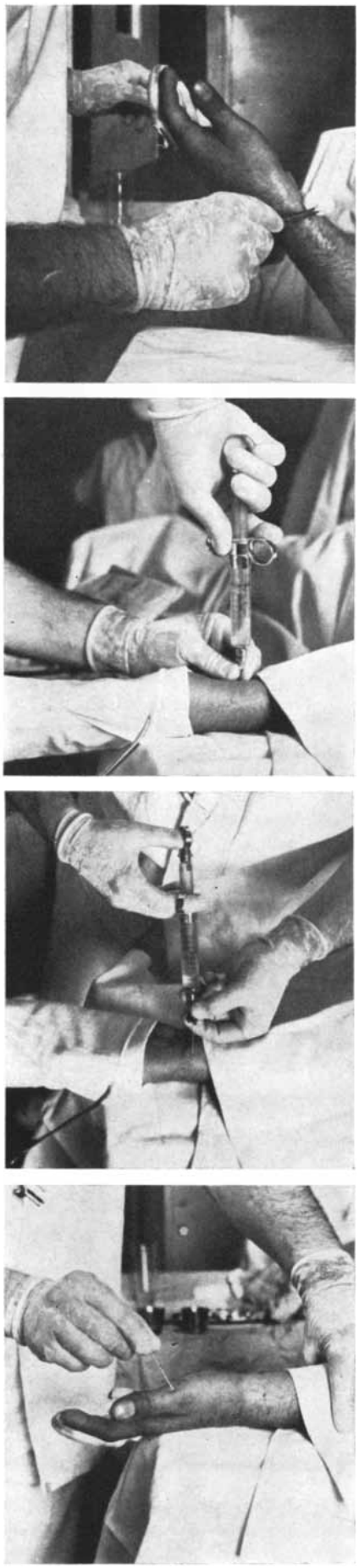
The Bible recounts how Elisha restored life to the son of the Shunammite woman by "mouth to mouth" inflation of the son's lungs. This ancient method of forcing air into the lungs of a victim of accident or disease may still be employed in desperate emergencies, but in well-run hospitals nowadays more effective and less unpleasant procedures are available for resuscitation. Anesthesia and resuscitation have been closely linked ever since the first anesthetic death, which occurred in England. A girl of 15 who was having an operation on her toe died under chloroform. The anesthetist, in an attempt at resuscitation, applied water to the patient's face and then succeeded in getting some brandy into her throat. Sir James Simpson, who had introduced chloroform into anesthesia two months prior to this, accused the anesthetist of asphyxiating the girl. This controversy was still in progress when a second fatality was reported, this one in Cincinnati. The hazards associated with anesthesia have not been entirely dispelled even to this day. The anesthetist, working with sick patients who are subjected to extraordinary strains on the heart and respiratory systems during surgery, must be alert to subtle changes for the worse in the patient's condition. He has become skillful in handling emergencies. During World War II an anesthetist was placed in charge of resuscitation in the Mediterranean theater, and he with his surgical colleagues evolved principles which have been applied to caring for the seriously wounded since that time.

Doubtless many discoveries will be made which will make anesthesia less unpleasant to the patient and allow greater freedom of work to the surgeon. But it remains true that the most important goal is increasing the safety of the anesthesia procedure. Progress is being made in this direction.

Anesthesia and the Mind

Sir Henry Dale, speaking in 1950 of the revolutionary advances in medicine over the past 50 years, remarked that medicine has not only drawn on the experimental sciences but has itself become "largely an experimental science." The indebtedness of medicine to advances in basic science is well recognized, but what is not so well known is the great debt basic science owes to disease. A great many advances in basic physiological science could not have been made without the exciting stimulus

anesthetic will be injected is located. In the fourth procaine is injected as a local anesthetic. In the fifth an "introducer" is inserted. In the last a hollow needle is inserted through the introducer and the anesthetic (tetracaine and glucose) is injected.



of the abnormalities produced by disease. In the same way, the phenomenon of anesthesia has been responsible for important biological discoveries. Among these is its illumination of the processes of the mind.

On the day after Christmas in the year 1799, Sir Humphry Davy, who was then plain Humphry and only 20 years old, made some remarkable observations under nitrous oxide:

"I felt a sense of tangible extension highly pleasurable in every limb; my visible impressions were dazzling and apparently magnified. I heard distinctly every sound in the room and was perfectly aware of my situation. I lost all connection with external things; trains of vivid visible images rapidly passed through my mind and even connected with words in such a manner as to produce perceptions perfectly novel. I existed in a world of newly connected and newly modified ideas. I theorified; I imagined that I made discoveries. When I was awakened from this semidelirious trance by Dr. Kinglake, who took the [gas] bag from my mouth, indignation and pride were the first feelings produced by the sight of the persons about me. My emotions were enthusiastic and sublime; and for a minute I walked about the room perfectly regardless of what was said to me. As I recovered my former state of mind, I felt an inclination to communicate the discoveries I had made during the experiment. I endeavored to recall the ideas, they were feeble and indistinct; one collection of terms, however, presented itself: and with the most intense belief and prophetic manner, I exclaimed to Dr. Kinglake, 'Nothing exists but thoughts!—the universe is composed of impressions, ideas, pleasures and pains!' "

Davy stumbled on a power of anesthetic agents which has only now begun to be explored in really systematic fashion. The anesthetic drugs can give us access to levels of consciousness which otherwise emerge only haphazardly in dreams or in trances. This was first clearly realized a century ago. In 1860 Benjamin Blood, aged 28, of Amsterdam, N. Y., apparently without knowledge of Davy's experience, made like findings on recovering from ether anesthesia. Blood spent some 14 years studying this phenomenon and published a book on his studies called *The Anaesthetic Revelation.* The psychologist William James said this book had been "one of the stepping-stones of my thinking."

It had been known for centuries that alcohol, opium, hashish and many other drugs were effective in releasing certain dreams and fantasies. The use of hypnosis for this purpose had also been known for a long time. But Blood appears to have been the first to make a deliberate study of the power of modern anesthetic agents to act on the mind. He tried to develop anesthetic tools to get at memories hidden in the subconscious. This was 70 years before they became effective instruments and 80 years before they were extensively used for narcoanalysis in World War II by Roy R. Grinker and others.

Experiments in Psychiatry

A lively period of human experimentation followed James's interest in the field. He was the leader in such studies in the U. S., as was Sir William Ramsay in England.

In 1929 the psychiatrist W. F. Lorenz pointed out the great significance of this instrument for psychiatry. He said: "An individual develops a psychosis following normal mental life; this psychosis is at a much lower level of mental activity than the normal. If at this point one precipitates unconsciousness by the use of an anesthetic agent, he can pierce through the stupor and reveal the mechanism. It can be observed upon going into this unconsciousness, as well as upon the return journey from it, that the patient's mental condition approaches the normal; but after his normal mental life has been attained, the various factors responsible for his original psychosis weigh on him, and after a period of some hours he retires to the more primitive level; apparently this seems to him a desirable refuge from normal consciousness."

At about the same time another psychiatrist, Erich Lindemann, began to study the effects of anesthetic agents in doses that did not produce unconsciousness. He found that they induced in normal individuals "a feeling of security

CONDUCTION ANESTHESIA is used during an operation on the hand. In the first picture the wrist is painted with iodine and alcohol. Then procaine is injected into the skin to deaden the pain of deeper injections. In the second picture procaine is injected into the median nerve of the wrist. In the third procaine is injected into the radial nerve of the wrist. Then procaine is injected into the ulnar nerve; by blocking these three nerves the sensory nerves of the hand are deadened. In the last picture the anesthetist pricks the hand with a needle to ascertain whether the nerve block is effective.

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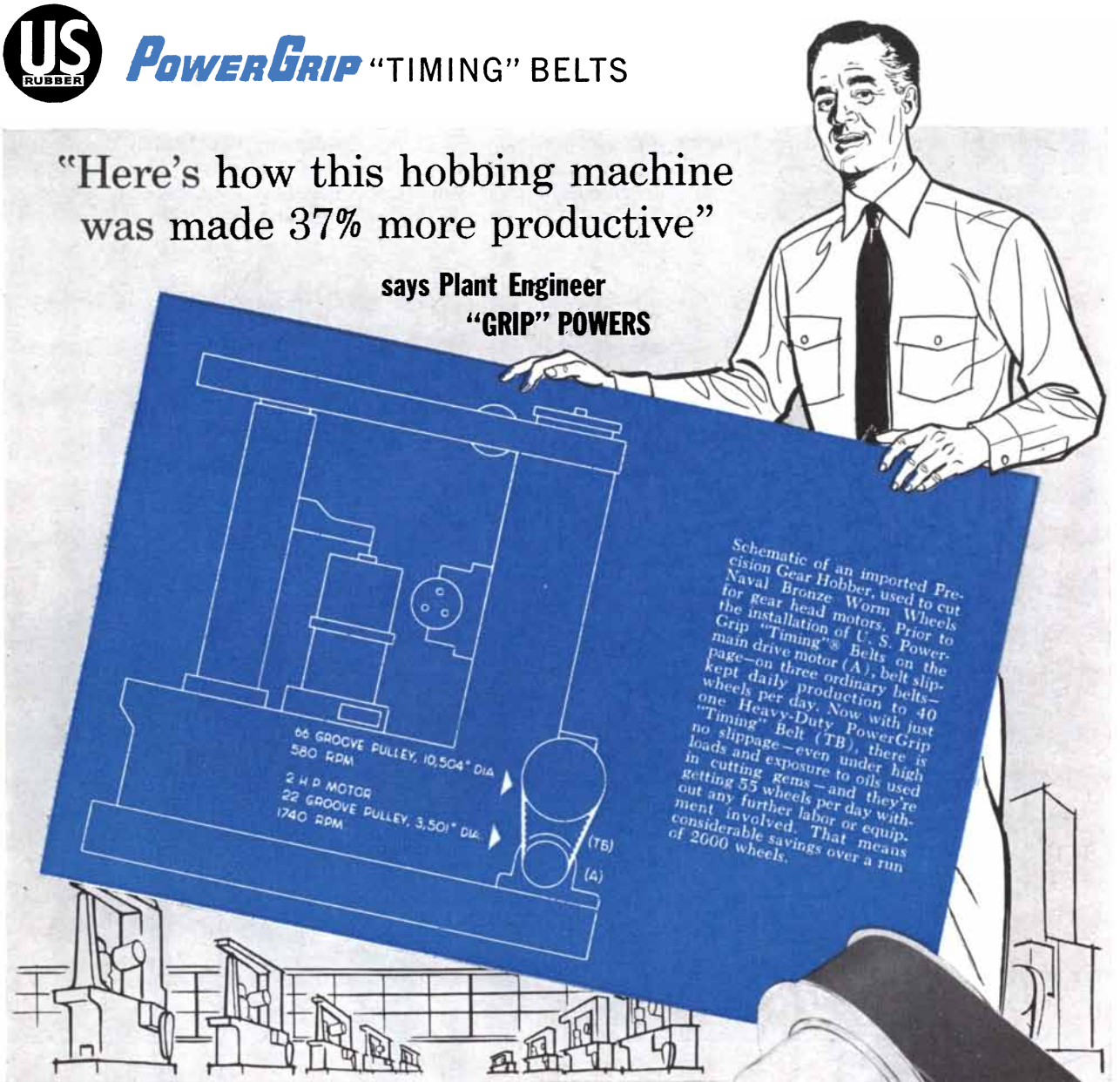

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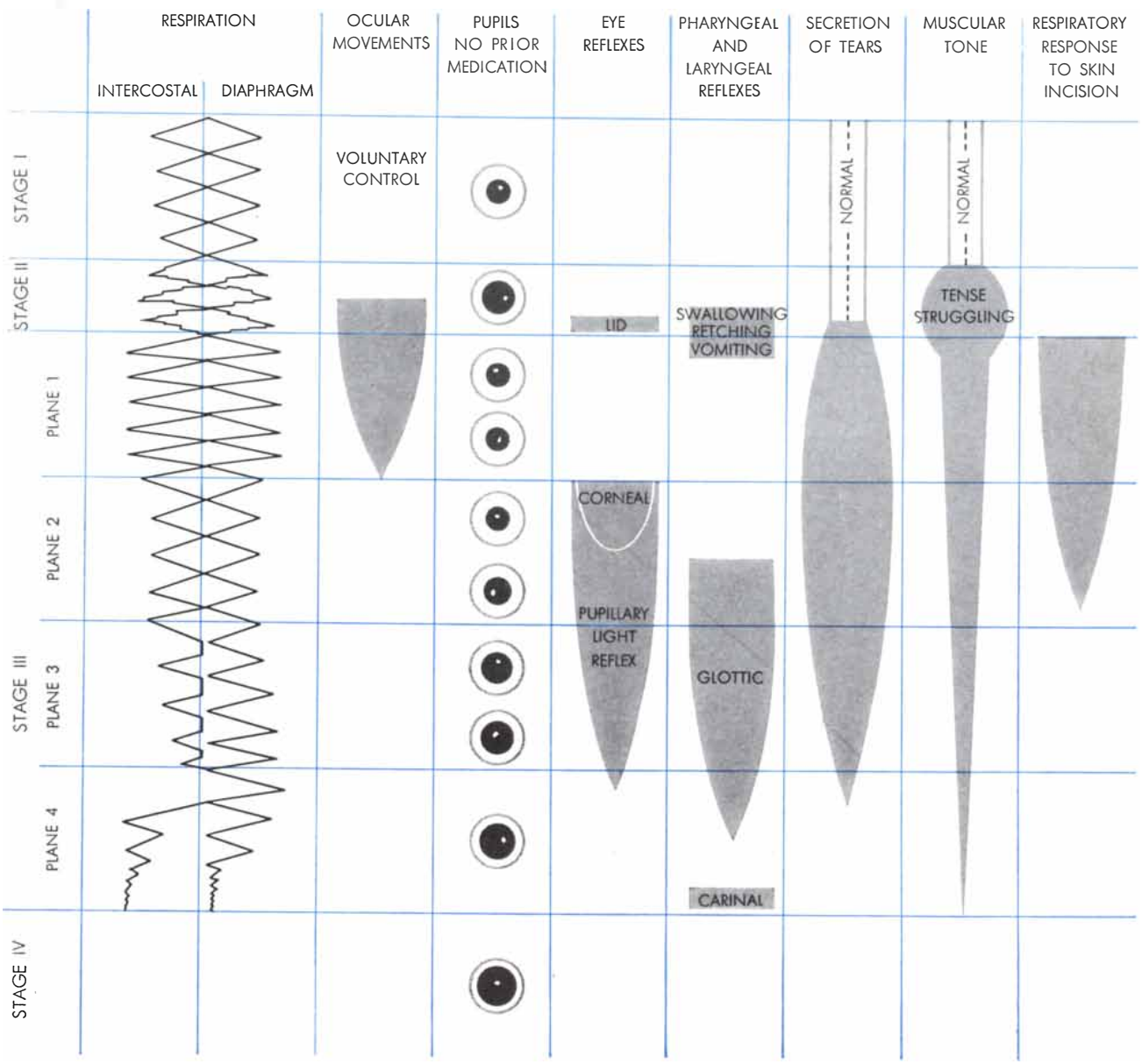
and well-being, a desire to communicate and to speak about problems of personal matters usually not spoken of to strangers. There was also the feeling of being unable to guard against saying things which one does not want to and an inability to refuse to answer questions even if they refer to very intimate matters." Among mentally ill individuals, patients who had been mute for months spoke. Depressed patients gave subjective reasons for their feelings of guilt. "Anxiety and apprehension gave place to mild indifference and a tendency to joke."

In our laboratory and others it has been established that the pain-relieving effect of drugs is generally due to their action on the mind. They seem to act by suppressing anxiety. It is evident that the surface has hardly been scratched in this area. The anesthetic drugs afford a great opportunity not only to explore the anesthetic process itself but also to get at mental processes and attitudes. Doubtless the truths to be discovered will in one sense be remote from human suffering, but broadly applied they should bring to mankind the power to dispel—by chemistry—not only pain of body but also distress of mind.



STAGES OF ANESTHESIA are outlined. In Stage I, which extends to the loss of consciousness, the patient progressively loses the sensation of pain. In Stage II, which extends from the loss of consciousness to the reestablishment of regular breathing, the eyes still move; the pupils are often dilated but still react to light; the eyelid reflex still occurs; the patient may swallow, retch, vomit or struggle tensely. In Stage III, during which surgery may be performed, the movements of the eyes gradually stop; the pupils dilate; the eyelid reflex and then the corneal and pupillary reflexes are extinguished; swallowing, retching and vomiting stop; the reflexes of the glottis and carina of the larynx are gradually abolished; the secretion of tears increases and then tapers off; the muscles relax; the response of breathing to cuts in the skin gradually fades. In Stage IV the pupils are completely dilated and breathing stops. Intercostal respiration refers to the movements of the ribs; diaphragm respiration, to movements of the diaphragm.

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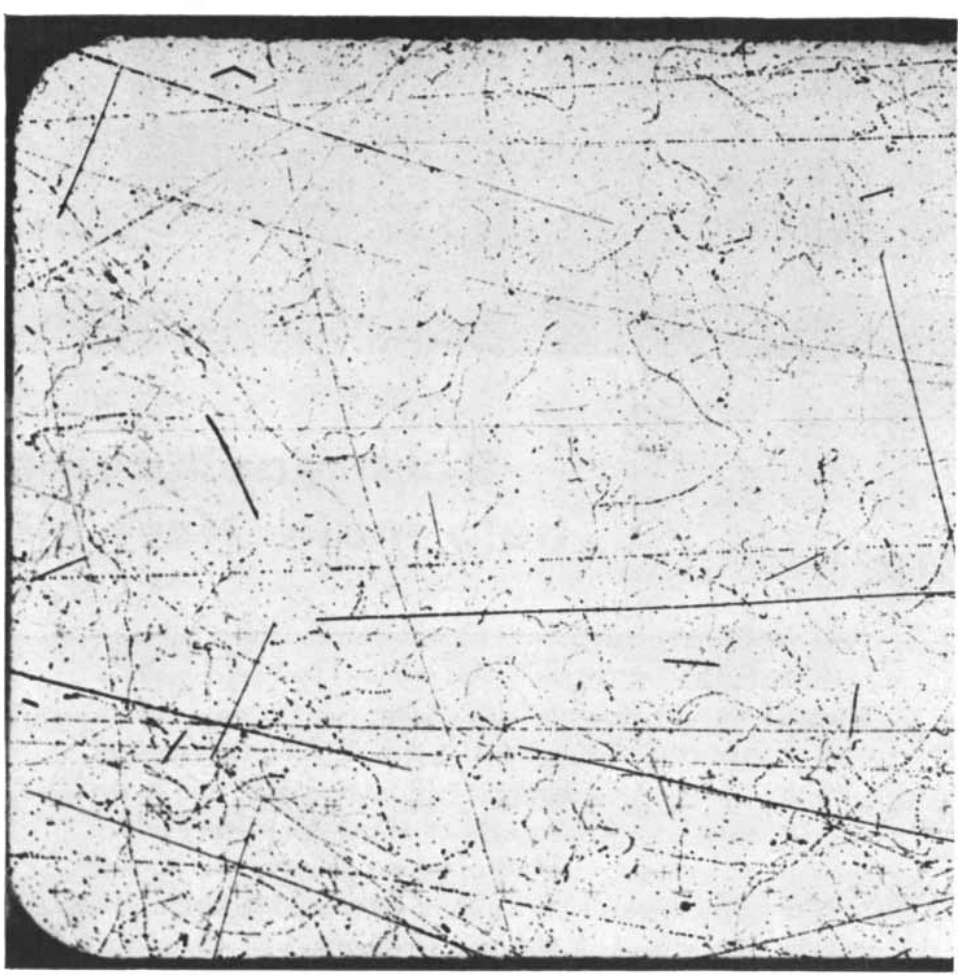
PIONS

These particles, also known as pi mesons, are an important atomic structural material. They appear to be the cement which holds protons and neutrons together in the nucleus

by Robert E. Marshak

The cement that holds the universe together is the force of gravity. The glue holding the atom together is electromagnetic attraction. But the glue that holds the nucleus of the atom together is a mystery that defies all our experience and knowledge of the physical world. It is a force so unlike any we know that we can hardly find words to describe it. We do have a clue, however, to which we can give a name. It is the pi meson, or pion. In some way, not yet understood, pions are certainly involved in the nuclear binding force. Now that these particles can be generated at will by high-energy bombardment of matter, their properties are being industriously explored. What have we learned about them?

Before entering this strange realm, let us retrace very quickly the steps by which the physicists got there, along the now familiar path of electromagnetic forces. Considering the operation of these forces in the macroscopic world—as electricity, magnetism, light and so on—Michael Faraday and James Clerk Maxwell developed the concept of fields of force, pervading all space. When physicists began to examine the microscopic world of the atom, they assumed that the same field concept applied there as well: that the force between one electron and another, or between an electron and the positive nucleus, obeyed the laws of the classical electromagnetic field. But eventually it became clear that much of the behavior of atoms and electrons could be explained only on the assumption that the field in the atom is quantized. In other words, in the light of the quantum theory physicists concluded that electromagnetic forces are exerted by an exchange of quanta or packets of energy between charged bodies. These quanta are photons—massless units of energy. The field around an electron, say, consists of photons which the electron is continually emitting and absorbing. When one electron repels another, photons are interchanged; the photons are emitted by one particle and absorbed by the other. Thus the quantum theory, which is often said to do away with physical models, actually gives a more concrete picture of electromagnetic interaction than the classical theory did. Two charged bodies influence each other not through an intangible field but by tossing little pellets back and forth.



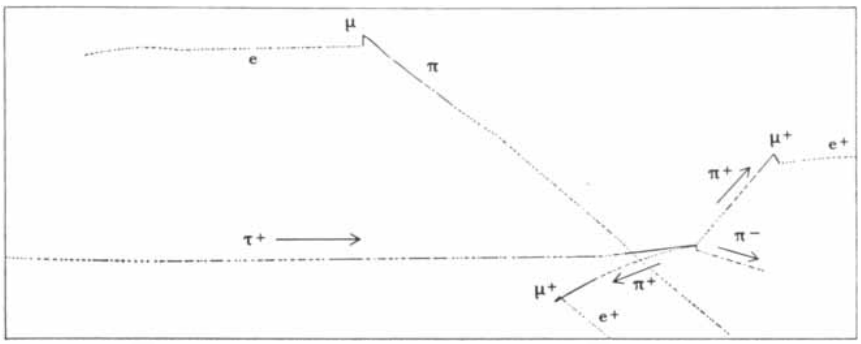
PION TRACKS are made visible as strings of tiny bubbles in a chamber of liquid propane. This photograph was made while the chamber was exposed to a beam of heavy mesons from the Brookhaven Cosmotron. As indicated in the drawing, one series of tracks shows

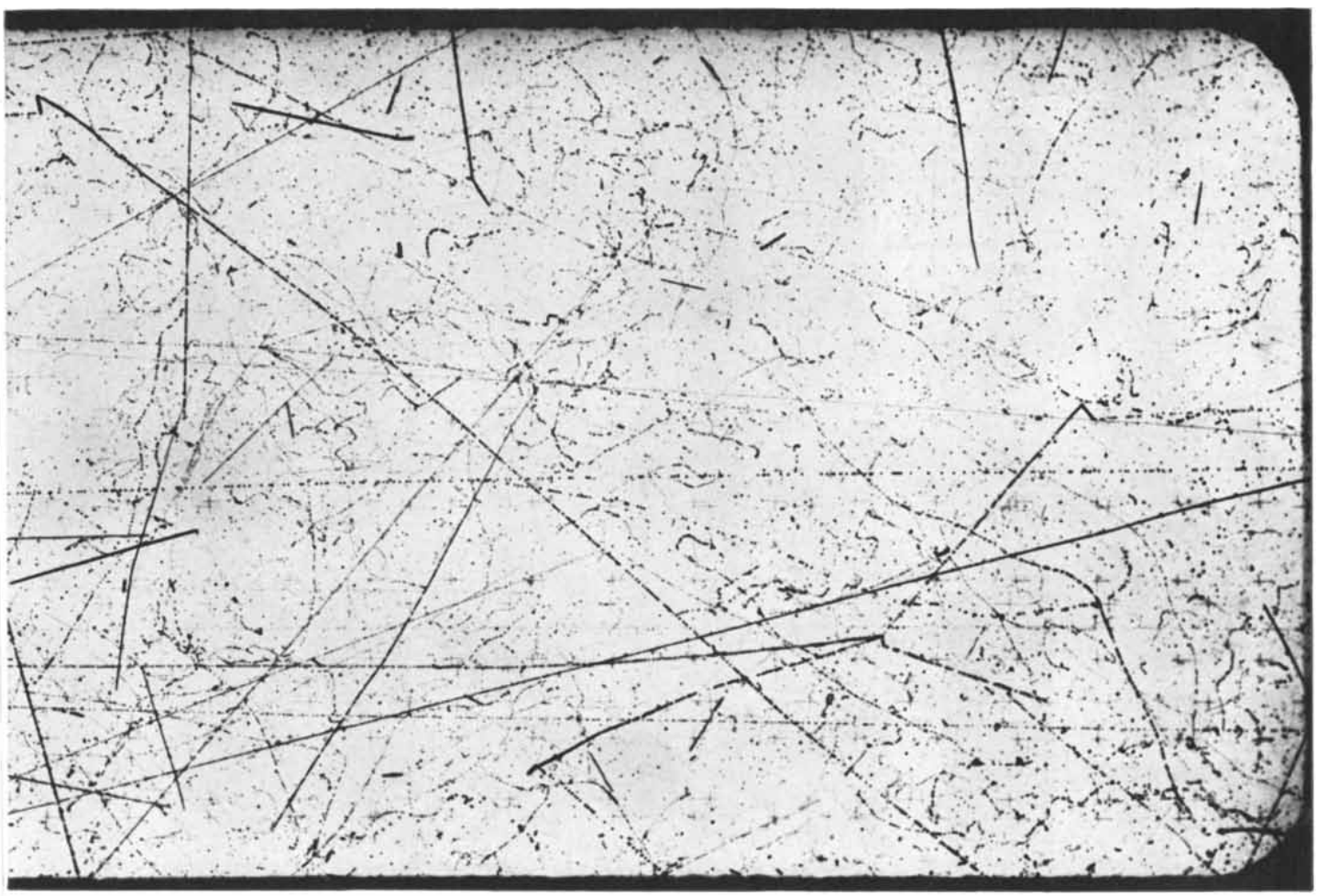
This conception was so successful in accounting for the forces on the atomic scale that the Japanese physicist Hideki Yukawa adopted it to attack the problem of the mysterious forces in the nucleus. He assumed that the force field in the nucleus, like that in the outer atom, is quantized. The attraction holding together protons and neutrons (nucleons) would thus be accounted for by a continual exchange of quanta of energy. But whereas the quantum of electromagnetic energy (the photon) is massless, Yukawa found that to explain the force of attraction in the nucleus, particularly its very short range, it had to be supposed that the nuclear quantum had an appreciable mass, which he calculated to be between 200 and 300 times that of an electron. To account for the great strength of the nuclear force, he assumed that the quanta were exchanged at a very rapid rate.

Yukawa's brilliant intuition was rewarded 12 years later (in 1947) by the discovery of the quanta, or particles, that he had proposed [see "The Multiplicity of Particles," by Robert E. Marshak; SCIENTIFIC AMERICAN, January, 1952]. The pi meson, or pion, has just the properties he predicted for it. Its mass is about 270 times that of the electron.

The notion that pions are exchanged between nucleons immediately raises some basic questions. To begin with, if a nucleon continually emits pions, what happens to the conservation of mass? The emission of a pion, with its appreciable mass, should reduce the mass of the nucleon, and yet in all our experiments the mass of a nucleon remains constant. The answer is that the emission and reabsorption of pions takes place so rapidly that we cannot detect it. Since any phenomenon that is undetectable cannot be regarded as "real," in the physical sense, we must speak of "virtual" emission and exchange of pions.

To understand a little more clearly what this means, and to see approximately how brief the appearance of a pion must be, we must recall the famous



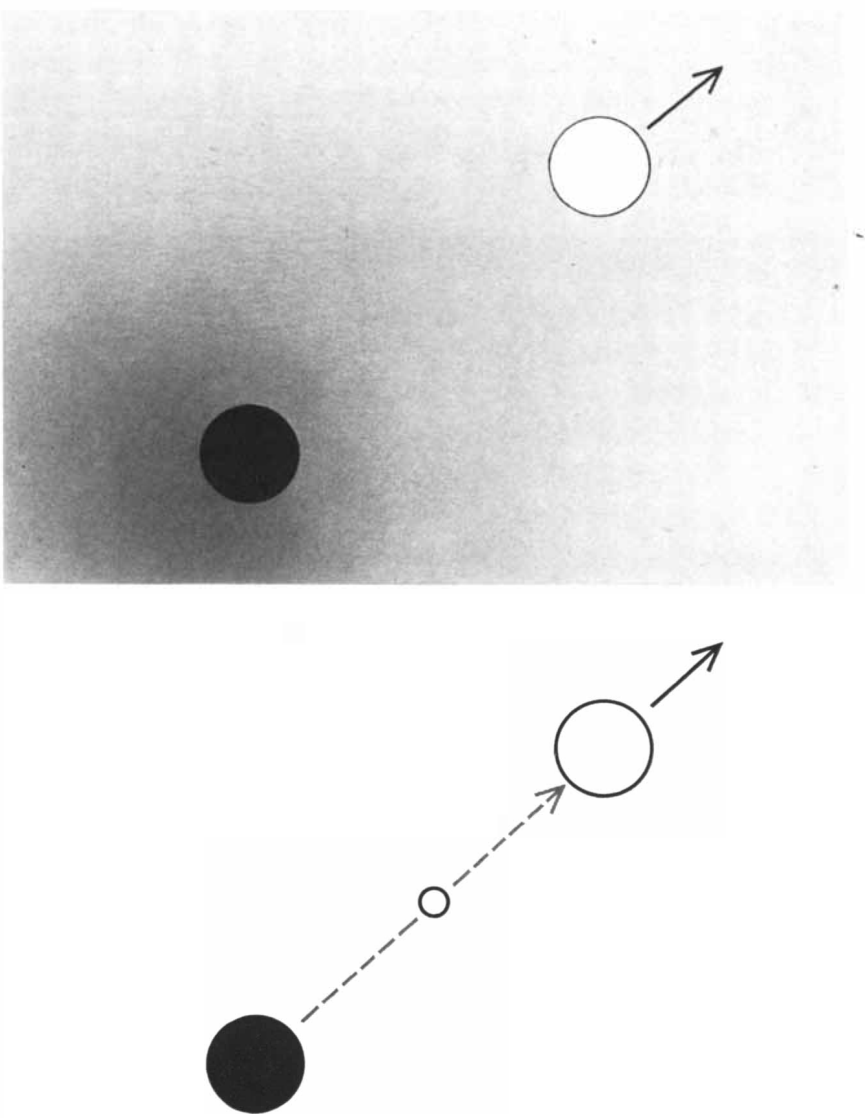


a tau meson (τ^+) entering from the left and decaying into two positive pions (π^+) and a negative pion (π^-). The positive pion decays into a mu meson (μ^+), which decays into an electron (e^+). Another pion enters the chamber from the lower right and decays into a mu meson at upper left. The experiment was performed by D. A. Glaser and his colleagues of the University of Michigan.

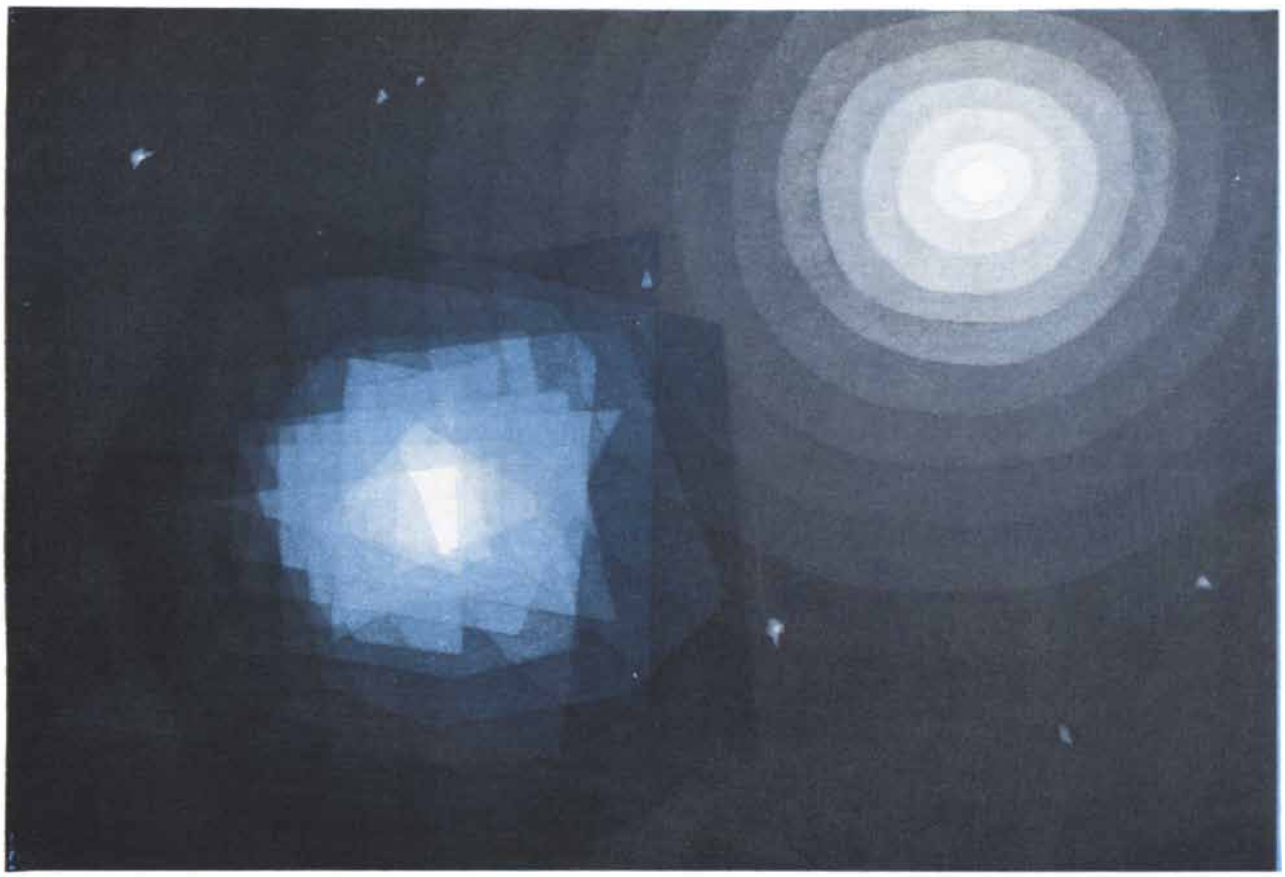
uncertainty principle. This principle sets a definite limit to our knowledge of very small-scale phenomena. It says, for example, that if we measure an electron's *position* exactly, we thereby destroy our ability to make any measurement whatever of its *momentum* and *vice versa*. If we want figures for position and momentum at the same time, we must settle for inexact measurements of both. The uncertainty principle of quantum theory tells us the maximum accuracy we can hope to attain: the uncertainty in position multiplied by the uncertainty in momentum must be at least as great as the value of Planck's constant, h.

Another pair of quantities which fall under the principle are energy and time. Any experiment for measuring the energy of a system requires a certain time to perform. Any such experiment also tends to alter the energy. Now it turns out that the shorter the time of measurement, the greater the effect on the energy. In other words, the more certain we are about the time at which the energy is determined, the less certain we can be about its amount. Again, the product of the two uncertainties can never be less than h.

The energy equivalent of the mass of a pion is 135 million electron volts. The calculation based on h tells us that the margin of uncertainty for the energy content of a nucleon will be at least 135 Mev when the time of measurement is 5×10^{-24} of a second. Hence if a pion is emitted and reabsorbed within this time,



ELECTROMAGNETIC FIELD around a charged particle such as an electron (*black circle*) is shown schematically according to classical theory (*above*) and quantum theory (*below*). The gray shading in the upper diagram represents the continuous classical field through which the particle was thought to exert its force on a second electron (*white circle*). The circle in lower diagram shows the field quantum or photon now thought to transfer the force.



"EARTH" one of a series of paintings of the planets by Simpson-Middleman, painters who have been finding their subject matter in science. To quote them: "Earth is distinguished among the planets by its oceans of water and its single moon. From these as a starting point, Earth in this painting has been imagined as a configuration of intersecting planes—layer on layer of blue—until it becomes a transparent crystal, glowing in space." Painting courtesy John Heller Gallery, Inc.

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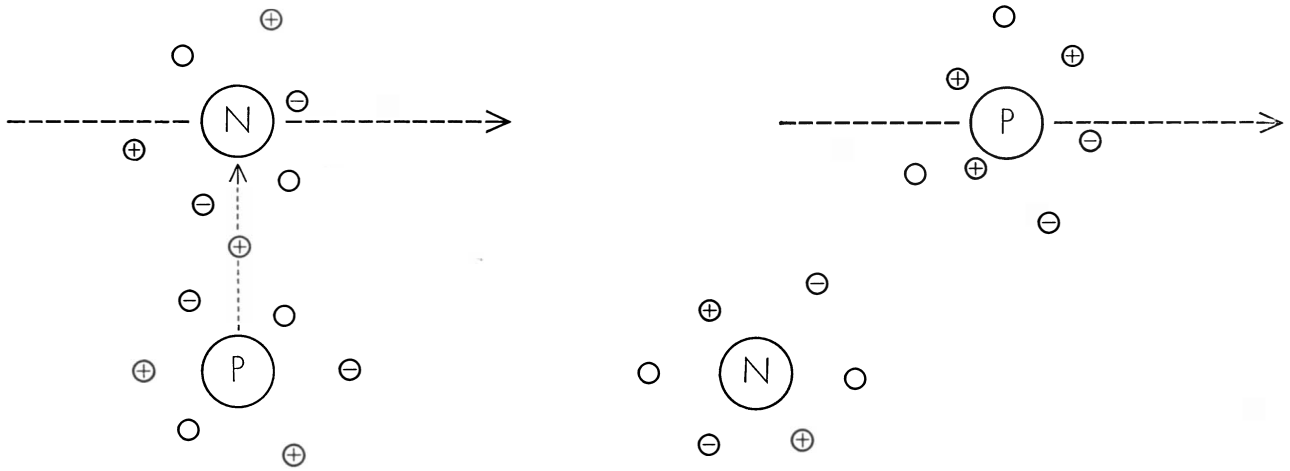


NUCLEAR FORCE FIELD consists of clouds of virtual pions (*small open circles*) which surround each nucleon. At left a moving neutron (*above*) passes close to a stationary proton (*below*) and picks up a positive pion. The moving particle is now a proton and the stationary one a neutron. By transferring neutral pions, nucleons are also able to interact without this exchange of charge.

it will be undetectable, *i.e.*, "virtual." In that time a pion, moving at practically the speed of light, could travel to about 1.4×10^{-13} of a centimeter from the center of a nucleon. This distance is just about the observed range of nuclear forces! The agreement seems a striking support for the theory that pions act as agents of these forces.

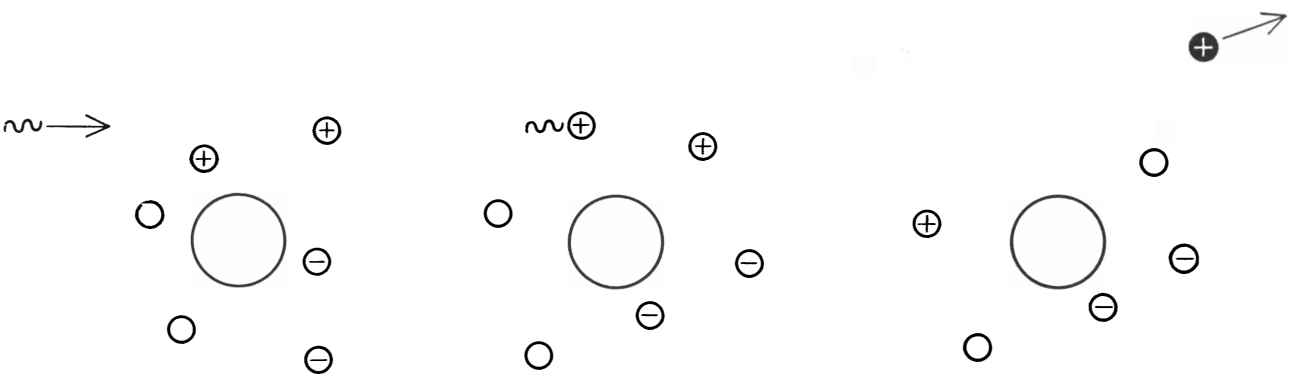
This conception of the pion accounts for another phenomenon observed in experiments. When hydrogen is bombarded by a beam of fast neutrons, many protons (hydrogen nuclei) shoot out in the forward direction at about the speed of the impinging neutrons, while a corresponding number of neutrons is found almost stationary within the target. It is altogether improbable that so many neutrons would hit protons dead center and transfer all their momentum to the protons. A much more plausible interpretation is that the emerging protons represent neutrons which were converted into protons during passage through the target. Such a conversion could occur if a neutron seized a positively charged pion: the neutron would thus become a proton, and the proton that lost the positive charge would become a neutron. Thus a neutron dashing through a proton target grabs a pion from a proton and leaves a neutron behind.

The attraction between nucleons in the nucleus of an atom (other than ordinary hydrogen, which has only one nucleon) may be exerted through such exchanges of pions. There should be positive, negative and neutral pions, to bind together protons with protons, protons with neutrons and neutrons with neutrons.

How is it that the ghostly "virtual" pions are in fact detectable as real particles? If we consider pions as packets of energy, it is not difficult to describe the circumstances under which we should be able to detect them. Suppose the energy equivalent of a pion is supplied to a nucleon, replacing the pion energy. A pion may then be released and detected before it is captured by another nucleon. Pions were first identified in the debris from cosmic ray collisions and then manufactured in high-energy accelerators by bombardment of nuclei.

All three forms of the pions have been found—positive, negative and neutral. The neutral pion has 264 times the mass of the electron. The charged pion, which gains a little mass from its interaction with the electromagnetic field, has a mass of 273. Pions are readily absorbed by nuclei. They are unstable. The charged pion decays into a lighter particle (called the mu meson) and a neutrino with a half-life of a few hundred-millionths of a second. The neutral pion decays much faster (half-life about 10^{-15} of a second) into two gamma rays.

Pions, produced in large quantities by bombarding targets such as carbon, are now formed into beams for probing nuclei. The way in which a beam of real pions is deflected or scattered by the target nuclei shows how the pions interact with the nuclear force field. The sim-



VIRTUAL PION MATERIALIZES if the system is provided with an amount of energy at least equivalent to the pion's rest mass. In these diagrams a high-energy gamma ray (*wavy line*) enters a meson cloud and strikes a virtual positive pion (*open circle*). The energy of the gamma ray is absorbed and the virtual pion turns into a real pion (*solid circle*). It can now escape from the nucleon.

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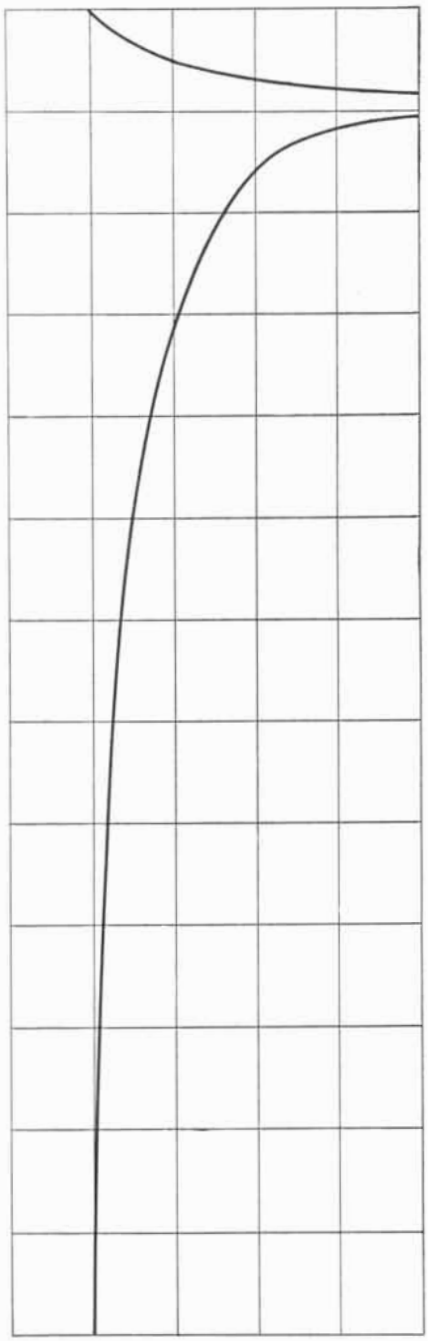
plest and most informative experiments are those on individual nucleons. Protons can be studied directly by bombarding a target of hydrogen. Neutrons are examined by bombarding heavy hydrogen, or deuterium, whose nucleus contains one proton and one neutron. When the proton's effect is subtracted out, the remaining pattern gives the neutron's interaction with the pion.



FIELD STRENGTHS due to electromagnetic and nuclear forces are indicated by these curves. Upper curve represents the electromagnetic field around a proton (which repels another proton). Lower curve is proton's nuclear field (which attracts another proton). Horizontal axis gives distance from proton in units of 1.4×10^{-13} centimeters. Vertical scale is arbitrary.

These experiments support a picture which, if rather obscure, at least fits together well as far as it goes. For instance, investigators of the nuclear forces have been interested in the fact that the force of attraction between nucleons seems to be exactly the same whether they are charged or uncharged (*i.e.*, protons or neutrons). This of course is entirely foreign to our experience in the world outside the atomic nucleus. Considering the hypothetical roles of charged and neutral pions in these several attractions, the investigators have calculated that nucleons must emit and absorb charged pions twice as frequently as neutral pions. To put it another way, the nucleon interacts twice as strongly with a charged pion field as with a neutral pion field. Scattering experiments with real pions have confirmed this assumption.

The nuclear force of attraction is very strong—so strong that, if the pion is its agent, a nucleon must emit virtual pions at a high rate, and must be surrounded at close quarters by a veritable cloud of them. This suggests that if enough energy could be supplied, it should be possible to materialize more than one real pion from a nucleon. This has indeed turned out to be true. The three-Bev Cosmotron at the Brookhaven National Laboratory produces an average of two pions per collision. The six-Bev Bevatron at Berkeley gives an average of more than three. In primary cosmic radiations, where there are energies as high as 10,000 Bev, as many as 20 real pions have been observed to emerge from a single collision.

Thus the proton and the neutron, once supposed to be the ultimate building blocks of matter, become less monolithic than they seemed. Each consists of a core surrounded by a fluctuating cloud of pions—an arrangement somewhat reminiscent of the atom with its nucleus and planetary electrons. Pion scattering experiments now indicate that nucleons may even have excited states, as the atom does. The excitation, produced when a pion hits a nucleon violently, takes the form of a temporary increase in the nucleon's charge. Presumably this state involves some rearrangement of the meson cloud, but the details are not yet known.

The inner region near the core of the nucleon, where the meson cloud is most dense, remains an area of mystery. We can probe it with very fast particles: the faster the projectiles, the deeper they penetrate. But our knowledge and theo-

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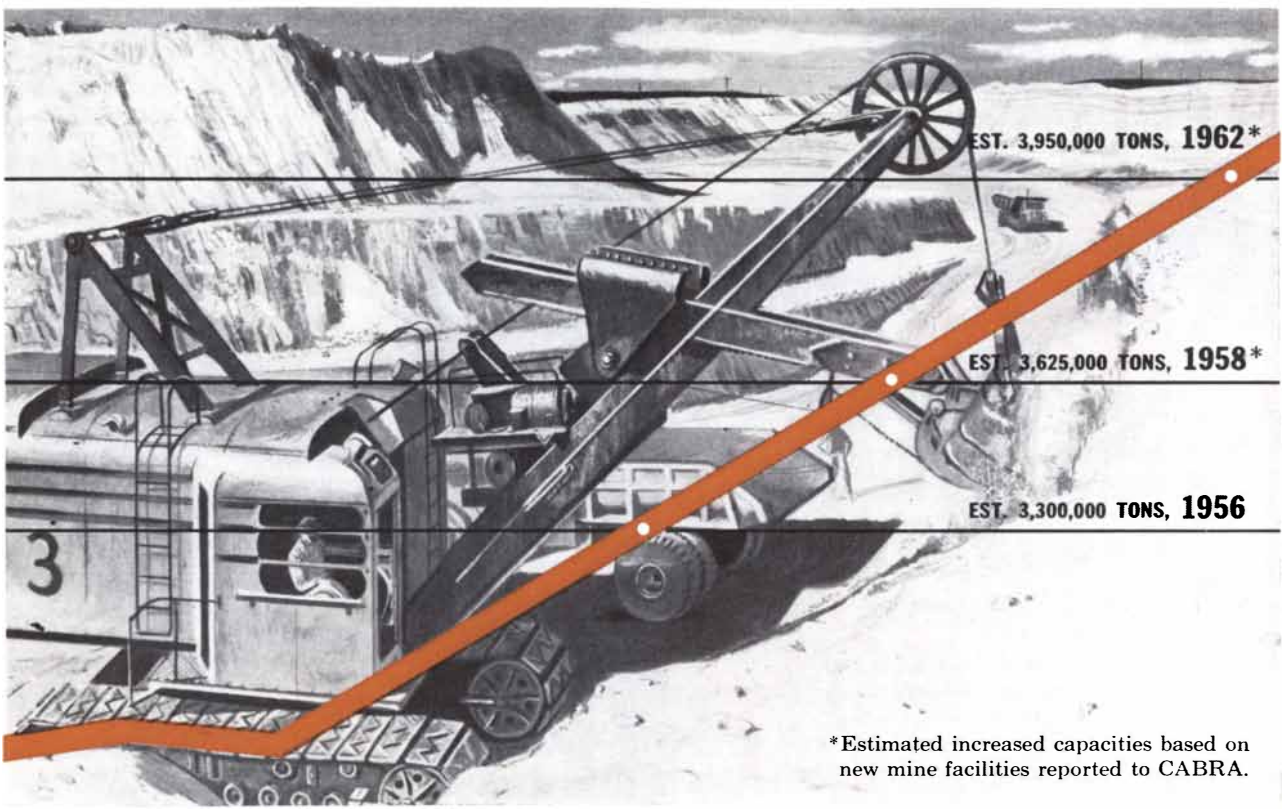

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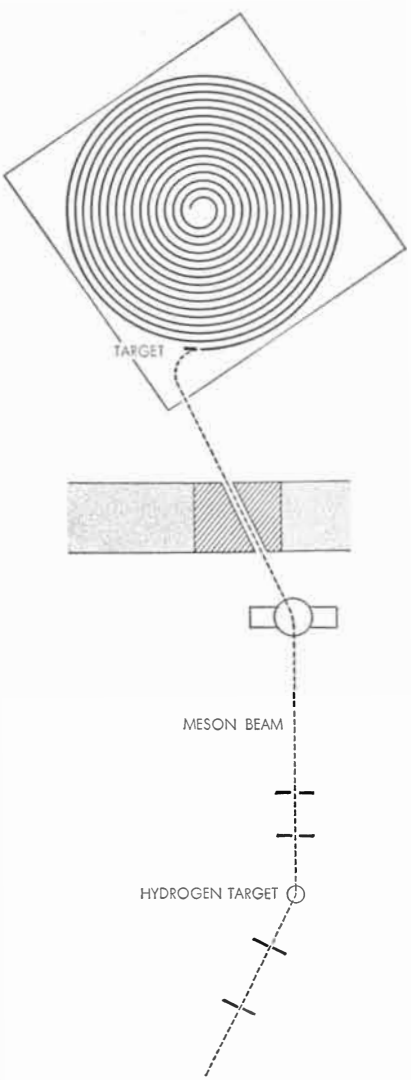
ries about the meson field are still too vague to yield equations which might account for the scattering patterns observed or predict how many pions will be produced at a given bombarding energy.

The chief difficulty is the fact that we must deal with a swarm of pions. Our mathematical techniques cannot effectively handle more than one pion at a time. Beyond this things become much too complicated. The problem appears to be a basic one, and it seems that only some radically new idea will enable us to solve it. And so the pion, while providing a tantalizing glimpse into the nuclear forces, serves also to deepen our ignorance.



PION SCATTERING experiment is diagrammed above. Meson beam from a cyclotron (*top*) is steered by a magnet to strike a sample of hydrogen. Counters in front and back of target record the numbers of particles that are deflected at various angles.

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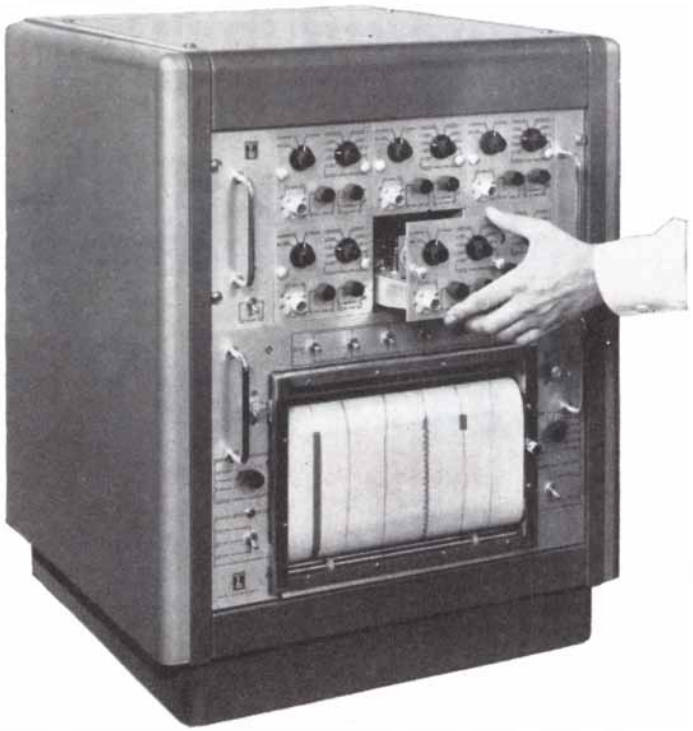

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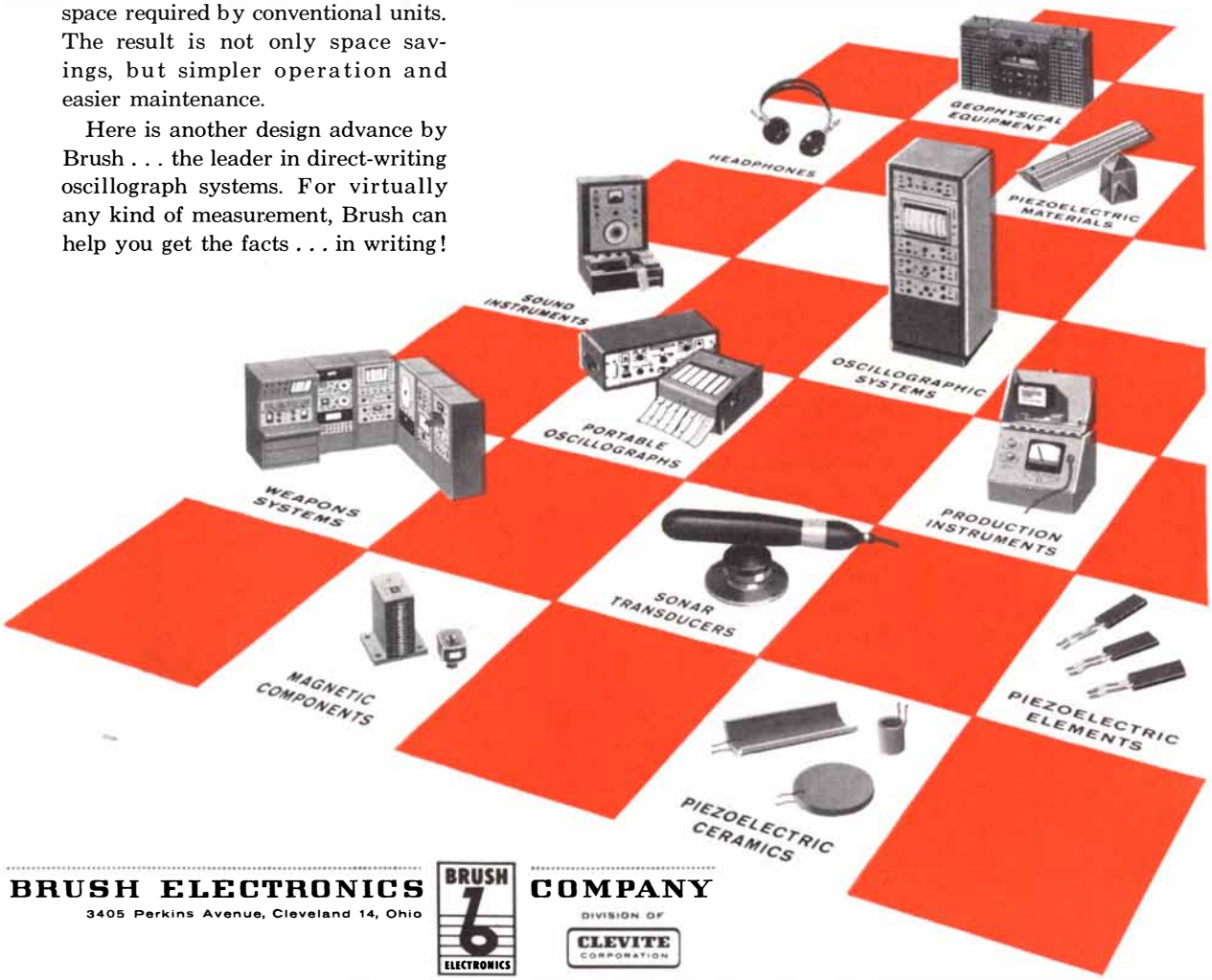

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The Red Blood Cell

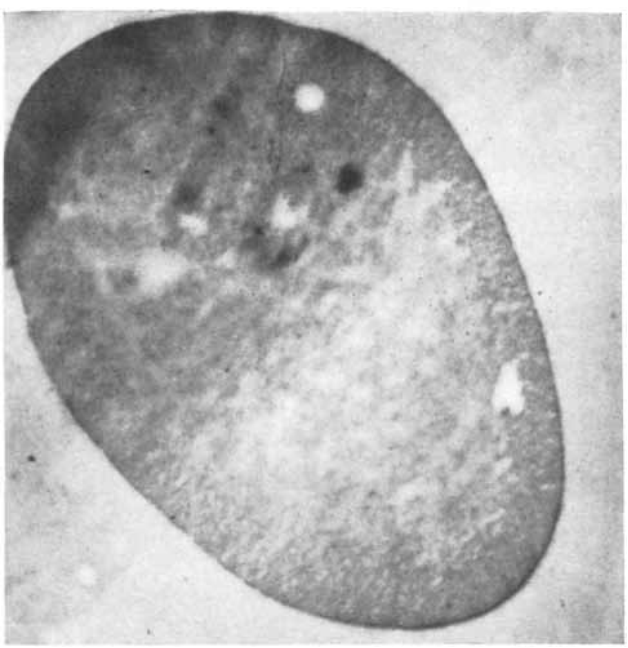
The red cell of vertebrates is a remarkably effective device for the transport of oxygen to other cells. Many workers seek to elucidate the intricate molecular structure of its surface

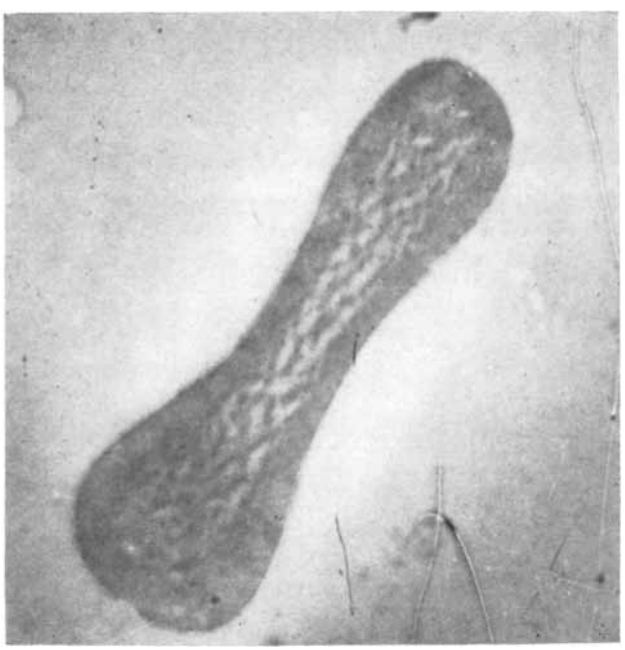
by Eric Ponder

The red blood cell is one of the principal advantages that enable vertebrates to enjoy the distinction of being classed as higher animals than invertebrates. It is an admirably convenient transport for hemoglobin, the red pigment which feeds oxygen to the tissues of the body. If hemoglobin were merely dissolved in the blood fluid, as it is in invertebrates, the blood would be so thick that the heart would have to do a great deal more work to pump it. Furthermore, the red cells, by making the flow in the blood vessels turbulent (like a stream running over stones), speed the transfer of oxygen from the vessels to the tissues. The red cells of mammals are a particularly excellent piece of biological engineering. They are biconcave in shape (like a doughnut with a thin section in the middle instead of a hole), and this facilitates quick entry of oxygen and other supplies to all parts of the cell. If the red cells were spherical, we would need about nine times as many of them to distribute oxygen in the body with the same speed.

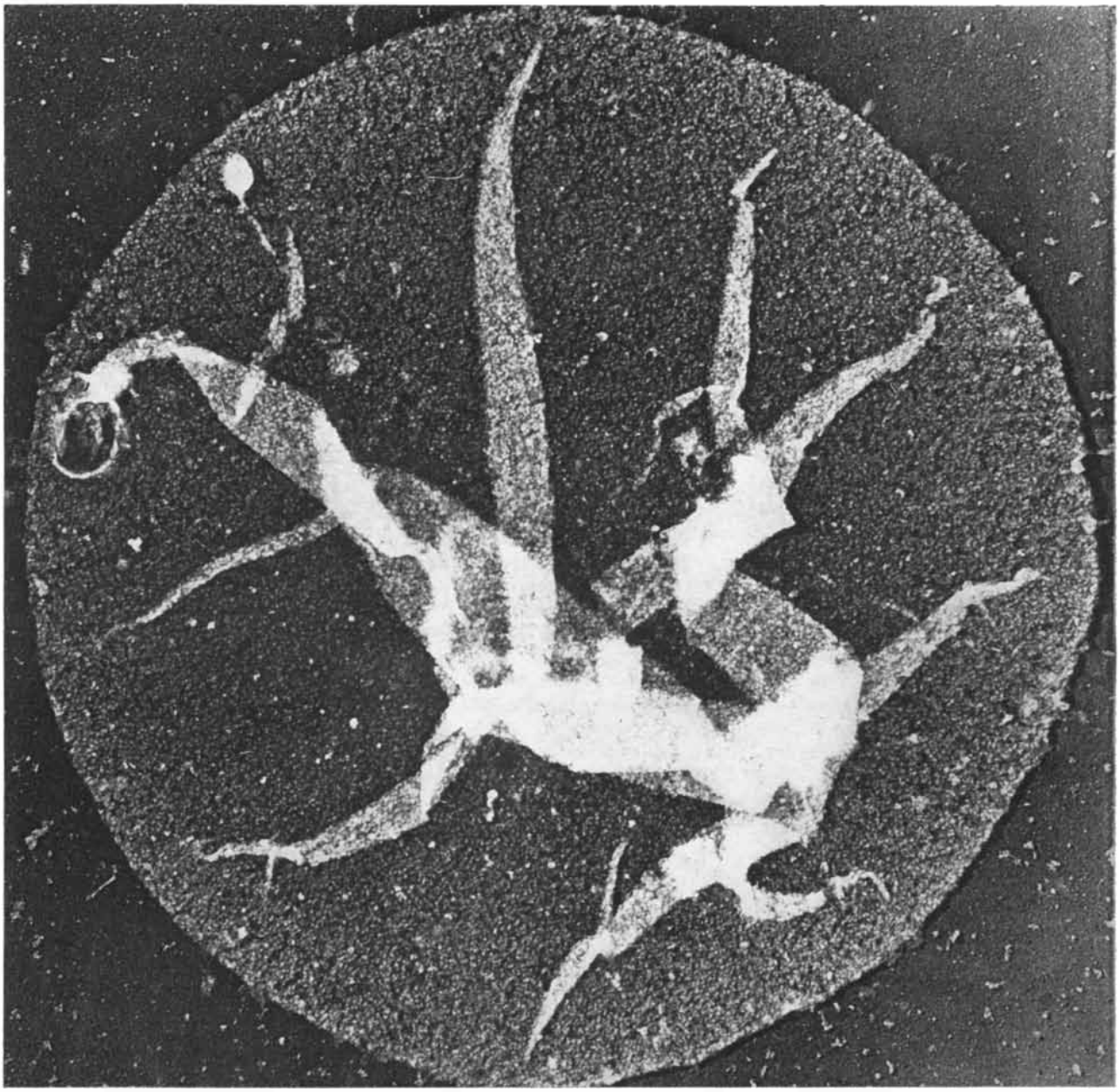
Until about 20 years ago the red cells of mammals were thought to be no more than inert carriers. The mammalian red cell has no nucleus—in which it is unlike the red cells of birds, fishes, reptiles and amphibians. It was believed to have no metabolism or life of its own, and was regarded as merely a very thin-skinned bag filled with hemoglobin. Some biologists questioned whether it was entitled to be called a cell at all. We have learned since that the red blood cell is indeed a living cell, with an active metabolism and an intricate structure. The main theme of this article is the fascinating investigation of its structure.

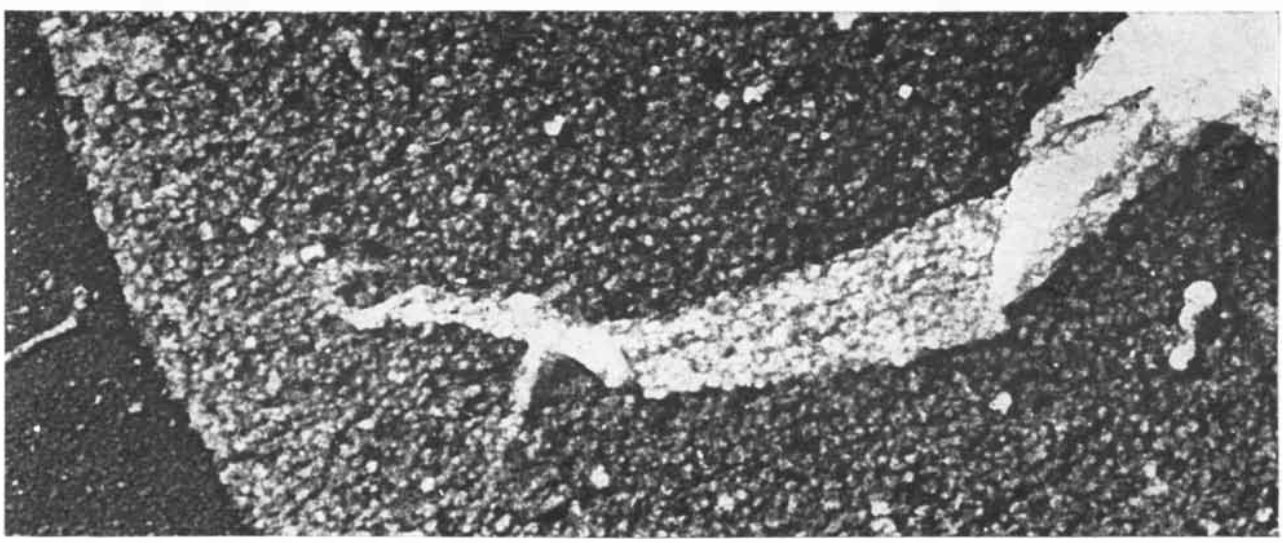
When the red cell is broken down and emptied of its hemoglobin, there remains a baglike structure known as the red-cell "ghost." Around 1936 the writer, working at the Carnegie Institution in Cold Spring Harbor, and Francis O. Schmitt and Richard S. Bear, then at Washington University in St. Louis, became interested in the fact that the ghost was birefringent. (Birefring-





HUMAN RED CELL sliced almost through its equator is shown in the electron micrograph at the left. In the micrograph at the right the same kind of cell is sliced at right angles to its equator, showing the characteristic biconcave cross section of the human red cell.





ence, or double refraction, is investigated by polarized light, which makes the object shine more or less brightly.) Was the birefringence due to the structure of the molecules themselves or to the pattern of arrangement of the molecules in the ghost? We concluded that both kinds of birefringence were present. The interesting point was that this meant the molecules in the surface layers of the red-cell ghost must be arranged in a patterned structure.

The ghost is composed of lipids (fatty substances) and proteins (other than hemoglobin). We found that the lipid molecules had an intrinsic birefringence and the proteins a birefringence of arrangement, at right angles to and almost canceling each other, so that the net birefringence was small. From these observations we deduced that in the structure of the ghost membrane the lipid molecules were stacked radially, while the protein molecules were wrapped around the ghost like string wrapped around a ball. We estimated that the membrane, far from being the extremely thin and simple skin it had been supposed, might be as much as several hundred Angstroms thick (there are 254 million Angstrom units to an inch).

As the first step toward determining the structure of the red-cell membrane (or what we call the "surface ultrastructure") we must obtain an accurate estimate of its thickness. Four methods have been used.

One is chemical analysis. The human red cell consists of about 64 per cent water, 28 per cent hemoglobin, 7 per cent lipids (cholesterol, lecithin and so on), and the remaining 3 per cent is made up of sugars, salts (including a number of organic phosphates), enzymes and other proteins. The ghost contains lipids and proteins other than hemoglobin in amounts sufficient to form continuous layers around the cell with combined thickness of 67 Angstroms. If we suppose that the original membrane is two thirds water, the thickness becomes 200 Angstroms. Assuming that the intact membrane also contains some hemoglobin and other substances which are lost when it is broken down to a ghost, we may get an estimate as high as 500 Angstroms for its thickness, on the basis of chemical analysis.

A second method uses the "leptoscope," an apparatus for measuring the thickness of very thin objects by comparing them with fine barium sulfate films of known thickness. The dry ghost membrane by this measurement comes to 200 Angstroms, to which must be added such losses of material as may have occurred during the breakdown of the cell.

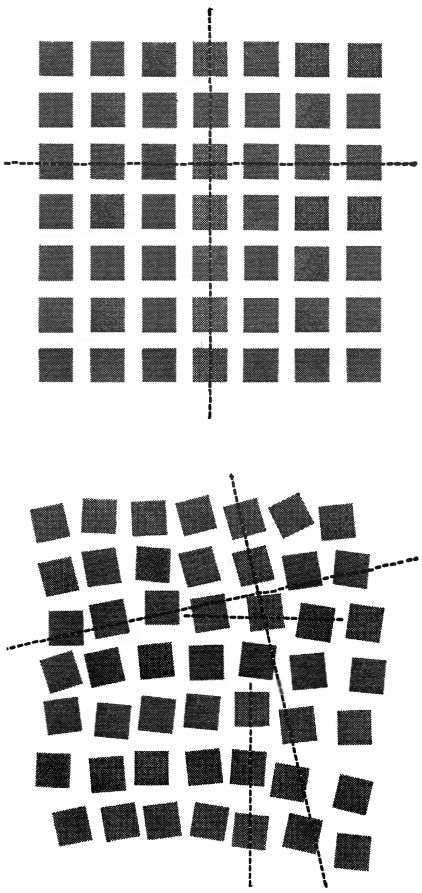
The third method is a study of ghosts with the electron microscope. Certain treatments, including mild heating, pit the surface of the red-cell ghost with craters, whose depth indicates the thickness of the membrane. Electron micrographs show these range from about 200 to 1,000 Angstroms. Again allowance must be made for the fact that the specimen is dehydrated: when wet it may be two or three times as thick.

The fourth method is direct electron microscopic study of sections of red cells which can now be sliced extremely thin by new techniques. In these pictures it is possible to discern a surface structure from 500 to 1,000 Angstroms in thickness [*see electron micrograph at the right on page 95*]. The structure (dry) is too thick to be made up entirely of lipid and nonhemoglobin protein: it must contain hemoglobin as well.

Many models of the red-cell surface ultrastructure have been proposed on the basis of the foregoing observations, and four of these are shown here [*see diagrams on pages 98, 101 and 102*]. They are all products of the imagination to some extent, because they are arrangements on the molecular scale, below the level of visibility. But all of them agree that lipids and proteins are intimately associated in a complex network to make up the red cell's membrane.

What of the internal structure of the mammalian red cell? The cell contains so many hemoglobin molecules that they must be packed very closely together, with a space of only about 10 Angstroms between one and the next. The important questions are: (1) are the hemoglobin molecules arranged in an orderly fashion, and (2) are other proteins present, winding themselves between the hemoglobin molecules like spaghetti among meat balls? If either of these two points could be decided, we could speak of an "internal ultrastructure"—less definite, perhaps, than the surface ultrastructure, but nevertheless real.

To obtain information about the arrangement of the molecules in the interior, red cells have been explored with X-ray beams. A perfectly ordered structure (*e.g.*, a crystal) scatters X-rays in one type of pattern; a disordered mass (*e.g.*, molecules in simple solution), in quite another. We find that the scattering by red cells gives a special pattern between these extremes. There is some order, but it is not the strict order of a crystal—rather, the order is like that



ARRANGEMENT OF MOLECULES of hemoglobin within the red cell is suggested by the lower schematic diagram. The squares at the top represent the orderly structure of a crystal. The squares at the bottom indicate the local order of hemoglobin molecules.

HUMAN RED CELL "GHOST" is enlarged 26,000 times in the electron micrograph at the top of the opposite page. The ghost is what is left of the red cell after its interior has been removed by putting it in distilled water. Under such conditions the cell is a sphere rather than a biconcave disk. The cell shown here was then deposited on a thin sheet of collodion, dried, plated with chromium and mounted in the electron microscope. The electron micrograph shows the collapsed sphere of the ghost. The whitish areas are the folded surface of the sphere. In the electron micrograph at the bottom of the page a section of the same ghost is enlarged 70,000 times to show its surface detail. The micrographs were made at Princeton University by James Hillier, Joseph F. Hoffman and Arthur K. Parpart. The red cell was contributed by Hoffman.

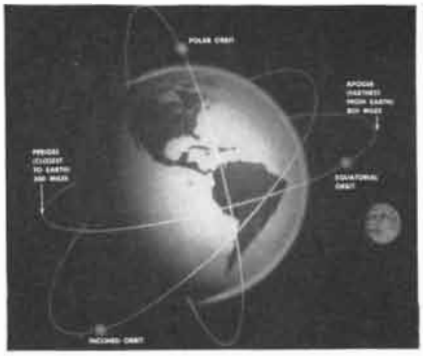
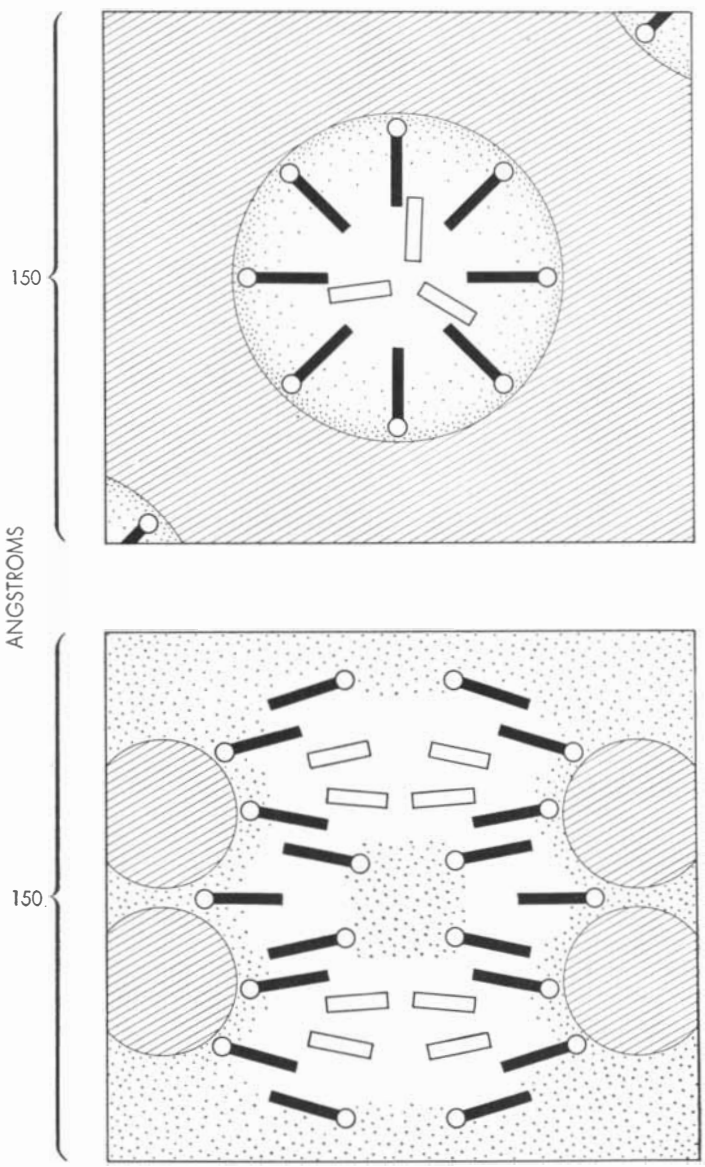


Illustration courtesy of *Popular Science Monthly.*

of people gathered at a crowded cocktail party. Each person stands in a certain ordered relation to his neighbors, but waiters can pass to and fro among the little groups and a person can move from one group to another without disturbing either the local or the over-all group pattern. This is the sort of picture we get when we explore red cells with X-rays. The hemoglobin molecules are not arranged in a regular pattern, but they seem to have a "short-range ordering," each molecule having a little effect upon its near neighbors [*see diagrams on preceding page*].

In the 19th century investigators suggested that the hemoglobin molecules in the red cell were embedded in a spongelike network ("stroma") of protein. This idea was abandoned around 1900, not because of any new experimental evidence but because theories of the time made it more convenient to regard the red cell as a bag containing a solution of hemoglobin. In recent years, however, some investigators have succeeded in extracting proteins other than hemoglobin from the cell, and interest in the possible existence of a stroma has been revived. But it is not certain that these proteins come from the cell interior, or that their amount is sufficient



MODEL OF RED CELL MEMBRANE proposed by Parpart and Robert Ballentine is seen in a surface view (*above*) and in cross section (*below*). Hatched areas represent protein. The open rectangles represent molecules of cholesterol; solid rectangles with circular heads, molecules of phospholipid. Water is present in the areas that are indicated by stippling.

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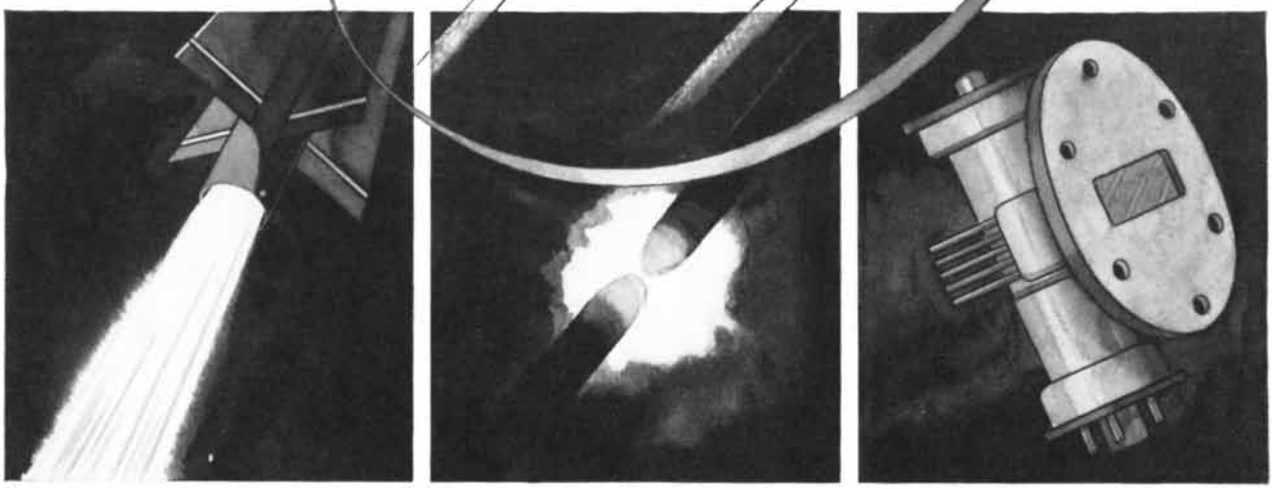

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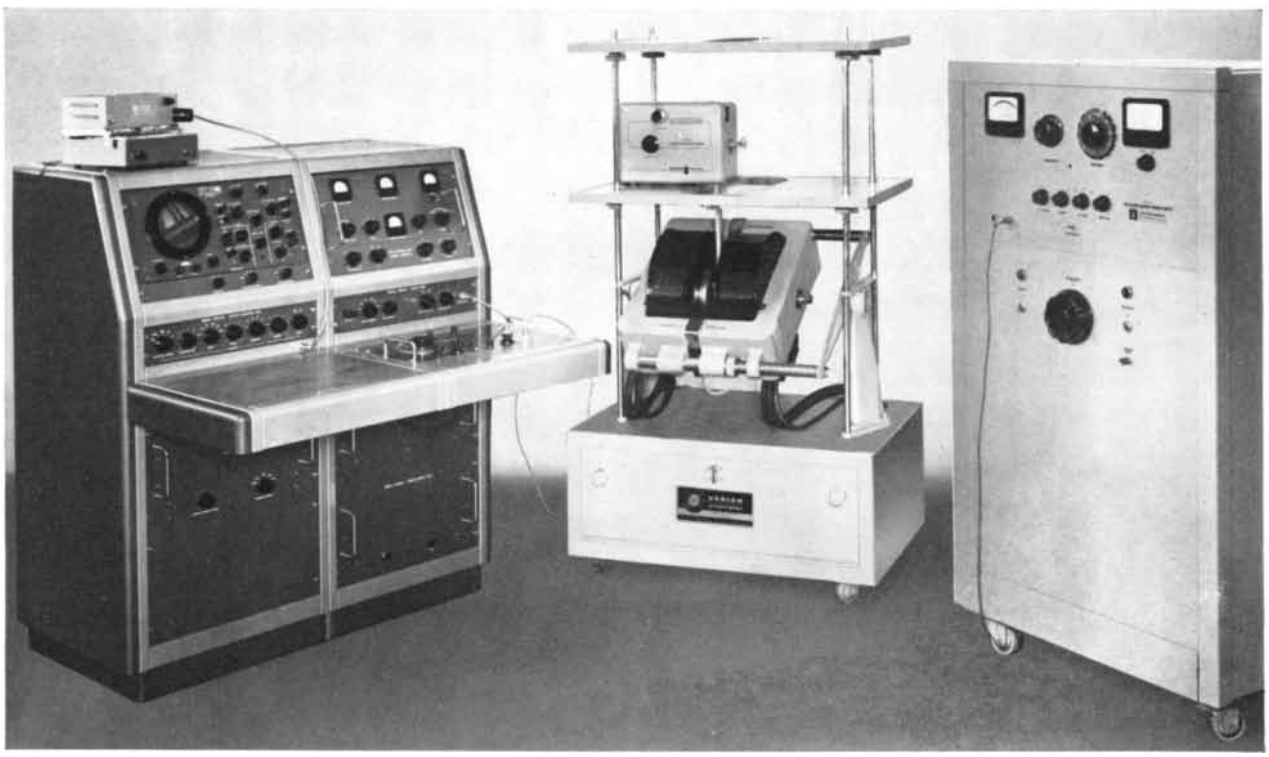

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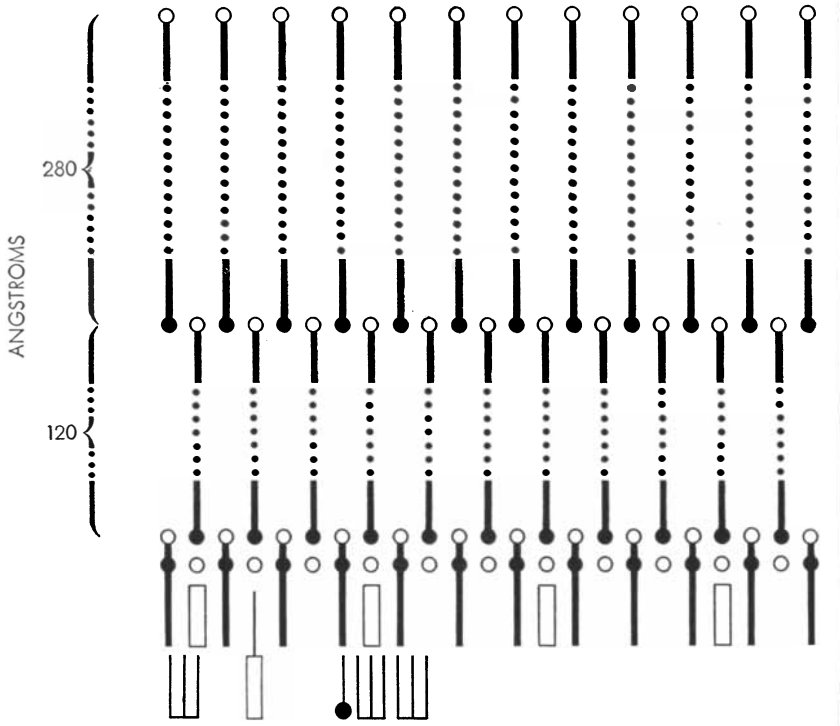
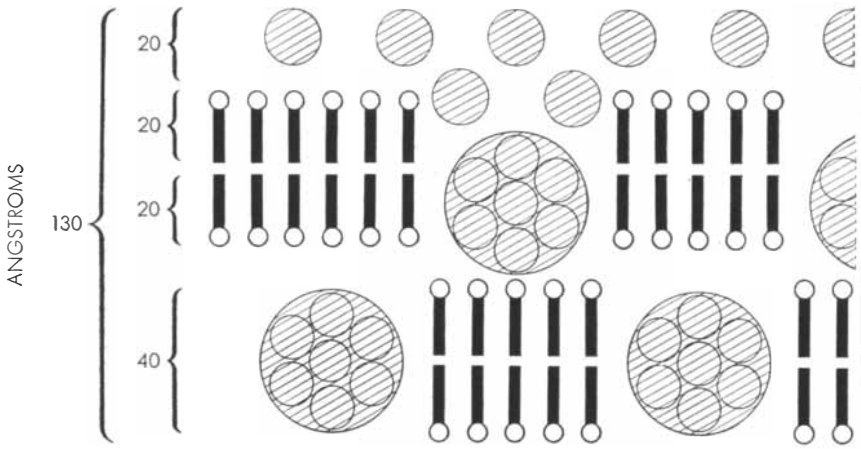


SECOND MODEL was suggested by A. Winkler and H. G. Bungenberg De Jong. It is shown in cross section. The solid rectangles with circular heads represent fatty acids. The open circles stand for positively ionized chemical groups; the solid circles, for negatively ionized groups. Cholesterol is represented by the open rectangles at the bottom.

to form anything but a very tenuous network there.

Our present picture, then, is that the mammalian red cell has a highly oriented structure at the surface, composed mainly of lipids and proteins with probably some hemoglobin, and a very much less ordered interior made up of hemoglobin molecules and possibly some other protein. As we go into the cell from the surface the concentration of lipids and associated proteins drops sharply, and the concentration of hemoglobin rises sharply, but there is no absolute dividing line between the membrane and the interior. Near the surface of the cell the hemoglobin molecules present are ordered, or oriented, by the surface ultrastructure, to which they seem to be attached in some manner. Their orientation declines toward the



THIRD MODEL is that of Ponder. Round-headed rectangles represent lipids of all types (cholesterol, phospholipid and fatty acids). Large shaded circles containing smaller circles are protein bundles cut in cross section. Circles at top represent a layer of albumin.

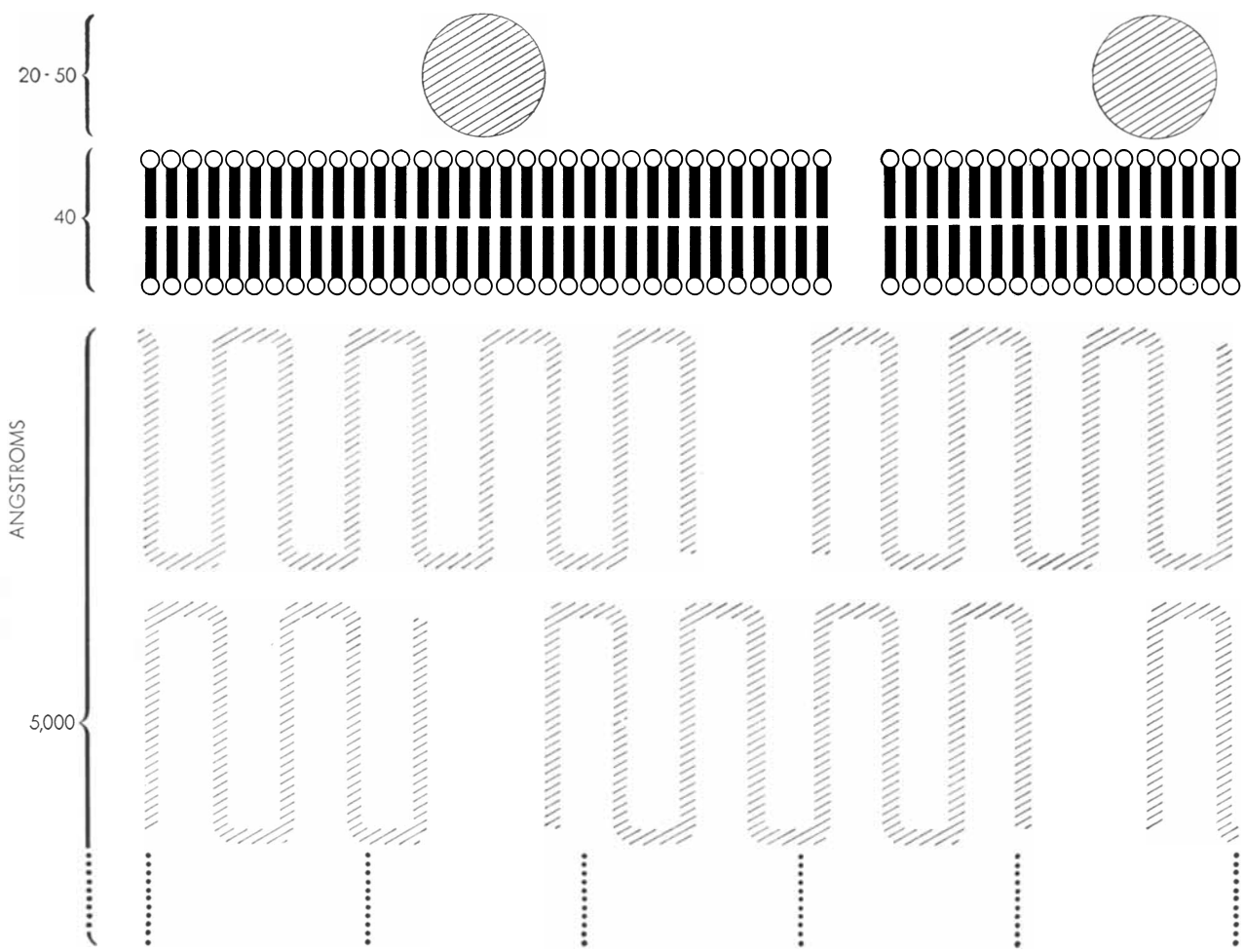
interior. A mild breakdown treatment of the cell removes only the comparatively unoriented hemoglobin in the interior, and produces a thick ghost with considerable hemoglobin in its structure. Harsher treatments wash out more hemoglobin and leave a thinner ghost.

This theory would explain why ghosts prepared by different methods contain different quantities of residual hemoglobin and why it is so difficult to wash hemoglobin completely out of ghosts. Two recent observations support the view that some hemoglobin is actually combined with other materials in the surface structure. Marcel Bessis of Paris found indications that the sickling of red cells, in the disease known as sickle cell anemia, is associated with threadlike forms that develop at the surfaces of the cells. These forms are soft and pliable when sufficient oxygen is present, but they become rigid rods when the oxygen concentration is reduced. A similar change is probably responsible for the distortion of the red cells to their rigid sickle shape. Now the forms in question are known to contain lipids, and they must also contain the abnormal hemoglobin that causes sickling. The conclusion is almost inescapable that the hemoglobin is combined with lipids.

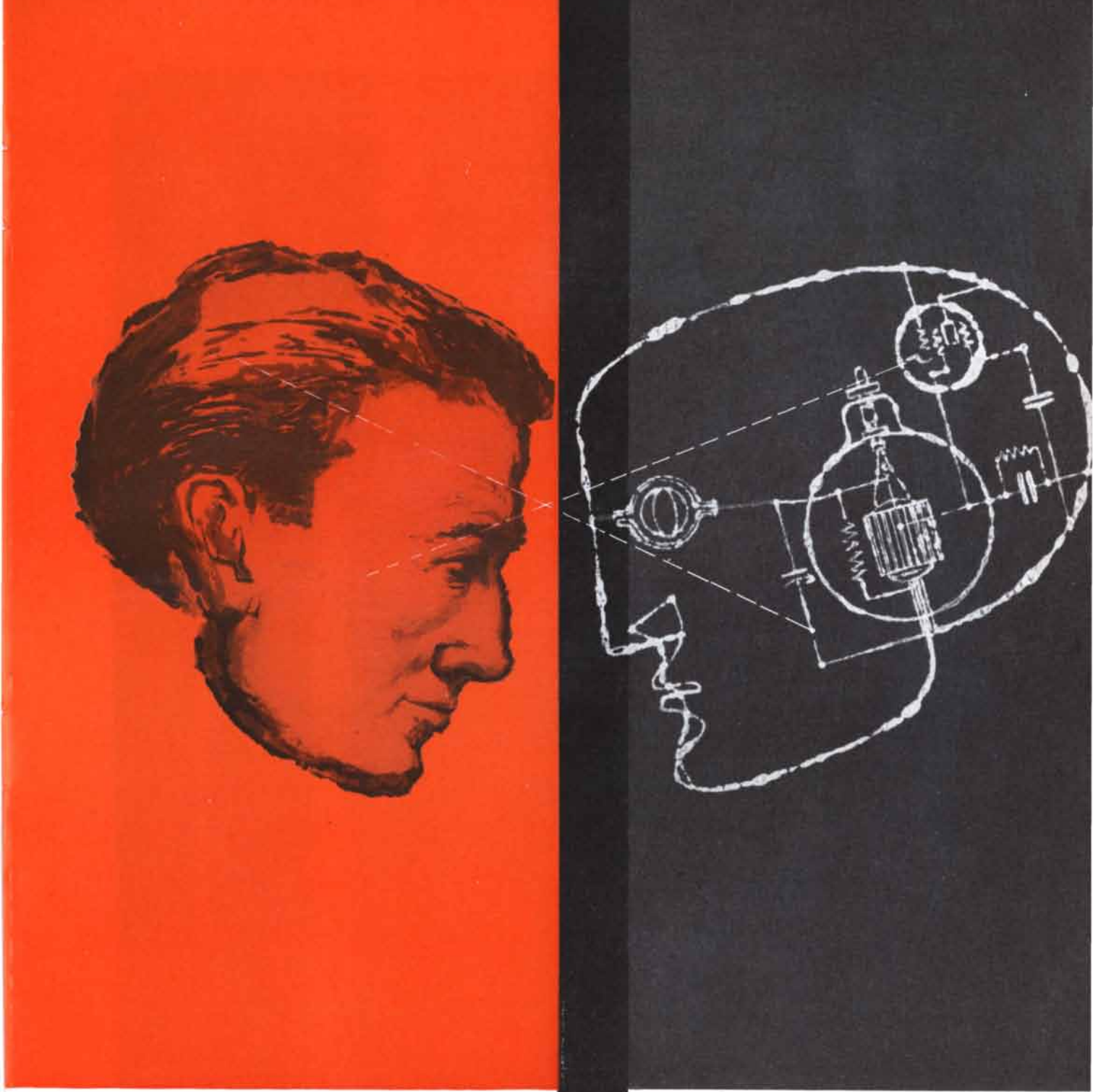
The second observation is that, whereas free hemoglobin will move along a paper strip with a flow of current (in the technique known as electrophoresis), a red-cell ghost containing hemoglobin will not. The hemoglobin evidently is fixed in some manner to the ghost. When the ghost is broken down to fragments (in which there are no baglike structures), some hemoglobin is freed and migrates along the strip.

The long-held notion that the mammalian red cell is merely a bag filled with dissolved hemoglobin is further disproved by experiments in fragmenting the cells. Red cells can be broken up by heat, by freezing or by various chemical attacks. They break into fragments of surprising variety. The fragments often retain hemoglobin and some of the properties of the whole red cell. For example, they will swell and shrink as the saltiness of the solution is changed, and spherical fragments can be restored to a flattened shape by the addition of serum albumin.

There are other observations, still rather mysterious, which nonetheless testify to the complex structure and the vitality of the red cell. One of the most striking appears when the cell is examined under a phase contrast microscope. The surface of the cell seems to move, as if wind were blowing over a field of wheat. This so-called "scintillation phenomenon" is believed to be connected with the cell's metabolism. It may mean that different parts of the surface of the cell are in different metabolic states at the same moment. The surface structure of the red cell gives every evidence of being a dynamic agent, constantly adjusting its permeability and other behavior to the metabolic needs of the cell.



FOURTH MODEL was suggested by J. M. Mitcheson. The round-headed rectangles are again all types of lipid. Beneath them, indicated by the hatched lines, are protein molecules folded into corrugations. A sparse layer of protein at the top is represented by circles.



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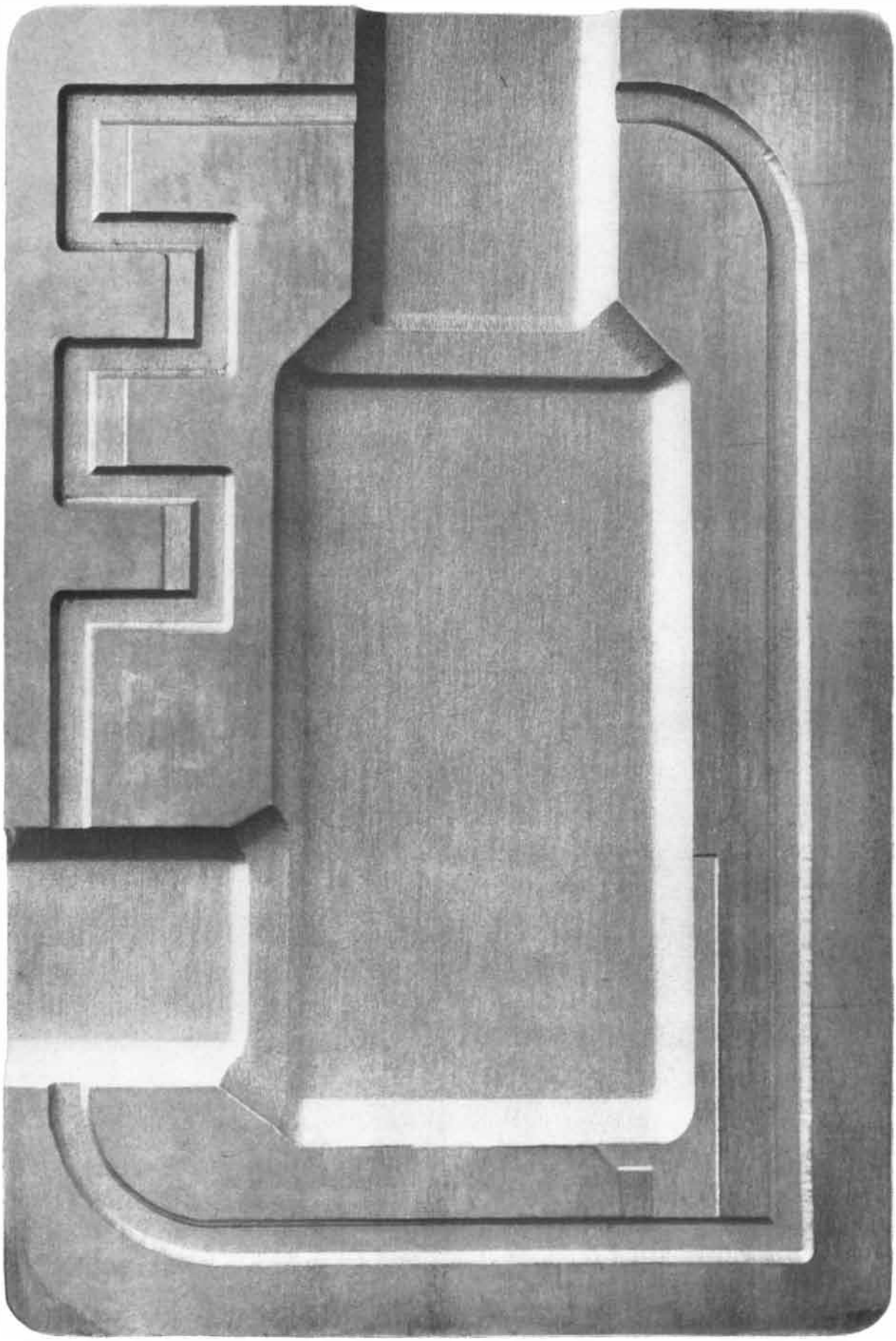


CHEMICAL MILLING

The art of cutting metals has recently been extended by new techniques of etching. These techniques not only shape metals but also will very likely shape the design of metal products

by Edmund L. Van Deusen

From his early stone-ax period on, man has been basically a whittler. It is a little startling to realize how much our advanced technology still depends on the cutting tool. It remains the principal implement with which we shape our world—till the soil, level land, make roads, fell trees, drill wells, dig minerals and fabricate most of our products. In the age of metals the cutting machines have become rather elaborate, but we mill metal, as man has always carved stone and wood, with versions of the old, familiar tools—the chisel, the drill, the planer, the router, the lathe.

One needs this reminder to appreciate the revolutionary nature of an innovation that has come within the last three and a half years. The innovation is a method of milling metals with chemicals rather than with cutting tools. Like most radically new developments at the beginning, it has excited little public notice—probably few persons outside the engineering profession are acquainted with it. But chemical milling is already a going concern in industry: several dozen companies have begun to work with the process, and some six million pounds of metal have been milled chemically in the U. S. so far.

Chemical milling is a classic instance of a truly big invention emerging from a small, almost trivial problem. The problem was a rocket casing on which engineers were working in the guided missile plant of North American Aviation, Inc., at Downey, Calif. A cylinder made of thin sheet aluminum had to be butt-welded at the seam where the edges of the rolled sheet met, but the weld kept failing because of the thinness of the edge of contact. Use of a thicker aluminum sheet would have made the casing too heavy. The engineers considered planing down a thick sheet and leaving a lip at the edge for the weld, but this would have been expensive and it would have been difficult, if not impossible, to roll the partly milled sheet into a perfect cylinder.

At this point Manuel Sanz, chief of the North American research group, had an inspiration. He conceived the idea of making the cylinder of heavy-gauge aluminum and planing down its thickness with chemicals in a corrosive bath. The edges of the sheet could be covered with tapes of resistant material so that a lip of the original sheet thickness would be left for the weld.

Sanz tested the idea on a small sheet of aluminum, and even he was amazed by the result of the experiment. The aluminum piece came out of the corrosive bath evenly thinned down: the chemical had etched metal away smoothly all over the exposed surface.

Sanz's laboratory notebook for that day, August 13, 1953, includes the phrase "chemical milling." It was immediately recognized that the experiment had given birth to a revolutionary technique which would have very wide and general use in handling metals. North American soon applied for a patent for "a chemical method of milling a formed metallic sheet" (granted in 1956 as patent No. 2,739,047). But it made no secret of Sanz's discovery, realizing that a great deal of work would have to be done to develop the idea on a practical basis and that it was primarily of interest to the chemical and metal industries. Within a few days after the experiment, several of the company's chemical suppliers joined North American in research to follow up the discovery.

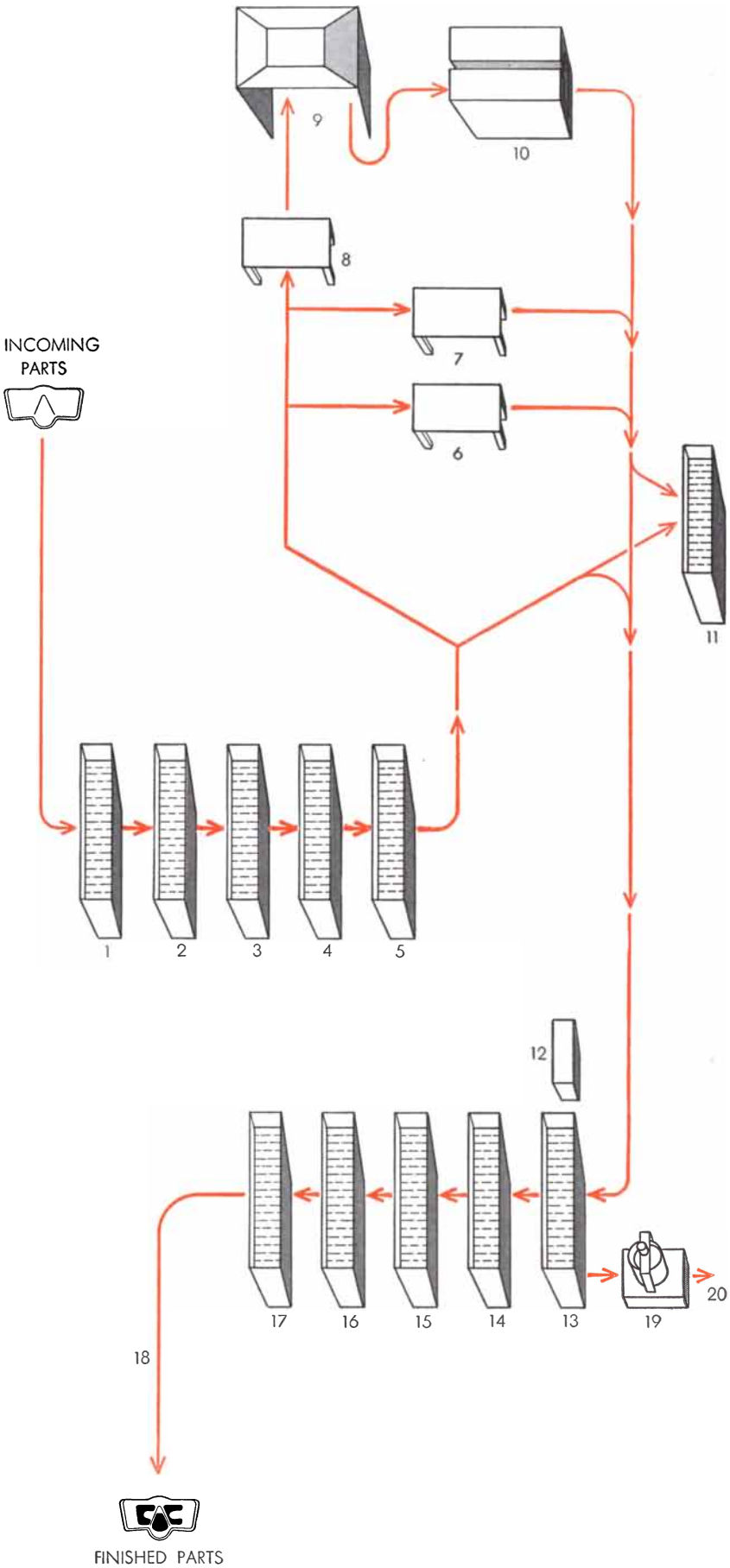
It was fortunate that the metal on which Sanz had tried his idea was aluminum. Of all the metals, aluminum lends itself most readily to chemical milling. It can be etched by acids, by alkalis and by various metal salts. Furthermore, commercial chemical companies had already had some experience in treating aluminum surfaces with chemicals, and Turco Products, Inc. (now one of North American's principal collaborators) was able to supply an etching solution which had been used on aluminum blinds.

At first thought, one may wonder what is so new about chemical milling. How does it differ from the ancient art of etching, which has been developed to such high skill in photoengraving?

Pictorial etching originated in the 16th century, when metalsmiths began to use the technique to engrave decorative designs in steel armor. Printers later adopted chemical etching as a convenient substitute for engraving with hand tools. The art reached a peak of refinement with the development of halftone photoengraving in the late 19th century. This very refinement brings out the basic difference between chemical milling and etching in the graphic arts. The photoengraver is a painstaking craftsman. He etches his plate with a series of minute, cautious "bites," and rarely removes more than a few thousandths of an inch of metal. His cuts into the plate must be very precisely controlled. One of his chief concerns is that the cuts be sharp and vertical, so that the tiny dots making up the halftone pattern on the surface are close together.

The attack in chemical milling differs

SLAB OF ALUMINUM shown on the opposite page was chemically milled by Turco Products, Inc., of Los Angeles, Calif. The object here is merely a sample to demonstrate what the technique can accomplish.



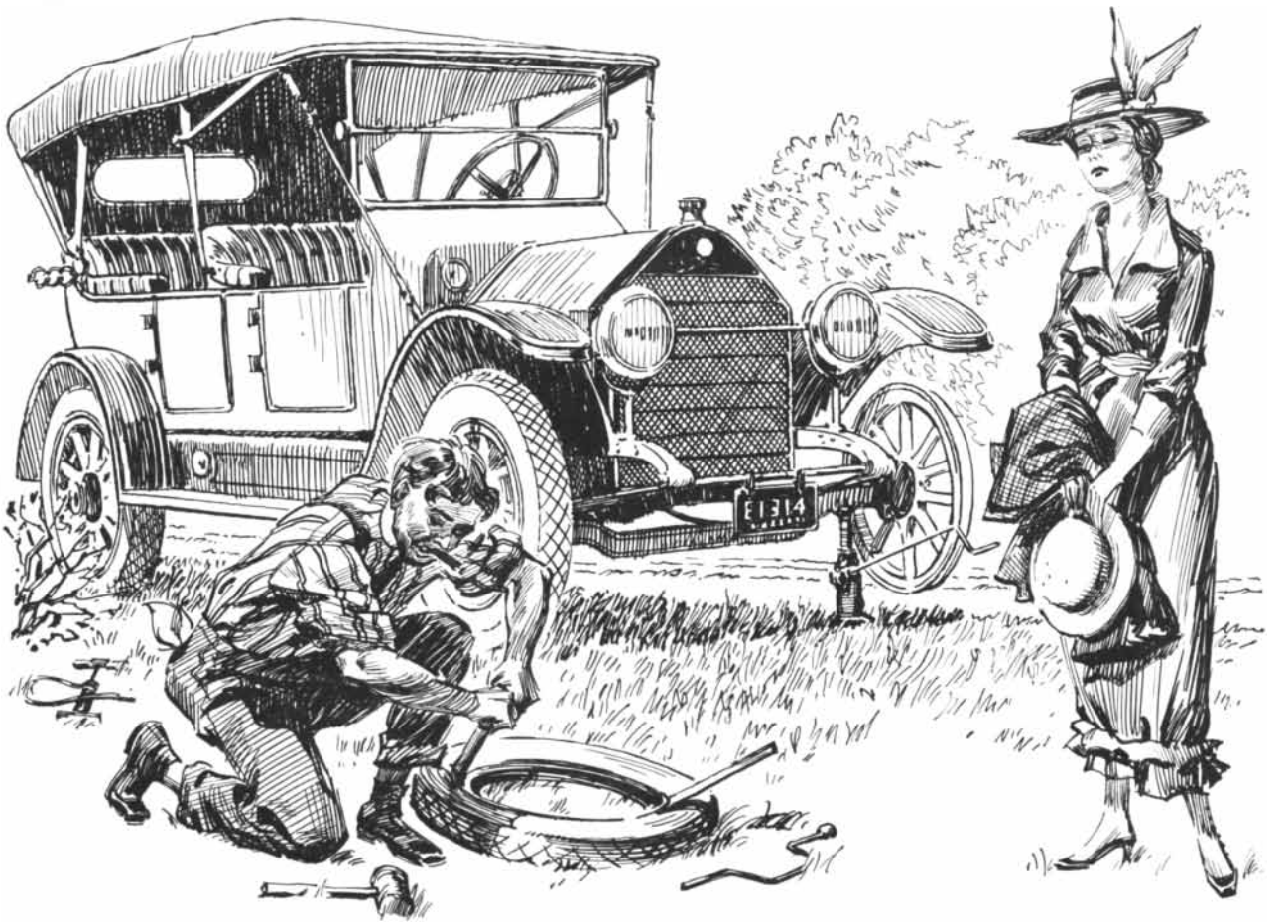
from this as painting a house differs from painting a picture. The object is to remove large amounts of metal over rather wide areas. As much as half an inch of metal may have to be planed off in one massive attack. The miller's concern is to etch the metal away smoothly and evenly over the whole exposed surface and to do this with a minimum of hand labor and at minimum cost. The steepness of the cut or undercutting by the acid at the edge of the masked area is generally only a minor problem or no problem at all.

Essentially chemical milling involves two operations: (1) masking the areas that are to be kept intact, and (2) etching the rest evenly to a certain depth. The process sounds simple, and it is simple, but to reduce it to practical and efficient engineering techniques is another matter. It has called for much research on etchants, masking materials and handling of the operations.

If the milling job in hand is merely to reduce the thickness of a metal sheet or enlarge the bore of a metal pipe, preparation is no problem. The sheet can simply be dipped in the etchant bath for a fixed time, then drawn out and quickly washed. The pipe can be "reamed" by pumping the etchant fluid through it. But most chemical-milling jobs, like Sanz's case of the rocket casing, require that some area or areas of the piece be kept at the original thickness. This calls for masking, and so far the masking operation has been the chief obstacle to establishing chemical milling on a mass-production basis, because it requires hand labor.

In the method most widely used, the piece is first sprayed with or dipped in

FLOW OF PARTS through a chemical milling plant is traced in this diagram. The incoming parts are degreased (1), cleaned with hot alkali (2), rinsed in cold water (3), bathed in chromic acid (4), rinsed in hot water (5). Some parts require no masking; they may go directly to the etching tank (13) or to the taper etching tank (11). Some parts are mechanically masked (6), others are masked with tape (7), still others are prepared for a coat of paint (8). These latter parts are sprayed with paint (9) and dried (10). The masked parts are now etched (11 or 13), rinsed in cold water (14), bathed to remove oxides (15), bathed to remove the masking material (16), rinsed in hot water (17). Finally they are inspected (18). The used etching solution is fractionated by a centrifuge (19) and saved (20). The control panel is also indicated (12).



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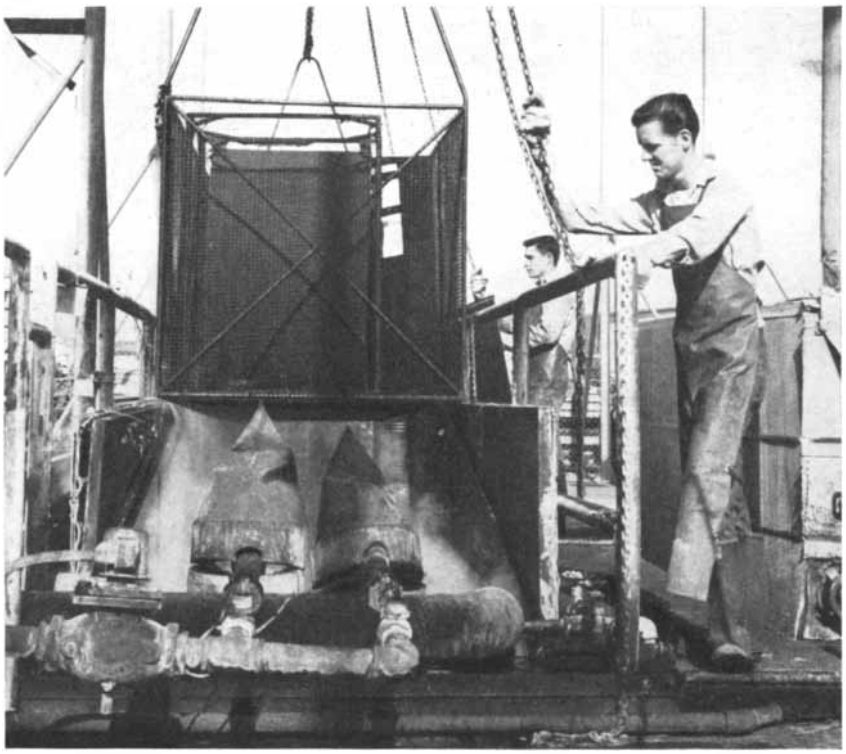
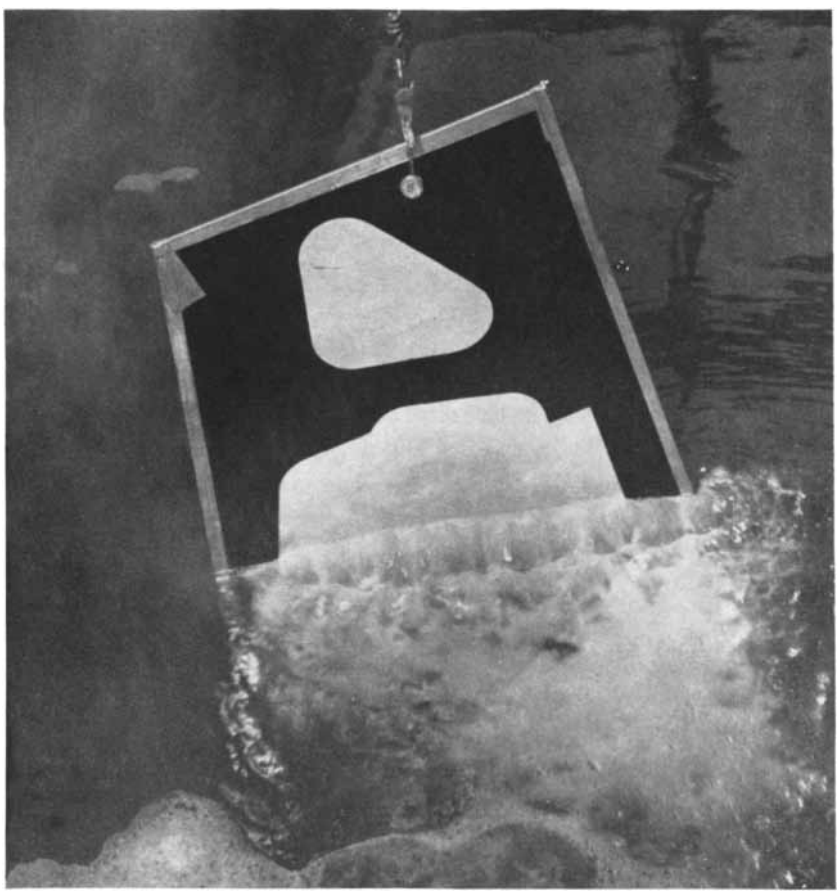


AIRPLANE AND MISSILE PARTS are chemically milled at the Downey, Calif., plant of North American Aviation, Inc. Here a basket of parts is lowered into a vat of caustic.



MISSILE PART enters caustic. The turbulence in the bath is caused by the etching, which begins immediately. The bright areas are exposed metal; the dark areas are masked.

a liquid which covers its entire surface with a resistant coat. Usually it is coated with several layers of the material, because a single pinhole in the coat could ruin the etching job. After the coating has been dried and cured, a template outlining the areas to be milled is laid on the piece, and the outlines are cut with a scribing instrument sharp enough to cut through the coating but not so sharp that it scratches the metal (a scratch would become a focal line for action by the etchant). The cut sections of coating are then stripped away by hand, and the piece is ready for the etchant bath.

To find a coating material which could easily be stripped away and yet would stick to the metal tightly enough to survive hours in a hot acid or caustic bath was a major problem. The most effective maskants found so far have been synthetic rubbers of the neoprene type. But vinyl plastics also are promising as a coating, particularly for steel.

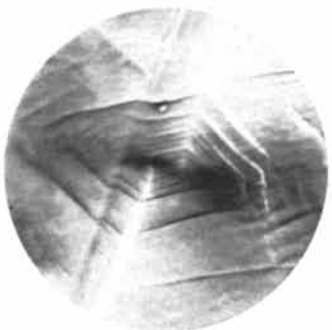
The chemical millers are inclined to believe, however, that this type of approach is a dead end. They are experimenting with other coating processes that would not require scribing and hand stripping. One approach under study is to "print" the maskant on the metal, either by a process like silk-screen printing or by a photographic method—that is, covering the metal with a light-sensitive material and projecting the masking pattern on it, so that the exposed areas of the material would harden after development and become a permanent coating. But the printing approach runs into a number of difficulties, among them the fact that the surfaces to be masked are often not flat but curved in complex shapes.

One thing is clear: if chemical milling is to become a true mass-production process, this masking problem is the major problem to be solved. It is a fascinating challenge, and a number of inventive individuals and organizations have taken it up.

Compared to masking, the etching operation in chemical milling is in an advanced stage of development. The design engineers have three main things to think about here. One is undercutting of the metal along the edge of the masked area. If the chemical eats under the mask edge smoothly and uniformly, this may actually be an advantage, because it rounds the milled edge and makes it stronger. But gas bubbles or sediment collecting in the etched pocket may cause the chemical to eat unevenly and produce a jagged edge or a scooped-out effect. One effective answer is to

Interesting Metal Structures Come to Light

Mr. Robert Mapes, Metallographer at Reynolds Metals Co., Richmond, Va., operating the new RCA EMU-3 Electron Microscope, with Dr. John T. McCormack, Metallurgical Consultant, looking on.



Aluminum grain structure, showing spiral dislocation. Parlodian replica. Chrome shadowed.

Aluminum grain showing sub-grain structure. Parlodian replica. Chrome shadowed.

. . . with the RCA Electron Microscope

In fundamental research with the electron microscope, Reynolds Metals Company examines metal structures by surface replica techniques and contrasts enhanced by "shadowing" with a thin film of chromium. Structures too small to be seen with the light microscope are clarified and features revealed by electron micrographs. Such studies are leading to improved performance and fabrication characteristics in the metals.

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Camden, N. J.

AIRPLANE PARTS ARE SPRAYED with maskant before they are etched at Downey plant of North American. The maskant, which covers the metal with a dark coat, is now baked.

MASKANT IS PEELED from a part in the pattern to be etched. The maskant is cut in the pattern by scribing it with a sharp tool. This must be done without scoring the metal.

PARTS ARE CHECKED by inspectors after etching. The inspector at the right measures the depth of the etch with a micrometer. These parts are rear air ducts for the F-100 fighter.

agitate the etchant fluid and the piece of metal being milled. Some chemical millers are trying out supersonic vibrations for this purpose.

The second problem is that of milling the surface smoothly. A corrosive bath is apt to pit the surface of a metal, because no metal, especially an alloy, is ever completely homogeneous in composition and structure; moreover, the etching chemical may produce an electrolytic action between different elements in the alloy. It is possible to improve control over the evenness of the etching action by a proper selection of bath chemicals. But primarily the smoothness achievable depends upon the metallurgical state of the metal. If it has been worked to a fine-grained condition, a smooth surface is easier to attain. Chemical milling can polish certain steel and titanium alloys to mirror smoothness.

Smoothness is important not for esthetic reasons but because it indicates that the milled metal is free of lines of weakness. There is some evidence that a piece of metal milled by chemicals is likely to have higher fatigue strength than one milled with a machine tool. Even if the chemically milled piece is no smoother than the other, the ridges of unevenness on its surface are rounded, whereas those produced by a machine tool are sharp and saw-toothed.

The third problem is to make sure that the etching proceeds at a uniform rate. This poses some very tricky problems in chemistry and chemical engineering. The etching rate depends in the first instance, of course, on the concentration of etchant in the bath. This means that to keep the etching rate uniform, the chemical must be replaced continuously as it is used up in the etching reaction. What is more, all the substances added to the bath to keep the surface smooth and the undercut clean must also be maintained at a constant concentration. And to keep the bath composition constant it is further necessary to remove the metallic salts created by the reaction of the etchant with the metal as fast as they are produced.

All this obviously cries for automatic machinery to keep the whole process under steady control. Chemical milling, like petroleum refining, is a natural candidate for the automatic-factory type of operation, based on feedback processes and instruments.

The metals already being milled commercially by the chemical process include aluminum, magnesium, steel and titanium. There are airplanes flying with chemically "machined" parts. The infant

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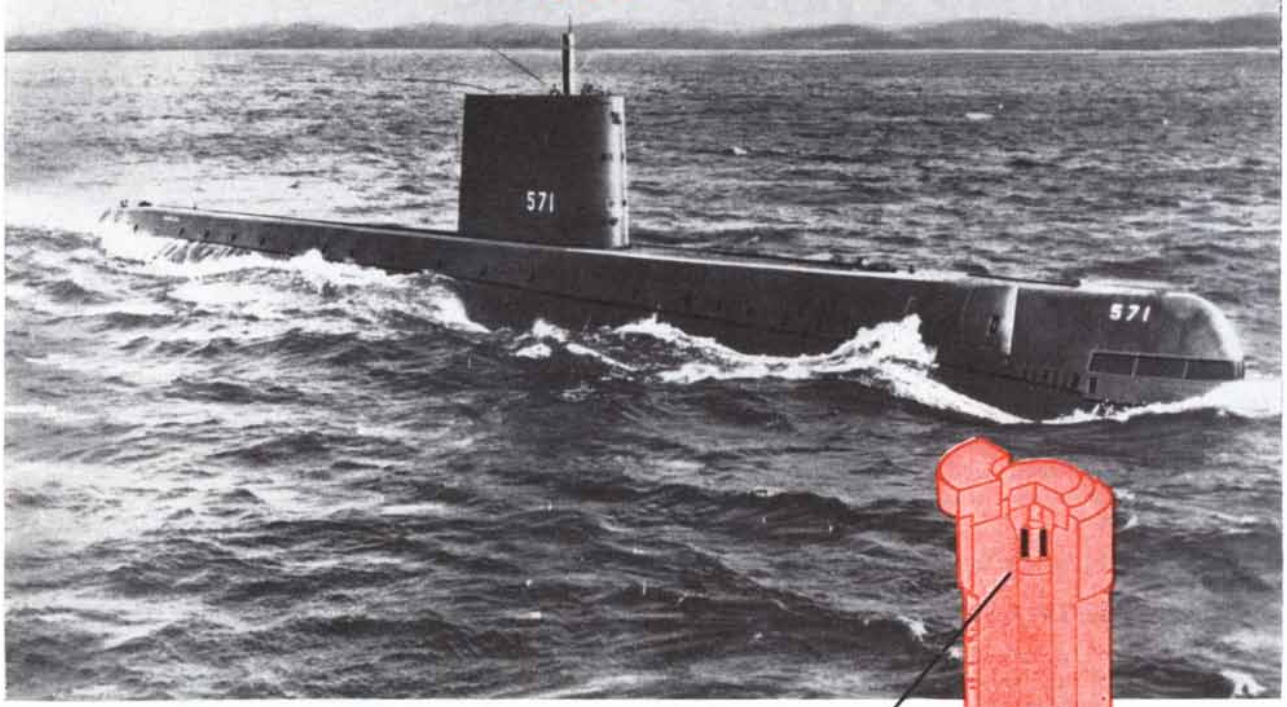

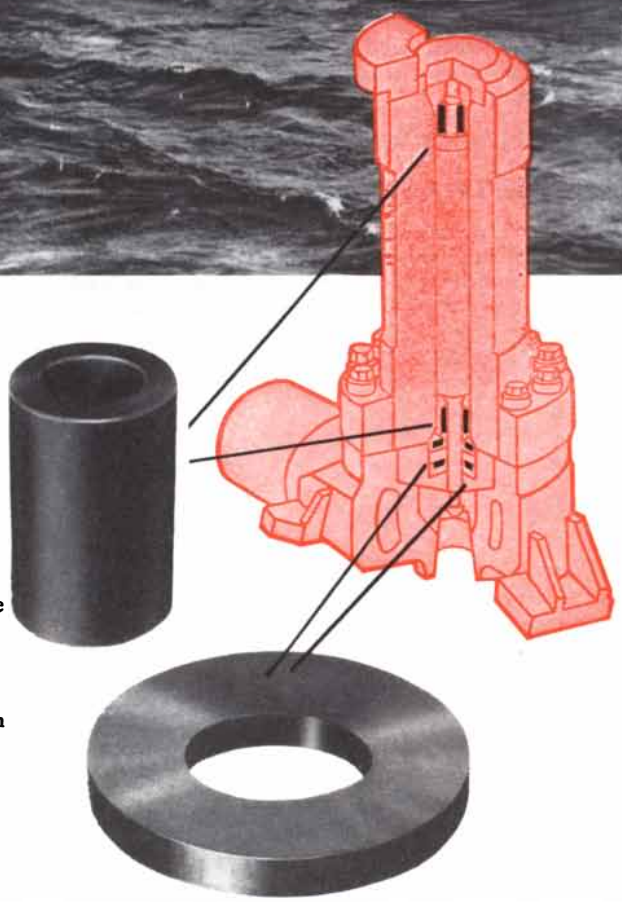

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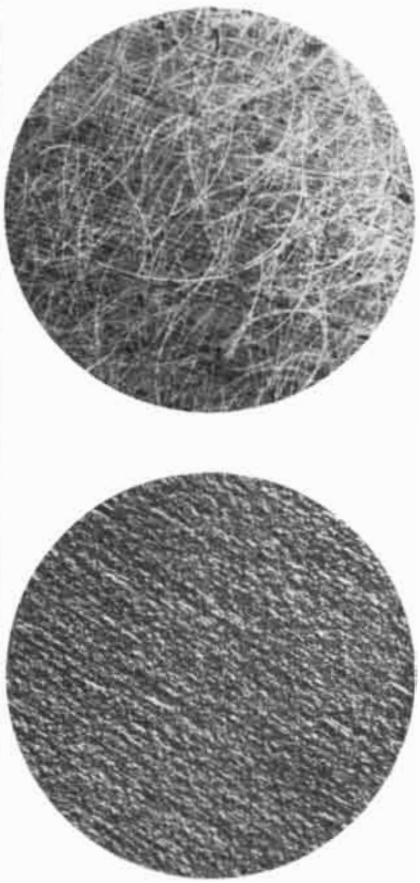
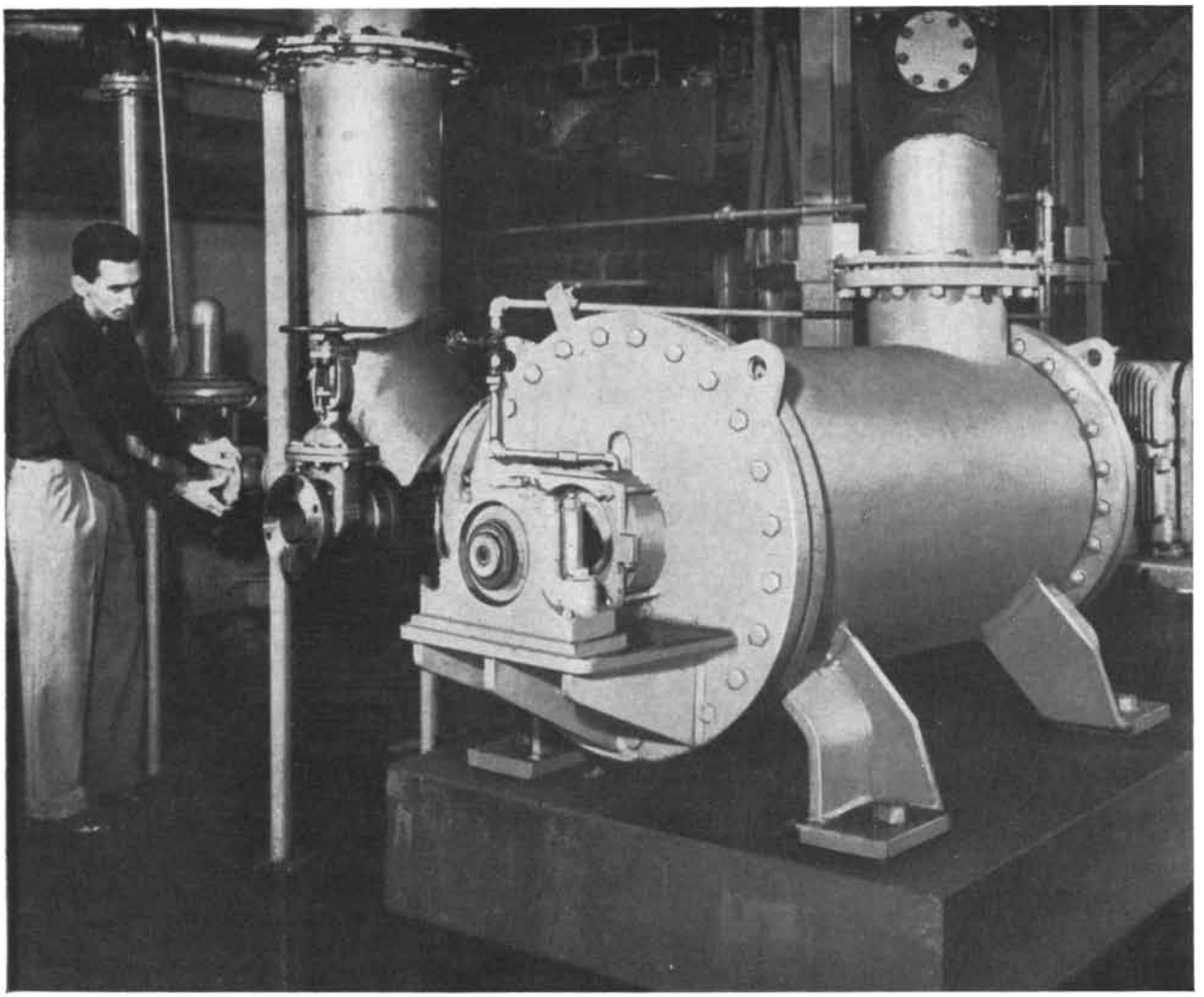
chemical milling industry is growing at a lusty rate. This fast start is due largely, of course, to the special demands of military production. Chemical milling has yet to compete directly with machine milling on a straight cost basis. Whether it will be able to do so is still a controversial question. Basically its big cost factor is its consumption of chemicals as etchants. On the other hand, it does not require expensive machinery and eventually should need very little manpower. Its equipment is, quite literally, just a series of "bathtubs."

In any case, chemical milling will certainly not put the machine-tool industry out of business. It has its limitations, just as the cutting tool does. Its great advantage, aside from its simplicity, is that it can perform operations no cutting tool can accomplish. Up to now most of our metal products have been fashioned or designed to be worked on with mechanical tools. With chemical milling we can look forward to forming metal in new and more complicated shapes.



SURFACES milled by chemical and mechanical means are compared in photomicrographs. The top surface is milled and polished mechanically; the bottom, chemically.



Chlorine dioxide mixer in service at the Carolina Division of Riegel Paper Corp. The unit was manufactured by Improved Machinery Inc. It is lined with ⅛" REM-CRU A-70 titanium sheet.

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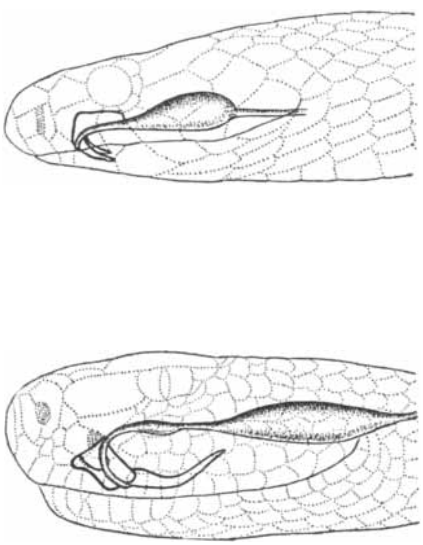
Snakebite

The seriousness of an encounter with a poisonous snake depends not only on the toxicity of its venom but also on its behavior and the amount of toxic substance it can deliver with one bite

by Sherman A. Minton, Jr.

Herpetologists insist that snakes are friends of mankind, but most of us are glad to steer clear of these friends. After due credit has been given them for their services in consuming insects and vermin, and for their fascinating virtues as pets and show animals, we must still take a cold view of their venomous aspects. Just how dangerous are the poison snakes? Prudence and self-protection make it worth while to look into this question, biologically and statistically.

It is a simple matter to measure the toxicity of a snake's venom by injecting carefully weighed doses into an experimental animal. But extrapolation from these tests to estimate the fatal dose for man may be misleading, if not dangerous. A favorite animal for such tests used to be the pigeon, which is highly sensitive to snake poison. Pigeon assays probably are the basis for the statement in a well-known textbook on tropical medicine that the fatal human dose of the venom of the North American copperhead is about 25 milligrams (dried). Since an average adult copperhead can deliver 50 milligrams of venom at a bite, many persons bitten by copperheads should, on this figuring, be candidates for the undertaker. Actually the copperhead bite is rarely fatal, even when the bitee gets no medical treatment.



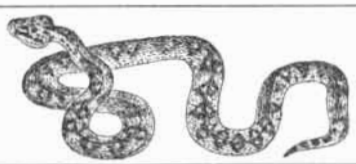
FANGS AND POISON GLAND of the Indian cobra (*top*) are compared with those of the western diamondback rattlesnake (*bottom*). The poison apparatus of the cobra is smaller but its venom is more toxic.

At the other extreme from the pigeon is the white mouse, which has replaced the pigeon as a favorite assay animal because it is so much more inexpensive and convenient to handle. The white mouse has amazing resistance to snake venoms, especially those of the pit vipers. Ounce for ounce, it is more than 12 times as resistant as the pigeon to a rattlesnake's poison. Now on the basis of mouse tests of the venom of the fer-de-lance, one might calculate the lethal dose of this tropical snake's poison for a 150-pound man as about 1,550 milligrams. But even a very large fer-de-lance delivers only about 300 milligrams at a bite. Thus we might conclude that one of the most dangerous snakes of tropical America should be unable to inflict fatal injury to an adult human being. Its hundreds of victims no doubt succumbed to fright!

Snakes, like other animals, vary in individual make-up and condition, and it is well to remember that this applies to the toxicity of their venom. Testing samples collected from two female timber rattlesnakes on the same day in the same place, I found one approximately five times more toxic than the other. This sort of variation can lead to real discrepancies, especially in the case of rare species when an investigator's entire sample may have come from only one or two animals.

What snakes have the most toxic venom? After giving due weight to all pertinent factors, we would put at the top of the list the poisons of the tiger snake of Australia (*Notechis scutatus*), the blue krait of India (*Bungarus candidus coeruleus*) and the krait of Formosa (*B. multicinctus*). Their venoms are lethal to the mouse in a dose of only two to five thousandths of a milligram: they are almost 50 times as toxic as potassium cyanide. There are several less-studied snakes whose venoms are probably of the same order of toxicity. Among them are the other species of kraits, the mambas of Africa (related to the cobras), the taipan of Australia and some of the sea snakes. The venoms of all these snakes are toxic to the nervous system, producing paralytic symptoms and death from depression of respiration and the heartbeat.

Extremely toxic venom does not in itself make a snake dangerous to man. It becomes a menace only if the snake makes the poison in sufficient quantity, has an effective means of delivering it and is skillful and aggressive in doing so. Many snakes with very powerful venoms have only small amounts of this secretion available for a bite. The tiger snake, for example, delivers less than a fifth as much venom (about 40 milligrams dry weight) as some of the large rattlesnakes. Other poisonous snakes are handicapped by having short fangs or an otherwise inefficient biting apparatus. On the other hand, a large snake with comparatively weak venom may be very dangerous. Among 21 types of snake venoms tested by W. H. A. Schöttler at

			LENGTH (FEET)	FANG LENGTH (MILLIMETERS)	VENOM YIELD (MILLIGRAMS)	LETHAL DOSE FOR MAN (MILLIGRAMS)
ELAPIDAE	NORTH AMERICAN CORAL SNAKE *MICRURUS FULVIUS*		2-2½	2	3-5	5
	BLUE KRAIT *BUNGARUS CANDIDUS*		3-4	2.5	5-10	1.5
	TIGER SNAKE *NOTECHIS SCUTATUS*		4-5	4	35-45	2
	INDIAN COBRA *NAJA NAJA*		4-5	4	175-250	20
	MAMBA *DENDROASPIS ANGUSTICEPS*		7½-9½	6	75-100	20
VIPERIDAE	AFRICAN PUFF ADDER *BITIS ARIETANS*		3½-4½	15	160-200	120
	RUSSELL'S VIPER *VIPERA RUSSELLI*		3-4	12	150-250	50
CROTALIDAE	FER-DE-LANCE *BOTHROPS ATROX*		4½-5½	17	80-160	70
	BUSHMASTER *LACHESIS MUTA*		7-9	25	300-500	150
	WESTERN DIAMONDBACK RATTLESNAKE *CROTALUS ATROX*		4-5	13	200-300	140

CHARACTERISTICS OF 10 POISONOUS SNAKES are given in this chart. The numbers for length, fang length and venom yield are given for average adult specimens. The venom yield is the average amount delivered in one bite. The estimated lethal dose for man is given for a man weighing 70 kilograms (154 pounds). The families to which the various species belong are at the far left.

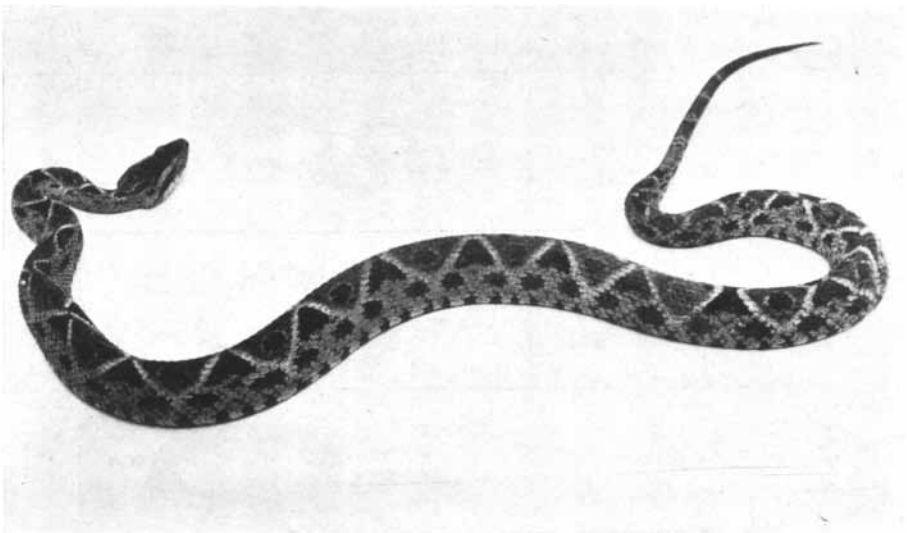
the Instituto Butantan in Brazil, the weakest was that of the bushmaster (*Lachesis muta*), yet the bushmaster is a very dangerous animal because of its great amount of venom, its huge fangs and its tremendous striking power.

Aggressiveness in serpents is extremely difficult to evaluate and requires intimate knowledge of the species. There is enormous individual variation. I have seen the blacktailed rattlesnake (*Crotalus molossus*), which has the reputation of being mild-tempered, defend itself savagely; I have also seen the western diamondback, usually aggressive, surrender without a fight. The late Raymond L. Ditmars, a world authority on herpetology, regarded the king cobra (*Ophiophagus hannah*) as "the most dangerous of all living wild creatures." But the Englishman M. W. F. Tweedie, who has had considerable experience with king cobras in Malaya, believes their savagery is greatly overemphasized. He cites the capture of a 15-foot specimen on a Singapore golf course by a golfer who seized it by the tail, thinking it was a python. The cobra made no effective resistance. Tweedie believes the reptile "had spent the whole of quite a long life" near the golf course, apparently without so much as frightening a sahib into topping his drive.

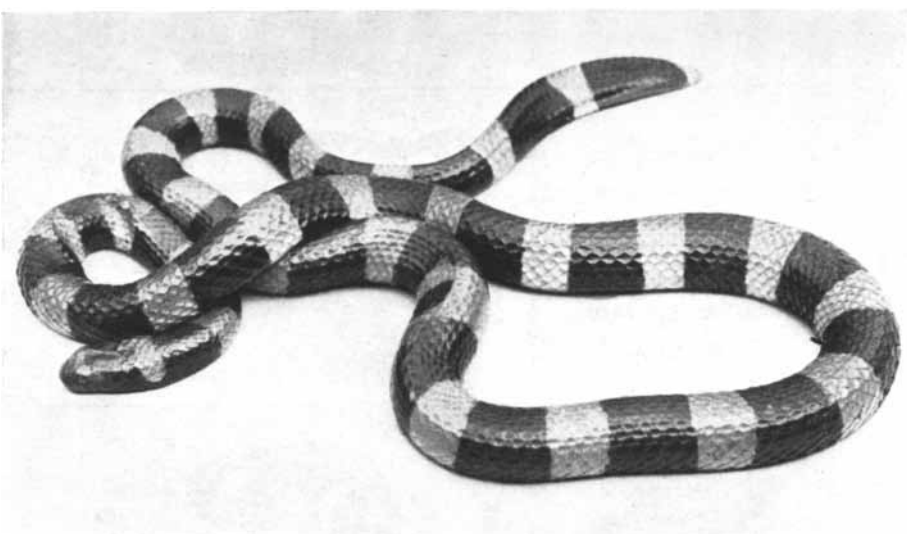
Many snakes are aggressive only under certain conditions or at particular times. An experienced herpetologist told me of his first experience with kraits in Java: "When the natives brought them in during the day, they were just as limp as so many pieces of rope, and I thought the krait was the most overrated snake in the East Indies. But that night I looked into the cage, and they were alert and full of the devil." An Indian physician, M. L. Ahuja, reports that in India most bites by the krait are inflicted at night, sometimes upon sleeping persons.

Among the other large and aggressive snakes, the mambas (*Dendroaspis angusticeps* and *D. polylepis*) of the African forests have great quickness and a fondness for climbing that permits them to inflict bites on the face and other upper parts of the body. The Australian taipan reaches a length of 10 feet or more and is reported to have a venom at least as toxic as that of the tiger snake. It is said to attack without provocation, and it has been known to bite effectively through a boot and a heavy sock.

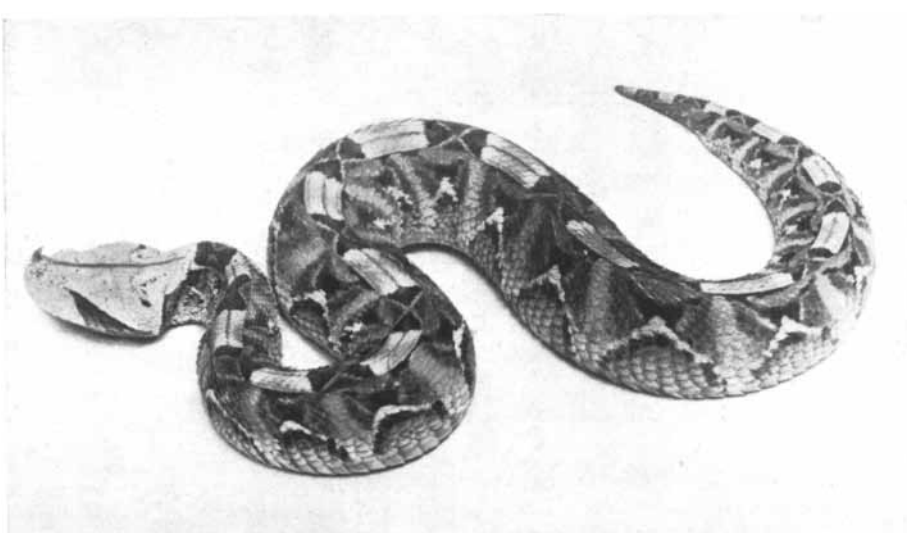
Occasionally a dangerous species may be underestimated by authorities who have had only limited experience with it. The great American herpetologist John E. Holbrook considered the coral snake



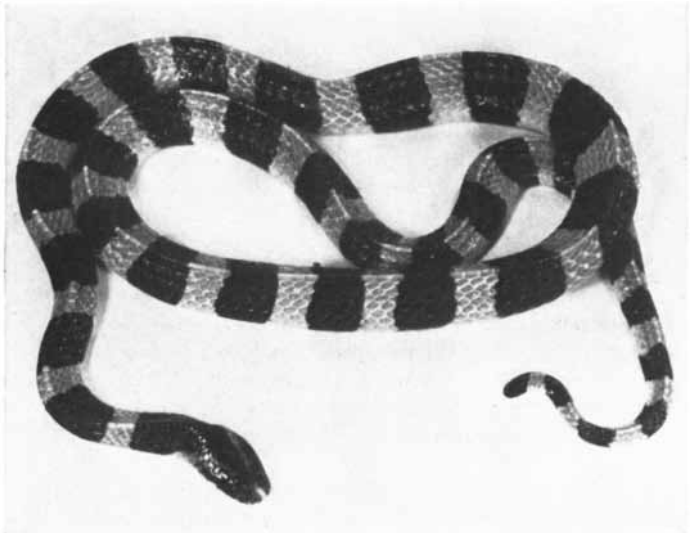
Jararacussu **(Bothrops jararacussu)**



Sea Snake **(Laticauda colubrina)**



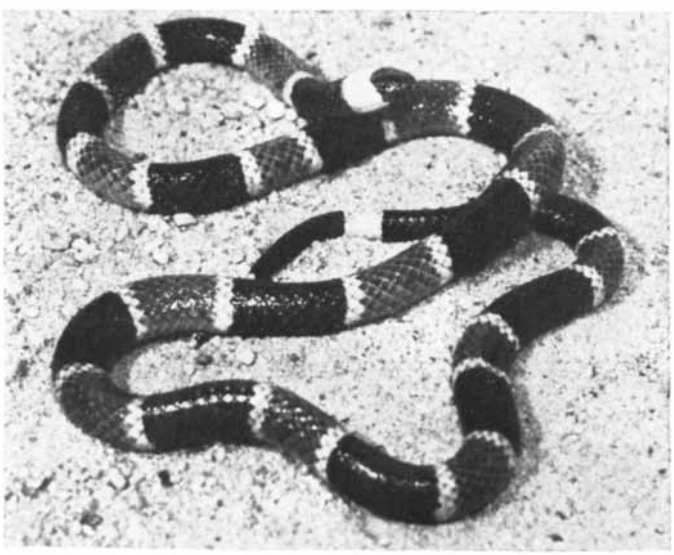
Gaboon Viper **(Bitis gabonica)**



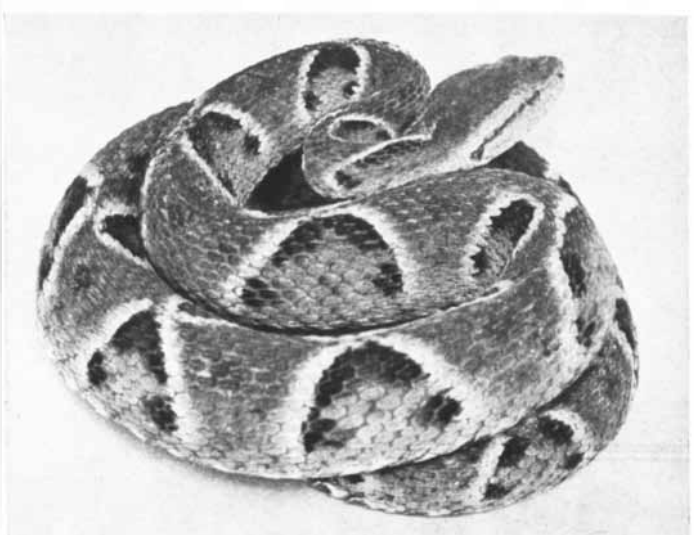
Banded Krait (Bungarus fasciatus)

Russell's Viper or Tic Polonga (Vipera russelli)

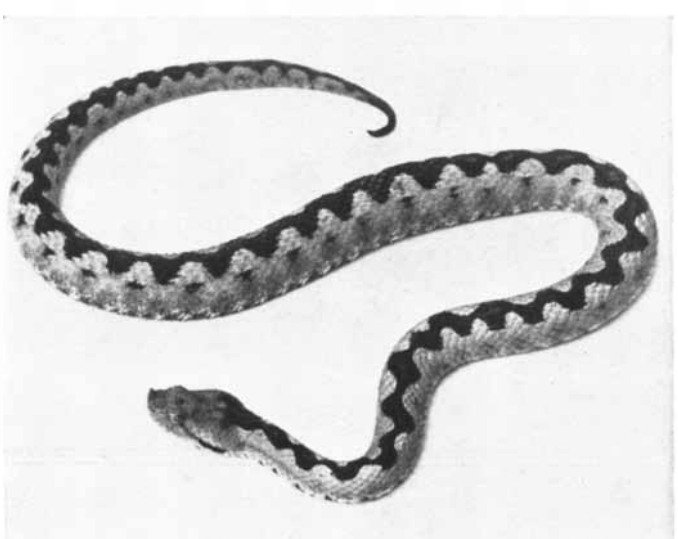
Indian Cobra (Naja naja)



Coral Snake (Micrurus fulvius)



Fer-de-lance (Bothrops atrox)



Long-nosed Viper (Vipera ammodytes)

of the southern U. S. (*Micrurus fulvius*) almost innocuous, and this opinion was prevalent among naturalists for many years. Our information now indicates, however, that coral snake bites are fatal in at least 20 per cent of the cases.

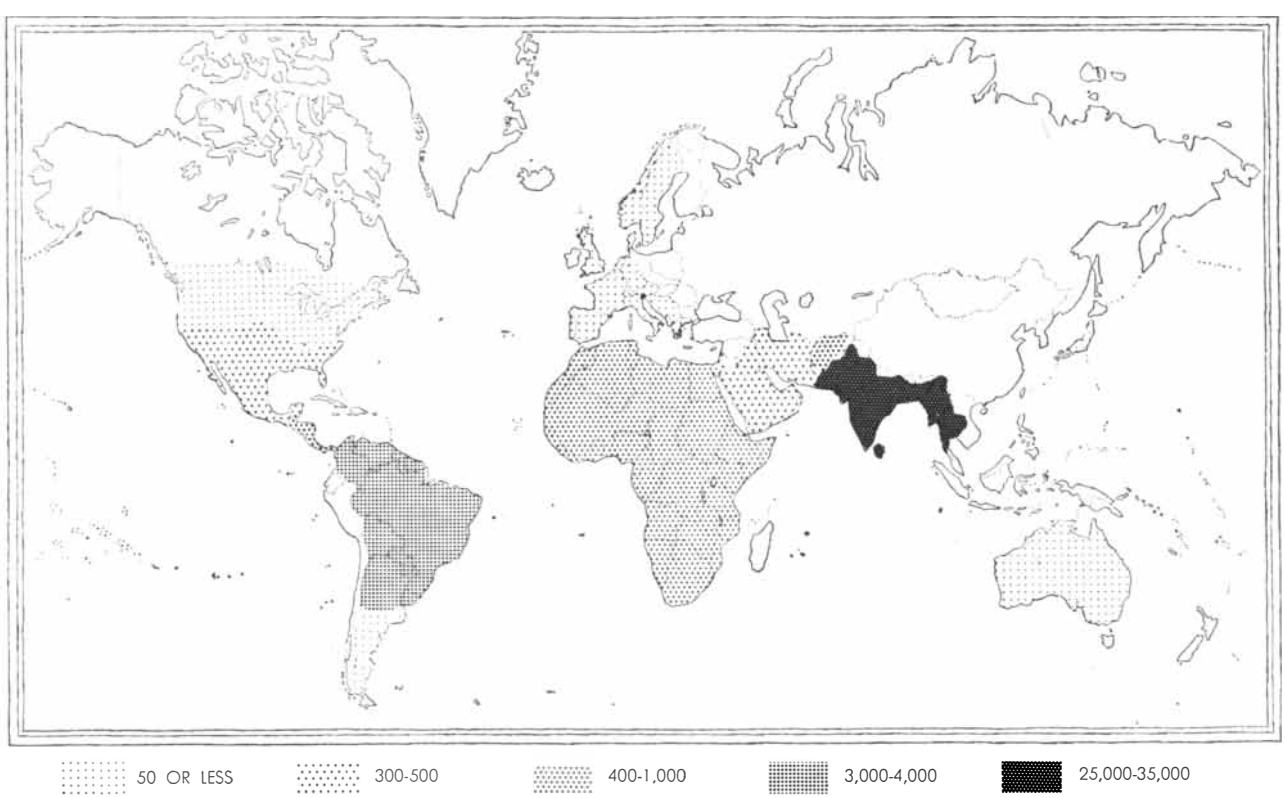
One of the most deadly of the small snakes is the saw-scaled or carpet viper (*Echis carinatus*), found in arid regions of the subtropical belt from India to West Africa. This evil-tempered serpent's venom is so toxic that fatalities from its bite have exceeded 80 per cent in some localities. A herpetologist who served with the U. S. Air Force in India during World War II returned with two of these reptiles and told me: "When I saw the first one, I knew it was some sort of small viper and guessed it was no more dangerous than our little pigmy rattlers. I didn't have a stick, so I just pinned its head with my fountain pen and grabbed it by the neck. I didn't know what a chance I'd taken until later, when I heard that a native had died from the bite of one of these snakes just 10 inches long. The one I picked up was more than twice that size." Incidentally, the "dusty brown snakeling" mentioned in Rudyard Kipling's "Rikki-tikki-tavi" was probably a carpet viper rather than a krait, which is a fair-sized serpent with a vivid ringed pattern.

A snake in the wild is not, of course, dangerous to the human population, and so some of the most deadly species are not much of a menace. For example, the taipan, a truly formidable reptile, kills few persons, for it has a rather limited range in thinly settled northern Australia. The mambas, the bushmaster and to a lesser extent the king cobra are primarily forest snakes whose contacts with human beings are rare. It is the snakes which thrive in heavily populated areas of the world that account for most of the deaths from snakebite. In some countries they are a fairly important public health problem.

How much of a problem they are depends in part on the customs and economy of the region. In the midwestern farm belt of the U. S. snakebites are rare, because mechanized agriculture creates conditions unfavorable for snakes and minimizes the farmers' exposure. In tropical and subtropical plantations, where hand labor predominates, the danger is much greater. Brush and other rubbish piled in the fields provides habitats for snakes, and some types of agriculture foster rats and other small rodents, which are a favorite food of many poisonous snakes. Irrigation seems to have been followed by increase of some kinds of rattlesnakes in the U. S. Southwest. Houses of thatch or loosely laid stone may provide refuges for snakes. A people who go about in bare legs or feet are vulnerable to short-fanged snakes such as the kraits. People who sleep on mats spread on the ground run a greater risk than those who use beds or hammocks.

Religious protection of snakes (*e.g.*, in parts of India, among the Hopi Indians in the U. S. and in rattlesnake cults of Southern mountaineers) increases the snakebite toll, and so too does the profession of snake charming. When religious zealots or entertainers handle poisonous snakes, the risk is very great. More often than not, however, the snakes are "milked" before handling, or their fangs are broken, or their mouths are sewed shut or otherwise mutilated. Some snake charmers actually handle only nonpoisonous reptiles, although they may exhibit poisonous ones.

Reliable information on the number of snakebites or snakebite deaths is at best difficult to obtain: for a region such as tropical Africa there is not enough information even for an intelligent guess. But the World Health Organization has collected approximate figures for a number of areas of the world. These indicate that southeastern Asia has the highest



MORTALITY DUE TO SNAKEBITE is plotted for those areas for which information is available. The numbers at the bottom represent the approximate number of people killed by snakebite each year in that area. The mortality is highest in Southeast Asia.

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Visible image in 1 minute

Box at right shows how xeroradiography works. There are three methods of utilizing this new inspection tool:

(1) Image can be viewed directly on original plate.

(2) Film record can be made by photographing the plate.

(3) Permanent paper "print" can be made directly from the plate.

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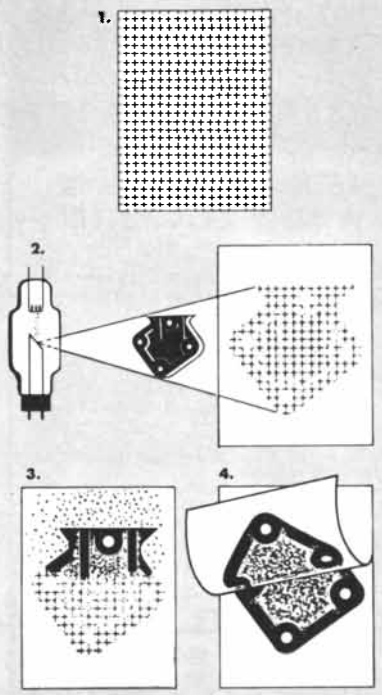
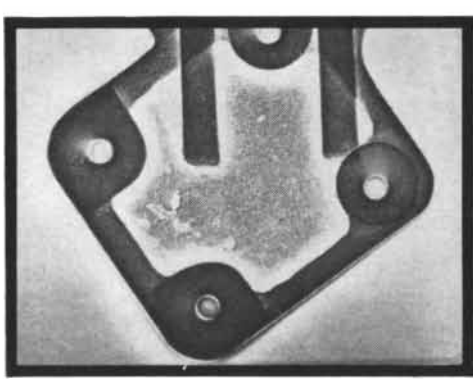


1. Aluminum plate, coated with photo-sensitive selenium, receives positive charge which is lost when exposed to x-rays.

2. X-rays penetrate specimen as in conventional radiography. Charge on plate "leaks" away proportionately to degree of x-radiation.

3. Negatively charged powder from spray gun adheres to positively charged area. Density varies with amount of charge. Image can be viewed directly, copied on film record, or transferred to paper.

4. Print can be made by pressing special paper on plate by rollers. Powder from plate is transferred, giving a positive image which is fixed permanently by applying heat. Plate is cleaned for re-use.



Xeroradiographic print of an aluminum casting. Note clear-cut definition of the dispersed porosity in the central section.

Xeroradiographic equipment (l. to r.): development unit, cleaner-cycler-charger-storage unit, accessory viewing unit.

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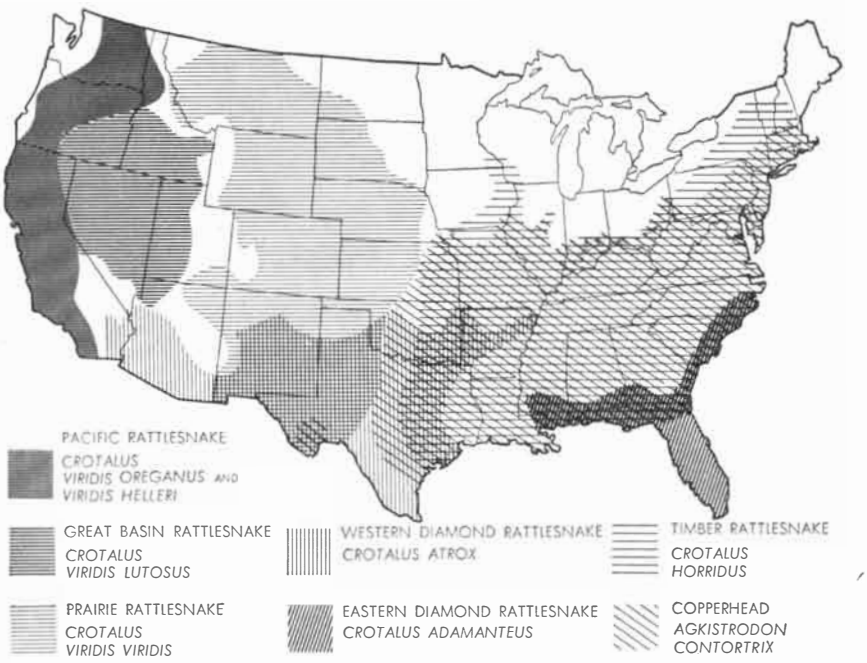


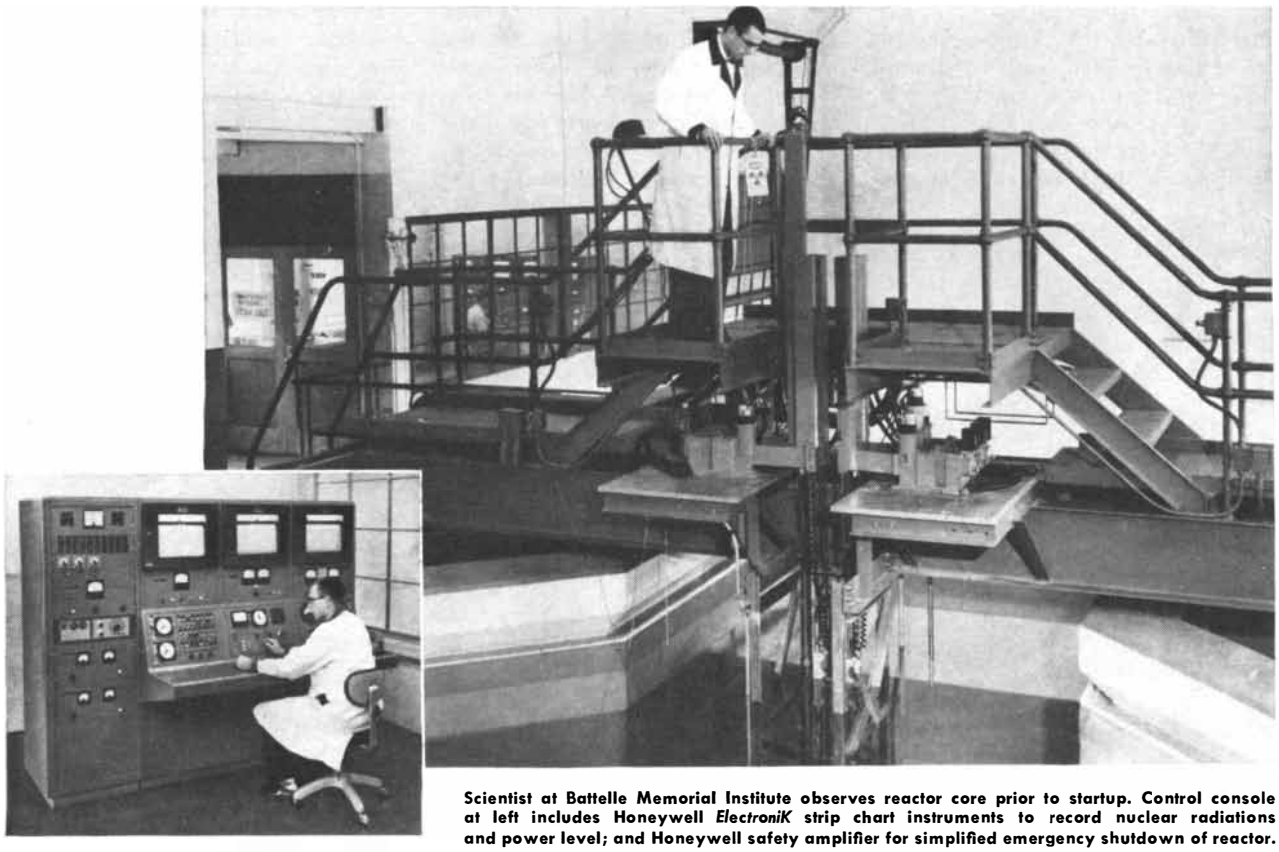
DISTRIBUTION OF SIX RATTLESNAKE SPECIES and the copperhead in the U. S. is plotted on this map. Some rattlesnake species are shown in the photographs on page 122.

death rates from snakebite. The most dangerous area seems to be in the Irrawaddy and Chindwin valleys of Burma, where several districts report 30 to 35 deaths per 100,000 of population annually. In India the rate is 10 to 12 per 100,000 in the worst areas, West Bengal and the Ganges delta. India as a whole reports some 7,000 to 12,000 snakebite deaths each year. The snakes most frequently incriminated in southeastern Asia are the Indian cobra, kraits and Russell's viper. All these species are well adapted to life in heavily populated areas, even within large cities. W. H. Headlee, recently returned from Thailand, tells me that cobras are found regularly in residential districts of Bangkok.

Next to Southeast Asia the second most dangerous area is tropical America, where the snakebite mortality is about 3,000 to 4,000 annually. Here the important species are the fer-de-lance and two of its close relatives, the jararaca and the jararacussu. These snakes are plentiful on sugar and coffee plantations.

North America, according to the World Health Organization study, has some 300 to 400 snakebite deaths per year. Only a minority of these occur in the U. S. In recent years the total number of deaths from poisoning by all types

WATER MOCCASIN (*Agkistrodon piscivorus piscivorus*) is photographed in its natural habitat. This snake, a member of the family Crotalidae, is closely related to the copperhead.



Scientist at Battelle Memorial Institute observes reactor core prior to startup. Control console at left includes Honeywell *ElectroniK* strip chart instruments to record nuclear radiations and power level; and Honeywell safety amplifier for simplified emergency shutdown of reactor.

Honeywell packaged control console

operates new swimming pool reactor

A new nuclear reactor, key part of the nation's first complete, privately-operated atomic research center, features a Honeywell control system. This new swimming pool type reactor at the Battelle Memorial Institute's Atomic Energy Research Center, Columbus, Ohio, was built by American Machine and Foundry Company. Honeywell engineered the electronic control portion of the console to AMF specifications, and delivered the console to the site completely assembled, ready for immediate installation.

The system features the new Honeywell-developed safety amplifier which provides simplified emergency shutdown of the reactor. Extra fuses and fast-acting relays overcome the dangers of locked magnets, snagged contacts and short circuits. Included in the system are a low-level period amplifier, which differentiates the log count rate meter output to give a period signal for safety during start-up, and a log N and period amplifier with two functions combined in a single unit for extra convenience and economy.

Honeywell's specialized staff of nuclear control engineers have been active in the atomic research program since its inception. Whether you're working with nuclear reactors for research, power or production, you'll find it advantageous to call on Honeywell for full control engineering service . . . including assistance with installation, testing and follow-up. Call your nearby Honeywell field engineer. He's as near as your phone.

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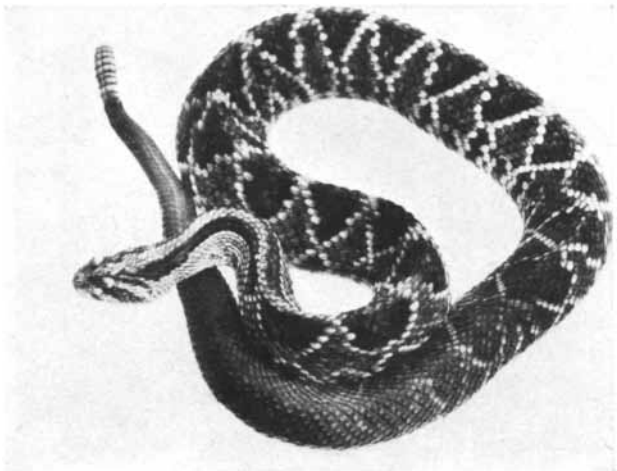
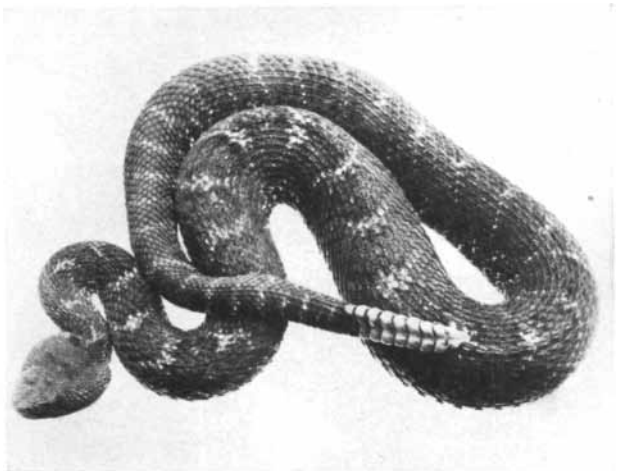
of venomous animals in the U. S. has ranged from 40 to 78. Scorpions in Arizona account for a fair number of deaths, and black widow spiders and other poisonous arthropods contribute a few more. It is likely that the average number of deaths from snakebites in the U. S. is less than 50 a year. Most of these can probably be charged up to rattlesnakes, particularly the eastern and western diamondbacks. The low mortality rate can be credited in part to the fact that snakebite victims usually get prompt and lavish medical care.

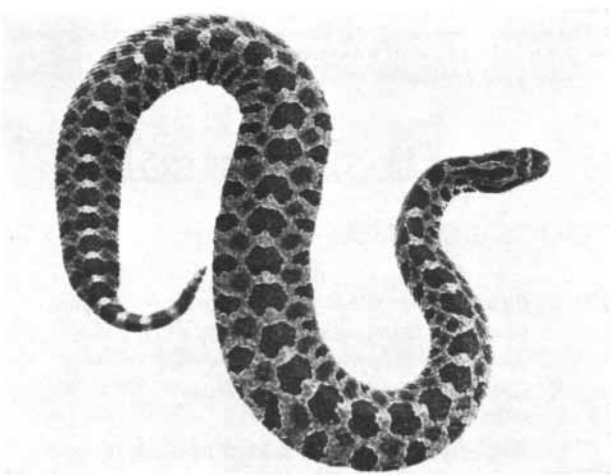
It is plain that mankind has reason to fear snakes, and rather surprising that more study has not been given to their venomous powers and contacts with the human population. Further research would make these dangerous enemies less formidable.



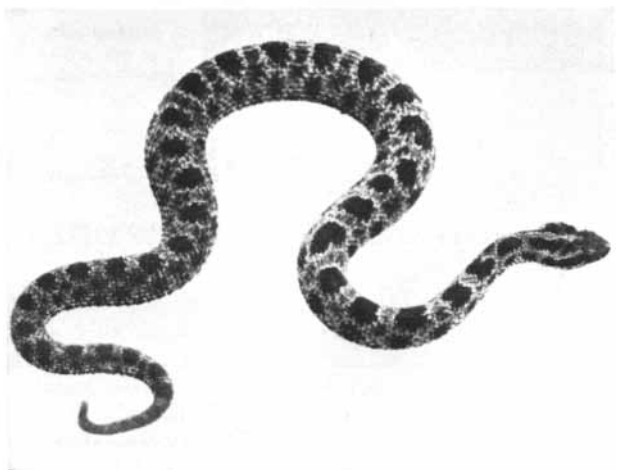
Central American Rattlesnake (Crotalus durissus durissus)



Arizona Black Rattlesnake (Crotalus viridis cerberus)



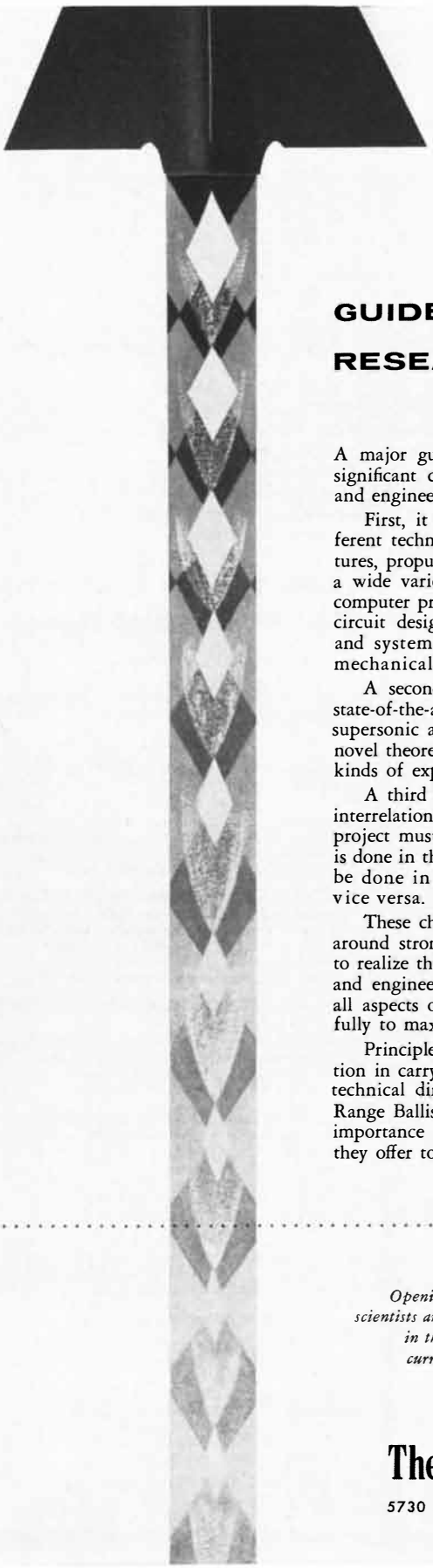
Eastern Massasauga (Sistrurus catenatus catenatus)



Southeastern Pigmy Rattlesnake (Sistrurus miliarius barbouri)

Western Diamondback Rattlesnake (Crotalus atrox)

Tiger Rattlesnake (Crotalus tigris)



GUIDED MISSILE RESEARCH and DEVELOPMENT

A major guided missile research and development program has several significant characteristics that are of particular interest to the scientist and engineer.

First, it requires concurrent development work in a number of different technical areas such as guidance and control, aerodynamics, structures, propulsion and warhead. Each of these large areas in turn contains a wide variety of specialized technical activities. As an example, digital computer projects in the guidance and control area involve logical design, circuit design, programming, data conversion and handling, component and system reliability, input-output design, and environmental and mechanical design.

A second characteristic is frequently the requirement for important state-of-the-art advances in several of the technical areas. For instance, the supersonic airframe needed for a new missile may necessitate not only novel theoretical calculations, but also the design and performance of new kinds of experiments.

A third characteristic of missile development work is that such close interrelationships exist among the various technical areas that the entire project must be treated as a single, indivisible entity. For example, what is done in the guidance portion of the system can affect directly what must be done in the propulsion and airframe portions of the system, and vice versa.

These characteristics make it clear why such work must be organized around strong teams of scientists and engineers. Further, for such teams to realize their full potential, they must be headed by competent scientists and engineers to provide the proper technical management. And finally, all aspects of the organization and its procedures must be tailored carefully to maximize the effectiveness of the technical people.

Principles such as these have guided The Ramo-Wooldridge Corporation in carrying out its responsibility for overall systems engineering and technical direction for the Air Force Intercontinental and Intermediate Range Ballistic Missiles. These major programs are characterized by their importance to the national welfare and by the high degree of challenge they offer to the qualified engineer and scientist.

Openings exist for scientists and engineers in these fields of current activity:

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Communications Systems
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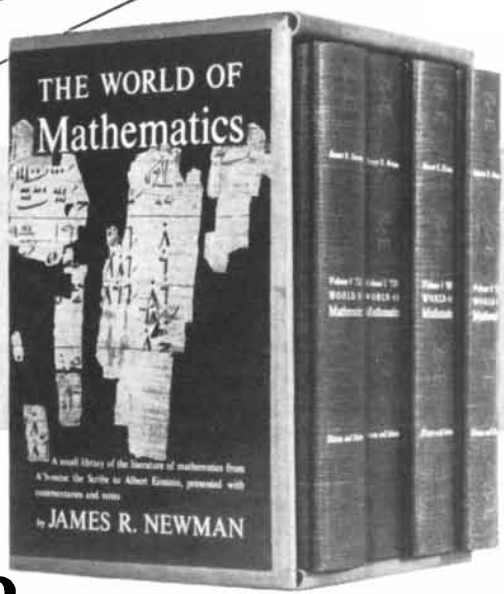

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BOOKS

A straightforward description of how an electronic computer does its work

by James R. Newman

FASTER, FASTER, by W. J. Eckert and Rebecca Jones. McGraw-Hill Book Company, Inc. ($3.75).

Electronic computers are hard to explain. This 160-page book is the clearest and most explicit account I have seen of the anatomy and operations of an electronic calculator. It deals with its subject in plain—though not easy—talk, plain enough on the whole for anyone who does not insist on being carried through a book and fanned with palmetto leaves every page of the way.

The machine the authors describe is the NORC, designed and built for the Navy as a research and development project at the Watson Scientific Computing Laboratory, operated jointly by Columbia University and the International Business Machines Corporation. NORC is the most powerful calculator now in operation. Its size, efficiency and capacity are impressive. There are five main portions: (1) a division which does the computing; (2) a random-access storage, whose tubes have a memory capacity of 3,600 "words"; (3) magnetic-tape units which read information into the machine, store intermediate results and record the final ones; (4) an output printer; (5) a control console.

NORC can perform and check 15,000 operations a second. Its two universal registers, where the arithmetic operations are performed, handle one million digits per second. The basic pulse of NORC is maintained by a system of equally spaced signals which throb through the machine at the rate of a million per second. For example, an operation such as "7 and 5 are 2 and 1 to carry" or "5 times 7 are 5 and 3 to carry" requires one microsecond. The pulse rate could be stepped up, but thus far the computer keeps well ahead of its masters simply by doing several things at once: for instance, in multiplication it performs 13 basic multiplications and additions simultaneously in a microsecond.

Many large electronic calculators use the binary system, in which all numbers are expressed by combinations of the two digits 0 and 1. NORC is a decimal machine, but it uses only the four digits 1, 2, 4 and 8 (in combination when necessary) to represent the digits from 1 to 9. The machine's method of "reading" and "writing" resembles the Braille system used by the blind. The information with which it deals is represented by numbers designated by a set of dots arranged in a matrix. The combinations of the matrix permit the writing of 16 characters. The presence or absence of a dot in a specific position is called a "bit" of information; four bits make a character, and a group of characters read as a unit constitutes a "word." NORC handles "words" of 16 decimal digits (64 bits) and two additional bits which are an "accuracy check." Sixteen decimal digits and a check also constitute an instruction word.

NORC does arithmetic pretty much as we do it. Suppose you wish to perform the following addition:

$$\begin{array}{r} 3694 \\ 8362 \\ \hline 12056 \end{array}$$

You start at the right and say: "4 and 2 are 6; 9 and 6 are 5 and 1 to carry; 6 and 3 and 1 are 0 and 1 to carry." The machine makes the same "statements," but at the rate of a million a second. Subtraction is done by complements. A subtraction which we would carry out this way:

$$\begin{array}{r} 3697146 \\ 2862159 \\ \hline 834987 \end{array}$$

is solved by the machine as follows:

$$\begin{array}{rr} & 10000000 \\ - & 2862159 \\ \hline & 7137841 \\ + & 3697146 \\ \hline & 10834987 \end{array}$$

The reason for using this trick is that it is easy to build a device which forms complements, and with its help subtraction can be performed by the regular addition machinery.

In performing a multiplication by hand we wait until all the multiples are completed before adding up the digits in the columns, but the machine gains some of its speed by starting the addition immediately. No sooner does the multiplication begin than the columns of subproducts flow into adding boxes. As the subsums from right to left are computed, they immediately flow into registers until the complete product has been formed. NORC divides as we do except that it does not have to fumble around making estimates of how many times the divisor goes into the partial dividend. The machine always chooses the correct multiple: the product generator provides all nine multiples of the divisor, they are tried simultaneously, and the correct one is selected and used.

What the authors describe as the most distinctive electronic element in NORC is its "dynamic pulse circuit." This is a small assembly of vacuum tubes, resistors, capacitors and diodes which operates as a unit. It can be thought of logically as "a little black box having an input terminal and an output terminal, each of which can be attached to a signal line of the machine. The box has the property that, when a signal is received at the input terminal at any given tick of the clock, a new signal will be emitted at the output at the next tick of the clock." Some 1,500 of these units constitute the backbone of NORC. One of their valuable features is their ability to transform a pulse which has been delayed or received in badly mutilated form into a "newborn pulse" which is "healthy, sharp and properly retimed." This is essential to the success of the machine, for it must without error or faltering circulate and shuttle back and forth billions of pulse signals in solving a single problem.

The dynamic pulse unit is so constructed that it can hold or store information in the logical and arithmetical

portion of the machine during the various operations. Normally when a unit has received a signal it emits a similar signal a millionth of a second later. But by a simple switching operation the output terminal of the unit can be connected to its own input, so that the signal continues to circulate until the electronic switch is cleared. By this method of marking time a signal can be held for as many microseconds as desired, until certain other steps have been completed and the information carried by the signal is needed for another operation.

NORC's memory consists of a set of storage tubes resembling television tubes. Information is recorded on the face of each tube and is read back when called for. Since the information, recorded in dots and dashes by an electron beam, fades rapidly, it has to be "refreshed," but this can be done as often as needed. The storage operates on an eight-microsecond schedule. In this interval it is possible to store a word, recover it or refresh it. If in an interval a word is not stored or used, it is automatically refreshed. The refreshing routine for the 3,600 locations, which are "visited one after the other in a fixed order," takes 29 thousandths of a second. Each tube in NORC has 900 bit-locations; 66 tubes, therefore, have a capacity of 900 words, and four sets of 66 tubes are used to store 3,600 words.

The recording of a bit of information on the face of a tube has some resemblances to the playing of a stream of water from a hose. The beam emitted from the rear of the tube strikes the surface with considerable force. Focusing on a small spot is accomplished by an adjustment similar to that of a hose nozzle. Some of the electrons that hit the desired spot stick to the surface, some knock other electrons out of it. Because more electrons are knocked out than stick to the interior surface, a "hole" is dug in the surface where the beam strikes. The "hole" grows only to a certain depth, for after a while it starts to "fill itself" from the surrounding material which "slides in." Thus an equilibrium is attained. To fill the "hole" one directs the beam at a nearby spot and the resulting "debris" fills up the "hole." To read information stored in the tube, "a conducting surface, to which a wire is attached, is placed outside the tube. While a hole is being dug at a spot by a beam, the electronic charge at the spot will change, and this change of charge will cause a small voltage pulse to appear on the wire attached to the conducting surface. This pulse is referred to as a 'dig pulse.' When the 'hole' is completed, the signal will cease. If the electron beam is then turned off and a short time later turned on while positioned at this previously dug 'hole,' no 'dig pulse' will appear, since the 'hole' has already been dug deep as possible. If, however, after digging the 'hole,' the electron beam is moved slightly to one side, the 'hole' will be filled. When the beam is again directed at the original spot, the signal will appear on the wire. Thus, by directing the beam at a spot, we can tell whether on the previous visitation the 'hole' was left open or filled. The signal must be amplified about 10,000 times to make it equal in amplitude to signals used elsewhere in the machine." A filled hole can represent the presence of a dot; an unfilled hole, its absence.

It is interesting to observe how well the code language of the machine lends itself to the properties of the magnetic tape. A small area of such a tape may be thought of as an aggregate of a large number of minute bar magnets, each with a "north" pole and a "south" pole. If most of these tiny magnets point in the same direction, the entire area will behave as a large magnet pointing in that direction. The areas themselves are oriented along the tape. As a tape moves rapidly past a small electromagnet—the "head" used for reading or writing—each change in the direction of the current of the coil produces a change in the direction of magnetization on the tape; conversely each change in the direction of magnetization on the tape moving under the "head" causes a pulse to appear in the coil of the electromagnet. A change of magnetic direction from north to south or *vice versa* is used to indicate a zero (absence of a dot) and "no change" is used to indicate a dot. Number words and instruction words, each consisting of 16 decimal digits, can thus be inscribed on or taken from the tape in the characters of the code.

What are the instructions of the machine and how are they executed? The basic procedure is to store information in the 3,600 locations and to have the machine visit each of them in succession and in an unending cycle to get orders. To illustrate the work entailed, consider the problem of computing the square root of a number, which involves successive approximations. For example, to take the square root R of a number N we can use the formula:

$$R = \tfrac{1}{2}\left(R_0 + \frac{N}{R_0}\right)$$

R_0 is the first approximation. In taking the square root of 2, we can start with 1 as a rough approximation, and the formula gives $R = 1.5$. The machine can be instructed to reapply the formula with closer and closer approximations until the difference between R^2 and 2 is less than the digit 1 in the tenth decimal. If it is required of the machine that it perform a sequence with instructions in locations 1 to 100 and repeat it six times, the procedure is roughly as follows. The number 6 is placed in a location higher than 100, say 150. In location 99 there is placed an instruction to subtract 1 from the number in location 150 and place the result in that location. In location 100 we place an instruction which says "Go to location 1 for the next instruction if the number in 150 is positive." The seventh time around the loop the number in 150 will of course be negative, since the positive number 6 will have been exhausted by six successive subtractions of 1. The transfer will therefore not take place; instead the machine will resume its rounds and turn to location 101 for its next instruction.

An instruction word consists of several parts, which may be designated as "check," P, Q, R, S and T, the letters representing numbers which specify arithmetical operations to be performed, storage locations, transfers and the like. For example, the instruction, "Take the number in storage location 168, multiply it by the number in location 362, round the answer to 5 decimals, and store the result in storage location 753," would in machine code be written:

Check	P	Q	R	S	T
	07	24	0168	0362	0753

Even this cursory sketch of NORC should make clear that its main job is to produce mountains of "cheap arithmetic" in a comparatively short time. This is a valuable skill, for it is a remarkable fact, often overlooked, that many of the most difficult problems susceptible of mathematical treatment can be solved by simple counting—carried to enormous lengths. In order to shorten such tasks, complex and ingenious mathematical functions have been devised, but these themselves require tedious exercises and often yield approximations inadequate for the problems at hand. The great electronic calculators promise to overcome these obstacles to scientific advance.

The authors describe five kinds of problems accessible to an arithmetical approach. The simplest category consists of linear equations in elementary

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algebra. In a set of equations such as

$$x-2y+z=28$$
$$3x+y+2z=14$$
$$x+3y-z=-31$$

all the numbers are small integers and the problem can be quickly solved by a beginner. But consider the set:

$$0.8752x-2.0143y+1.1017z=29.8431$$
$$2.9468x+1.9842y+2.1106z=12.2672$$
$$1.0163x+2.9741y-0.9235z=30.4851$$

The solution involves 11 multiplications, 11 additions and 8 divisions. It would take even a skilled person half an hour with pencil and paper to do this problem. NORC—for which the problem is really much too small—could do it in a hundredth of a second. Ninety-six equations with 96 unknowns, whose solution involves 603,631 operations and would take a human being two years, can be solved by NORC in one minute.

NORC is very good on problems concerning the paths of projectiles, which call for numerical solution of a differential equation. The usual approach leads quickly to "formidable mathematical difficulties and involved analytical developments." But the machine can handle the problem simply by very rapid juggling of a whole series of equations of motion reflecting changes in speed, average speed, effect of wind resistance, effect of gravity and so on. Since the machine is tireless, time intervals can be made very small and as high a degree of accuracy can be attained as desired.

The electronic calculator has made feasible an arithmetical solution of the classic three-body problem—the interaction of three bodies in a gravitational field. Mathematicians and astronomers have occupied themselves with such concerns since Newton's time (our solar system with its nine major planets is a 10-body problem), but "no satisfactory solution in the mathematical sense has been found," though reasonably accurate practical solutions have been achieved by using much algebra and arithmetic. A few years ago an electronic computer tackled a six-body problem (Jupiter, Saturn, Uranus, Neptune, Plato and the sun). The paths of the five planets were traced backward to the year 1653 and forward to 2060. More than 12 million arithmetical operations involving 16-digit numbers were performed. The result was a tracking of the paths of these planets to a closer approximation than could be measured by observation.

The solution of partial differential equations (in which two or more independent variables are involved instead of one) poses the most severe difficulties. Erwin Schrödinger's equation for atomic and molecular systems, which corresponds to Newton's equations for planetary systems and the motions of ordinary bodies, has so far been solved for only the simplest cases, such as the hydrogen atom. In other instances the approximations have not been fine enough to give better than "more or less rough explanations" of the chemical properties of many atoms and molecules. Accurate numerical solutions for a number of important cases should now, the authors believe, be obtainable in a reasonable time with NORC. Similarly, with the help of this machine and its improved successors, physicists can hope to tackle complex problems in the theory of stresses and strains, the propagation of radio waves, diffusion, heat flow and the like. And even some of the intricate, troublesome problems of the theory of fluids, which when studied in fine detail seem to resolve into infinitely chaotic motions, may not lie beyond NORC's capacity.

NORC is a hard-working, superbly useful tool. It is absurd, nevertheless, to fall into a coma of veneration in speaking of it, to compare it to the brain. If we insist on congratulations, they should be addressed to ourselves, for it is man who is clever, not this nest of wires and tubes.

Short Reviews

ATOMIC QUEST, by Arthur Holly Compton. Oxford University Press ($5). ATOMS AND PEOPLE, by Ralph Lapp. Harper & Brothers ($4). These two books, covering similar ground, strikingly reflect important divergences in outlook on atomic energy in the U. S. Both volumes sketch the history of the atomic energy program, both discuss the peacetime use of atomic energy and the social and ethical consequences of nuclear weapons. But their points of view are very different. Compton, a Nobel prize winner in physics, was from the beginning a key figure in the atomic bomb project, and was director of the Metallurgical Laboratory when the first chain reaction was achieved. Having taken part in the day-to-day work as well as in most of the high-level decision making, Compton is in a good position to describe the progress of the bomb from the time of Albert Einstein's letter to President Roosevelt to the fateful events at Hiroshima and Nagasaki. He gives a de-

tailed account of these happenings, with a clear impression of the magnitude of the undertaking, the uncertainties that had to be overcome, the blunders made, the boldness, ingenuity and determination required to reach the goal. His disposition is to accept all that was decided and done by the men with whom he was associated as the best possible course. Compton not only sees both sides of every question but is sometimes apt to take both sides. Thus he upholds J. Robert Oppenheimer's integrity but approves the action of the men who dismissed him. Compton appreciated the arguments against using the bomb in Japan and respected the men who proposed them, but he ended on the official side because he also respected those who favored dropping the bomb. "Developments such as these," he says, "are beyond human control. They represent . . . an aspect of evolution. They are part of the life of society that follows from the endowment that man has been given by his Creator." Lapp is a pricklier fellow than Compton. He is a capable physicist who worked on the bomb and later held a high government post as an adviser on the military uses of atomic energy. In the past few years he has devoted his time to explaining to the public by his writings and lectures the implications of atomic warfare. More than any other single person he has hacked at the curtain of secrecy which keeps the public ignorant of atomic matters, and in the course of his disclosures he has dealt many blows to atomic officialdom. Lapp insists that official policy has been disingenuous and untruthful on such matters as the fission-fusion-fission bomb, fallout and the dangers of radiostrontium. He sets forth an astonishing record, supported by quotations from official spokesmen. It is to be hoped that his critique of policies of the Atomic Energy Commission will get a wider reading than the critical reports of the Joint Congressional Committee on Atomic Energy, which all too few persons have read.

RISK AND GAMBLING, by John Cohen and Mark Hansel. Philosophical Library ($3.50). Probability, said Bishop Joseph Butler, is the very guide of life. He might have added that it is an uncertain guide. Every day in every way we face uncertainties and have to act upon them. A pedestrian judges his chances of crossing safely against the light; an investor weighs the likelihood of a stock going up or down; a scientist assesses his evidence; a judge and jury balance testimony; a gambler decides how to place

his stakes. In large and small things we act on incomplete knowledge. How are our actions determined? Clearly we cannot take the time, even if we possessed the requisite skill and had gathered all the relevant data, to compute the mathematical probabilities involved. On the other hand we do not proceed haphazardly. Even children do not make purely random choices. Evidently certain principles underlie the way "we actually choose, estimate, predict, judge or take risks." This book by two British psychologists is a report of an experimental study of risk taking. They attempted to discover how we express our states of uncertainty, what principles guide us, how they change during development from childhood to maturity. A typical procedure was to ask a youngster to predict the colors of beads drawn from several urns containing both blue and yellow beads in different proportions. This, of course, is the classic example of an independent event, in that its outcome is wholly unrelated to the events preceding it. But just as older persons resist the idea of independence in chance sequences and are apt to think that if a coin falls heads six times in a row there is greater likelihood of its falling tails than heads on the seventh toss, so children favor the event which helps to even up matters. A child of six or seven tends to give judgments of alternate outcomes: after a blue bead comes a yellow, after a head, a tail, and so on. This is his way of saying the outcomes are independent. As children grow older, the authors found, they relinquish simple alternation and on some vague intuition of symmetry choose the outcome that has happened less often previously. In adolescence, with the advent of a greater sophistication, we begin to grasp the notion of true independence, but even so we still (following a deep-seated inclination, as if a normal distribution curve were built into the mind as the ideal model) favor a pattern of predictions according to which binary events occur with equal frequency. Other chapters in this interesting volume treat of our everyday processes of sampling, risk taking, guessing and estimating, subjective probability in gambling.

SYMPOSIUM ON MONTE CARLO METHODS, edited by Herbert A. Meyer. John Wiley & Sons, Inc. ($7.50). Since the concept of probability is itself subject to radically different interpretations, it is not surprising, as the editor of this volume points out, that the term "Monte Carlo methods" is in lively dispute. But for ordinary purposes it is sufficient to

define the approach as a method of solving an extremely complex problem by using a probabilistic model which in repeated trials yields closer and closer approximations to the solution of the equation. An ever-widening range of applications has been found for Monte Carlo, and the term undoubtedly has a picturesqueness and charm of its own, so that it is now synonymous "with any use of random sampling in treatment of either deterministic or probabilistic problems." In this symposium are gathered 20 papers based on talks at a statistical congress held at the University of Florida in March, 1954. They illustrate the omnibus character the term has assumed. Among the subjects are the problem of "random walks," the calculation of gamma-ray diffusion, the experimental determination of values in complex problems of aerodynamics, a Monte Carlo technique for problems of insurance mortality rates. An introductory paper by A. W. Marshall surveying the evolution and progress of Monte Carlo is most useful. This is an interesting collection which will appeal to specialists in several fields.

THE ACCIDENT SYNDROME, by Morris S. Schulzinger. Charles C. Thomas ($6.50). If a pedestrian is hit on the head by a falling flowerpot, or a passenger is injured in a train collision, it cannot be said that the victim contributed to his misfortune. There are, however, a great many accidents for which the persons involved are at least partly responsible. In recent years a theory has been advanced, and widely accepted, attributing most accidents to a "small, fixed group of 'accident-prone' individuals." These individuals, it is suggested, cannot avoid catastrophe—not because of unkind fate or the constellation under which they were born but because of psychological factors which make them peculiarly vulnerable to mishap, if, indeed, they do not directly invite it. The problem is serious: accidents annually kill 100,000 persons in the U. S., permanently disable 400,000 and cause a loss of $10 billion. Any theory, therefore, which sheds light on the causes of accidents, and thus offers the possibility of prevention, deserves a careful hearing. The author of this book is a practicing physician who over a 20-year period studied some 35,000 consecutive accidental injuries in a relatively stable population where he served as an industrial and family doctor. Dr. Schulzinger submitted this large body of information to statistical analysis. He concludes that the theory of accident-proneness on the

part of a fixed group in the population does not stand the test. Over a sufficiently long period of observation the small group responsible for most of the accidents is "essentially a changing group, with new persons constantly falling in and out of it." Accidents, says Dr. Schulzinger, are a widespread endemic affliction, part of a disease pattern—"the accident syndrome." At one time or another in their lives many persons are ideal candidates for accidents, but as circumstances change, this susceptibility fades. In other words, while the majority of accidents are not entirely accidental, they are apt to be solitary experiences. Foremost among the "accident makers" are maladjusted young males. Considering the average of persons, times and circumstances, an accident is "most likely to occur to: a young man, age 21, on a hot and humid summer day, during the months of June and July, on a weekend or holiday, while driving a car or with aggressive behavior, during the late evening hours if not working, . . ." and so on. The least likely person to suffer an accident is a "healthy, well-adjusted young girl, age 13, born and reared in a normal, secure and loving home," etc. Inexperience, drinking, fatigue, inner conflict, a strife-ridden home, over-authoritative parents, are among the factors augmenting the likelihood of an accident. Notable progress has been made during the past 50 years in the prevention of accidents by mechanical devices, by factory rules and procedures, by municipal ordinances. Training and education have helped. Nevertheless the number of accidents is steadily rising, and Schulzinger believes that the enormous effort expended in safety education has yielded disappointing results. His thesis suggests that the causes of accidents cannot be attacked successfully by appeals to reason, exhortations or the threat of punishment—any more than juvenile delinquency, say, can be reduced by such measures. What seems to be called for is a deeper social therapy.

THE EARTH WE LIVE ON, by Ruth Moore. Alfred A. Knopf ($6). Miss Moore's latest book is the story of geological discovery from the speculations of Hesiod to the geochronometrical theories of J. Laurence Kulp of the Lamont Geological Observatory. In no branch of knowledge have more exciting changes taken place, in none has there been more ingenious blending of observation and imagination. Miss Moore singles out the landmarks of geological thought and sketches the lives of

the men who made them. Jean Guettard in the 18th century was one of the first to recognize that the earth had an "unsuspected, perhaps a violent past." Later in the century the Frenchman Nicolas Desmarest and the German Abraham Gottlob Werner quarreled over whether basalt, the dense black rock spread over Europe, had been formed by volcanoes and fire or was a sedimentary stone which had settled down grain by grain in the ancient seas. It is through such quarrels that science advances. James Hutton conceived the earth to be a product of constant change, with enormous forces from below again and again bursting the crust and thrusting up new lands and mountains. The indefatigable Georges Cuvier, who discovered fossil elephants; his compatriot Alexandre Brongniart, who studied the marine shells of the Paris basin; and the self-taught English surveyor William Smith established in the early 1800s the principles of paleontological stratigraphy. They showed how the skeletons of ancient animals could be used to determine both the history of living organisms and the chronology of the changes in the earth itself. Louis Agassiz, the famous 19th-century naturalist, explored the crevasses of the Alps, climbed the Jungfrau, wrote a magnificent book on fossil fish and drew a picture of a world covered with ice. Sir Charles Lyell's *Principles of Geology* established an orderly system of the knowledge gained up to the 19th century and convincingly refuted old prejudices—among them the beliefs that earthquakes and floods were caused by a "mysterious and extraordinary agency" and that the earth was only a few thousand years old. The slow and inexorable forces of gravity, pressure, erosion and the like, said Lyell, were the primary explanation of the major changes that had taken place. Others whose labors Miss Moore describes include the paleontologist James Hall; the diminutive, one-armed John Wesley Powell, navigator of the wild Green and Colorado Rivers; Sir William Logan, who mapped the Canadian Shield; Clarence Dutton, student of the Grand Canyon district and of the high plateaus of Utah. The last section of the book deals with Harold Urey's researches on the origin of the earth; the inquiries of Sir Harold Jeffreys, Sir Edward Bullard and S. K. Runcorn concerning the earth's magnetism and internal structure; J. Tuzo Wilson's hypotheses as to how the continents grew; V. M. Goldschmidt's and Brian Mason's contributions to geochemistry, and Kulp's attempts to fix the age of the planet. It is a wonderfully varied chroni-

cle, well narrated. Miss Moore's explanations are not always as clear and sure as one would like, but this is a better job than her popularization of evolution, and it is a major merit of her survey that it does not duck the hard parts of the subject.

A PICTURE HISTORY OF MOUNTAINEERING, by Ronald W. Clark. The Macmillan Company ($5.95). From beginning to end this is an engrossing picture history of what Sir Frederick Pollock once called "a taste and a pursuit." Clark's account opens with a fine photograph of Mont Aiguille, climbed in 1492, with the aid of ladders and other "subtle means and engines," by Antoine de Ville on command of his liege, Charles VIII of France. Over the centuries, as the pictures show, the means and engines became subtler and more elaborate, but it was no longer necessary to enforce hazardous ascents by royal command. Many men were quite willing to risk their lives to experience the incomparable joy of standing on top of a high place. Before the end of the 19th century mountaineering had become a popular sport in the Alps, in the Caucasus, in North America and in the Himalayas. Among the early photographs in this book are gigantic wet plates made by the Bisson brothers in the Mont Blanc massif in 1860; also Vittorio Sella's masterpieces of glaciers and crevasses and his incomparable panoramic scenes of the Alps. Portraits are presented of the great Victorian and Edwardian climbers—Sir Alfred Wills, who first scrambled up the Wetterhorn; Edward Whymper, who conquered the Matterhorn; John Tyndall, a pioneer of the golden age of mountaineering, and many others. The text accompanying the pictures is too brief: one hungers for more information, but this itself is a tribute to the variety and interest of the illustrations.

EXCAVATIONS AT GOZLU KULE, TARSUS, VOL. II, edited by Hetty Goldman. Princeton University Press ($36). At the southwest edge of modern Tarsus in Turkey, rising conspicuously from the flat coastal plain, is a mound called Gozlu Kule. This heap, some 80 feet high and 1,000 feet long, is a veritable layer cake of history. The town of Tarsus was the capital of Cilicia and the birthplace of St. Paul. From the Neolithic Age through the present many peoples lived in the area; through successive accumulations and denudations the mound grew to its present size. It holds the remains of Hittite, Roman, Hellenistic and

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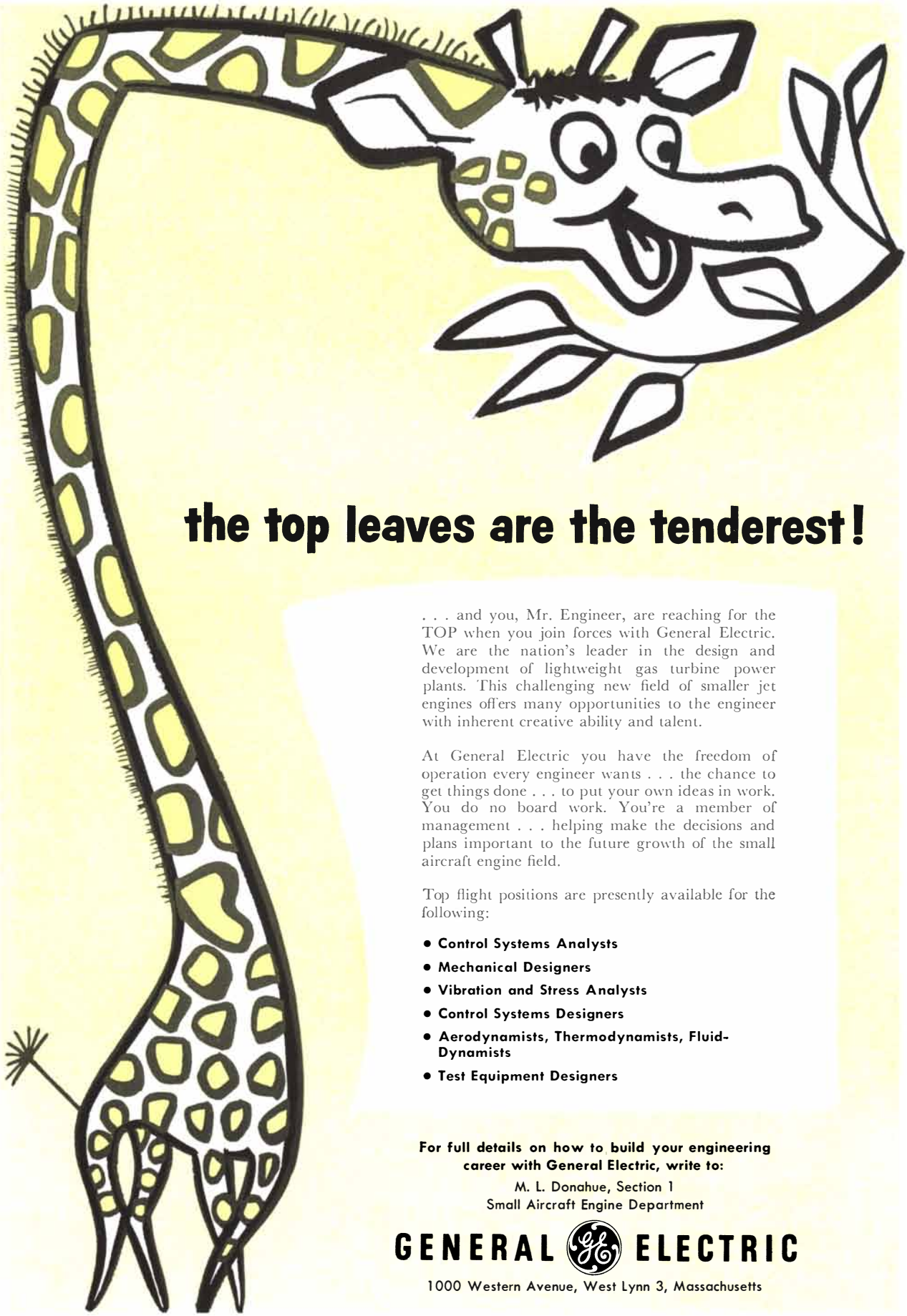
Islamic cultures. Between 1935 and 1939 Miss Goldman directed excavations in the mound under the auspices of Bryn Mawr College, the Archaeological Institute of America, the Fogg Art Museum and the Institute for Advanced Study. The investigations were interrupted by the war and resumed in the late 1940s. They uncovered houses and streets, graves and human skeletons, Hellenistic and Roman coins, lamps, vases, kitchenware, terra-cotta figurines, statues, tiles, ovens, hearths, cisterns, mangers, inscribed stones, gold and silver jewelry, loom weights, glass containers. It is a remarkable fact that one society built its structures directly on top of the remains of its predecessor. Sometimes the earlier works were erased; sometimes a telescoping of cultures occurred; sometimes the newcomers' activities merely blanketed the deposits below. Excavations had to stop at a depth of 100 feet, because of infiltration of water. But the diggers reached Bronze Age and Neolithic settlements containing pottery, obsidian flakes, hieroglyphic seals, knucklebones, nails, fishhooks, rivets, chisels, tweezers, needles, pins, knives, axes, arrowheads, spears, swords, mortars and pestles, amulets, bracelets, pendants, idols and miscellaneous other objects of stone, metal, clay and bone. In this book, consisting of four volumes (two of text and two of illustrations), the discoveries are meticulously described and pictured. Altogether Miss Goldman and her collaborators have produced a model report of a model excavation. While these are austere reference books for serious students, almost any reader leafing through the pages will be filled with admiration at the skill of archaeological reconstruction—the ability to reconstitute history by reading it backward and downward in a mound of debris.

Notes

INTRODUCTION TO MATHEMATICAL LOGIC, VOL. I, by Alonzo Church. Princeton University Press ($7.50). A revised and much enlarged edition of a basic treatise.

THE BIRTH OF CIVILIZATION IN THE NEAR EAST, by Henri Frankfort. Doubleday Anchor Books (85 cents). A reissue of an admirable book, with 32 pages of illustrations.

GASEOUS NEBULAE, by L. H. Aller. John Wiley & Sons, Inc. ($11). Volume three in the International Astrophysics Series.



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MATHEMATICAL GAMES

A new kind of magic square with remarkable properties

by Martin Gardner

Magic squares have intrigued mathematicians for more than 2,000 years. In the traditional form the square is constructed so that the numbers in each row, each column and each diagonal add up to the same total. Presented here is a magic square of a new type [*see below*]. It seems to have no system: the numbers appear to be distributed in the matrix at random. Nevertheless the square possesses a magical property as astonishing to most mathematicians as it is to laymen.

A convenient way to play the game is to equip yourself with five pennies and 20 little paper markers (say pieces of paper matches). Now ask your victim to pick any number in the square. Lay a penny on this number and eliminate all the other numbers in the same row and in the same column by covering them with markers. The victim then picks any uncovered number. Again, as before, you put a penny on this number and cover all others in the same row and column. Repeat this procedure twice more and you will have one uncovered cell left; you cover this with the fifth penny.

When you add up the five numbers covered by the five pennies, you get 57—the number of the New Year! This is no accident: you were able to predict in advance to your victim that the total would be 57, no matter what numbers he chose for covering by the pennies. Although his choices seemingly were made at random, actually they were forced in such a manner that the total was bound to be 57. It will be the same on every repetition of the experiment.

If you enjoy solving mathematical puzzles, you may wish to pause at this point to analyze the square and see if you can discover its secret yourself.

Like most tricks, this one is absurdly

19	8	11	25	7
12	1	4	18	0
16	5	8	22	4
21	10	13	27	9
14	3	6	20	2

A magic square

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	12	1	4	18	0
7	19	8	11	25	7
0	12	1	4	18	0
4	16	5	8	22	4
9	21	10	13	27	9
2	14	3	6	20	2

	1	2	3	4
0	1	2	3	4
4	5	6	7	8
8	9	10	11	12
12	13	14	15	16

An explanation of how the square is generated

simple when explained. The square is nothing more than an old-fashioned addition table, arranged in a tricky way. The table is generated by two sets of numbers: 12, 1, 4, 18, 0 and 7, 0, 4, 9, 2. The sum of these numbers, of course, is 57. If you write the first set of numbers horizontally above the top row of the square, and the second set vertically beside the first column [*diagram at left at the top of this page*], you can see how the numbers in the cells are determined. The number in the first cell (top row, first column) is the sum of 12 and 7, and so on through the square.

You can construct a magic square of this kind as large as you like and with any combination of numbers you choose. It does not matter in the least how many cells the square contains or what numbers are used for generating it. They may be positive or negative, integers or fractions, rationals or irrationals. The resulting table will always possess the magic property of forcing a number by the procedure described, and this number will always be the sum of the two sets of numbers that generate the table. In the case given here you could break the number 57 into any eight numbers that add up to that sum.

The underlying principle of the trick is now easy to see. Each number in the square represents the sum of a pair of numbers in the two generating sets. That particular pair is eliminated when a penny is placed on the number. The mechanism of the game forces each successive penny to lie in a different row and column. Thus the five pennies represent the sums of five different pairs of the 10 generating numbers, and the total is the sum of the 10 numbers.

One of the simplest ways to form an addition table on a square matrix is to start with 1 in the upper left corner, then continue from left to right with integers in serial order. A four-by-four matrix of this sort becomes an addition table for the two sets of numbers 1, 2, 3, 4 and 0, 4, 8, 12 [*diagram at right at top of this page*]. This matrix will force the number 34.

The forced number is of course a function of the size of the square. If n is the number of cells on a side, then the forced number will be $(n^3 + n)$ divided by 2. If you start with a number higher than 1 (call it a) and continue in serial order, the forced number will be $(n^3 + n)$ divided by $2 + n\ (a - 1)$.

By means of the second formula it is easy to calculate the starting number for

		3¼	

16¼	18¼	15¼	17¼
8¼	10¼	7¼	9¼
4¼	6¼	3¼	5¼
12¼	14¼	11¼	13¼

How to make a square that will produce any number

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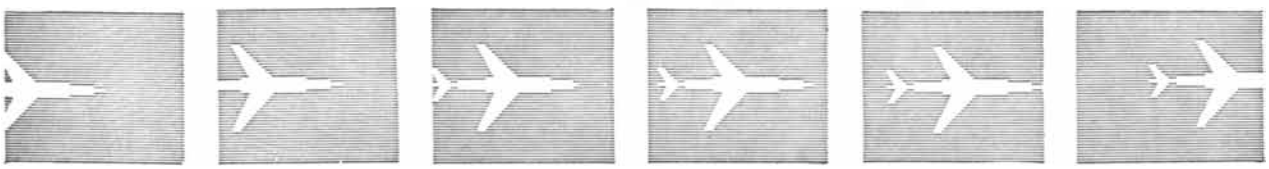
a matrix of any desired size that will force any desired number. An interesting impromptu stunt is to ask someone to give you a number above 30 (this is specified to avoid bothersome minus numbers), then proceed to draw quickly a four-by-four matrix that will force that number. The only calculation you need make (it can be done in your head) is to subtract 30 from the number he names, then divide by four. For example, he calls out 43. Subtracting 30 gives 13. Dividing 13 by 4 results in 3 1/4. If you put this number in the first cell of a four-by-four matrix, then continue in serial order with 4 1/4, 5 1/4 . . . , you will produce a magic square that will force 43. To make the square more baffling, however, the order of the numbers should be scrambled. For instance, you might put the first number, 3 1/4, in a cell in the third row [*diagram at left at bottom of page 140*], and the next three numbers (4 1/4, 5 1/4 and 6 1/4) in the same row in a random order. Now you may write the next four numbers in another row (it does not matter which), but they must be in the same order you followed before. Do exactly the same with the last two rows, and the final result will be the square shown [*bottom of page 140*]. (If you want to avoid fractions and still force the number 43, you can drop the 1/4 after all the numbers and add 1 to each of the four highest whole numbers, making them 16, 17, 18 and 19. Similarly you would add 2 to these numbers if the fractions were 2/4, or 3 if it were 3/4.)

Interchanges of order in rows or in columns have no effect on the square's magic property, and by scrambling the cells in this manner you make the matrix appear much more mysterious than it really is.

I have not been able to find out who first discovered this delightful version of the magic square, which is applicable to multiplication as well as to addition boxes. A stunt with numbered cards based on the principle was published by Maurice Kraitchik in his *Mathematical Recreations* in 1942. Since then several mathematically inclined conjurors have introduced variations on the theme. For instance, Mel Stover of Winnipeg observed that if you draw a square around 16 numbers on any calendar page (here's a use for your discarded 1956 calendar!) the square forms a table which forces a number twice the sum of the two numbers at diagonally opposite corners. The use of playing cards also opens up intriguing possibilities. The principle still has many ramifications to be explored.

ENGINEERS · SCIENTISTS



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THE AMATEUR SCIENTIST

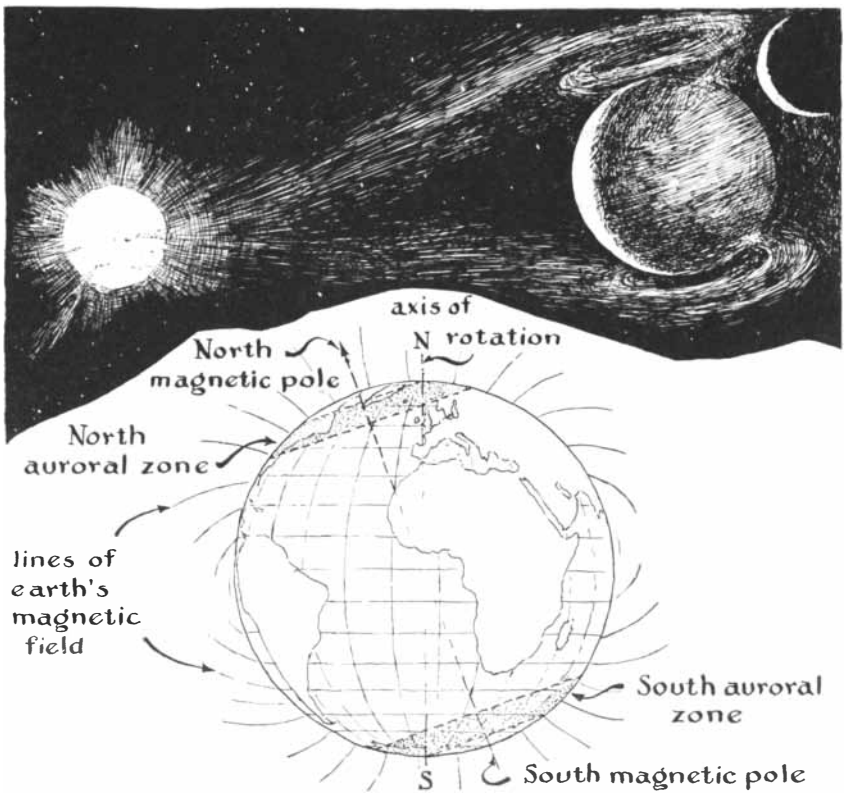
About amateur observations of the aurora during the International Geophysical Year

The International Geophysical Year, which gets under way in six months, will provide an unparalleled opportunity for amateur collaboration on group projects of high importance. Whether you go in for short-wave radio, weather watching, skin diving, stargazing, mountain climbing, perusing the old logs of clipper ships or any of a host of similar avocations, a place for your talents can be found on some scientific team of the IGY. During the period from July 1 of this year through December, 1958, specialists in many fields of science will be actively measuring the large-scale forces that shape our environment, and they are counting on help from amateurs.

No individual observer can see far enough to comprehend at any instant more than a small fraction of the planet's total geophysical pattern. As Lloyd V. Berkner, vice president of the Special Committee for the IGY, has pointed out, man's existence so far has been confined within a veneer at the surface of the earth about as thick, relatively, as the map paper covering a 12-inch globe. We can dive to the ocean's floor or dig holes in the earth about five miles deep. A rocket-powered plane recently carried an observer to an altitude of 25 miles. These excursions represent the present vertical limits of our firsthand observations. Within this relatively thin zone we can, at least potentially, roam the surface of the planet at will. But few observations at any one site are descriptive of the whole. The atmosphere and oceans are in complex fluid motion; sunlight, which powers terrestrial phenomena, falls unevenly on the surface of the earth; the forces at work in the interior constantly reshape the crust in varying amounts at unpredictable places and times. Accordingly, the only hope of answering the many unanswered questions of geophysics lies in gathering and analyzing the simultaneous observations of many scientists working in collaboration throughout the world. There are simply not enough scientists available for the job. Hence, if the objectives of the IGY are to be fully attained, amateurs must lend a hand.

One of the many facets of the IGY program to which amateurs can make a contribution is the observation of auroras. Under certain favorable conditions the night sky, particularly in the latitudes within about 20 degrees of the earth's magnetic poles, fills with magnificent displays of pastel-colored light called the polar aurora. From remotest times auroras have been a mixed source of mystery, awe, terror and delight. They have been ascribed to every conceivable cause from gods locked in battle to the bombardment of the atmosphere by solar debris.

Auroras are grouped in three main classes: rayed, homogeneous and pulsating. Fredrik Carl Stormer of Norway, the first dedicated student of auroras, subdivided their forms into arcs, bands, draperies, coronas and flames. It is now generally agreed that auroral displays are caused by energy from the sun. Some specialists suggest that the glow arises when jets of high-speed solar particles ionize the upper atmosphere by collision in a reaction like that observed in gas-discharge tubes. Others hold that the ionizing energy comes from ultraviolet rays liberated by the sun. Both ideas will be investigated during the IGY, along with numerous other questions. Do auroras occur in the daytime?



Electrified particles from the sun create auroral effects in the earth's upper atmosphere

How are they associated with geomagnetic storms? Why do some auroras penetrate to the low latitudes? Do auroras occur simultaneously at the North and South Poles? Do they ever meet at the geomagnetic equator? Such questions are broadly significant because auroras act as visual indicators of incoming energy and can serve as instruments for measuring and analyzing the effects of at least some portion of the total energy received from the sun.

Sydney Chapman, president of the Special Committee for the IGY and coordinator of the auroral program, writes the following review of the plans.

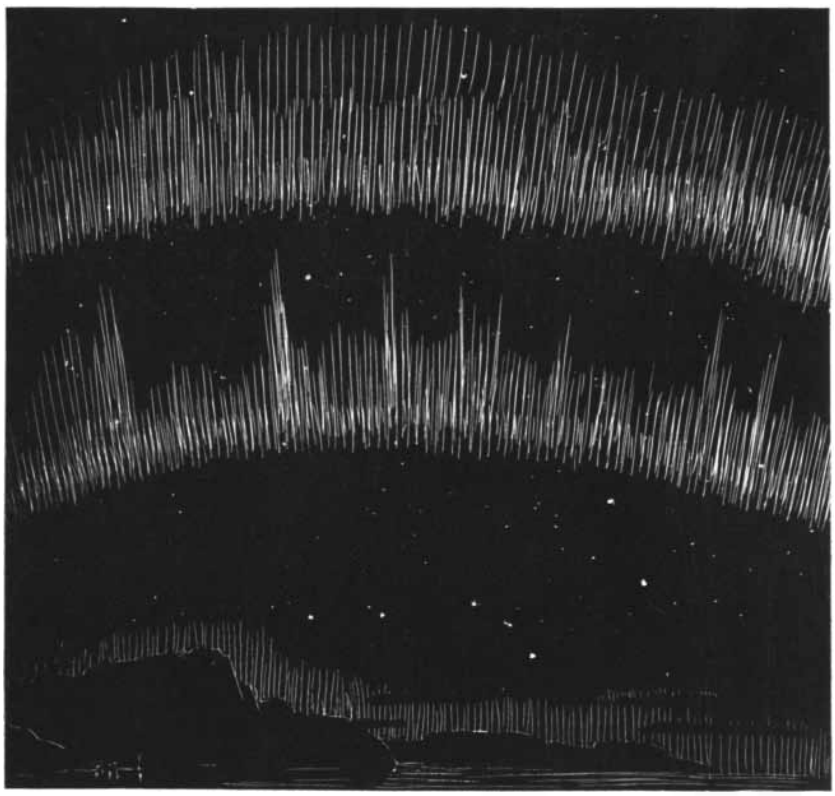
"I am glad to say that the IGY auroral program for the high latitudes is now well organized, both in the Arctic and the Antarctic. There will be networks of all-sky cameras, research by spectrographs, radar and other microwave apparatus as well as comprehensive coverage by visual observers.

"These facilities, however, will not cover the cases which are in some respects the most remarkable—the auroras that accompany great magnetic storms and extend far beyond the usual geographical range into the lower latitudes, sometimes even into the tropics. Many countries lying in the middle and low latitudes have failed to organize auroral programs, under the mistaken impression that the phenomenon never occurs in their locality. My object in addressing amateurs through these columns is to correct this impression and enlist their cooperation.

"It is not certain, of course, that there will be even one tropical aurora during the IGY. It is known, however, that they are most likely to occur in years when the sun is especially active and spotted, and it is expected that the IGY will span such a period. Moreover, a careful watch may prove that tropical auroras are not so rare as presently supposed.

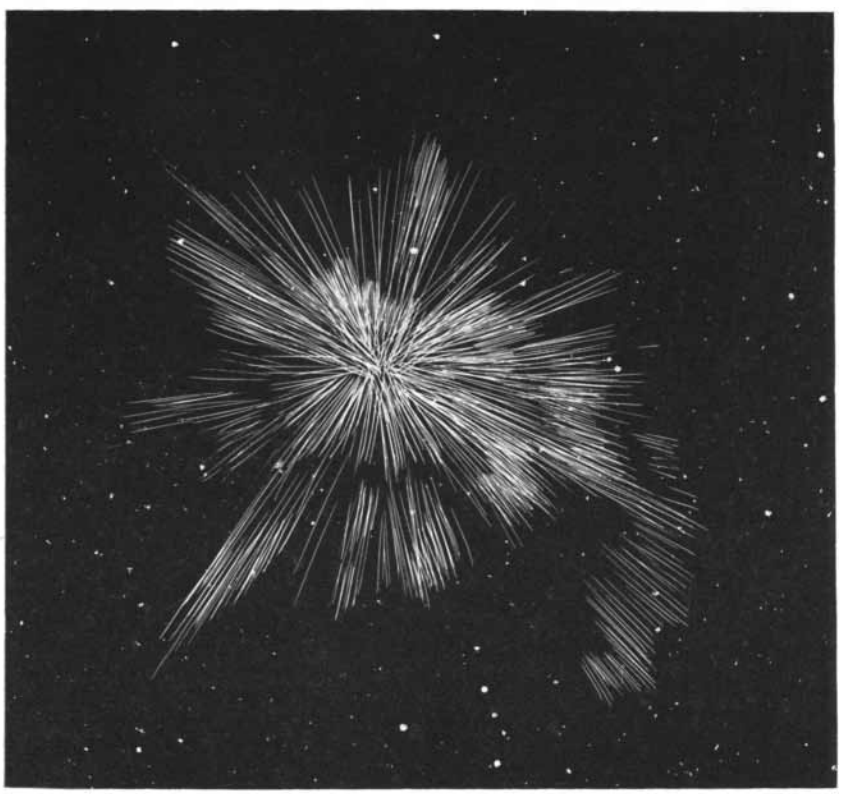
"As an essential part of the world-wide IGY plans, there will be an official center responsible for alerting observers when periods of exceptional solar activity are anticipated. The prediction and warning group will be located at the Fort Belvoir radio forecasting center of the National Bureau of Standards near Washington, D.C. Solar data will be channeled to this center from a chain of solar observatories girdling the earth and keeping, so far as practicable, a continuous watch on the varied kinds of activity on the sun. The center will also receive magnetic, ionospheric and cosmic-ray data from many parts of the world. Warning notices will be issued from

A drapery aurora. The bright star above the horizon at left is Antares in Scorpio



Rayed auroral arcs in the Northern sky. The Big Dipper is just above the horizon

Homogeneous auroral band in the eastern sky partly obscures the constellation of Orion



Auroral corona converges at 24 hours right ascension and 35 degrees north declination

time to time as required through communications media found to be most appropriate and effective for each region. The IGY National Committee for each nation will be responsible for the distribution of these notices within its own territory, apart from radio broadcasts receivable throughout the world.

"The warning notices will be of two kinds. The less urgent will announce 'alert' periods; the more urgent will proclaim 'special world intervals.' Alerts will be announced when the state of the sun indicates a growing activity likely to result in auroral, magnetic and other terrestrial effects of more than average interest. Solar activity that seems likely to result in intense and widespread terrestrial effects will call for the proclamation of a special world interval. During these intervals the full resources of elaborately equipped observatories will go into action on a 24-hour basis.

"The warnings are designed, of course, to economize the time of observers. It is hoped that observers will cover both types of warnings, but particularly the special ones, when the watch has the greatest chance of being fruitful.

"The auroral watch will be shorn of some of its value if confined to the early part of the night. It is hoped that night-long watches will be kept. Night workers who are regularly up between midnight and dawn and who can devote some time to observing are especially urged to participate in the program, particularly those who live in the tropics or whose work takes them into rural areas of the low latitudes.

"In addition to the world prediction and warning center, it is hoped to form a world-wide organization, consisting of one auroral reporter in each participating nation, for handling auroral reports from individual observers. Each reporter will collect and forward the observations to the auroral data center. The names and addresses of auroral reporters will be made available to interested amateurs through their respective national IGY committees. Canadian amateurs who wish to participate in auroral work should communicate with Peter M. Millman at the National Research Council in Ottawa. U. S. amateurs should write to Carl W. Gartlein at Cornell University in Ithaca, N. Y.

"The amateur will need little if any special equipment for participating in the program. Any device that improves the accuracy of the report, however, will add to its value. A navigating officer at sea, familiar with the compass and sextant, can obviously make better measure-

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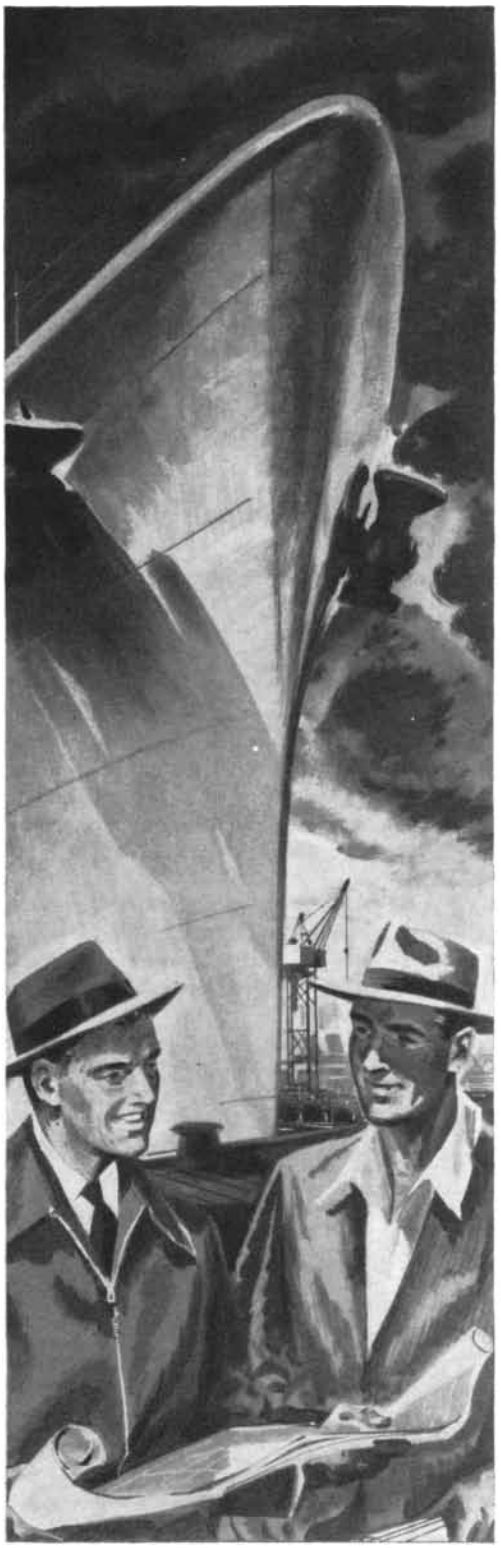

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ments of the angular elevation and azimuth of auroral features than an observer who relies solely on his eyes. It is hoped that many observers will find it possible to improve the accuracy of their estimates by erecting one or more poles with pegs inserted at calibrated intervals of elevation with respect to a spot to be occupied during observations.

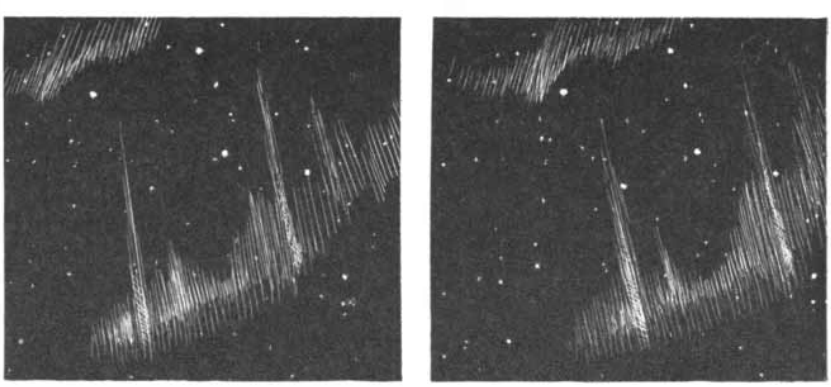
"Amateur astronomers who are familiar with the sky will be able to specify the position of auroral features with reference to the constellations. The precise time of observations must be given in all cases, of course.

"In the higher latitudes amateurs may wish to equip themselves with light filters for isolating particular colors of the auroral radiation. Suitable filters enable you to see auroras in bright moonlight or near sunset or dawn far more clearly than is possible by the unaided eye. The auroral spectrum in the visual region is dominated by two colors emitted by excited atoms of oxygen—green at 5,577 Angstroms and red from a pair of closely spaced spectral lines at 6,300 and 6,363 Angstroms. Absorption filters that favor these colors can be purchased from photographic supply dealers for a few dollars. Observations of low-latitude auroras made with interference filters capable of giving more precise information about the spectral composition of sections of the displays would be of great interest. In addition to enhancing the value of observations, filters and pocket spectroscopes (because of the special qualities of auroral light) can aid observers in all latitudes in detecting auroras hidden by clouds. This was dramatically demonstrated on September 25, 1909, when clouds obscured an aurora from observers in London. Its presence was readily detected by means of a small pocket spectroscope.

"Photographs also can be of great value. The exposure should include background stars or other positional references such as calibrated poles. So far as I know, the lowest geomagnetic latitude from which an auroral photograph has been made was in Greece. The aurora appeared in a plate exposed by W. N. Abbott of the Athens Observatory on the Greek island of Spetsai just before dawn on August 19, 1950. He was recording the zodiacal light with an astrographic camera. Abbott thinks it likely that the aurora occurred near the end of his 25-minute exposure. Its presence on the plate was not suspected until the plate was developed weeks later. The aurora was almost due east from the island. I have made many inquiries without success in an effort to unearth photographs of other low-latitude auroras. Amateurs resourceful enough to shoot one during the IGY will have bagged a rare prize.

"Even before the IGY begins, amateurs can join in a project which merits enthusiastic support. This is a search of historic records for observations of past auroras. An item found recently in the New York *Times* for August 29, 1859, illustrates how rewarding such a search can be. It said: 'New York—An Auro Borealis of extraordinary brilliancy and extent lighted up the heavens last evening and filled the streets with admiring crowds of upturned faces. The auro began to appear in the northwest about half-past seven and increased in brilliancy until half-past ten, when it gradually disappeared. The bars of light were at first horizontal but they afterwards assumed a vertical form, flashing with amazing luminousness and extending from the southwest to the northeast; on opposite sides of the heavens. There were at the same time luminous masses of a brilliant formation producing a most singular effect. There was a fresh northwest wind at the time and the atmosphere was very cool.'

"Similar accounts can be recovered from newspaper and magazine files, li-



Stereographic pair of auroral drawings for "cross-eyed" viewing

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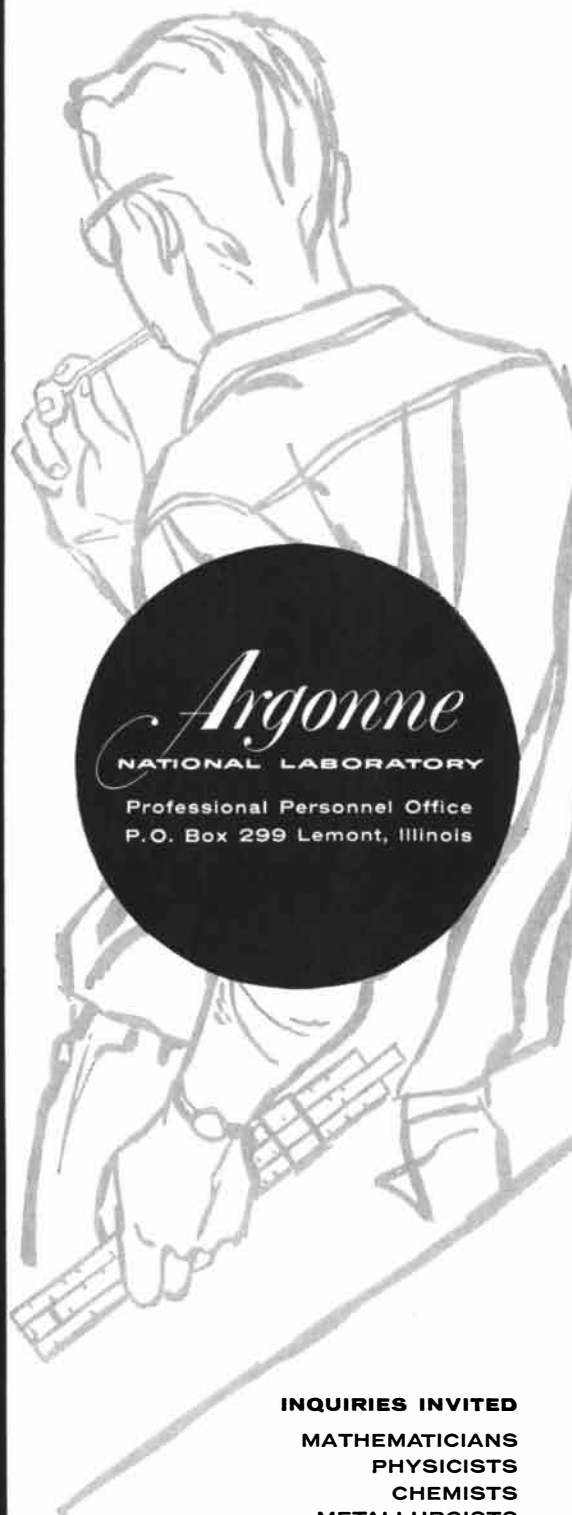

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braries, diaries, letters, the minutes of scientific organizations, historical societies, entries in ship logs and so on. A few countries have collected records of auroras seen locally. Such a project would indeed constitute a valuable enterprise. One of the best collections ever made on a world-wide basis was assembled in 1873 by Hermann Fritz, professor at the Zurich Polytechnic Institute. It covered the period from 503 B.C. to 1872 A.D. From the collection Fritz established that in the Northern Hemisphere auroras occur with highest frequency in a belt about 20 degrees from the geomagnetic pole. But his records also disclosed a liberal sprinkling of auroral observations farther south. They indicate that an aurora appears in the tropics about once in 10 years.

"The aurora mentioned in the New

1848	NOVEMBER 17
**1859	AUGUST 28 – SEPTEMBER 2
1870	OCTOBER 26
**1872	FEBRUARY 4
1872	OCTOBER 14 – OCTOBER 18
*1882	NOVEMBER 17
*1903	OCTOBER 31
*1909	SEPTEMBER 25
1920	MARCH 22
*1921	MAY 13
*1938	JANUARY 25
*1938	APRIL 16
*1940	MARCH 24
*1941	MARCH 1
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Lester Kilpatrick received his BSEE from Texas Tech in 1946, his MSEE from M.I.T. two years later. During 8 years at North American, he has earned a national reputation as an authority on digital computers. With his wife and 4 year old son, he likes to spend week ends "at the beach."

Navy vet E. A. O'Hern joined Autonetics in 1951 after earning his BS, MS and Ph.D. from Purdue University. A Research Supervisor, he has developed advanced techniques for analysis of autopilot-controlled flexible airborne vehicles. His hobbies include baseball, basketball and music.

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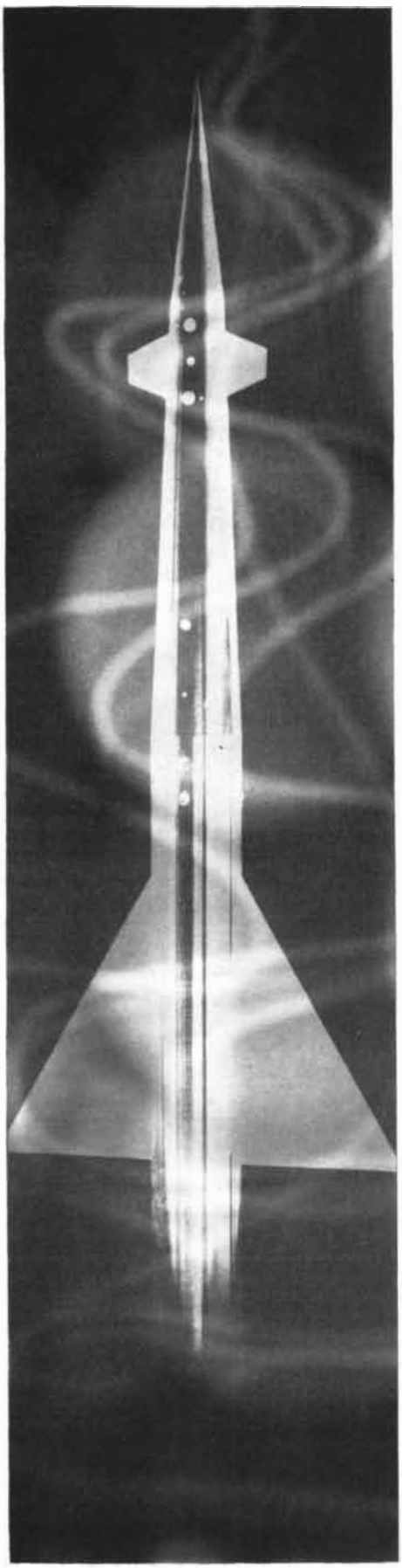

York *Times* was one of the greatest on record. From August 28 through September 2, 1859, there was a violent outbreak of sunspots and solar flares, and for several nights before and afterward auroras were intermittently widespread over the globe. They were brilliant in Honolulu.

"Another great tropical aurora occurred on February 4, 1872. This display was seen from Bombay and seven other places in India between the latitudes of 27 degrees and 36 degrees North. Other tropical places from which it was seen include Santo Domingo, Guatemala, Aden, the West Indies and, in the Southern Hemisphere, the islands of Reunion and Mauritius. Many of the descriptions of it are vivid and striking. This aurora was accompanied by an outstanding magnetic storm which for some hours interrupted or disturbed telegraphic cable communications all over the regions of the globe where such facilities then existed.

"During the present century there have been several outstanding auroras. One, which accompanied an intense magnetic storm on September 25, 1909, was observed at Singapore, just one degree north of the Equator! It was also observed at Batavia, six degrees south of the Equator.

"There was a tropical aurora on May 13, 1921, about four years after the sunspot maximum of 1917. It is interesting that of the 12 greatest magnetic storms occurring within the past 81 years, three fell approximately four years after the sunspot maximum. The great aurora of 1872 followed the sunspot maximum of 1870 by about a year and a half. In contrast, that of 1859 preceded the sunspot maximum by six months. The 1921 tropical aurora was observed from Samoa and from Tongatabu, 14 degrees and 21 degrees South latitude.

"It seems likely that other tropical auroras have occurred during the present century, but I have been unable to locate records of them. Our known records of the great auroras of 1859, 1872, 1909 and 1921 are woefully fragmentary and inadequate, although the displays were doubtless observed by tens of thousands of people, perhaps even by millions. As in earlier times, many residents in low latitudes may have viewed these strange appearances in the sky with superstitious awe, unaware of their nature and scientific interest. But some observers doubtless made careful accounts of what they saw. The files should be searched carefully for those great auroras.

"It is not surprising that records of the past auroras are scarce. Their signifi-

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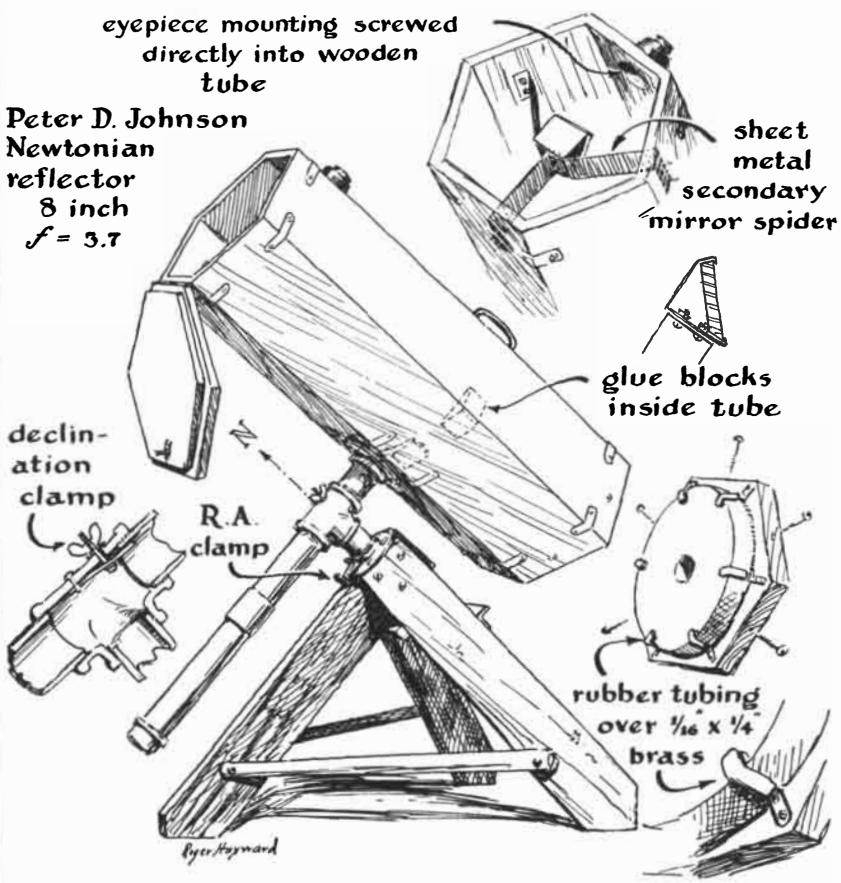
cance was not widely appreciated—even after the great contribution of Fritz. I, too, am guilty, having started the collection of data for the 1872 aurora only within the past few years. Though I have been interested in magnetic storms since 1917, I made no attempt to interview observers at the time of the 1921 tropical aurora. In 1954 I tried to collect information about it from Tongatabu, but it was too late: memory had faded. Better success attended an effort to recall observations of the 1872 aurora in India. Through the kindness of Indian friends, I recovered some valuable contemporary newspaper accounts.

"There have been 18 great outbreaks of auroras in the past 109 years [*see table on page 150*]. Any references to them by observers, however brief, would be helpful. Amateurs in all parts of the world are urged to thumb through all promising records for the dates indicated. The project should not require many hours. All findings should be forwarded to D. S. Kimball at the Yale University Observatory in New Haven, Conn. With this amateur contribution we may recover some thrilling accounts, which would otherwise be lost, from the generations of men who had the rare fortune to behold these great natural spectacles."

Peter D. Johnson of Schenectady, N. Y., is one of the many amateurs around the world who are preparing to participate in the visual tracking of the earth satellites to be launched during the International Geophysical Year. Part of his preparation has been the construction of a telescope of the "rich field" type designed for satellite observing.

"The mirror of the instrument," he writes, "is eight inches in diameter with a 29½-inch focal length. This focal ratio, about *f*/3.7, means that the mirror requires careful parabolizing, of course, because of its deep curve. The low power at which the telescope is to be used, however, imposes a somewhat less stringent requirement on the shape of the curve than in the case of conventional instruments designed for observing stars. The mirror is held in place by means of six Z-shaped brackets fastened to a wooden hexagon which fits inside the plywood tube of the instrument [*see drawing on this page*]. Rubber tubing slipped over the Z-strips protects the



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RADAR—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control—Information Handling—Displays		M C	M C X	M C X	M C X	M C X	M C X	M C X	M C X	M C X	M C X			
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mirror from the metal. The strips make a snug fit but do not exert enough pressure to strain the mirror. The hexagonal mount is fastened at the end of the tube by means of wood screws inserted through longitudinal slots in the tube. The slots provide adjustment for aligning the optical system. The alignment is made only once, hence the adjusting mechanism need not be elegant.

"For the eyepiece I use one of the inch-and-one-quarter eyepieces advertised by the Edmund Scientific Corporation. In combination with the mirror it yields a field of view approximately three degrees in diameter. The off-axis aberrations of the mirror and inadequacies of the eyepiece impair the quality of the image somewhat as the edge of the field is approached. The good portion of the field, however, is more than adequate for the average eye.

"The tube is made rigid by fastening the six sidepieces of plywood together with 120-degree brass strips and by gluing small triangular pieces of plywood inside. The tripod is made of two-by-fours braced with aluminum pipe and beams from a defunct aluminum clothesline tree. The equatorial mount on which the tube rotates is made of two-inch pipe fittings. The threads comprising the bearing surfaces in declination and right ascension were lapped with 600-mesh Carborundum, followed by 303 emery and finally coated with beeswax for smooth operation. The counterbalance weight is an eight-pound sash weight placed inside the capped pipe opposite the telescope. The instrument was made without the aid of machine tools other than an electric hand drill. All parts except the optics are available at your local hardware store and lumberyard.

"This is the fifth reflecting telescope I have made and put into operation. A six-inch $f/5.6$ is my most professional mirror so far. I have an eight-inch $f/5.6$ with a four-inch $f/7.5$ guide telescope adapted for photographic work and a four-inch $f/13$ unaluminized job with which I am experimenting in the hope of using it for solar observation during the forthcoming sunspot maximum.

"The generally short focal length of my mirrors is dictated by the miserable seeing conditions prevalent in Schenectady and the resulting necessity for portability. My tendency to inelegance and simplicity is dictated by the lack of machine tools and by my experience as a physical chemist in an industrial laboratory, which has shown that by designing equipment to do the jobs you want to do—and no more—it is possible to eliminate much unnecessary complexity."

INDEX OF ADVERTISERS

JANUARY, 1957

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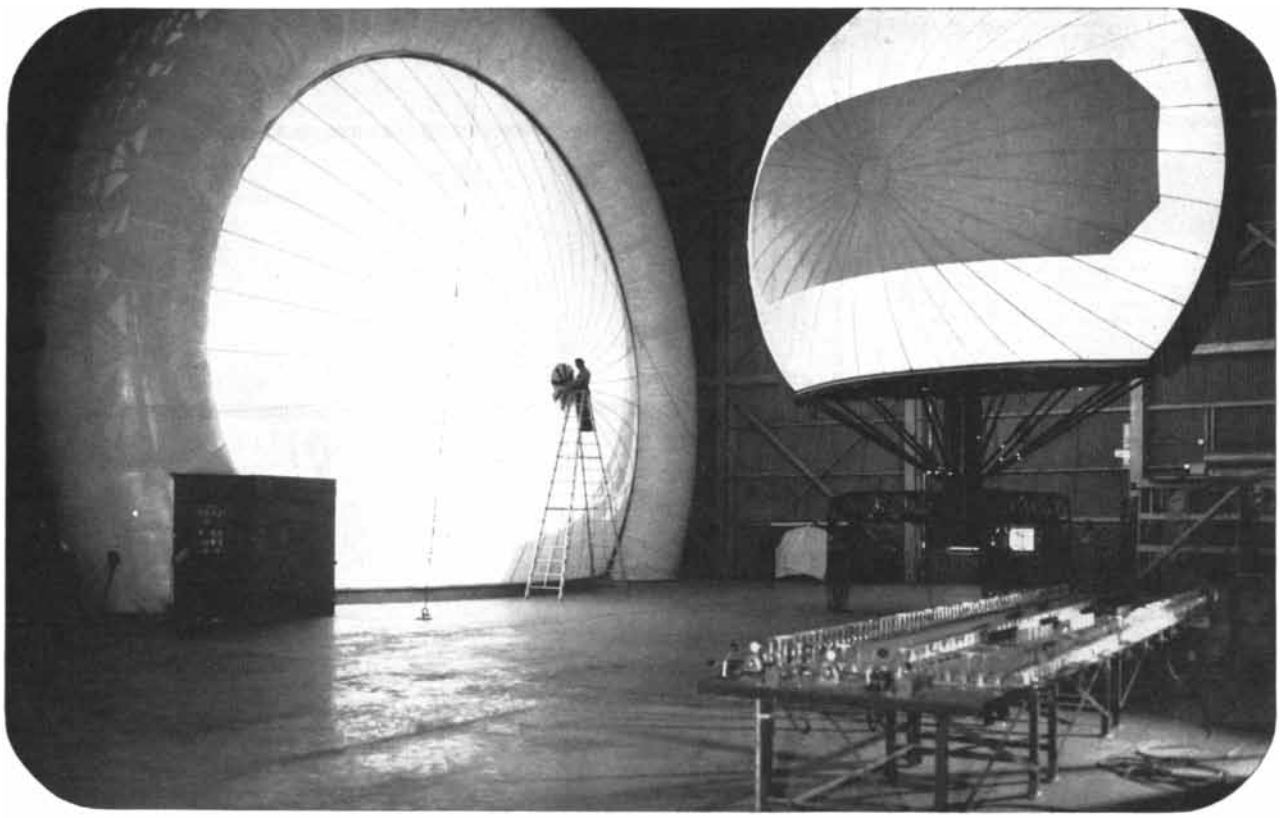

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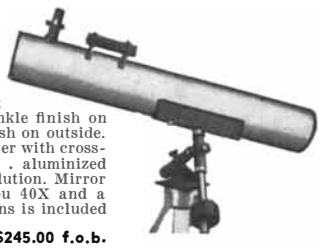

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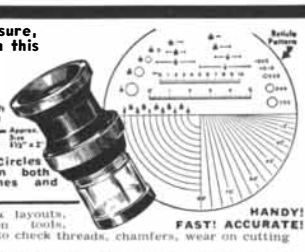

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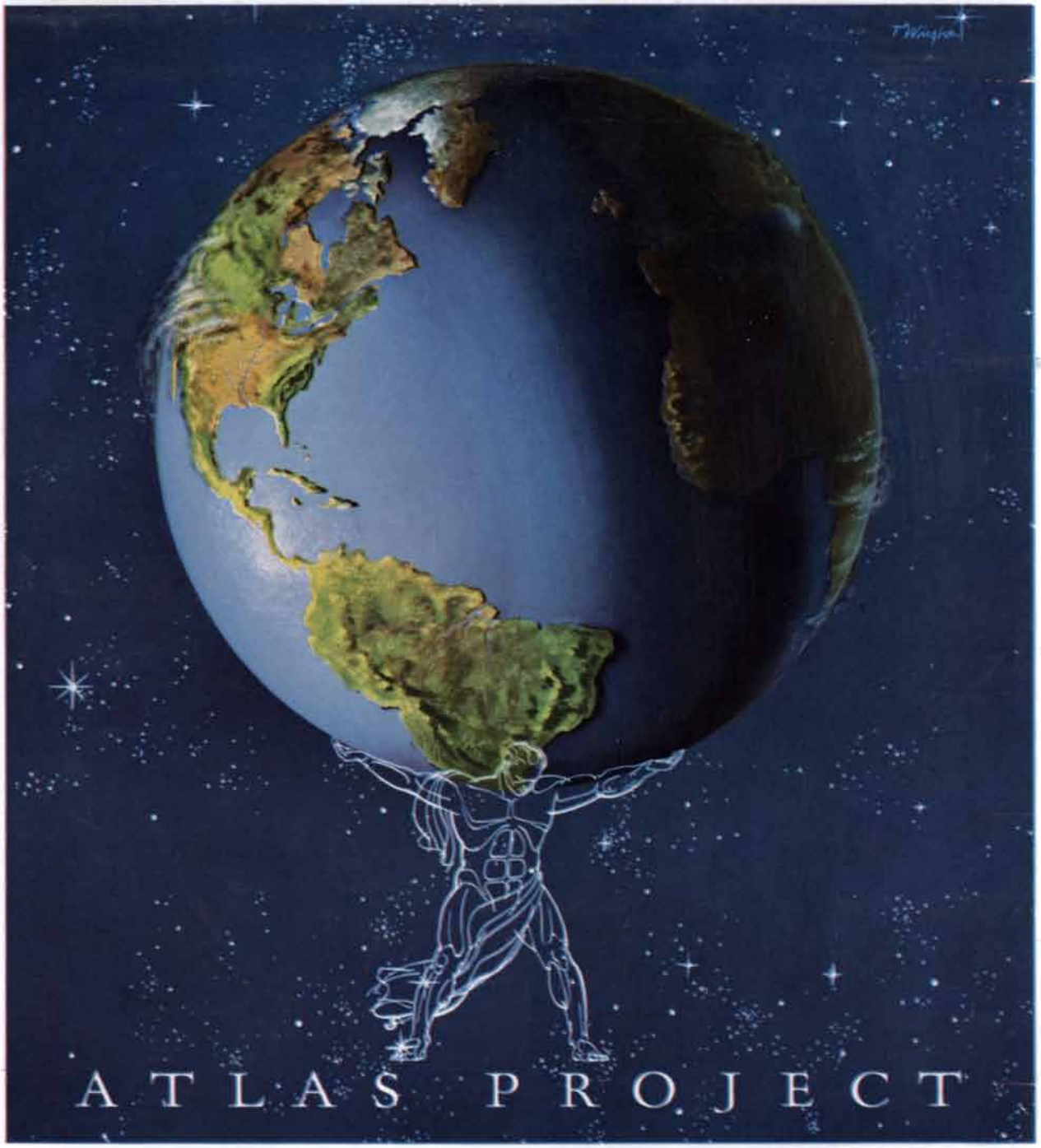

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