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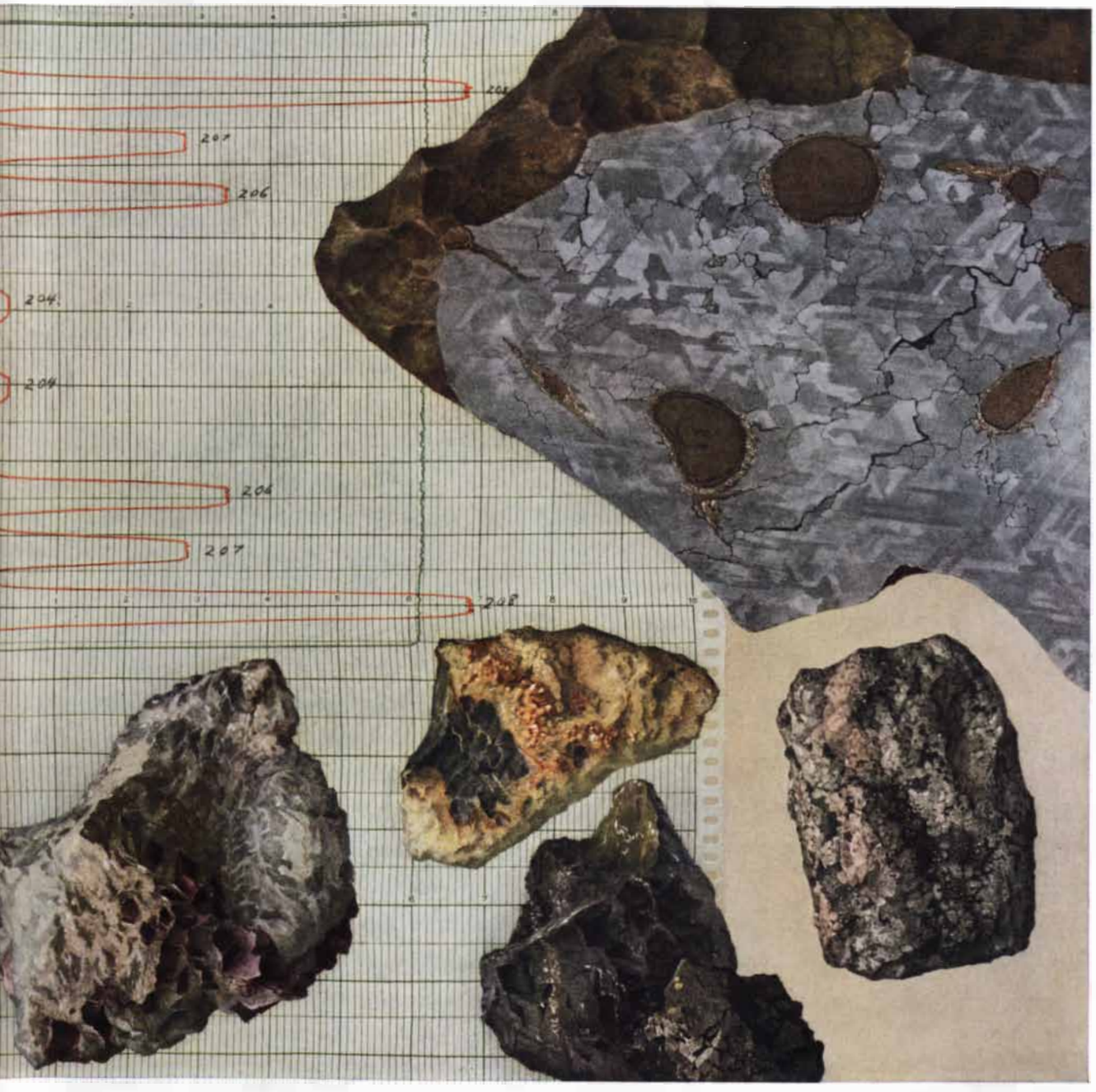

AGE OF THE SOLAR SYSTEM

FIFTY CENTS

April 1957

"Timber" in the tall corn

YOU'LL FIND no lusty-lunged woodcutter to warn farmers of danger in their cornfields. Soil pests such as corn rootworms do their dirty work in secret, feasting underground on tender young roots. And when the anchoring roots are cut, the plant tumbles in the first brisk wind.

But today, farmers have aldrin—a potent insecticide that destroys corn rootworms, wireworms, seed corn maggots, white grubs, and other cornfield soil pests. Applied before or during planting, aldrin kills underground pests when they touch, taste, or breathe it. The expense of replanting "spotty" stands is eliminated. Corn can grow straight and tall for easy mechanical picking.

Helping farmers grow bigger crops with higher quality yields by controlling insects is one of many ways Shell Chemical serves the farmer.

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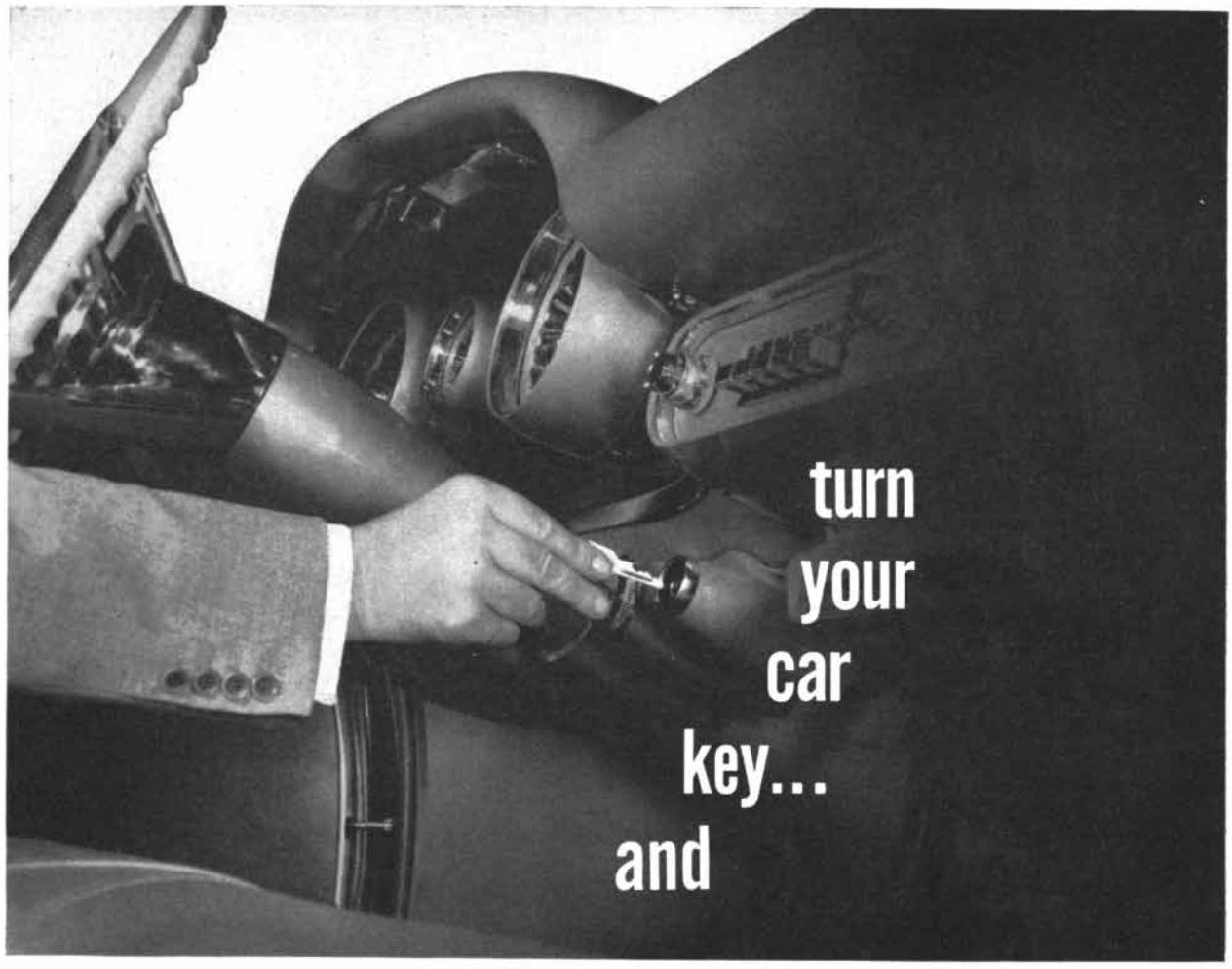
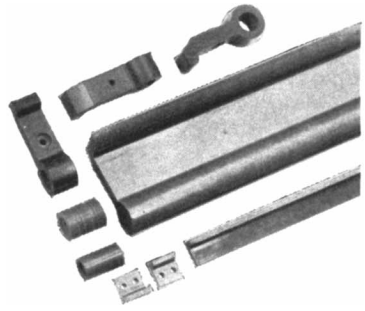


Synthane laminated plastics report for work



Breaker Arms for tractors and outboard motors are cut from lengths of molded laminated. Breaker arm bushings and rubber angles are important ignition components.

A turn of the ignition key and the thousands of parts which make up your car go to work as a team. Under the dash or under the hood are dozens of parts made of Synthane laminated plastics. They may seem insignificant but they're as necessary as an owner's license.

Take away Synthane laminated plastics and you have a car that won't start, a generator that won't run, lights that won't light, or a silent radio or motionless fan—which may give you some idea of the importance of a product like Synthane in the automotive industry.

Synthane laminates are excellent electrical insulators—they resist moisture—smile at oil—are easy to machine and mechanically strong. Synthane laminated plastics are available in sheets, rods and tubes or as parts completely fabricated to your designs and specifications.

For more information about the many properties of Synthane laminated plastics and how you can benefit by using Synthane materials and fabricating services, write for our latest product catalog. Synthane Corporation, 2 River Road, Oaks, Pa.

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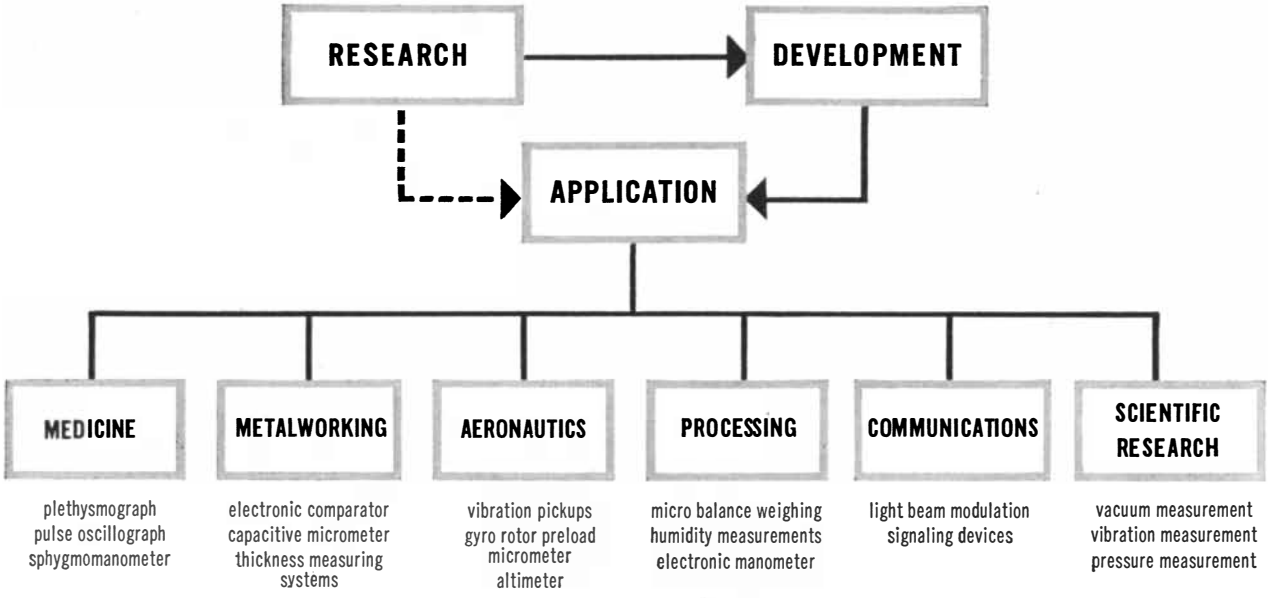

an idea is the solution to every problem

Decker Aviation is a company of ideas.

Not long ago, for example, Decker took the idea of an ionization transducer and brought the idea to reality . . . then used it imaginatively to solve pressing problems in any number of far flung fields.

In medicine, Decker applied the transducer to the improvement of such basic instruments as the plethysmograph . . . giving medical researchers a new magnitude of sensitivity in their explorations.

For geophysical research, Decker ideas made possible instrumentation that, mounted in the nose of an Aerobee-Hi rocket reaching an altitude of 125 miles, continuously and accurately measured both ram and ambient atmospheric pressures at speeds in excess of a mile per second.

Applying new ideas to the micrometer comparator, Decker gave the production line an instrument for measuring an object without physical contact to within a few millionths of an inch.

All the examples listed on this page hardly begin to show the extent of Decker accomplishments. For one problem after another, we have found the idea . . . developed it into a solution . . . built prototypes . . . even manufactured finished instruments.

We would honor an opportunity to evaluate your problems. Our ideas may very well be their solution.

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Philadelphia

Established 1845 **SCIENTIFIC AMERICAN** April, 1957 Volume 196 Number 4

ARTICLES

DEPARTMENTS

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

THE COVER

The painting on the cover depicts a collection of objects used to determine the minimum age of the solar system (*see page 80*). At bottom center are two samples of uraninite, the upper from New Mexico and the lower from the Belgian Congo. The yellow stone above them is becquerelite from the Belgian Congo. At lower left is a sample of lepidolite from Sweden; at lower right, a sample of granite from Germany. At upper right is a metallic meteorite found in Arizona; one of its faces has been cut and etched. In the left background is a red trace on the record of a mass spectrometer.

THE ILLUSTRATIONS

Cover painting
by John Langley Howard

Page	Source
45-46	University of Michigan
47	James Egleson
48	James Egleson (*top*), Paul Weller
49-50	James Egleson
51	Paul Weller
52-53	James Egleson
54-58	William Vandivert
59	Sara Love
60-61	Sara Love (*top*), William Vandivert
62	A. Franceschetti
63	Sara Love
64-66	John Langley Howard
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130	B. O. Phinney
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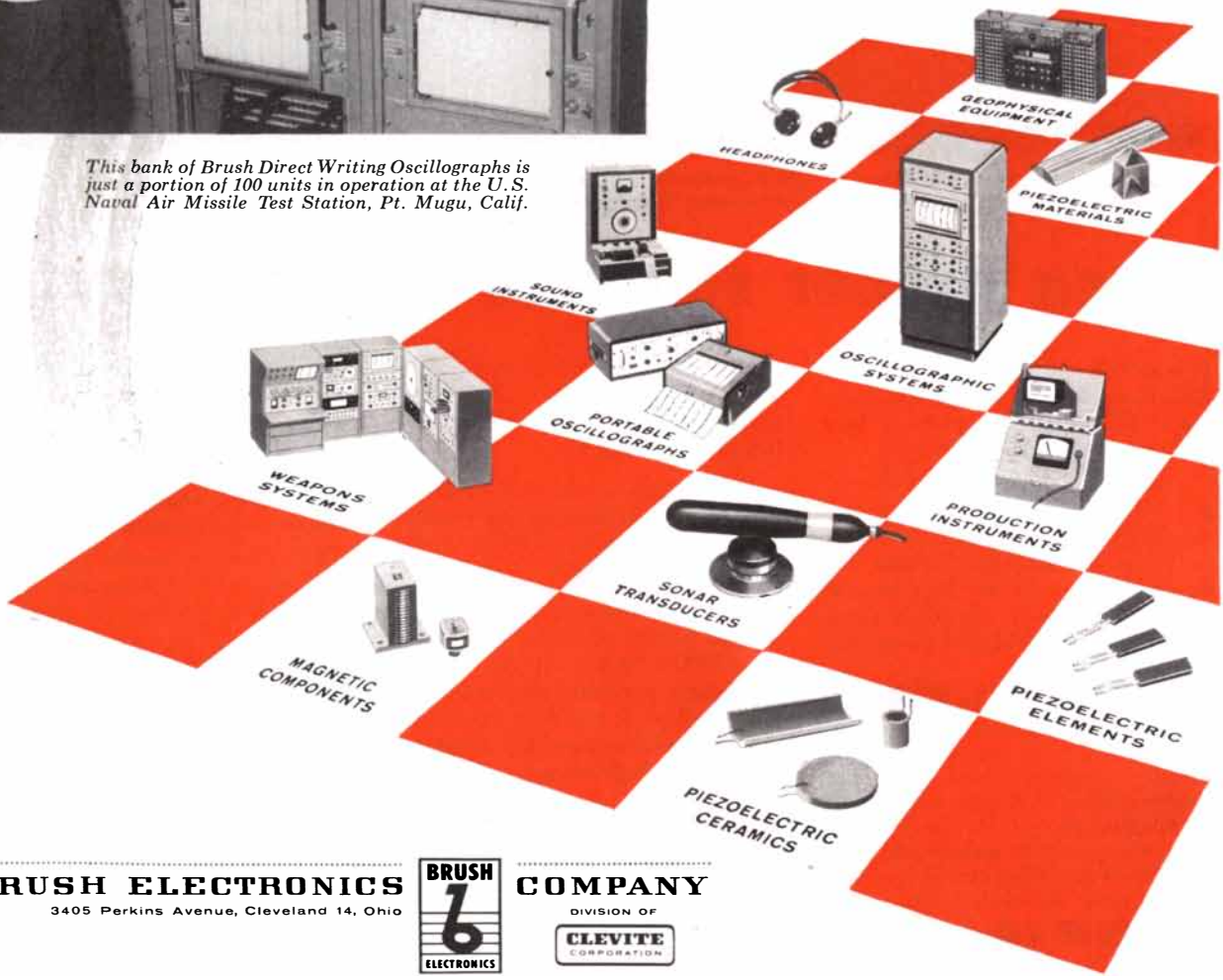
138-139	Irving Geis
140	High Altitude Observatory (*top*), Sacramento Peak Observatory
142-146	Irving Geis
166-170	Joseph Low
175-180	Roger Hayward

"MISSILE TO EARTH: FLIGHT ACCORDING TO PLAN"

This bank of Brush Direct Writing Oscillographs is just a portion of 100 units in operation at the U. S. Naval Air Missile Test Station, Pt. Mugu, Calif.

On Brush Oscillographic Systems, telemetered data from test missiles are instantaneously recorded, providing an immediate, accurate record of acceleration, pressure, pitch, yaw, and scores of other variables. This information is essential to keep pace with the advanced requirements for missile progress. Here is another critical application where Brush equipment was chosen. When you select instrumentation remember—*there are more channels of Brush industrial direct writing oscillographs in use than all other makes combined.*



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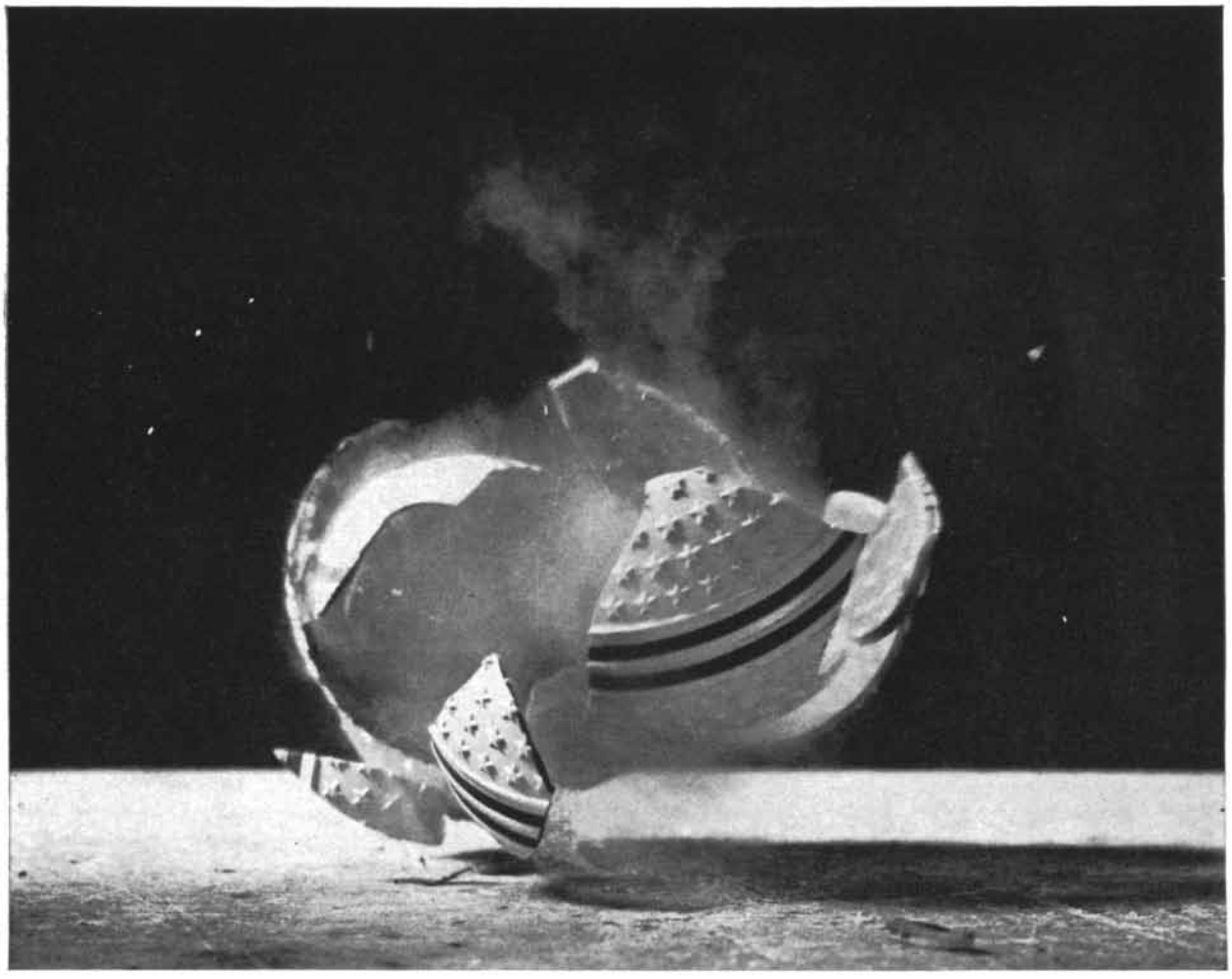

A child's rubber ball, chilled to —320°F., shatters when dropped. Electronic flash tripped by microphone 1.035 milli-seconds after contact. Photographed by Ralph Bartholomew, Jr.

When rubber shatters like pottery...

It happens right before your eyes. Still you can hardly believe the fantastic things that take place at deep sub-zero temperatures.

Rubber breaks like a clay flowerpot. Mercury freezes so hard you can hammer nails with it. Hammer a frozen orange with it, and the chips of fruit fly off like bits of granite. The very air itself turns into a bluish liquid that pours like boiling water.

You feel as if you had awakened in some dizzying space-man world. And when you see metals like tough structural steel crack up under a blow as if they were glass, you realize the puzzle confronting men who have to work with temperatures reaching down into the depths near Absolute Zero.

An oxygen vaporizer, for example, has to withstand a bursting pressure test of more than two tons per square inch at —300°F. A helium liquefier works at 455° below zero Fahrenheit.

How in the world do they make equipment to stand such pressures and temperatures without breaking up or bursting?

Strangely enough, the practical answer to this difficulty is an easy one: INCO Nickel Alloys. One of the many peculiar advantages of nickel alloys is the fact that these sub-zero temperatures have little or no effect on their inherent toughness and ductility. They simply become still harder, still stronger.

(By the way, if you would like more data on this subject you are welcome to a copy of "High Properties at Low Temperatures" by our Director of Technical Service.)

The point is, maybe you are being bothered with some metal problem in your product or plant that would be just as easy to solve with one of these INCO Nickel Alloys. The first step is to outline the trouble and send it along for study to The International Nickel Company, Inc., 67 Wall St., New York 5, N. Y.

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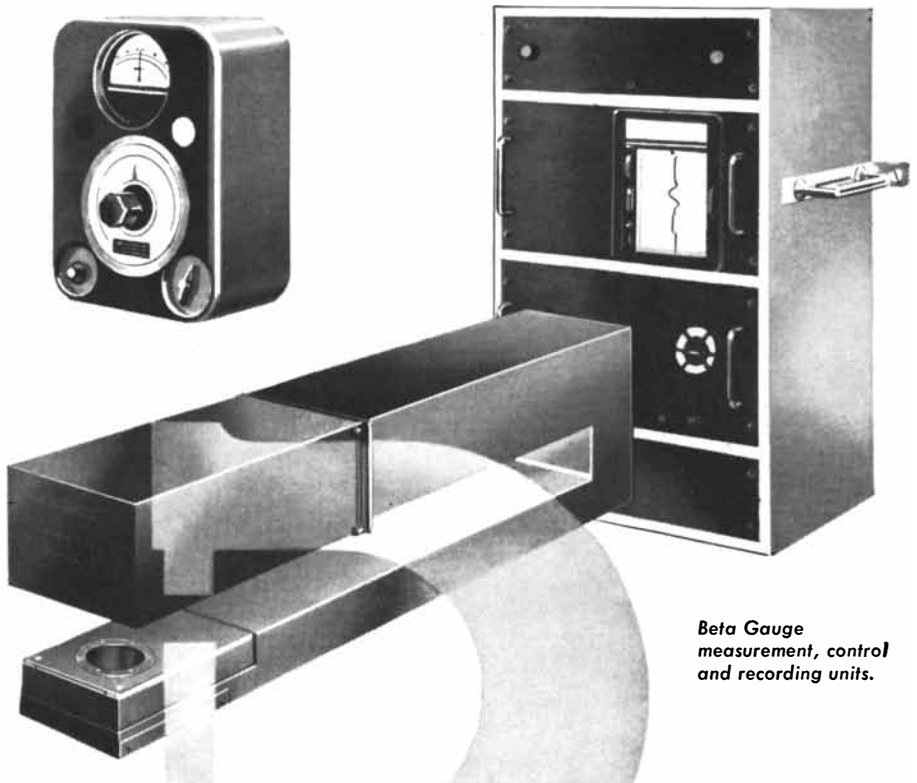
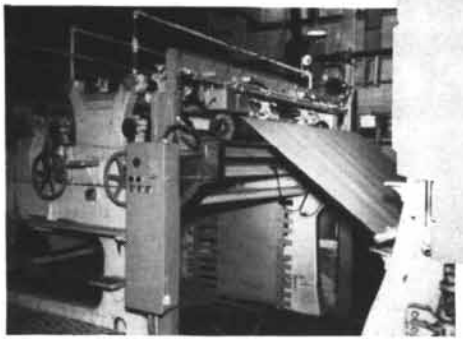


Beta Gauge measurement, control and recording units.

This nuclear "mike" measures and controls moving sheet materials



Nuclear system measures materials during production, sounds alarm at any deviation from specifications, eliminates stoppages.

Systems Frieseke & Hoepfner

Though it never touches the material, Curtiss-Wright's Nuclear Measurement System measures or weighs plastics, metals, paper, textiles, etc. far more accurately than has ever been possible before . . . and does it *during production.*

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***Nuclear Measurement* by**

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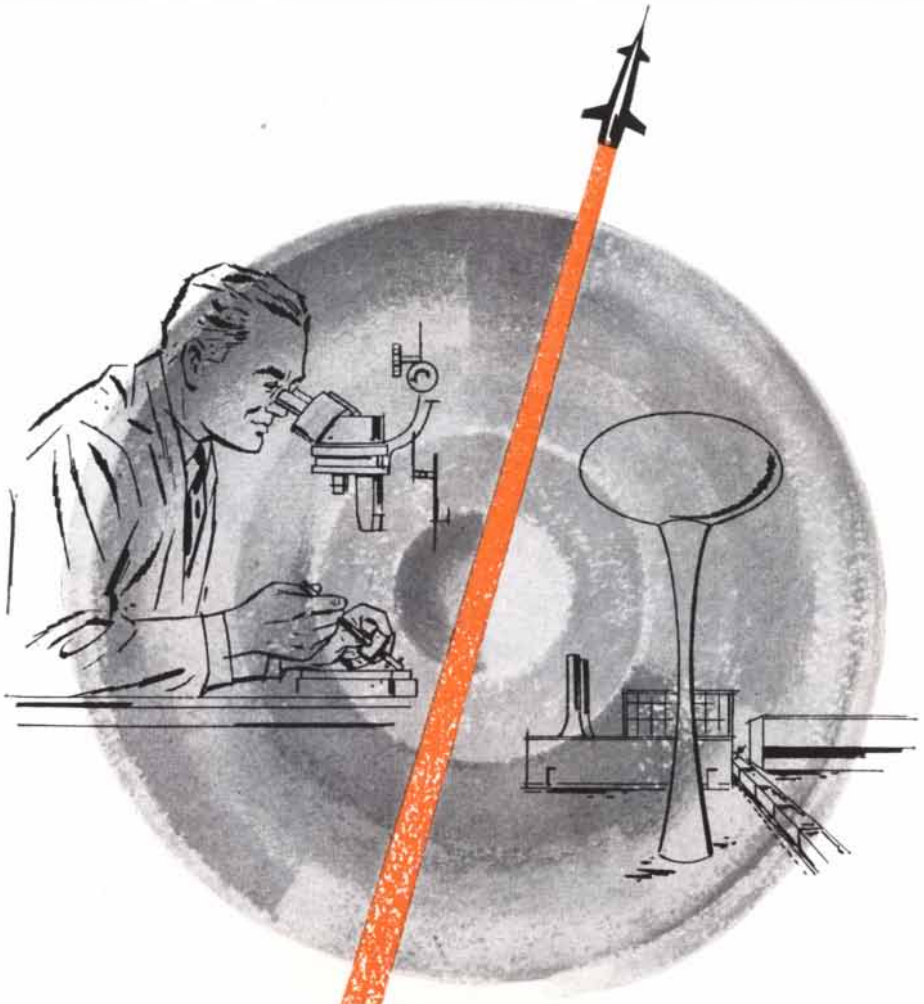

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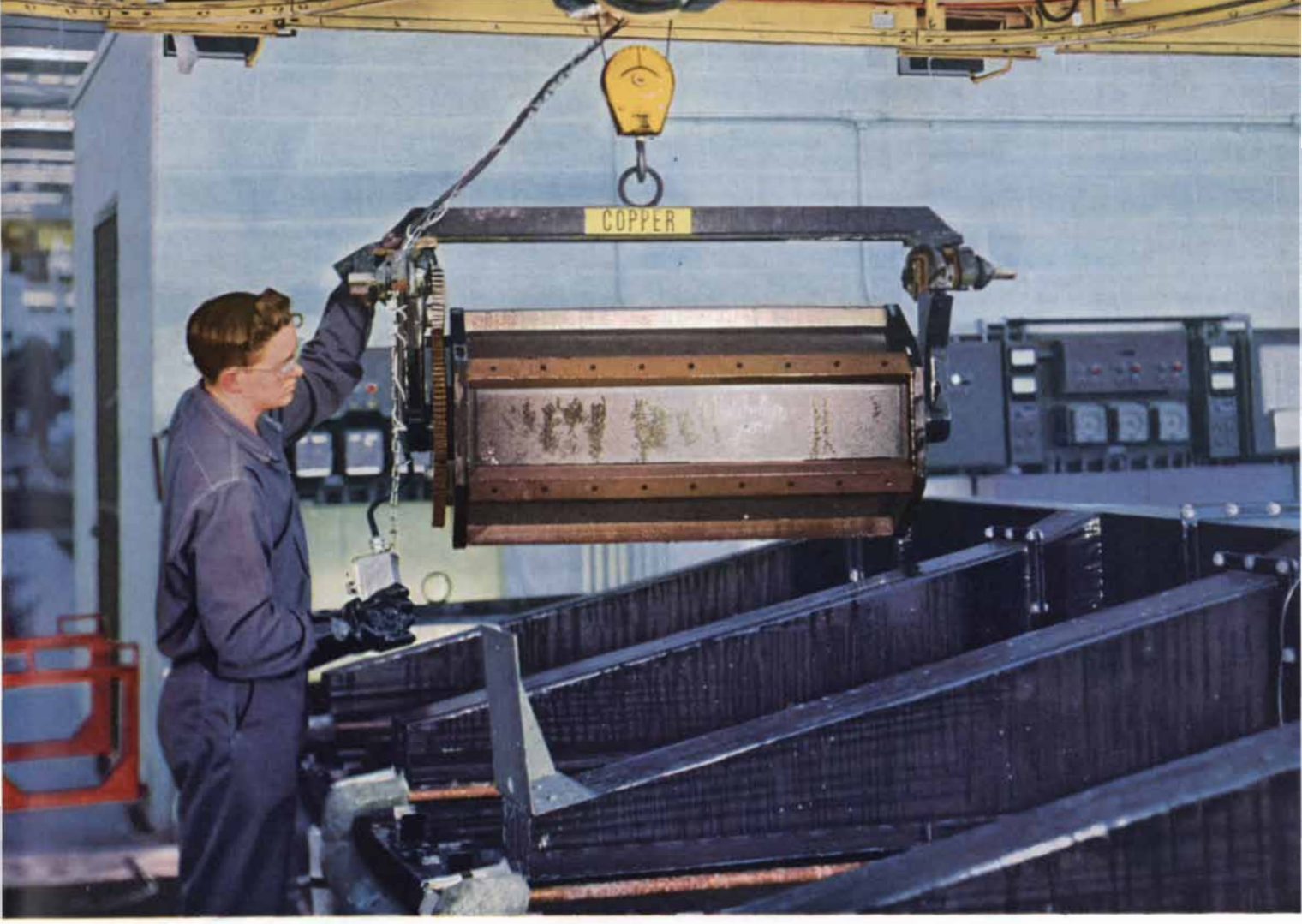

Photo courtesy American Hard Rubber Company, New York, N. Y. and Udylite Corporation, Detroit, Michigan

New Answer to a Barrel of Hot Problems

Hot problem for a leading supplier of electroplating barrels was finding the right material for the cylinders. In the face of repeated exposure to heat, hard wear and corrosive plating solutions, these cylinders had to keep rolling without contaminating the baths. After many tries, they found the answer—a new, clean-running hard rubber with three times longer life.

The major advance of this new material over its predecessors springs from the fact that it's made with CHEMIGUM nitrile rubber. Its manufacturer uses CHEMIGUM for a combination of strength plus resistance to high temperatures, chemicals and solvents never before achieved in hard rubber.

Besides better barrels for plating, CHEMIGUM as hard rubber has wide applications as pipe fittings and other equipment for handling chemicals at high temperatures. In other forms, CHEMIGUM finds use in many other products requiring unusual resistance to oils, solvents and chemicals over a wide range of temperatures.

If you have a need for an unusually versatile oil-resistant rubber of high quality, be sure you have the full story on CHEMIGUM. It's easy to get. Just write to: Goodyear, Chemical Division, Dept. D-9457, Akron 16, Ohio.

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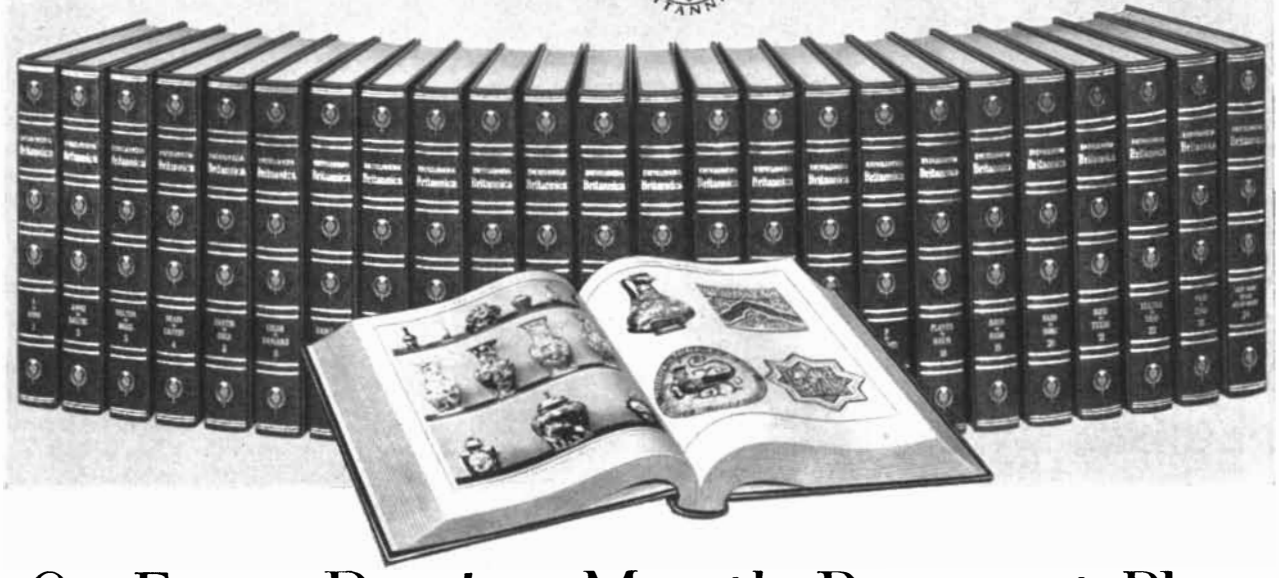

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LETTERS

Sirs:

The fascinating article by B. Rensch on the intelligence of the elephant [SCIENTIFIC AMERICAN, February] makes an interesting case for the proboscidian brain. But what about the nose? The ancients, mindful of the skill and intelligence of the elephant in peace and war, remarked on this: ". . . a great nose, thin and crooked, which men call the proboscis. That is the hand of the beast; with it they easily do whatsoever they will" [Oppian in the *Cynegetica*, Book II, page 478]. ". . . They breathe, drink and smell with the proboscis, which is not inaptly termed their 'hand' " [Pliny, in *The Natural History*, Vol. II, Book VIII, Chapter 10]. ". . . The animal itself regards his trunk as a hand and uses it to hurl weapons" [Philostratus, Book II, Chapter XII].

In more recent studies on the evolution of the elephant, Richard S. Lull [*American Journal of Science*, Vol. 25; March, 1908] stressed the significance of the finger-like projections of the elephant trunk and the ability of the animal to bring objects before its eyes, inferring a *causal* relation between "manual" prehension and mental comprehension.

Very recently, in *Scientific American* [May, 1956], Julian H. Steward, the University of Illinois anthropologist, extended this same reasoning to man's cultural evolution: ". . . there may have been an intimate relation between the development of a flint weapon held in the hand and the receding of the apelike jaw and the protruding canine teeth. . . . There were other consequences of this development. The brain centers that register the experiences of the hands grew larger, and this in turn gave the hands greater sensitivity and skill." Whether we like to admit it or not, could it not be that the grasping of objects may have been basic to the grasping of ideas, and in turn to the intelligent contemplation of the nature of nature?

And are not the genes controlling man's dexterity still asserting themselves in the "do-it-yourself" spirit of modern man, in the handicraftsmanship of a Winston Churchill and other great intellectuals—whether labeled manual work, hobbies or cultural pursuits—and in the application of similar skills to the health and welfare of man in medicine and dentistry? In the final analysis it may have been the superiority of the human hands—freed for action by an erect posture—which "outwitted" the elephant, its formidable tusks, its versatile trunk, and its enormous brain notwithstanding.

REIDAR F. SOGNNAES

Harvard School of Dental Medicine
Boston, Mass.

Sirs:

Problem 4 of Martin Gardner's collection in the February *Scientific American* can be given an additional twist. Suppose the logician knows that "pish" and "tush" are the native words for "yes" and "no" but has forgotten which is which, though otherwise he can speak the native language. He can still determine which road leads to the village.

He points to one of the roads and asks, "If I asked you whether the road I am pointing to is the road to the village would you say pish?" If the native replies, "Pish," the logician can conclude that the road pointed to is the road to the village even though he will still be in the dark as to whether the native is a liar or a truth-teller and as to whether "pish" means yes or no. If the native says, "Tush," he may draw the opposite conclusion.

JOHN MCCARTHY

Hanover, N. H.

Sirs:

The compilation of problems by Martin Gardner in the February issue of your magazine is most interesting to me. It is

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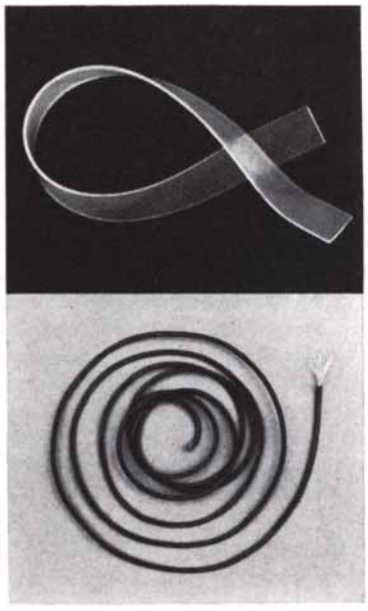
- *nylon milk bottles*
- *farming fish*
- *paper coating*



Nylon milk bottles

When you're looking to laboratory-stage plastics for new developments, it is somewhat startling to realize that a new raw material has come from one of the better established plastics, nylon.

For nylon—first a synthetic fiber and more recently a new molding compound—is now extrudable as well. The extrusion industry can, for the first time, utilize PLASKON nylon with standard equipment and standard techniques.

The import of this development is underlined by the products made possible. Tough, transparent milk bottles and packaging films. Strong, sterilizable baby bottles and aerosol bombs. Flexible, high-burst-strength lubricating systems and speedometer cables. Abrasion-resistant wire covering and automotive scuff pads.

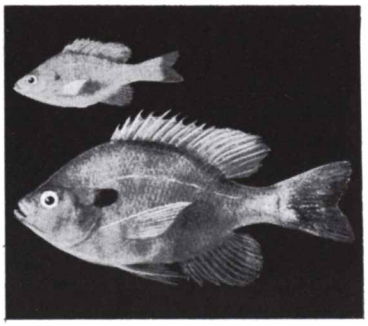
A 5 mil extruded sheet, for example, is remarkably tough and transparent. Other impressive properties are high impact resistance over a wide temperature range, good chemical resistance, ease of colorability with a penetrating dye or by pigmentation of pellets.

Several grades of PLASKON nylon – polycaprolactam-type – generally known as "nylon 6" — are available for extrusion: PLASKON 8201 for general purpose extrusion; a heat-stabilized form for high temperature and wire covering applications; special high viscosity and flexible grades.

Farming fish

We were going to say, "Don't forget to give your fish their fertilizer this year."

What we mean is this: don't forget to give your algae their fertilizer this year. Well-fertilized algae make better meals for plankton, which make better food for insects, upon which feed small fish, which in turn end up on the menus of large fish.



You can improve fishing within a single year by applying plant food to ponds. Fish in fertilized ponds can become five times larger, both fatter and longer.

Applying the fertilizer is almost as easy as pulling the fish out on the end of a line. You can either spread it from the side of a boat or, on larger ponds, use the newest techniques of aerial application. Free-flowing ARCADIAN fertilizers can be quickly and easily spread on a pond by conventional dusting planes.

The best fertilizers for fish ponds have a high nitrogen analysis. Their nitrogen-phosphorus-potash (N-P-K) ratio should be at least 2-2-1 or 1-1-1. Like ARCADIAN 12-12-12.

Paper coating

A key problem in coating paper on today's fast machine coaters is viscosity control. The aim: to increase total solids content (for better coating) without increasing viscosity.

Experimental data prepared by the Nitrogen Division research group indicate that small amounts of urea give large viscosity reductions and drastically lower the rate of viscosity increase on standing. Urea also lowers thixotropic index and permits use of adhesive dispersions with higher solids content.

A paper titled "Viscosity Control of Paper Coating Adhesives" contains 15 substantiating graphs. We'd be pleased to send a copy.

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

Please send me further information:

- ☐ Extruded nylon
- ☐ Fertilizing fish ponds
- ☐ Urea for viscosity control

Name_____

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realized that authorship of such problems is very difficult to establish. However, I claim priority on Problem 7, which was published over my name (as Number Q-12) in *Mathematics Magazine* for September-October, 1950; Leo Moser of the University of Alberta proposed a generalization of the problem in a later issue of the same journal . . . .

FRANK HAWTHORNE

Supervisor of Mathematics Education
State Education Department
Albany, N. Y.

Sirs:

Mr. McCarthy's pish-tush variation on the logic problem is delightful. Several other readers also called attention to this ultimate (or is it the ultimate?) twist.

As Mr. Hawthorne's letter indicates, 1944 seems to mark the first publication of the problem about the hunter who circles the South Pole, though other letters suggest that many people thought of it independently and before that date.

A number of readers seemed to think that Problem 8, about the suburban commuter, requires that the wife normally arrive at the station exactly in time to meet her husband's train. Further reflection should make clear, however, that it does not matter in the least if the wife usually arrives early and waits at the station for the train. It is only necessary that on this particular occasion she leave home at such time that she will meet her husband on his trek home.

MARTIN GARDNER

New York, N. Y.

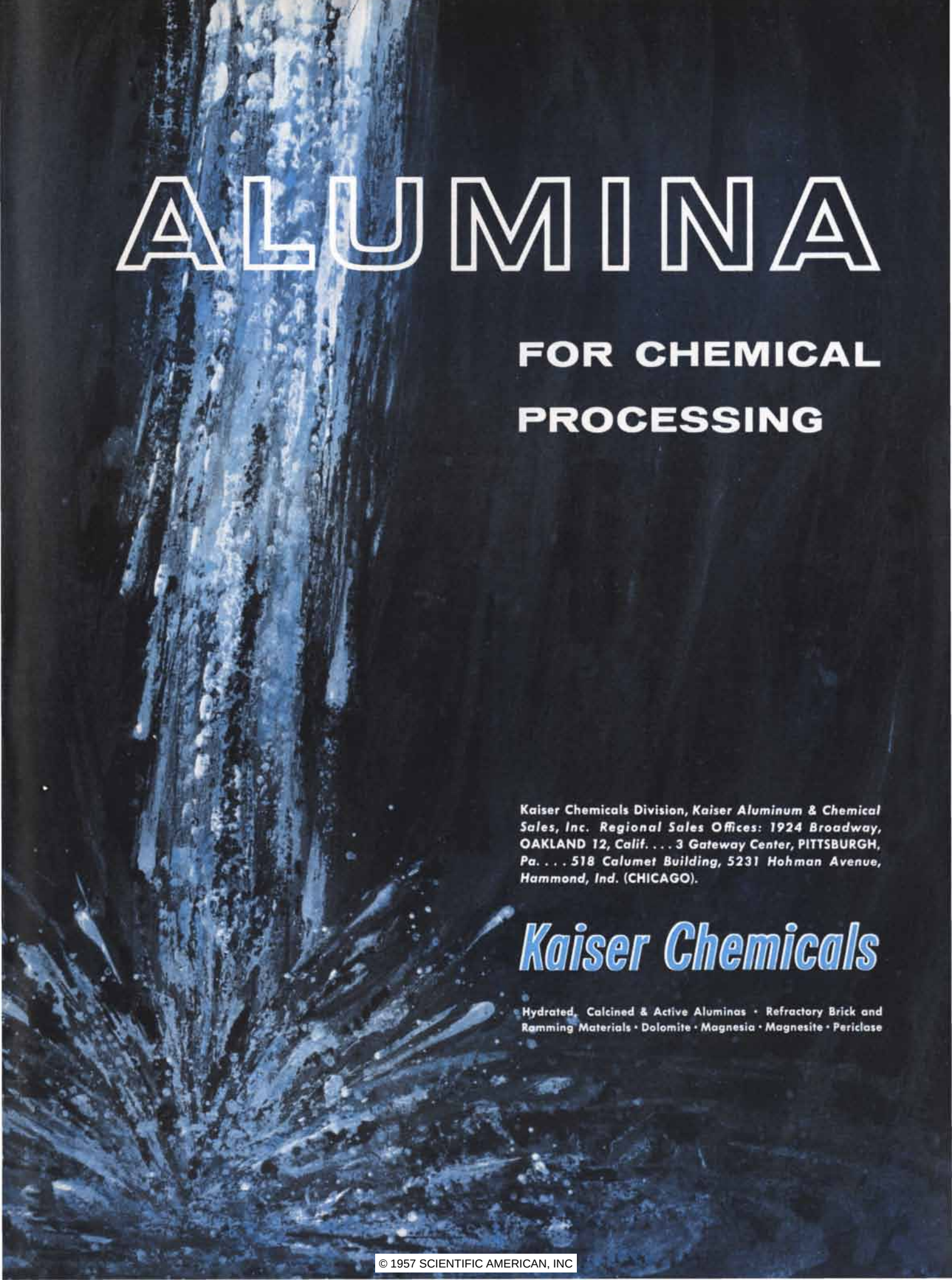
Sirs:

"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" ["Science and the Citizen," SCIENTIFIC AMERICAN, January].

Skins gleamed as satin, black and gold,
  Beside our forest blaze,
And braggart hunting tales were told
  Of breathless hunting days.

We ate the little roasted quail
  That, spitted, dripping, turned;
And tale was piled on vaunted tale
  As branch on branch was burned.

They came from far across the sea
  To ask which we preferred—



Which creature would we rather be?
Each lad replied, "A bird."

By river and by track they came
To ask each maiden coy.
Each giggling girl replied the same—
"A boy," she said, "A boy."

And so they learned a simple truth.
From dawn of Man to doom,
We all aspire, in surging youth,
To what we would consume.

RALPH A. LEWIN

Marine Biological Laboratory
Woods Hole, Mass.

Sirs:

With the article "Anesthesia" [SCIENTIFIC AMERICAN, January] you published a chart showing the levels of anesthesia and their correlates, such as various reflexes. Another correlate of considerable significance and clinical value is the brain wave.

The electroencephalographic signal has been found to be closely correlated with depth of anesthesia. In fact, it has even been used in a feedback loop, controlling an anesthesia machine to maintain a constant level of anesthesia. This system has been used in at least fifty abdominal operations at the Mayo Clinic ["Electroencephalographically Controlled Anesthesia in Abdominal Surgery," *Journal of the American Medical Association,* Vol. 144, pages 1,081-1,083; 1950].

As an anesthesia monitoring device it is valuable not only in determining level of anesthesia but in detecting circulatory and respiratory malfunction, since the electroencephalographic pattern is very sensitive to brain anoxia. . . .

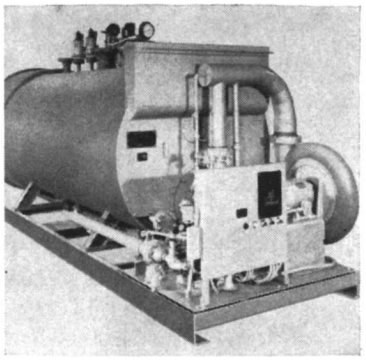
JOHN H. BORROWMAN

Stanford, Calif.

ADDENDUM

The article "Heart Metabolism" [SCIENTIFIC AMERICAN, February] mentioned a technique whereby small spheres were injected into the coronary artery of experimental animals. This technique was developed by Clarence M. Agress of the University of California at Los Angeles.

Deep cooked . . . and always uniform in color and flavor



A horizontal vaporizer (above) is used by the Wise Potato Chip Co. Low pressure performance (144 p.s.i. at 750°F.) of Dowtherm permits the use of compact, thin-walled equipment.

Wise Potato Chip Company solves uniform process heating problem with Dowtherm, Dow heat transfer medium

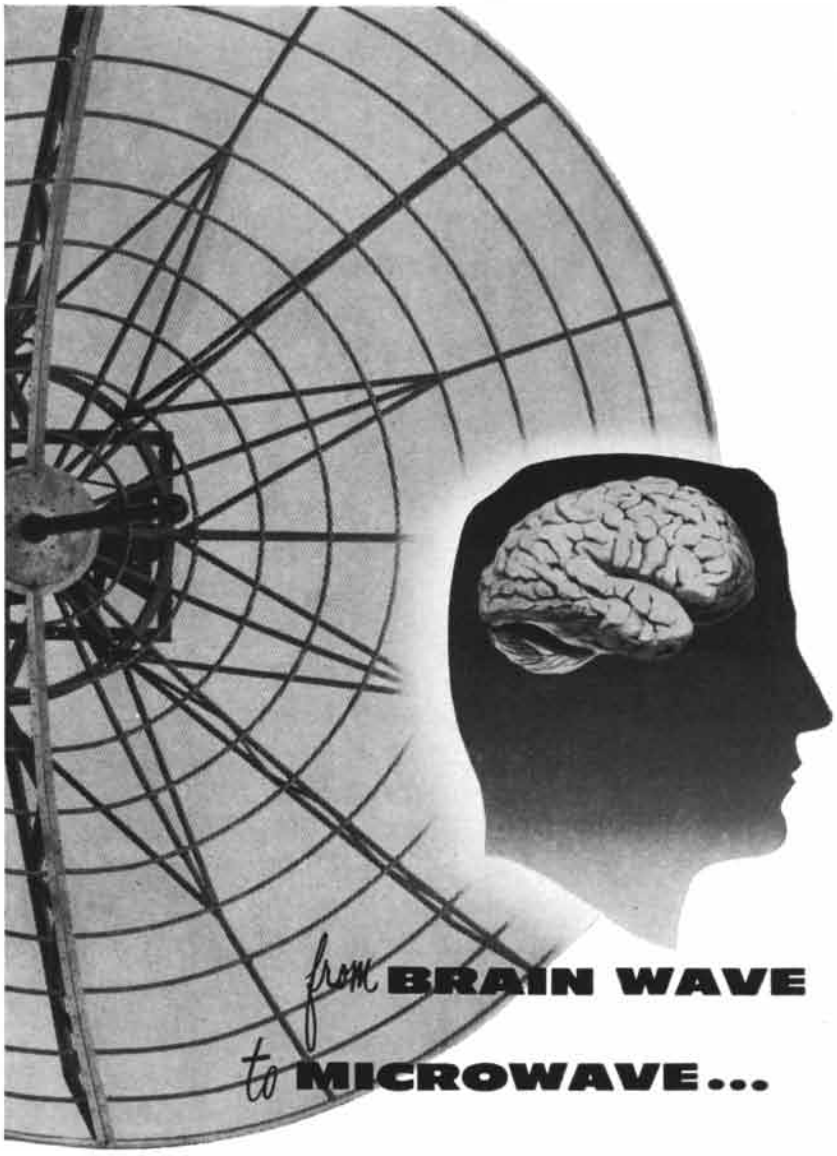
Faced with the unique problem of deep cooking uniform color, taste and crispness into their chips, a few years ago the Wise Potato Chip Company, Berwick, Pennsylvania, sought the answer to maintaining a constant temperature with varying heat loads.

Intense examination of many heating systems led the Wise Potato Chip Company to select an entirely closed heating system using Dowtherm® as a vapor heating medium.

These results were soon apparent: Now heating efficiency is very greatly improved. Fuel costs are reduced. Fire hazards are reduced because with Dowtherm the heating source is placed far from the processing area. Quality is controlled more easily by the use of Dowtherm.

For your own peace of mind, if you have a process heating problem ranging from 350° to 750°F., we advise you to talk with us. We might have the answer that will improve your product—and save your company money. THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. BD 845L.

YOU CAN DEPEND ON DOW



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Over 100 separate Kay-designed instruments are presently being used as basic research tools in industrial, governmental and educational laboratories.

These units, designed and precision manufactured by Kay Electric Company, serve a wide variety of fields by providing extremely accurate test, measurement and analytical data from sub-audio to microwave frequencies.

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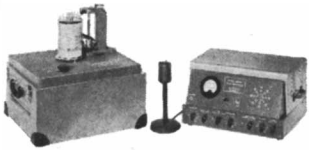
Sona-Graph

Basic Research Tool for Sub-Audio & Audio Frequencies



A sound spectrograph which produces permanent visual records of complex audio and sub-audio frequency waves. Three different recorded analyses of the waves are provided: the first relates frequency and intensity to time; the second relates intensity to frequency at any selected time; and the third relates average available amplitude to time.

The Sona-Graph is presently being used for phonetic studies, speech education of the deaf, speech impediment correction and foreign language instruction. Non-speech uses include studies of noise, vibration, shock and impulse-type waves. The Sona-Graph is particularly applicable to the Fourier analysis of waves of short duration.

Modified forms of the Sona-Graph are also being used for the study of cardiographic, encephalographic and subsonic waves. Range: 5-8,000 cps.

Price: **$1995.00** f.o.b. plant

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Mega-Sweep

Wide Range, Wide Band Sweeping Oscillator
The Basic Sweeping Oscillator in Industry for Over A Decade

- **CONTINUOUSLY TUNABLE THRU VIDEO VHF AND UHF FREQUENCIES, 50KC-950MC RANGE**
- **SWEEP WIDTHS TO 40 MC**
- **SINGLE DIAL TUNING**

Used with a standard cathode ray oscilloscope, the Kay Calibrated Mega-Sweep will display the response characteristic of wide band circuits over the frequency range of approximately 50 kc to 950 mc. It features a calibrated dial indication of the approximate output frequency. The center frequency of the sweeping output voltage may thus be set to an accuracy of about 10%. The calibrated Mega-Sweep is the ideal instrument for use in alignment of amplifiers and filters . . . also as an FM source of wide range for instructional and laboratory purposes.

SPECIFICATIONS

Freq. Range: 50 kc to 950 mc.
Freq. Sweep: Sawtooth, adjustable to 40 mc. Repetition rate, 50 to 100 c/s.
RF Output: High, approx. 100 mv max. into open circuit. **Low,** 5 mv into open circuit.
RF Output Control: Microwave attenuator continuously variable to 26 db.
Output Waveform: Less than 5% harmonic distortion at max. output.
Meter: Provides crystal detector current for peak output.
Regulated Power Supply: 105-125 v., 50 to 60 cps. Power Input, 100 watts.

Price: **$495.00** f.o.b. Plant

KAY

Transifier

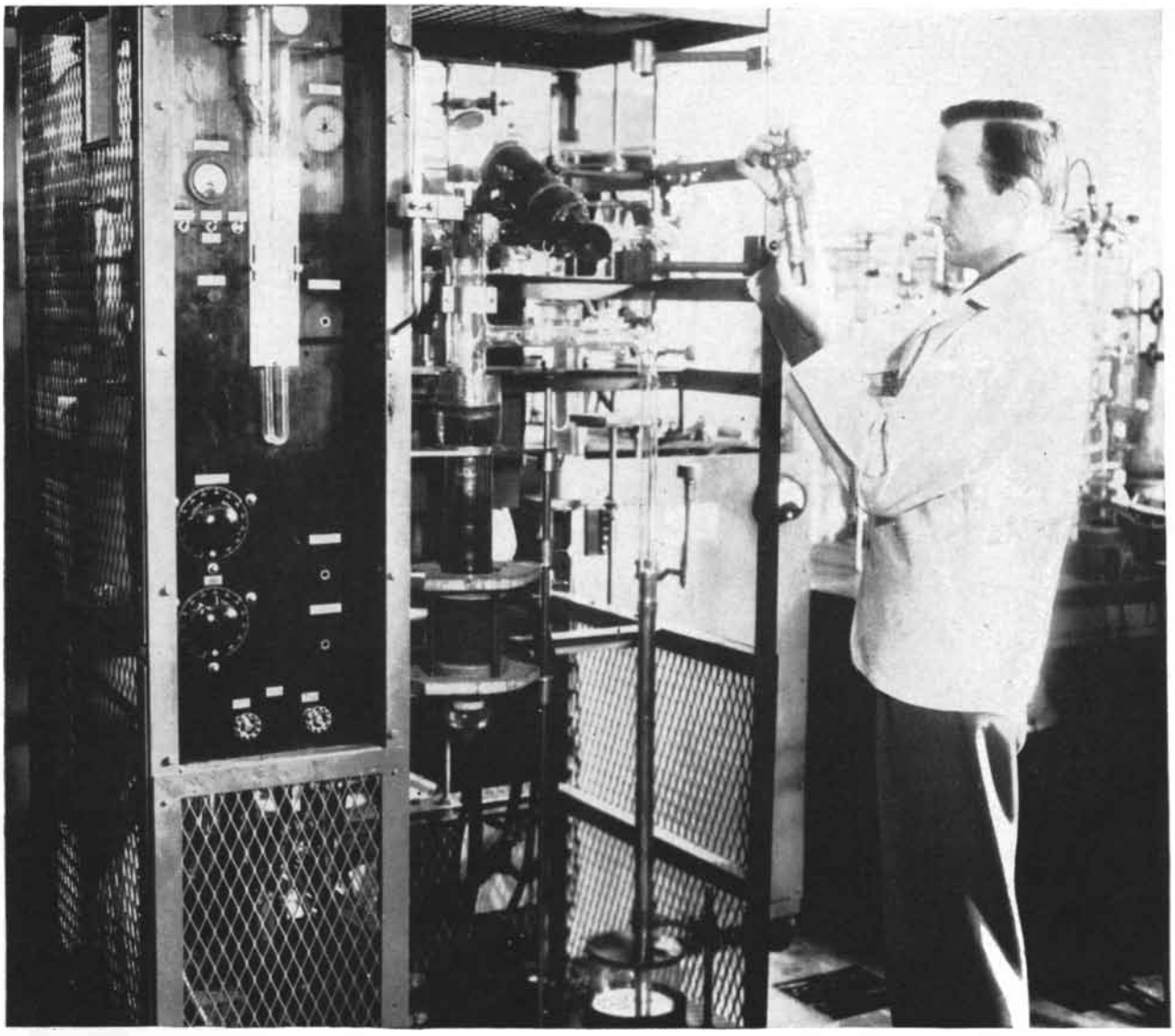
MODEL 126A
First Transistorized Audio-Video Amplifier

The Kay Transifier is the first sub-miniature broad band audio-video amplifier. The unit is portable, has no hum and is a modular plug-in amplifier with a built-in feedback circuit for stabilized signal gain.

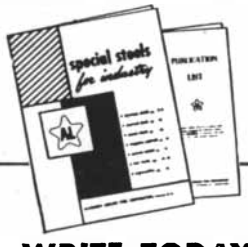
The unit is completely self-contained in a cast-aluminum housing with standard banana plug input and output. Long life battery power is obtained by using low drain, low voltage transistors.

The Transifier is ideal as a low cost unit for extending the gain of video, audio and other instrument amplifiers; vacuum tube voltmeters, cathode ray oscilloscopes and tape recorders.

Price: **$85.00** f.o.b Plant



They search so that you may find



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The technician above, in the last-word Research Laboratory recently built near our Brackenridge, Pa., plant, is running an involved analytical test on apparatus of our own devising—developed because we wanted more accurate answers on special alloy steel problems than we could get in any other way. In all of the A-L plant laboratories, the hunt for alloy steels of improved properties and greater value is always at full speed, so that *you* can have the materials you need to cut your costs or improve the competitive position of your products. ● Whenever you're trying to take a step ahead in resisting corrosion, heat, wear or great stress, or in securing special electrical characteristics, call on us. *Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.*

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One of many ways Erie Forge & Steel Corporation has cut production costs over $100,000 through the help of Socony Mobil

At Erie Forge & Steel Corporation, where the world's largest crankshafts are produced, equipment and methods are constantly scrutinized for ways to increase production and reduce maintenance costs. Plant records show how Socony Mobil has helped.

For example: During machining of Diesel crankshaft pins, metal particles welded to cutting tool tip. This excessive build-up resulted in rough finish of pin surfaces. This necessitated re-machining of up to 18 crankshaft pins a day.

A Mobil lubrication engineer analyzed the operation . . . recommended a special Mobil cutting oil. Rough finish trouble disappeared, resulting in savings of $30,000 in one year *This one saving alone more than paid for the plant's annual cost of lubricants.*

This is Correct Lubrication in Action—the *only* program that combines 91 years of lubrication knowledge with the most experienced lubrication engineers and quality products. Why not find out how it can cut your operating costs?

This complete cost-cutting service can be yours!

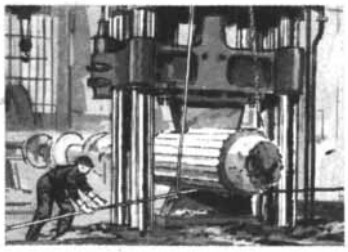
After a Mobil representative thoroughly analyzes your plant's lubrication needs, a program of Correct Lubrication is put into action. Here are some of the ways this program benefited the Erie Forge & Steel Corporation.

World's Greatest Lubrication Knowledge—Since 1866, Socony Mobil has worked with every type of industry, on every kind of machine operation. **This vast experience enabled Mobil to suggest a cleaning method to Erie Forge that eliminated monthly dismantling of hydraulic and circulating systems . . . saved $49,719 in four years.**

Continuous research and product development—Socony Mobil products are continually improved . . . new products developed to meet industry's latest needs. **A new Mobil extreme-pressure gear lubricant was recommended for Alliance 75-ton cranes. It cut wear under overload conditions . . . prolonged gear life . . . saved $1,500 in labor and material cost.**

Periodic product analyses—This service provides a thorough check on lubricant and machine performance . . . can detect trouble before it reaches the serious stage. **Analyses of samples taken from central coolant system at Erie Forge indicated bacterial contamination. Steps were taken to arrest condition, thus avoiding shutdown of all boring and sawing operations.**

Experienced engineers—Mobil engineers work closely with plant personnel . . . can call on years of practical experience to cut plant production costs. **At Erie Forge & Steel Corporation rams on hydraulic presses had to be repacked every two weeks due to high-temperature operation. Recommendation by Mobil engineer greatly extended packing life . . . cut labor costs . . . saved $20,000 in four months.**



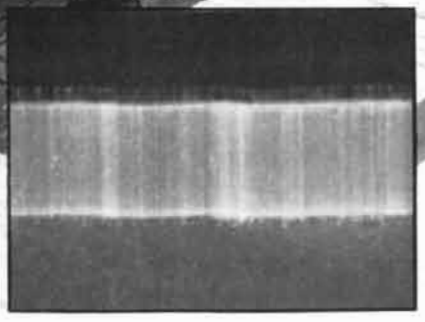
Correct Lubrication

A proved program to reduce maintenance costs

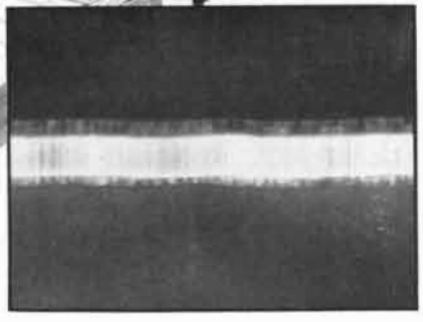
SOCONY MOBIL OIL COMPANY, INC., and Affiliates: MAGNOLIA PETROLEUM CO., GENERAL PETROLEUM CORP., MOBIL OVERSEAS OIL CO., INC.

How turning

In the physics department of the Armstrong Research and Development Center, intensity and duration of noise are measured and charted by sensitive electronic equipment. Graphs produced are similar to those shown in the diagram on facing page.



IN THIS PHOTOMICROGRAPH, light-colored band is blur caused by movement of a thin line drawn on edge of untreated vibrating metal panel. Width of this band indicates how much panel moves during vibration.



NARROW BAND in this photomicrograph shows greatly reduced vibration after asphalt-saturated felt paper is bonded to panel surface. Part of vibrational energy is turned to heat as felt flexes with the panel.

sound into heat

helps make metal products quiet

Noise can be a real problem when metal panels are used in a product. Take the sheet metal roof of your car, for instance. It would produce enough noise to make your ears ring . . . would, that is, if science had not found a way to convert noisy vibration into harmless heat.

This quieting is done most often by bonding soft, fibrous materials, such as asphalt-saturated felt paper, to the underside of the car roof.

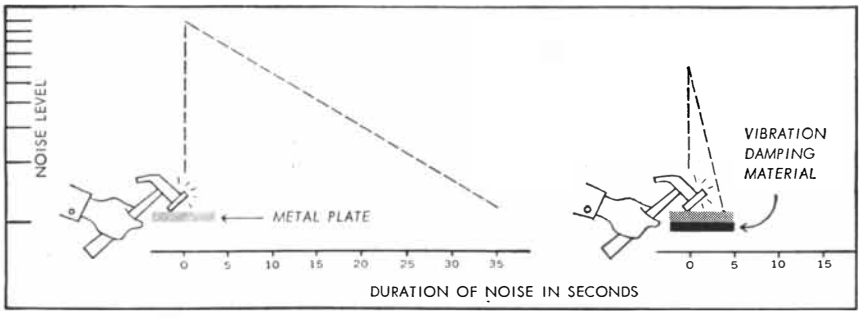
To understand how these materials work, think first of what happens when you rapidly bend a piece of wire back and forth. It gets hot. Some of the energy you put into bending it is converted to heat as tiny particles in the metal are forced to rub against each other.

The same sort of thing takes place in a sheet of saturated felt paper bonded to a vibrating metal panel. As the felt flexes back and forth in unison with the panel, the felt fibers rub against each other. The friction developed by these rubbing fibers soaks up a large part of the panel's vibrational energy, turning it into heat. Since the vibration is deadened or damped, much less noise is produced.

Fortunately, you can suppress a lot of noise and make only a little bit of heat. It has been estimated, for instance, that the heat generated in an hour by the felt on a typical, continuously vibrating panel would not be enough to raise the temperature of a teaspoon of water 2° F. Yet the amount of sound eliminated in such a case could make the difference between an automobile ride you would enjoy and one you wouldn't.

The principle of vibration damping is simple and workable. It quiets . . . and makes products seem more substantial, less "tinny." And it's adaptable to all sorts of products . . . household appliances, metal furniture and cabinets, automobiles, and many others. Of course, the specific variables involved must be properly evaluated before top efficiency can be achieved in any particular case. That's why the many years of Armstrong experience and research in vibration damping and related sound control problems can be so valuable to manufacturers. For suggestions about your vibration damping problems, write to Armstrong Cork Company, Industrial Division, 8204 Inland Road, Lancaster, Pennsylvania.

TO DEMONSTRATE how flexing of felt changes vibrational energy to frictional heat, interlock fingers, then move wrists down. Tangled felt fibers rub against each other developing friction just as your fingers do.



CURVE AT LEFT shows what happens when an untreated metal panel is "shock-excited" as by a hammer blow. Noise rises to instantaneous peak, then diminishes slowly as vibration continues for relatively long period.

WITH IDENTICAL SHOCK, level of noise created by the panel after being treated with vibration damping felt is lower at peak and dies out faster (curve at right). Both amplitude and duration of vibration are reduced.

50 AND 100 YEARS AGO

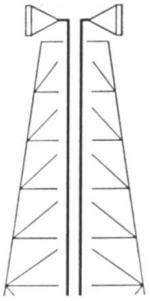
SCIENTIFIC AMERICAN

APRIL, 1907: "Commander Robert E. Peary has definitely decided to make another attempt to reach the North Pole. He stated that he would sail from New York as near July 1 next as possible. Sufficient money has been raised, he said, for repairing his ship, the *Roosevelt*, and a fund of $100,000 necessary to equip the expedition would be available before July 1. Commander Peary said that he expected to arrive among the ice fields by the middle of July. His equipment and crew, he said, would be practically the same as on his recently completed expedition. He will buy 200 dogs when he arrives in Greenland. He expects that the trip may be made in about the same length of time as the 1905 trip, which required 16 months."

"The possibility of the construction of a 30-knot liner, capable of crossing the Atlantic in four days, has recently been made the subject of discussion by the naval architect who was responsible for the design of the battleship *Oregon*. This gentleman states that the plans are practically finished for the construction of a torpedo-boat destroyer of 625 tons displacement and 12,000 horse-power, which is expected to be able to maintain a sea speed of 30 knots an hour. This will be sufficient to carry such a vessel over the transatlantic course of 3,000 knots in about four days' time. The interest in this destroyer lies in the fact that it is to be furnished with producer-gas engines, and that it will represent the first attempt to apply this system of propulsion to a high-speed vessel. According to the designer, the machinery will weigh only 210 tons, or about 35 pounds per horse-power."

"Jamestown, described as a 'Colonial city beautiful' has sprung up at Sewell's Point, on the shores of Hampton Roads, and Norfolk and the towns that nestle about this historic body of water are prepared to receive the throngs of visitors to the Jamestown Exposition, which will be formally opened by President Roosevelt April 26. The Exposition is

What kind of men develop microwave highways?



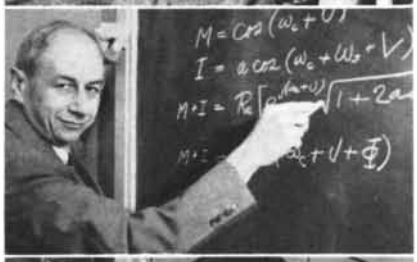
The great microwave systems that relay telephone conversations along with television programs from coast to coast will have to work harder than ever to meet growing demands for service. But at Bell Laboratories scientists have been making important advances in the art of microwave communication. These advances are being applied in the development of a new and more efficient system in which single beams of microwaves will carry simultaneously many more telephone conversations and television programs than is now possible.

The development of the new system demands the varied skills of men in many fields of science and engineering. Just a few of the specialists necessary are . . .

PHYSICISTS like J. A. Weiss, Ph.D. in Physics, Ohio State, to harness the properties of ferrites in new ways for better control of the transmission of microwaves.

MICROWAVE ENGINEERS like P. R. Wickliffe, M.S. in E.E., M.I.T., to design new circuitry. Microwaves must be conducted, controlled and amplified through waveguides which resemble pipes.

MECHANICAL ENGINEERS like W. O. Fullerton, B.S. in E.E., Iowa State, to embody new principles in designing the many structures and devices used in microwave telephony—with all parts feasible to manufacture, practical to install and easy to maintain.



SYSTEMS ANALYSTS like J. P. Kinzer, M.E., Stevens Institute, for over-all system planning and prediction. Mr. Kinzer works with numerical quantities and characteristics to predict on paper the performance of an operating system. What will it do? How must it perform to meet the needs?

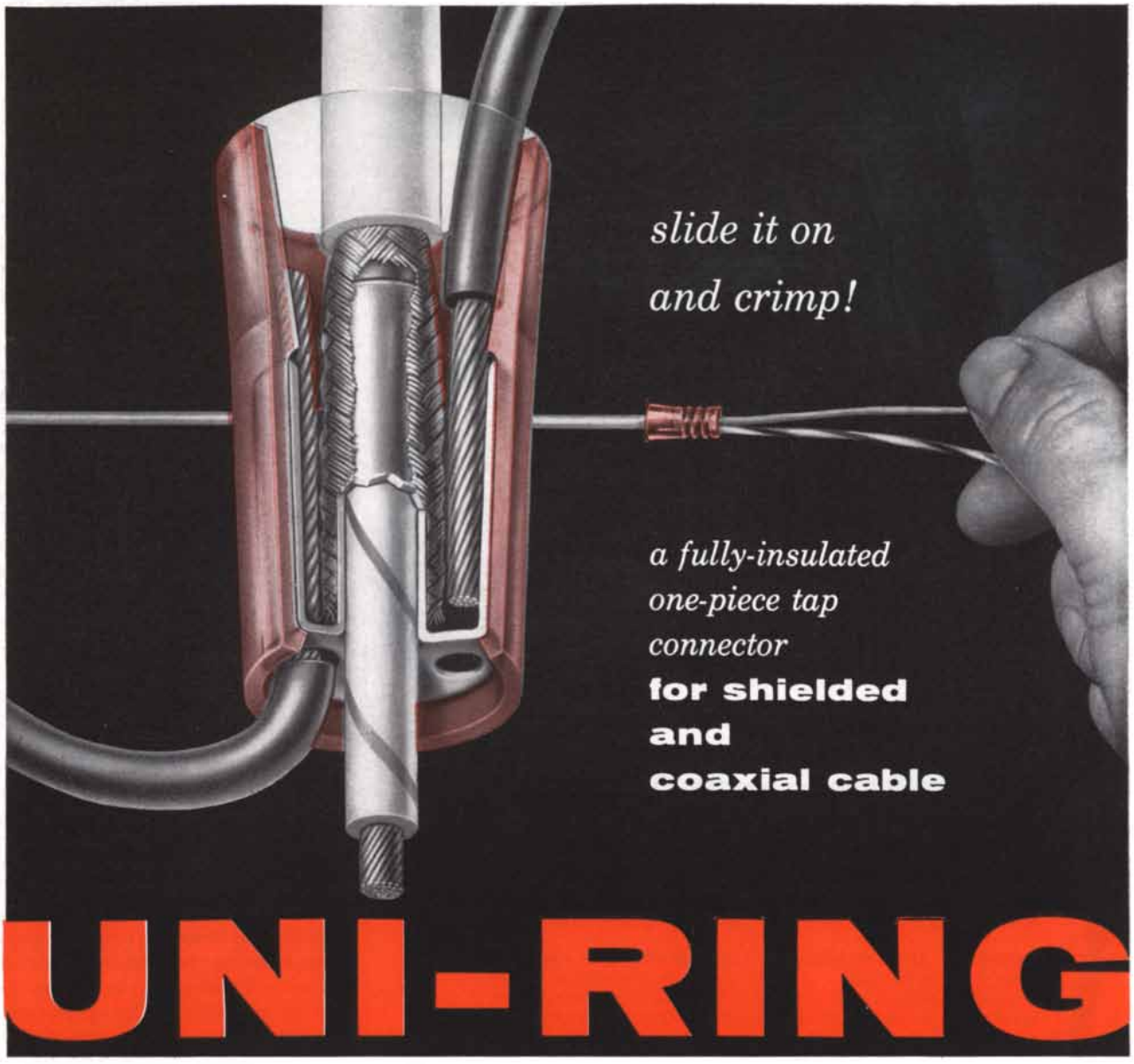
ELECTRONIC ENGINEERS like B. C. Bellows, B.S. in Engineering, Cornell, for the development of "watch-dog" equipment to protect against failure. Protective devices must operate automatically in split seconds to maintain uninterrupted service.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

in celebration of the tercentenary of the establishment of the first permanent English settlement in the New World at Jamestown. Unquestionably the most imposing feature connected with the opening of the Exposition will be the long lines of battleships and cruisers which have gathered from all parts of the world to do honor to the occasion. Of the 67 ships of importance there assembled, 27 fly the flags of friendly foreign nations, and the balance that of the United States. The visiting ships, including those of the larger size, are mainly of the armored-cruiser type, the remainder consisting of protected cruisers and a few gunboats. To be exact, there are 14 armored vessels, 9 protected cruisers, 2 gunboats, and 1 training ship. In the main, the foreign ships are representative of the latest ideas of the powers in the various types that are represented, up to the close of what might be called the *ante-bellum* period, or the period which closed with the Russo-Japanese War. There is, however, one important exception, which is furnished by the Japanese themselves, who have sent over, in that splendid ship the *Tsukuba,* the first of a new type—the cruiser-battleship—to make its appearance on the high seas. In dispatching the *Tsukuba* to Jamestown, the Japanese have at once paid us the compliment of sending their latest and finest ship of its class, and, incidentally, they present to the United States concrete evidence of the fact that they are now entirely independent of foreign ship-builders."

APRIL, 1857: "The New York *Tribune* very properly contends that the great value of artichokes has never been understood generally by American farmers. They will produce a thousand bushels per acre with little or no cultivation, upon a moist rich soil, and the roots will keep undug through the winter; or they may be plowed out and used for fodder in the fall, and hogs may be turned in upon the grounds in the spring to root up the small roots (this gives the land an excellent preparation for any other crop). The same roots have been long grown in all the New England states in little patches, for the amusement of the pigs and pleasure of the boys, who are fond of digging and eating them raw in early spring. Sometimes they are used for pickles but seldom cooked in the



UNI-RING

UNI-RING offers a tremendous saving in installation time over any previous method of tapping or terminating shielded or coaxial cable. As the inner ring slides under the shielded braid, the tap wire is held between the braid and the outer ring. Single or multiple taps, from either the front or back of the connector, can be accommodated . . . A single crimp, using the same basic HYTOOLS used for installing HYRINGS, completes the uniform, secure, and insulated assembly.

The protecting nylon insulation extends beyond both ends of the UNI-RING, eliminating metal-to-metal contact and preventing harmful wire-chafing in tight locations. The UNI-RING is color-coded to indicate conductor sizes.

UNI-RING's one-piece design insures electrical integrity, prevents heating, and eliminates noises caused by isolated metal parts.

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BURNDY

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Northern states, while in the South they make a common dish upon many tables."

"It is a well-established fact that the yellow fever—a disease formerly confined to the cities and districts of the far South—has, within a few years, become quite serious in Northern seaport places. The introduction of the yellow fever into the garrison on Governor's Island, harbor of New York, is attributed to the arrival of invalid soldiers from the forces in Florida. The illness and death of their comrade at Morris Island is satisfactory on this point, and shows that the rigorous execution of the quarantine law excluded at least one case from the city. We have every reason to believe, if it be capable of excluding one source of disease, it is capable of excluding many, and may finally arrive at that state of executive perfection as to exclude all. When that happy period shall arrive, merchants as well as citizens will believe that there is some virtue in well-regulated and vigorously executed quarantine laws."

"From the number of communications which we have received on the 'divining rod,' we cannot question the *honest* belief of a number of our readers in its virtues. There are many phenomena in nature which are yet sealed up to us, and the divining rod may be one of these; still, we must say that we are skeptics in the powers or virtues which are attributed to it. We believe that any man of a reflecting and observing mind can guess where water may be obtained by boring, without a divining rod, as well as another person with one. Our opinion may be wrong, but we cannot come to any other conclusion by reasoning on the subject from scientific data. If, however, we are at any period of time after this convinced by ocular demonstration that there is scientific virtue in the divining rod, we will frankly make the change of our views known."

"M. von Humboldt has written to the Astronomical Society of Berlin on certain appearances connected with the zodiacal light, drawing attention to new facts connected with that phenomenon, from which it appears that this remarkable light is not confined to the west, as was supposed, but has been seen by himself and others in the east, at the same time. The conclusion drawn from the various observations made in regard to this phenomenon is that the earth is surrounded by a nebulous ring lying within the moon's orbit, confirming the views of Rev. G. Jones."

Quarter-inch steel plate is melted with an acetylene torch, but the supporting ALFRAX® BI brick stays cool enough to be held by hand.

Refractories...for really high temperature **insulation**

The problem of heat insulation at extreme temperatures is solved by two of Carborundum's refractories:

One is made of fused alumina "bubbles" or hollow spheres, bonded and high fired. These selected bubbles give proper balance between the number of surface temperature drops and total pore space (about 65% porosity) to effectively decrease heat flow between hot and cold faces. The alumina imparts high hot strength to the finished refractory, trade-marked ALFRAX BI. Under a load of 12½ psi and a temperature of 2732° F held for 1¾ hrs., less than 1% contraction occurred. No contraction whatever developed in 5 hour reheat tests at 3092° F. This combination of properties makes ALFRAX BI refractories unique in their ability to insulate at temperatures where other materials are impractical.

The other is FIBERFRAX® ceramic fiber, produced by blowing an alumina-silica fusion. Among its properties are high insulating values, light weight, resiliency, and corrosion resistance. All are retained at 2300° F. In some cases, this fiber can be used successfully up to 3000° F. It is supplied in long and short staple, rope, board, paper, block, blanket, etc.

These products are but two of the many super refractories pioneered by Carborundum. Among them you are almost certain to find answers to your refractory and high-temperature problems. For help, fill in and mail this coupon today.

CARBORUNDUM
Registered Trade Mark

MAIL THIS COUPON TODAY

Refractories Division,
The Carborundum Company, Perth Amboy, N. J., Dept. Q47

Please send me:

- ☐ Forthcoming issue of Refractories Magazine
- ☐ Bulletin on Properties of Carborundum's Super Refractories
- ☐ Here is a description of my high temperature problem. Can you help me?

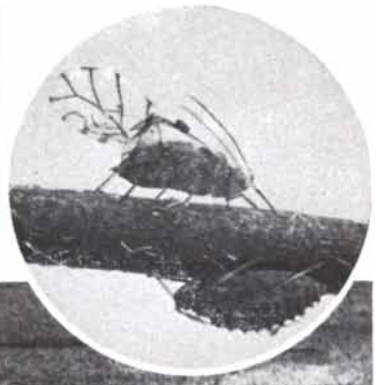
Name_____ Title_____

Company_____

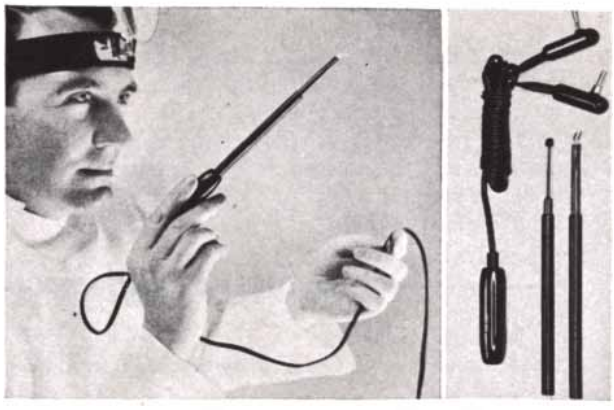
Street_____

City_____ Zone_____ State_____

Life ...on the Chemical Newsfront



SINCE ITS FIRST APPEARANCE IN 1954, the spotted alfalfa aphid has spread like wildfire and now poses a threat to every alfalfa-growing region of the U. S. Unless controlled, this prolific pest can ruin fields. Since alfalfa is fed to cattle, and sprays often are needed as close as seven days to harvest, the insecticide must be effective yet not leave toxic residues. Cyanamid's malathion is the only recommended insecticide which fits both these specifications... and also offers safety in handling. Light area in photo shows complete destruction of alfalfa by aphids where the spray plane missed a corner of the field. **(Phosphates and Nitrogen Division)**



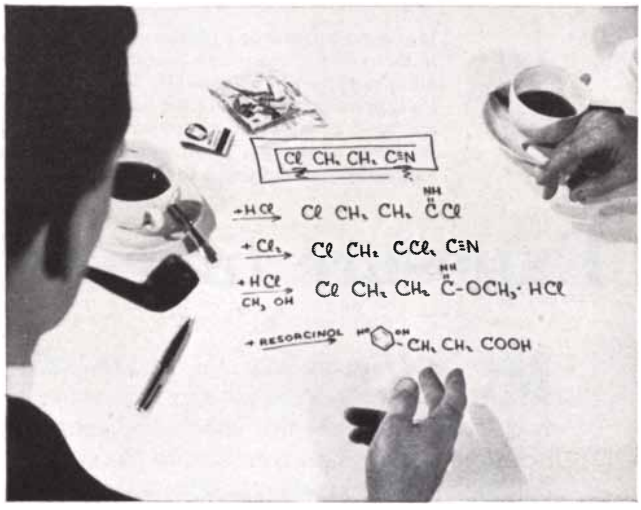
HIGH-FREQUENCY ELECTRODES are encased in mineral-filled CYMEL® Melamine Molding Compound in a new electrosurgical instrument manufactured by the Birtcher Corp. of Los Angeles. Used in the removal of tonsils, cervical cysts and surface growths, this instrument benefits from the excellent insulation and precision molding characteristics of CYMEL by insuring proper spacing and action of the electrodes. Handles and cord tips are molded of alpha cellulose-filled CYMEL, also an excellent insulator. All surfaces are exceptionally hard and chip resistant, and can be sterilized easily. **(Plastics and Resins Division)**

SMOOTH, PERFECT SURFACES on molded plastic products depend in part on a clean, even coating of mold lubricant. Stearates are commonly used for mold lubrication, and new processing equipment has been installed at Cyanamid's stearates plant to insure freedom from contamination at each manufacturing step. The resulting grades of aluminum, zinc, calcium and magnesium stearates can be counted on for trouble-free application where quality is critical. Molders of MELMAC® quality melamine dinnerware, for example, can count on Cyanamid stearates to obtain the characteristic fine surface finish. **(Industrial Chemicals Division, Dept.A)**

LASTING FRESHNESS CAN NOW BE "BUILT IN" to clothing, linens, and other textiles normally subject to perspiration-based odors. Having no significant odor itself, perspiration is subject to attack by certain bacteria which produce objectionable by-products. Cyanamid's new CYANA® Purifying Agent controls these bacteria, keeping the garments fresh indefinitely. Applied easily to textiles at the mill, CYANA Purifying Agent is unusual in its ability to maintain protection through repeated launderings, in many cases for garment's life. **(Organic Chemicals Division)**

VACUUM PACKING OF RUBBER ACCELERATORS is now carried out in Cyanamid's new MBTS (benzothiazole disulfide) plant. The new bagging process applies suction through the bag walls during filling, densifying the contents. The smaller, neater bag of Cyanamid MBTS is easier to handle, more efficient to unit-load and store. Free-flowing characteristics are not affected. Cyanamid is the first to apply this packaging technique to high-grade rubber chemicals.

(Organic Chemicals Division)



BETA-CHLOROPROPIONITRILE combines the reactivity of an aliphatic nitrile with that of an alkyl chloride, leading to many reaction possibilities including application in certain polymers. For example, a mixture of ethylenic compounds copolymerized in the presence of beta-chloropropionitrile leads to interesting elastomers. Extensive data on the reactions of beta-chloropropionitrile and many other promising intermediates and experimental samples of this reactive compound are available on request from Cyanamid.

(New Product Development Department)

CHEMICAL PROGRESS WEEK-APRIL 8-12

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

Here's an unusual picture—the blazing inferno of an open hearth furnace "boil." Taken in the merest fraction of a second by a high-speed movie camera, it gives a rarely intimate glimpse of the process by which furnace iron, ore and scrap are transformed into refined steel. Such revealing pictures of the boiling bath of steel and slag disclose to the furnace operator and plant metallurgist significant action hitherto only vaguely perceived—enable the scientist to better understand the kinetics of heat transfer and chemical reaction at temperatures approaching 3000 degrees F.

Exposure time-1/6000 of a second!

MOTION PICTURES like this, taken 120 times faster than a lightning flash, make it possible to observe—in slow motion—characteristic actions and reactions in the steelmaking process so violent and instantaneous that they have hitherto defied analysis.

For, by the use of a high-speed camera that can take up to 3000 frames *per second*, one second of action filmed, when projected at the usual 16 frames per second, takes almost 4 minutes to be viewed.

Such a tremendous magnification of time has enabled the scientists at United States Steel's Fundamental Research Laboratory not only to see clearly, but to study carefully, phenomena that occur far too fast for the eye even to distinguish. It has helped to clear up and record many significant happenings that formerly were merely guessed at—has provided us with data that promise to be of important assistance in the development of ever better steels.

Already the information obtained with the high-speed camera has led to a clearer understanding of some of the complex mechanisms operative in blast furnaces and open hearth furnaces, and has shed additional light on such diverse processes as arc welding, quenching procedures and impact testing.

Fundamental research of this kind is typical of the painstaking steps by which United States Steel is constantly striving to meet the most exacting steel requirements of today and to anticipate those of tomorrow. United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pa.

USS

UNITED STATES STEEL

ALUNDUM* High-Purity Fused Alumina

...has many important advantages that may benefit your own operations

ALUNDUM fused alpha alumina, one of many electrochemically refined materials produced by Norton Company, is gaining increased preference for many industrial uses.

It is available in a number of forms. Of these, 38 ALUNDUM grain has proved particularly successful in applications demanding high purity. Electrically fused from Bayer-processed alumina, this white grain is 99.49% pure Al_2O_3. It is insoluble in common solvents, extremely resistant to reduction and is an amphoteric refractory with high dielectric strength. Other characteristics include:

Melting point	about 3600°F.
Specific gravity	3.94
Crystal structure	hexagonal system (rhombohedral division)
Hardness	9.0 Mohs' scale
Index of refraction	1.76 mean

Norton Also Electrochemically Refines

CRYSTOLON* silicon carbide, MAGNORITE* magnesium oxide, NORBIDE* boron carbide, FUSED ZIRCONIA and many others, including a number still under development. Having varied applications in many fields, these high-melting materials are also basic ingredients of the famous Norton Refractory Rx's — refractories *engineered and prescribed* for the widest range of uses.

For Your Own Requirements

Norton Company not only supplies these materials in crude form but is ready to work with you in processing or fabricating them to your own particular requirements. The new booklet, *Norton Refractory Grain — Electrochemically Refined,* brings you detailed information. Write for your copy to NORTON COMPANY, Refractories Division, 543 New Bond Street, Worcester 6, Massachusetts.

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

Thanks to the inherent hardness, chemical stability and high density of Norton high-purity fused alumina, engineers in various fields are finding it widely useful. For example:

For Catalytic Reactions

Norton fused alpha alumina carriers are outstanding for chemical stability and resistance to abrasion and erosion. Available in the form of spheres, rings and pellets they are used in fixed bed oxidation reactions where the application requires a low surface area (less than $1 m^2/gm$) carrier. Inert, dense ALUNDUM spheres are also available for space filler applications. Other types of ALUNDUM catalyst carriers having surface areas in the range 5–60 m^2/gm are also available.

In Thermal Cracking Reactors

Particularly in Wulff Process Generators for cracking light hydrocarbons to produce acetylene gas and Koppers-Hasche Generators for cracking light hydrocarbons to produce a variety of gases and petrochemicals — checkers made of Norton ALUNDUM high-purity fused alumina provide definite advantages. Their excellent heat transfer properties, high refractoriness and resistance to erosion caused by hot gases are important. Their ability to withstand the thermal stresses of intermittent operation assures long life. And their purity prevents side reactions with the reacting gases, thus safeguarding product quality.

In Pebble Heaters

ALUNDUM heat exchange pebbles are giving excellent results in pebble heaters for heating gases above operating temperatures permissible in conventional tube furnaces. Their great resistance to abrasion, impact and repeated heating and cooling make them the ideal heat transfer medium in these devices. Also, their high refractoriness prevents them from the softening and "bridging" together that causes stoppages in the heater's moving bed.

In Gas Synthesis Generators

ALUNDUM fired shapes, backed up with ALUNDUM insulating castable, provide ideal linings for generators of this type because of their high-purity, high refractoriness, chemical stability, and inertness to reaction with contacting atmospheres.

Many Other Uses

for Norton high-purity fused alumina materials include: pure oxides and sintered refractories, refractory cements, wear-resistant parts, laboratory ware, etc.

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REFRACTORIES
Engineered... Rx ...Prescribed
Making better products . . . to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories
BEHR-MANNING PRODUCTS: Coated Abrasives • Sharpening Stones • Behr-cat Tapes

THE AUTHORS

PHILIP MORRISON ("The Overthrow of Parity") is associate professor of physics at Cornell University, where he has done pioneer work applying physical theory in a number of fields, including microbiology. He graduated from the Carnegie Institute of Technology in 1936, then studied theoretical physics under J. Robert Oppenheimer at the University of California, where he received his doctorate in 1940. When World War II broke out, Morrison left a lectureship at the University of Illinois to join the Metallurgical Laboratory of the University of Chicago, and later became a group leader at the Los Alamos Laboratory of the Manhattan District. Morrison joined the Cornell faculty in 1946. His article "The Neutrino" appeared in the January, 1956, issue of this magazine.

THEODORE X. BARBER ("Experiments in Hypnosis") is associated with Harvard University's Laboratory of Social Relations. He is at present conducting experiments in hypnosis and psychosomatic medicine under a grant from the National Institute of Mental Health. He was trained in the classics at St. John's College in Annapolis, Md., then spent two years studying philosophy and comparative literature at the New School for Social Research. After that he turned to science, studied zoology and physiology for three years at George Washington University and went on to take a doctorate in psychology at American University in Washington, D. C. Barber's middle initial stands for Xenophon.

P. B. MEDAWAR ("Skin Transplants") is Jodrell Professor of Zoology and Comparative Anatomy at University College London. He studied anatomy and morphology under H. W. Florey at the University of Oxford, where he was awarded several prize fellowships at Magdalen and St. John's colleges. After 10 years as a lecturer at Oxford, he went to the University of Birmingham as chairman of the department of zoology from 1947 to 1951. Medawar became interested in skin grafts 15 years ago when the British Medical Research Council asked him to investigate the reaction to these transplants. He has been studying this topic on and off ever since, with time out for work on several other problems of cellular and quantitative biology. Besides his academic du-

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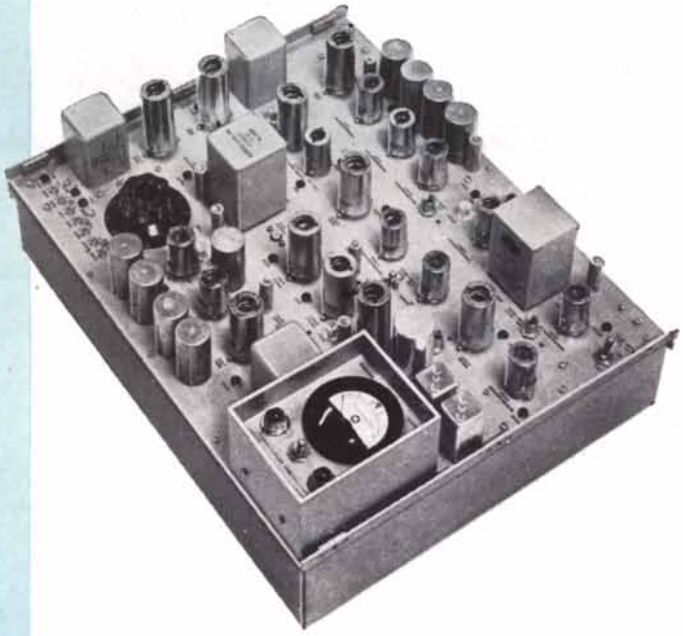
Scatter communication, which is ordinarily hampered by fading, can be made reliable by diversity reception.

This calls for two or more receivers operating independently and simultaneously from the same signal. Originally, an automatic switching arrangement selected the stronger of the receiver outputs. Even the near-instantaneous act of switching often upsets teletype reception, and an improved method was needed.

REL achieved the solution with the first successful combiner, which continually couples the output of all receivers in a diversity system. In addition, the combined signal is always stronger than that of any one receiver alone. The compact REL combiner *(right)* remains unchallenged in simplicity and reliability.

The same imagination and facilities which so brilliantly served in this case are also available for the solution of your specialized radio problem.



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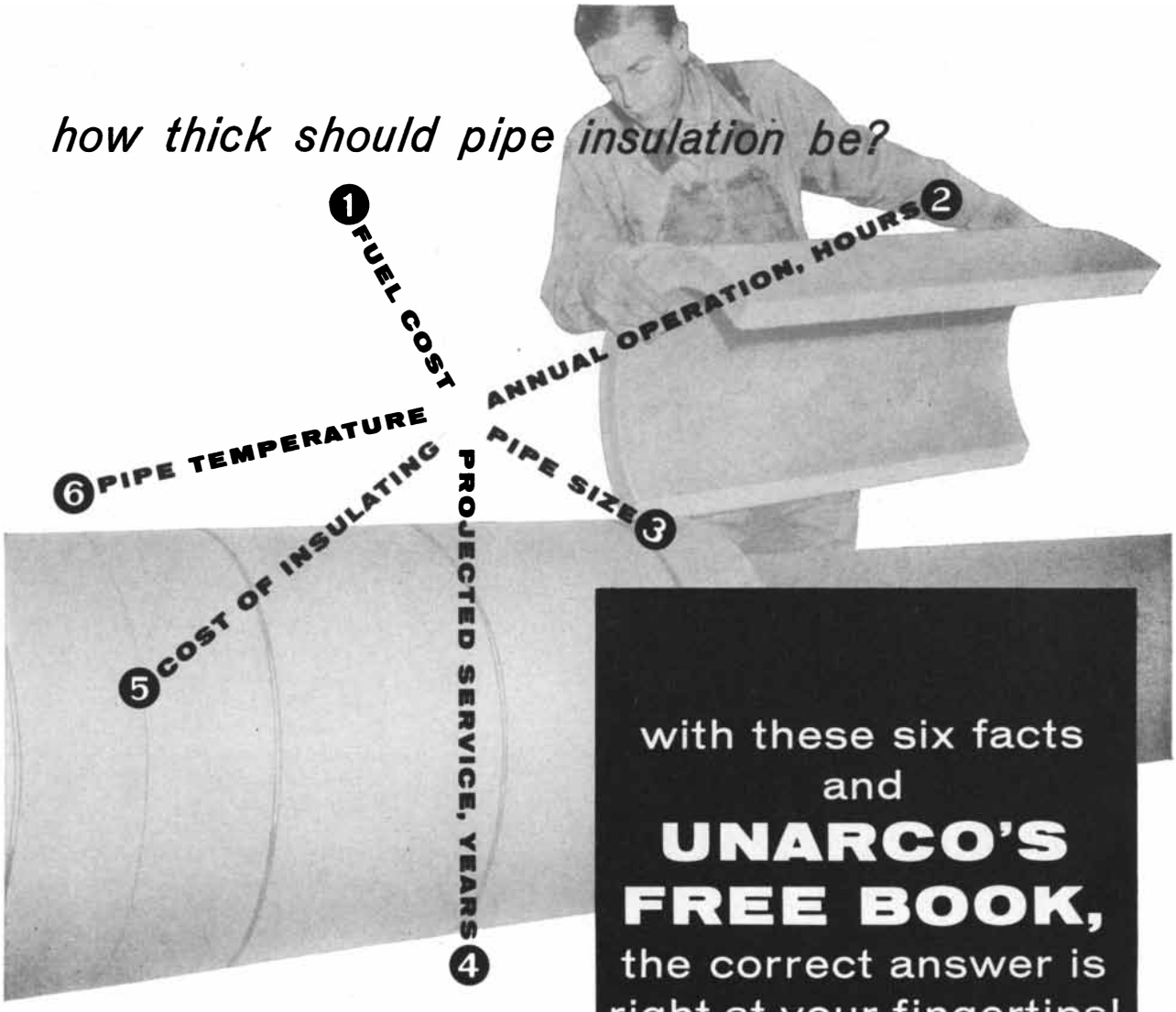
ties, Medawar serves on the British Agricultural Research Council and on the University Grants Committee, which advises the British Treasury on the distribution of funds to all of Britain's universities. He was elected to the Royal Society in 1949.

HARRISON BROWN ("The Age of the Solar System") is professor of geochemistry at the California Institute of Technology. He graduated from the University of California in 1938 and took a Ph.D. at the Johns Hopkins University in 1941. After wartime service in the Clinton Laboratories at Oak Ridge, Tenn., where he was assistant director of the chemical division, he returned to a post at the University of Chicago's Institute for Nuclear Studies. He transferred to Cal Tech in 1951. At present he is studying the distribution of elements in meteorites. Brown is the author of two popular books on science, *Must Destruction Be Our Destiny?* and *The Challenge of Man's Future;* a third, *The Next Hundred Years,* written in collaboration with his colleagues John Weir and James Bonner, will be published this year. Brown reviewed Immanuel Velikovsky's *Earth in Upheaval* in the March, 1956, issue.

P. F. SCHOLANDER ("The Wonderful Net") heads the new Institute of Zoophysiology at the University of Oslo. When the Institute was established some months ago, its first project was an expedition to Barro Colorado Island in the Panama Canal Zone to study the physiology of blood-vessel nets in the sloth. Scholander was born in Orebro, a town in Sweden, and later moved to Norway. As a student at the University of Oslo, he says, "I found an intellectual outlet from medical studies in music and lichenology, which took me on expeditions to Greenland and Spitsbergen. In 1932 I undeservedly received my degree in medicine, and in 1934 a Ph.D. in botany was bestowed upon me. I then turned to the study of diving in seals, whales and penguins, and have worked in comparative physiology ever since." Scholander came to the U. S. in 1939 as a Rockefeller Fellow to study diving with Laurence Irving of Swarthmore College. During World War II he was an aviation physiologist for the U. S. Air Force and became a naturalized U. S. citizen. He later studied climatic adaptation in the Arctic Research Laboratory at Point Barrow in Alaska, did research on cell respiration at the Harvard Medical School and worked at the Woods Hole Oceanographic Institution, where

how thick should pipe insulation be?



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Too much insulation can be just as wasteful as *too little*. Every insulation-dollar you spend, which is not amortized by fuel-savings, represents needless investment. But, until UNARCO developed "J" Factor Tables, engineers had no *easy way* to determine the most economical thickness.

With today's "J" Factor Tables—and knowing the cost of fuel, hours of operation, life expectancy of the installation, pipe sizes and temperatures, and the cost of insulation, installed—it's merely a matter of ready reference to pick out the right thickness to use.

Time-saving UNARCO "J" Factor Tables should be in every engineer's file. Everything is condensed into five simple charts covering pipe temperatures up to 1200° F. and insulation thicknesses from 1″ to 6½″. This, and much other pertinent data, is included in UNARCO'S free new 40-page book.

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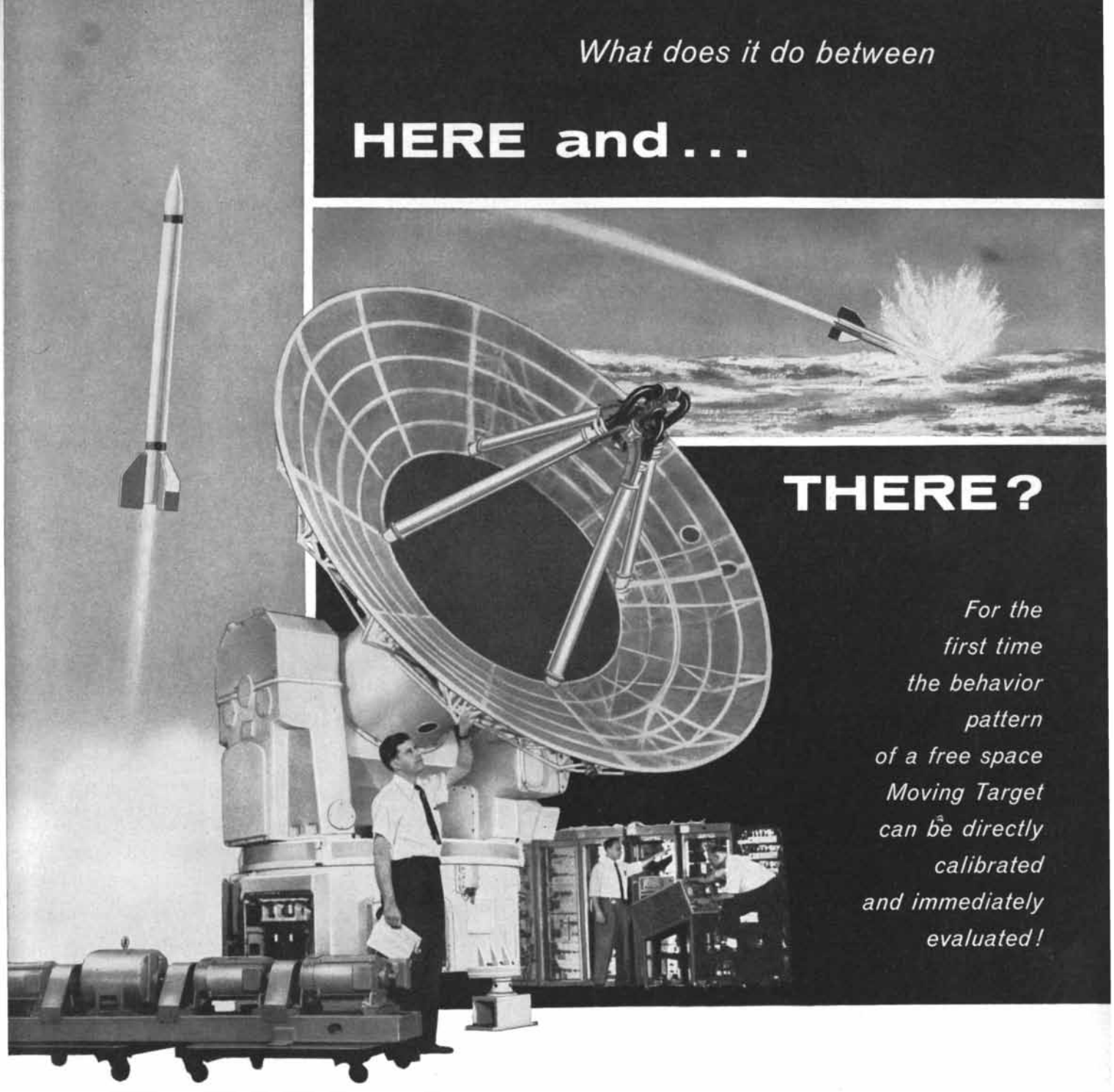
"I had three wonderful years studying my pet subject, gas secretion in the swim bladders of fishes, and stretching the limits of oceanography to include such problems as the rise of sap in tall trees and the canned meteorology frozen in glaciers." Scholander adds: "I have two great hobbies in life. One is science, stretching from whales to single cells, from the tropics to the arctic and from the tops of trees to the depths of the ocean. The other hobby is playing the violin in the laboratory."

ANDRÉ CLASSE ("The Whistled Language of La Gomera") is a lecturer on phonetics at the University of Glasgow. He was born in France and graduated from the Sorbonne. After receiving a Litt.D. from the University of Glasgow in 1939 (his thesis was a book entitled *The Rhythm of English Prose*), he taught French for several years, and published works on the pronunciation of French and English. Classe associates his love of phonetics with a deep interest in music and an amateur interest in electronics. "My ambition," he says, "is to find another novel subject like the whistled language which will take me to a pleasant part of the world like the Canary Islands."

FRANK B. SALISBURY ("Plant Growth Substances") is assistant professor of botany at the Colorado Agricultural and Mechanical College, which on May 1 will become Colorado State University. He was born in Provo, Utah, and graduated from the University of Utah in 1951. After taking an M.A. there, he went to the California Institute of Technology for his Ph.D. He studied plant physiology under James Bonner and minored in geochemistry under Harrison Brown (whose article "The Age of the Solar System" appears in this issue). Most of Salisbury's research work has been on the chemistry of flowering.

WALTER ORR ROBERTS ("Sun Clouds and Rain Clouds") directs the High Altitude Observatory of the University of Colorado. He began his career in astronomy as an amateur telescope-maker under the tutelage of Albert Ingalls' department on the subject in this magazine. Roberts has received three degrees from Harvard University, including a Ph.D. in solar astrophysics. He went to the High Altitude Observatory in 1940 to help set up its coronagraphic station. He was the author of an earlier article on sun clouds ("Corpuscles from the Sun") in the February, 1955, issue of SCIENTIFIC AMERICAN.



The proof of any guided missile is its performance. Not only is it necessary to provide accurate trajectory data in order to determine its effectiveness, but this must be made immediately available.

To meet both requirements is the purpose of the AN/FPS-16 instrumentation radar. This is the first radar developed specifically for Range Instrumentation. It has demonstrated its ability to track with accuracy in darkness, through clouds—under any atmospheric conditions—over extended ranges, and to yield data that can be reduced almost instantaneously to final form. This unit can also be assigned to plot performance of missile, satellite, drone and other free space moving targets.

In the past, this data has depended upon optical devices, triangulation systems with long base lines and precision limitations, modified radar equipment and data reduction methods often requiring months for computation. The immediate availability of data evaluation provided by the AN/FPS-16, now being built by RCA under cognizance of the Navy Bureau of Aeronautics for all services, is a great forward step in Range Instrumentation.

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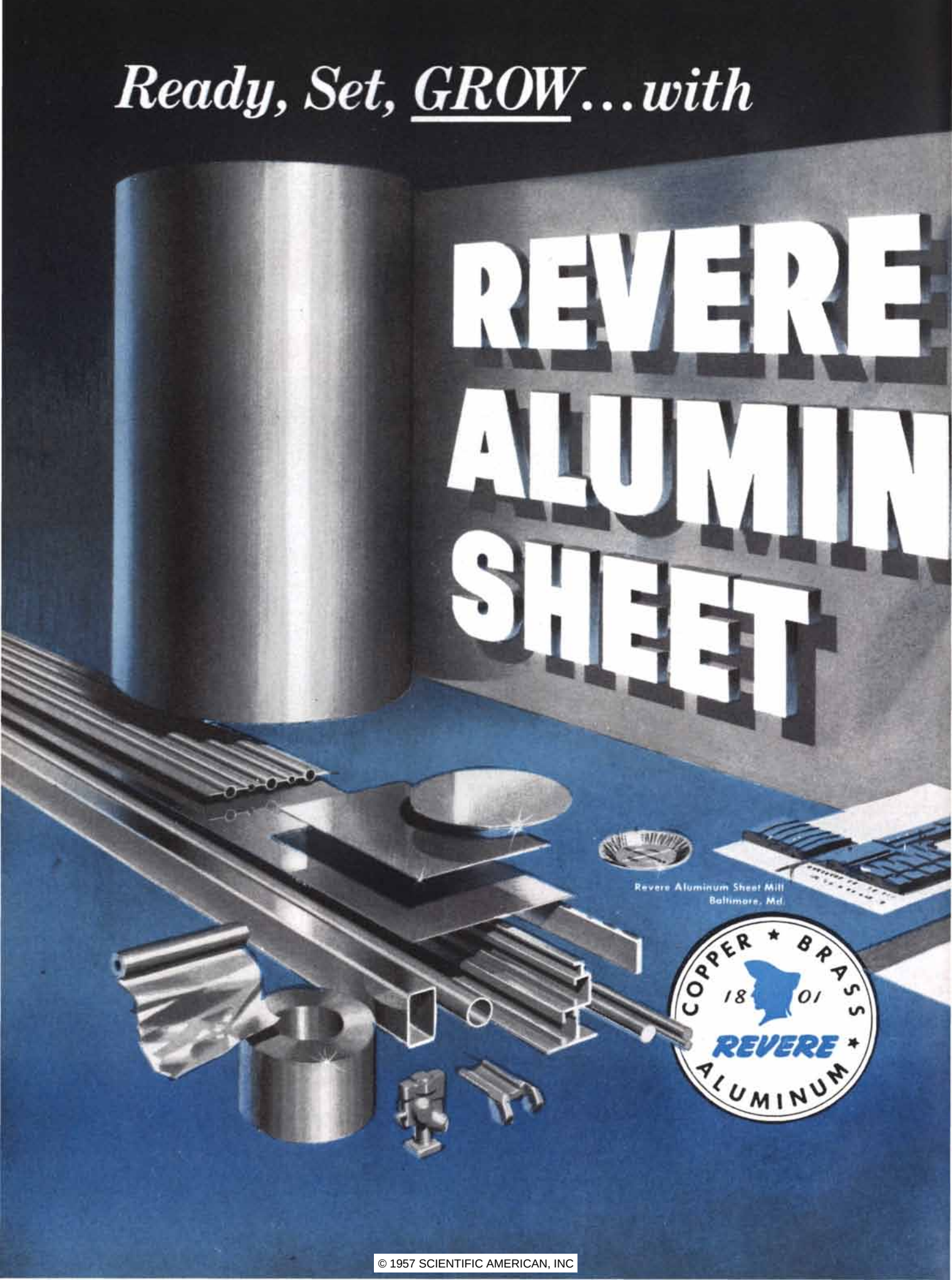

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Baltimore, Md.

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You will find that Revere Aluminum Sheet passes smoothly and economically through your processes, that it brings to your products all the advantages you expect from fine aluminum.

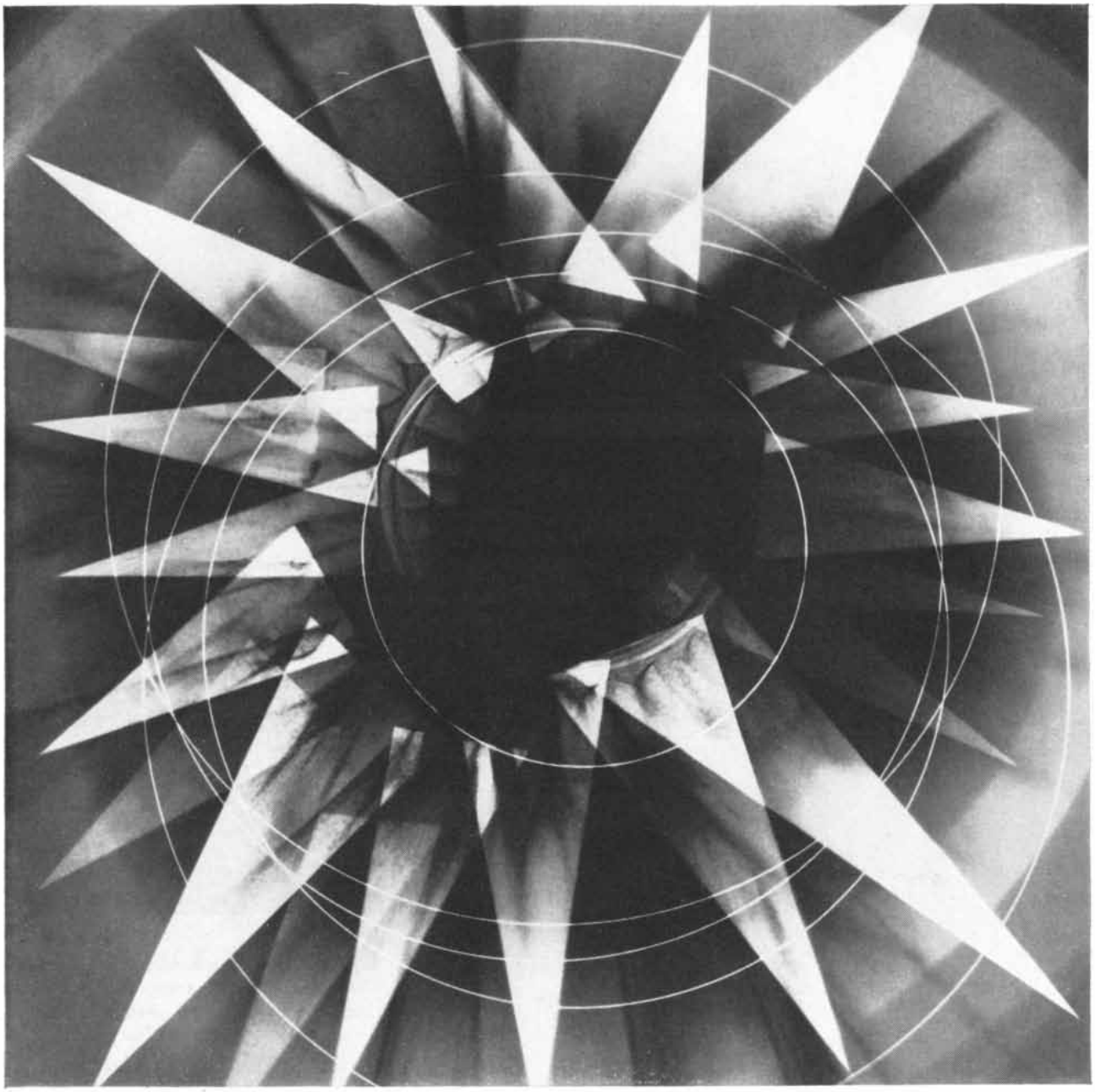
Three Revere plants, located in the East, the Mid-West and on the Pacific Coast, can bring mill service and technical consultation close to your own doorstep. These plants will have the backing of Revere's primary aluminum operation, scheduled to begin production in 1958.

It will pay you to tie the growth of your business to the most dependable sources of supply—such as Revere, which is in aluminum in a BIG WAY. Revere Copper and Brass Incorporated. Founded by Paul Revere in 1801. Executive Offices: 230 Park Avenue, New York 17, N. Y.

Revere Aluminum Mill Products include coiled and flat sheet, both plain and embossed, circles, blanks, Tube-In-Strip, extruded products, seamless drawn tube, welded tube, rolled shapes, electrical conductors, forgings, foil and frozen food containers.

New Revere Aluminum Sheet Mill
Chicago, Ill.

← Projected for 1957: New Revere Aluminum Sheet Mill Santa Ana, Calif.



breaking the barriers
with Utica Vacuum Metals

Now that supersonic flight has become routine, today's challenge lies in developing *metals* and *means* of cracking the thermal barrier.

The metals problem has already been partially solved by superalloys produced through Vacuum Melting. This process, as developed by Utica, has yielded such super refractory alloys as Udimet 500—a clean, pure alloy combining unsurpassed stress-rupture life with superior high tensile strength in the 1200° F to 1800° F range. *At 1600° F, Udimet 500 has a tensile strength of over 100,000 PSI.*

In addition to the development of new and superalloys, Utica specializes in upgrading the quality of existing alloys.

VACUUM MELTING
provides these properties

- High temperature corrosion resistance
- Increased ductility
- Extreme cleanliness
- Precise chemical control
- Longer stress-rupture life
- Increased tensile strength
- Better fatigue resistance
- Greater yield strength
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DAYSTROM REACTOR TRAINING CENTER

for

TOMORROW'S NUCLEAR RESEARCH

TWO PHASE D.A.R.T. PROGRAM OFFERS COMPLETE RESEARCH REACTOR CONSTRUCTION AND TRAINING

Practical nuclear training for selected industrial personnel and university faculty members is offered by Daystrom at the new Training Center in West Caldwell, New Jersey.

This two phase program encompasses:

D. A. R. T. REACTOR TRAINING

This specialized curriculum is designed to include lectures and training in:

1. Basic reactor technology and theory
2. Operation of an actual D.A.R.T. Reactor
3. Applications of nuclear research reactors
4. Maintenance of reactor controls and instruments
5. Preparation to qualify for licensing by the A.E.C. as a reactor operator capable of instructing others in the operation and use of the D.A.R.T. Reactor.

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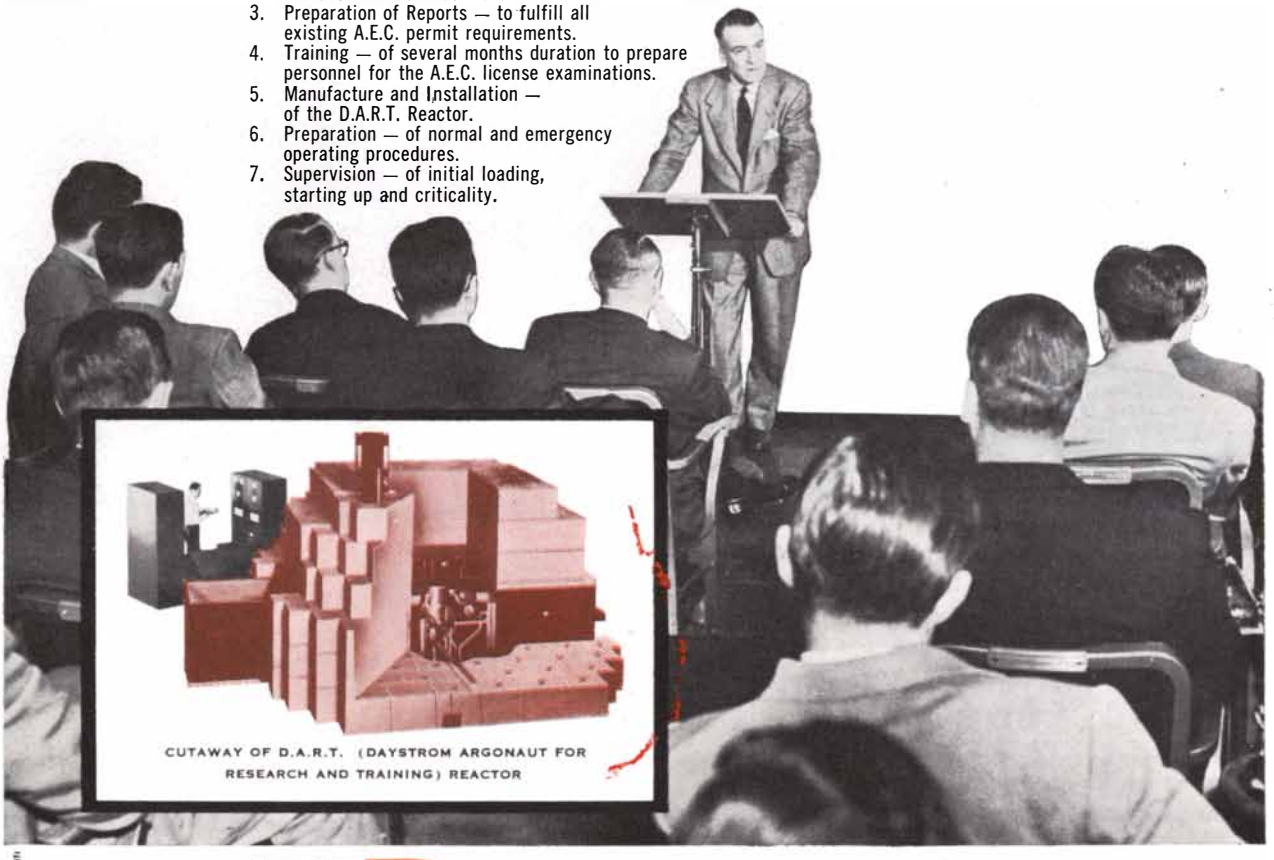
Low-cost D.A.R.T. Reactors capable of producing 10 thermal kilowatts, will be manufactured in quantity by Daystrom. The following comprehensive list of services is offered in support of a D.A.R.T. installation on any university campus or selected industrial site:

1. Technical Consultation — to determine and design facilities most suited to the client's requirements.
2. Site Investigations — to evaluate and select the best available location.
3. Preparation of Reports — to fulfill all existing A.E.C. permit requirements.
4. Training — of several months duration to prepare personnel for the A.E.C. license examinations.
5. Manufacture and Installation — of the D.A.R.T. Reactor.
6. Preparation — of normal and emergency operating procedures.
7. Supervision — of initial loading, starting up and criticality.



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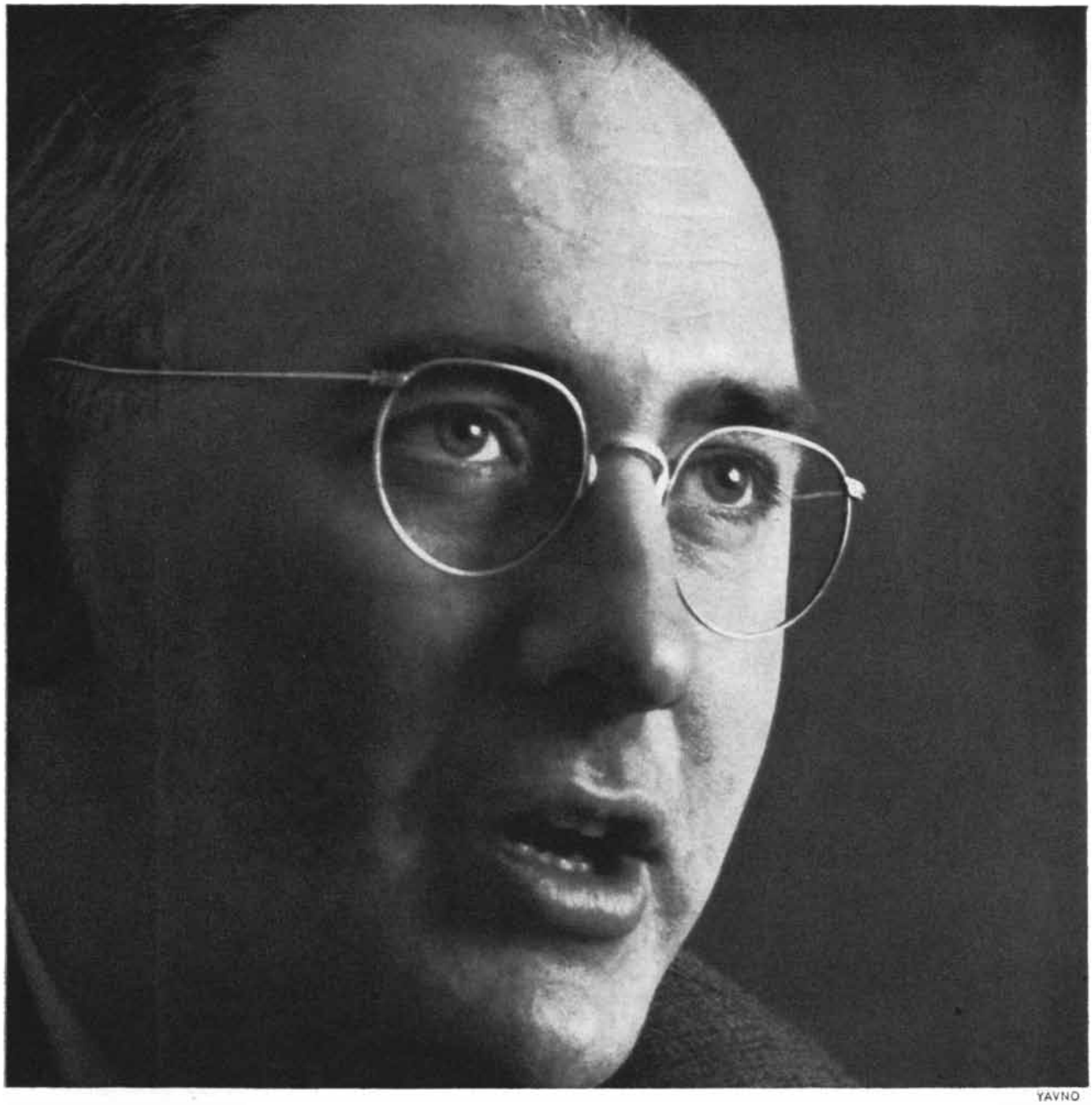


YAVNO

...on the engineer and national security

"With our national security at stake, engineers have responsibilities greater than in any preceding age. They face two vital questions: What military *posture* will ensure greatest security? What *means* — what weapon systems — will provide the desired military posture? These questions cannot be answered in purely technical terms; in addition to those factors with which engineers are at home, social, political, strategic, tactical, and operational factors must be considered. Today their influence on national policy decisions must be understood if we are to build and deploy a military capability that can deter war. In choosing weapon systems it is no longer enough to maximize speed, power, altitude, and payload. As more and more powerful weapons become attainable it is imperative that their use be increasingly determined by the real needs of our civilization."

— E. J. Barlow, Head of the Engineering Division

THE RAND CORPORATION SANTA MONICA, CALIFORNIA

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

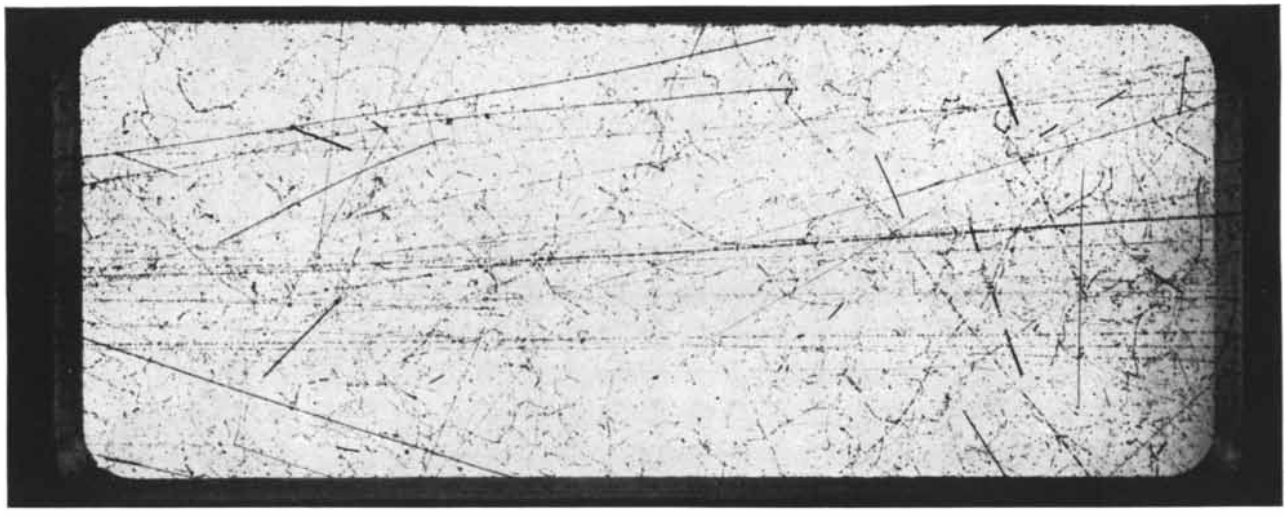
Established 1845 SCIENTIFIC AMERICAN April, 1957 Volume 196 Number 4

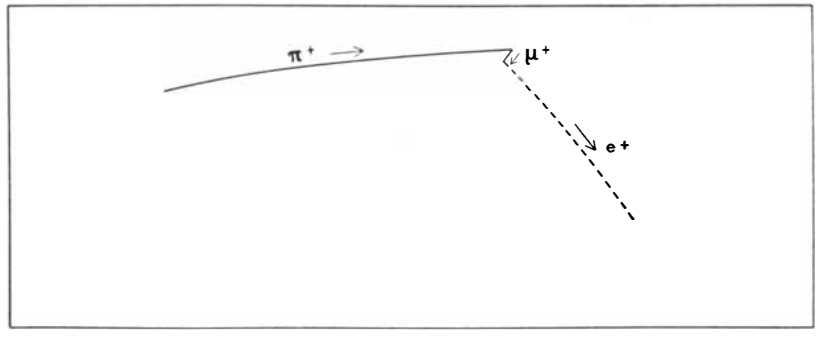
The Overthrow of Parity

Conservation of parity was a law of quantum physics which said that there is no absolute distinction in nature between right and left. Experiments now show that such a distinction exists

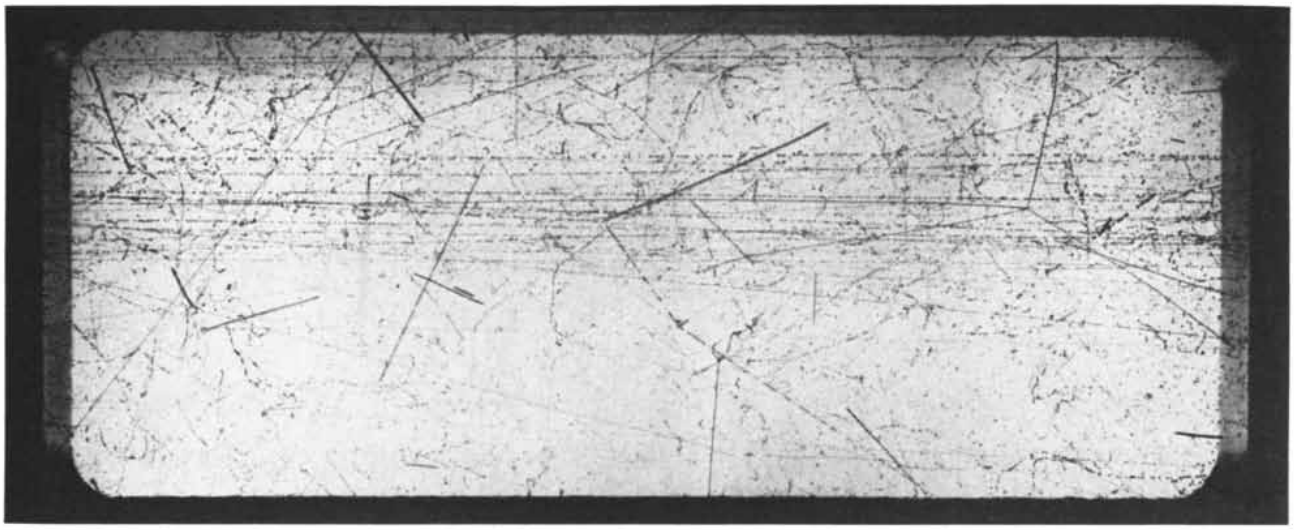
by Philip Morrison

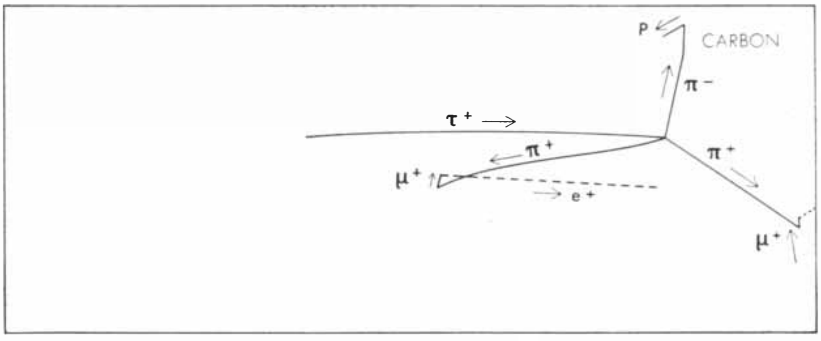
In the days when philosophers, acute in observation but as yet unaided by the tools of modern science, were primary founts of insight into the nature of the physical world, the philosopher Gottfried Wilhelm von Leibniz formulated a "great principle" which was to bear greater fruits than he knew. It was a proposition which at first thought seems absurdly simple and self-evident: namely, that "two states indiscernible from each other are the same state." Leibniz argued it on grounds which today we would find theological rather than scientific. Yet it has become one of the firmest pillars of modern physics. It underlies the theory of relativity and those laws of conservation—of energy, momentum and so on—upon which our understanding of nature is built. And it is now given deeper and sharper mean-



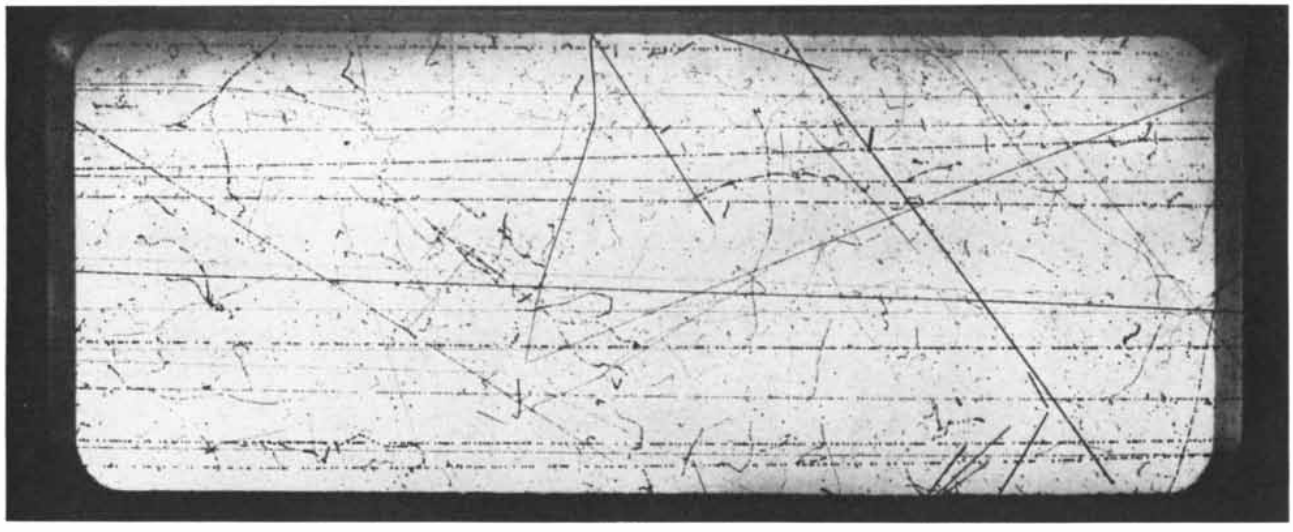


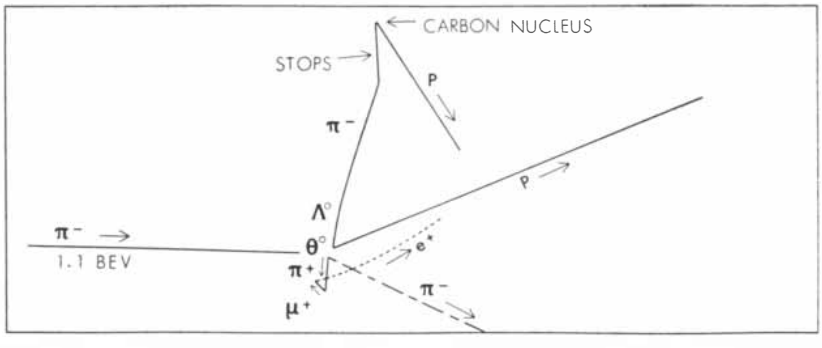
PI AND MU MESON DECAYS are processes in which parity is not conserved. This photograph records an example of both events. It shows bubble tracks made by particles from the Brookhaven Cosmotron in a chamber of liquid propane. As shown in the drawing at right, a pi meson (π^+) enters at left and decays into a mu meson (μ^+) about halfway across the chamber. The mu meson then decays into a positive electron (e^+).





TAU PARTICLE (τ^+) **decays into three pi mesons. The one shown here enters at the left and travels almost to the right-hand end before bursting into a three-pronged path. The lower prongs represent positive pions, the upper prong a negative one. The experiments shown were performed by Donald A. Glaser, J. L. Brown, D. I. Meyer and M. L. Perl of the University of Michigan.**



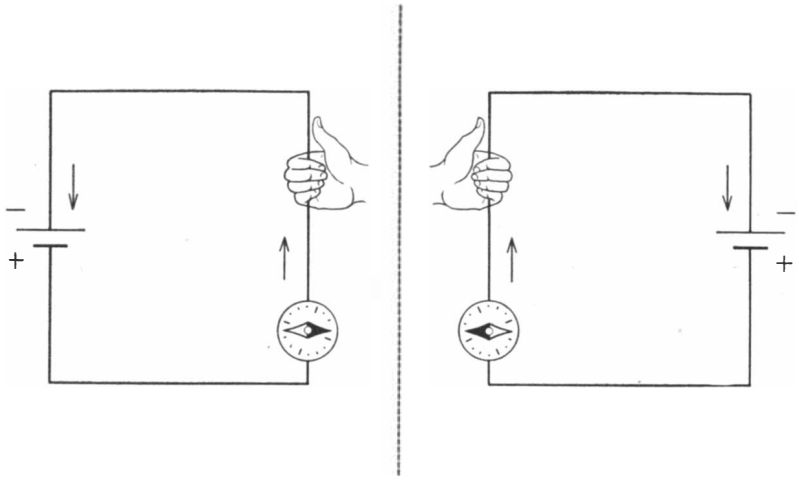


THETA PARTICLE (θ°) **decays into two pi mesons. The theta in this photograph, being neutral, forms no bubbles and cannot be seen until it decays into a double prong. The theta decay is the lower of the two double-prong events shown in the drawing. This photograph also shows the birth of the theta particle. It was formed from the collision of a pi meson with a proton in the chamber.**

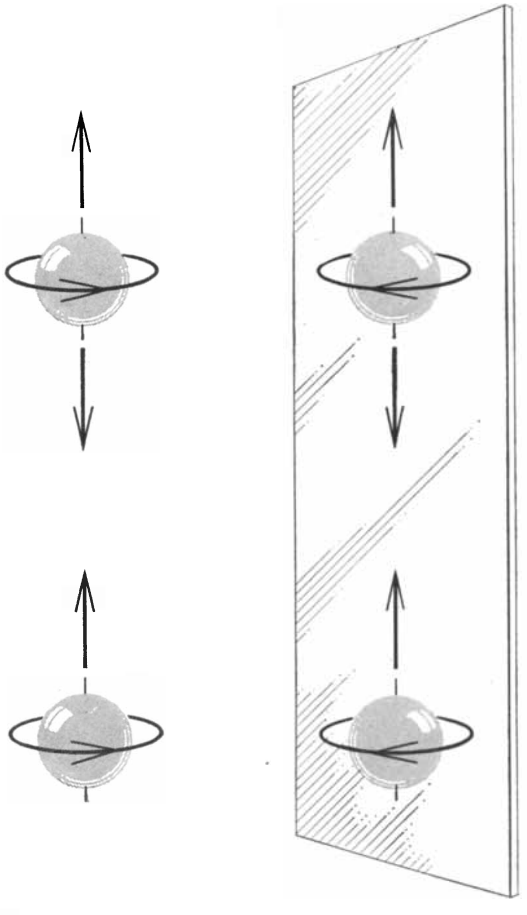
ing than ever by the amazing event in physics which is the topic of this article —the overthrow of the "parity principle" and the unraveling of the nature of left and right.

The important word in Leibniz's axiom is "indiscernible." Modern physics has been profoundly concerned with what is discernible and what is not. One of its strongest and most fruitful assumptions has been that among the indiscernibles are absolute space, time and direction. It is not hard to present examples. Think of the conventional world map. To each place are assigned a latitude and a longitude—a pair of numbers. The numbers are of great utility and convenience, but they are in no sense real attributes of the places; they have no physical significance. If the starting point for counting were to be shifted from Greenwich to Timbuktu, the numbers would change but no mountains would be moved. The numbers are merely arbitrary labels. And this is the manner in which space in general is treated in physics. The coordinates specifying positions in space describe only relative positions. We try to formulate our physical laws by the use of mathematical schemes in which absolute positions in space never enter. Whatever our frame of reference, we say, space remains invariant.

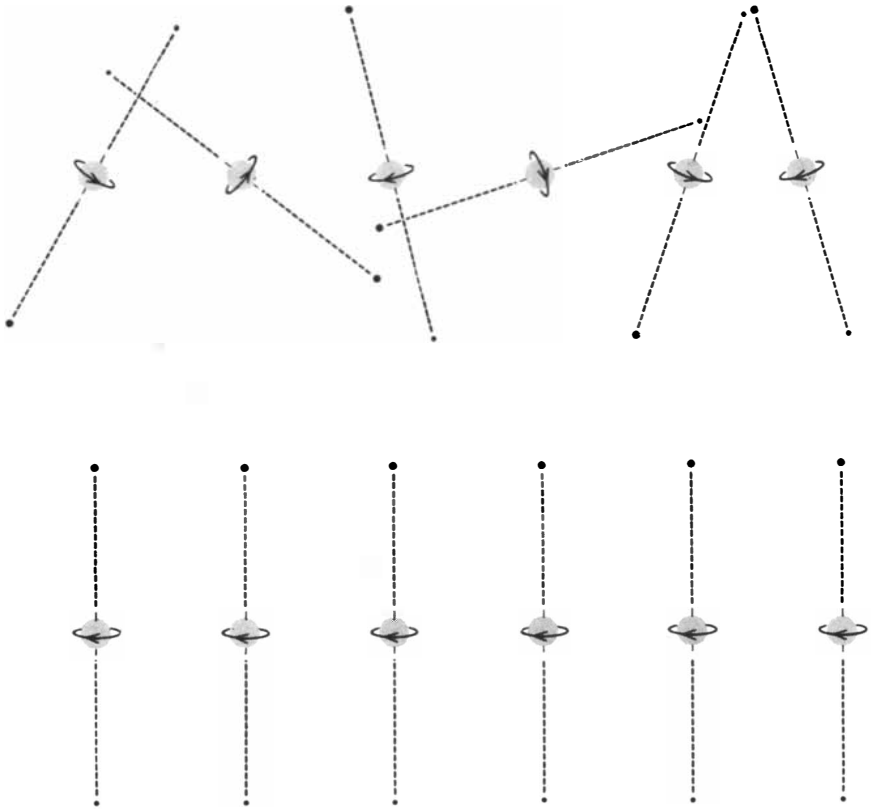
Let us take a more dramatic and comprehensive example. Suppose that a skilled director is going to produce on a stage before you some physical event or phenomenon—any whatever—without offering you clues to the date of the event, the directional orientation of the stage or the location of the theater. Could you determine any of these by any certain evidence? Indeed not. You may, of course, date the performance as lying within your lifetime, but this is clearly a subjective (*i.e.*, relative) time. (Indeed, Rip van Winkle could not succeed even in that.) You can judge which direction within the theater is up and which down, but "up" and "down" are merely relative to the earth; consider that you are in a theater in Australia and you will begin to realize the problem of attempting to determine the absolute orientation. A sharper test would be to use a compass to find "north," but this fails too, for the director can falsify the magnetic field, and in any case locating "north" on the earth tells you nothing about your absolute orientation in space. Nor can you locate the theater, even if you can look out a window and see a familiar landmark or a familiar star. The earth itself moves, and so do all the ex-



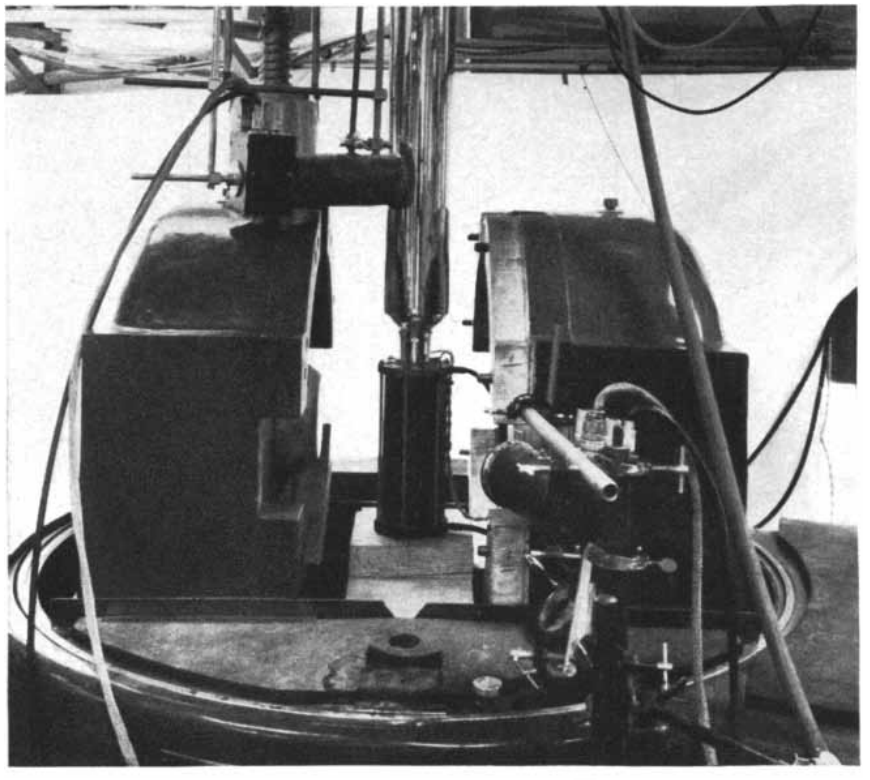
RIGHT-HAND RULE relating the directions of an electric current and its resulting magnetic field (thumb points with current, fingers point with the north-seeking pole of a test compass needle) becomes a left-hand rule when the experiment is reflected in a mirror. In this drawing, the "real" experiment is seen at the left and its mirror image at the right.



MIRROR REFLECTION of a spinning ball could not be detected if the ball ejected particles equally in both directions along its axis. Image at top right looks just like the real ball turned upside down. Reflection can be detected if there is a preferred direction for the ejection of particles. Thus the image at bottom cannot be mistaken for the real thing.



SPINNING NUCLEI of cobalt 60 (*gray circles*) emit electrons (*large dots*) preferentially in one direction along their spin axes and anti-neutrinos (*small dots*) in the other. The effect is ordinarily undetectable (*top*) but can be seen when spin axes are aligned (*bottom*).



WU-AMBLER APPARATUS detects electrons from aligned cobalt nuclei. Vertical black cylinder is the coil which furnishes aligning field. Horizontal tube is a photomultiplier.

ternal reference points. No, in principle and in practice absolute location in time or space and absolute direction are all indiscernibles.

These facts are of basic importance in physics. The indiscernibility of absolute coordinates lies at the basis of Albert Einstein's construction of the special theory of relativity, as is emphasized by the very name of his theory. And the fact that physical equations cannot refer to absolute time, space or orientation leads logically, by mathematical reasoning which we need not review here, to the classical laws of the conservation of energy and momentum.

The conservation "law" that concerns us now is the conservation of "parity," which rests upon the assumed indiscernibility of right from left. The indiscernibility principle can be put this way: there is no absolute distinction between a real object (or event) and its mirror image. A right-hand glove and a left-hand glove are surely different, but if accurately made they are precise counterparts; looking at a right-hand glove in a mirror, you cannot tell from its properties that you are not looking at a left-hand glove. The looking-glass world of people is admittedly unusual. Your mirror image is badly brought up: it offers to greet you with its left hand instead of its right, and it writes oddly. But the curiousness of the mirror world is largely conventional. There is no reason to doubt that such a world could exist. Indeed, any good director could set and coach a performance so that you could not distinguish it from the mirror image of a conventional performance.

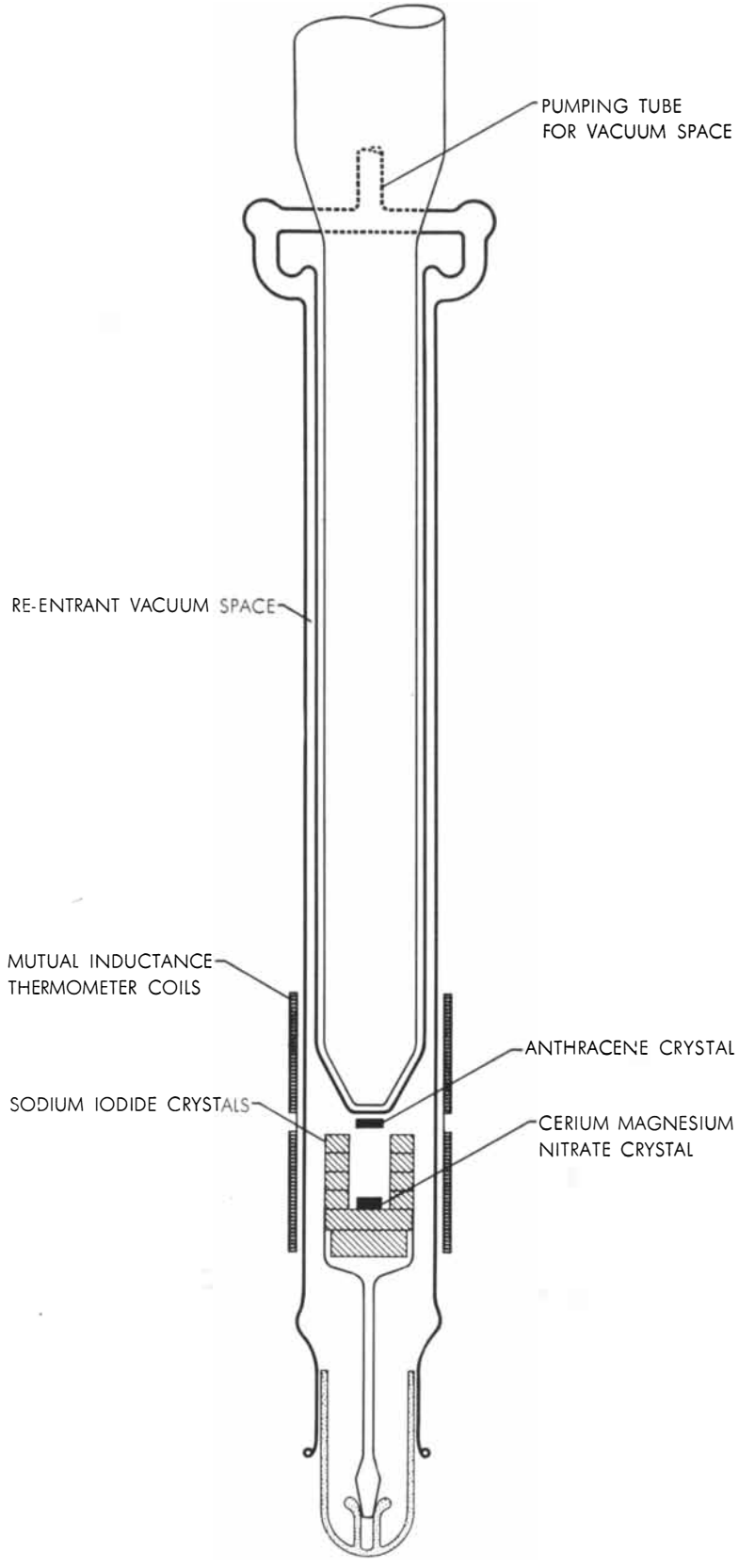
The physical principle of the indistinguishability of right and left implies that for every scene, every experiment, an exact mirror counterpart is possible. It is true that nature seems to favor a specific orientation (right-handed or left-handed) for the spiraling shells of snails and other animals, and for molecules of living matter. But this provides no conclusive evidence for the physicist: he sees that the molecule would function exactly the same way were it mirrored, and he can envision a world of living beings just like our own in which the "handedness" was simply reversed. The looking-glass world of life could function exactly like the actual world.

Until the startling events of the past few months, it seemed that the invariance of left and right was as unassailable as the invariance of time or space. All experience had buttressed the idea that no intrinsic difference could be found to

distinguish physical phenomena in a looking-glass world from the real world. All the seeming guides for distinguishing left from right failed on analysis to do any such thing. A student of electricity might cite the famous right-hand rule for telling the direction of an electromagnetic field: if you grasp a wire with your right hand so that the thumb points in the direction of the current's flow, your finger tips point in the direction in which a north pole moves in the magnetic field around the wire. But not so fast. What distinguishes a north pole from a south pole? True, you may refer me to a compass needle. The "north"-seeking end of the needle is colored blue and stamped with a big N. But this convention could be reversed without the least difficulty. If we switched the label N to the other end of the needle, the experiment would work with the left hand. So only convention distinguishes our experiment from its mirror counterpart. No intrinsic physical distinction, either in the macroscopic or the microscopic world, exists between a north magnetic pole and a south. All our right-hand rules are pure convention: there is nothing in the laws of electromagnetic fields that permits an absolute distinction between right and left.

The power of this idea of spatial symmetry ought now to be clear. If we begin by postulating mirror invariance, we can infer the indistinguishability of magnetic north and south poles. The latter in turn is an important principle in the microworld of particles, permitting us to give an orderly account of certain phenomena in that world. It implies the principle of the conservation of "parity," just as the invariance of space and time implies the conservation of energy.

"Parity" is a mathematical concept, impossible to define in physical terms. It is a property of the so-called wave function by which quantum mechanics describes the wave characteristics of a particle and represents its position in space. The variables of a wave function are just those coordinates that we use to locate spatial positions. Now it is not hard to see that if we change the sign of one coordinate (*i.e.*, from plus to minus), this is equivalent to reflecting the system in a mirror. Parity is the term that describes the effect of such a reversal upon the wave function. If the wave function remains unchanged when the sign of one of its three spatial variables is reversed, we say that the function has "even" parity. If reversal of the sign of the variable reverses the sign of the wave function, we call its parity "odd." In short, parity has one of two values—even or odd. And

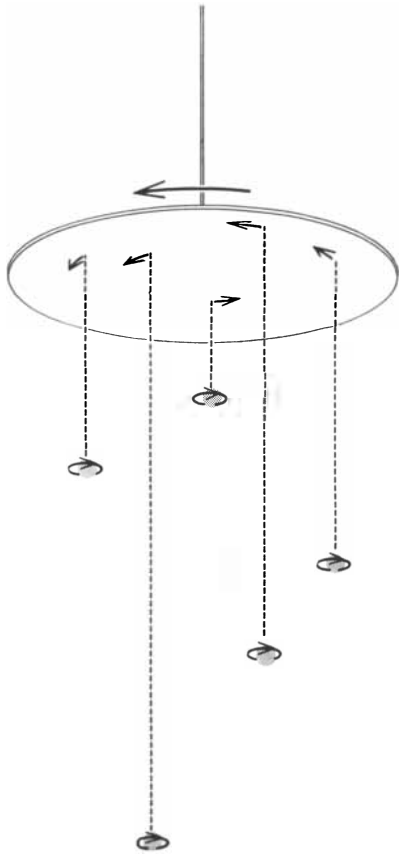


VACUUM CHAMBER for cobalt experiment is diagrammed above. The cobalt layer is deposited on the top of the cerium magnesium nitrate crystal. Anthracene crystal flashes when electrons strike it. Sodium iodide crystals count gamma rays from the cobalt, and indicate the degree of alignment. The large finger above the anthracene is a lucite rod which conducts the light of anthracene scintillations to amplifying and counting system.

all our experience, as well as theory, has indicated that in an isolated system parity never changes its value—*i.e.*, parity is always conserved.

Or rather, almost all. We are now confronted with a flat failure of parity conservation. The story goes back to about a year ago, when two extremely imaginative and ingenious investigators of the newly discovered "strange" particles of the atomic world made a really novel suggestion.

The two—Tsung Dao Lee of Columbia University and Chen Ning Yang of the Institute for Advanced Study—were absorbed in what was perhaps the most baffling paradox in this new realm of strangeness: the so-called "tau-theta puzzle." There were two mesons, called tau and theta. Tau, in the course of time, disintegrated into three pi mesons; theta, into two pi mesons. What was baffling was that in every property except the mode of decay, tau and theta were identical twins. Could they be one and the same particle? Decay of a particle by two different modes was certainly permitted by theory and precedent, but in this case the principle of conservation of parity stood in the way. Tau decayed to a set of pions of odd parity, theta to even-parity pions. The law of unchanging parity said that tau and theta must have different parity and therefore be different particles.



SCREW DIRECTION could theoretically be specified by an aluminum disk, mounted to rotate around vertical axis, and coated on underside with cobalt 60. Electrons ejected downward have predominantly one spin, and impart opposite spin to disk. Upward electrons are absorbed by aluminum. Thus the disk always spins in direction shown. The device was suggested by J. R. Zacharias of the Massachusetts Institute of Technology.

Yet the undownable question remained: Why were tau and theta exactly alike in every respect except this one? Lee and Yang boldly faced up to an embarrassing but insistent possibility: perhaps the parity-conservation law simply broke down in the realm of particle decays like tau's and theta's!

Their boldness was not rash. They could take the stand that while mirror invariance, from which the parity-conservation idea was derived, might hold in all other realms, it need not necessarily apply in the world of tau and theta. For the decay of tau and theta belongs to a very special class of reaction known as "weak interactions." The forces involved in them are very weak indeed—much weaker even than the forces which bind electrons in atoms. The forces are measured by the time it takes, with a given amount of available energy, for a particle emission to occur. By this measure the force entailed in a weak interaction such as the decay of tau or theta is smaller by a factor of 100 billion than the binding force on an atomic electron. Yang and Lee felt that the previous tests of mirror invariance in other fields of phenomena might have no validity in this untested realm of weak and subtle interactions.

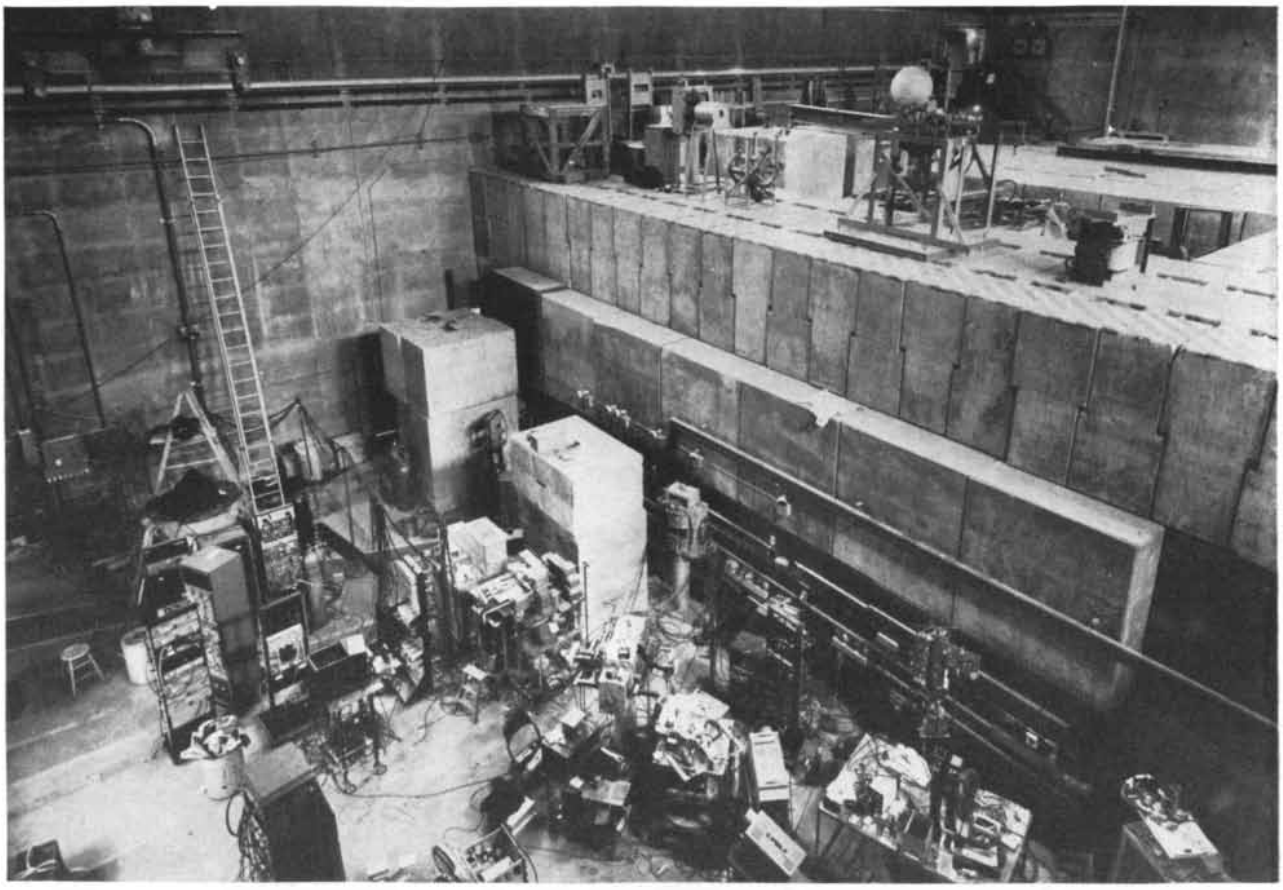
They proposed an experiment to test whether right and left could or could not be distinguished in this realm. Tau and theta particles themselves were poor candidates as subjects for such a test, for their lifetime is short—only about a billionth of a second. But the beta-decay (emission of beta particles) of radioactive atomic nuclei also belongs to the family of weak interactions, and these decays, taking place at much lower levels of available energy, have conveniently long lifetimes—measured in seconds or even years (*e.g.*, the beta-decay half life of cobalt 60 is 5.3 years). In essence Yang and Lee's proposal for the test experiment was simply to line up the spins of beta-emitting nuclei along the same axis, and then see whether the beta particles were emitted preferentially in one direction or the other along the axis. Neither direction would have any significance, conventional or otherwise: there is no arrowhead on the axis. But the preferred direction of beta-emission by the spinning nuclei would in fact define an arrowhead—the direction of advance of a right-hand or left-hand screw—and its mirror image would be discernibly reversed from the real thing. The experiment should leave no doubt about a distinction between left and right in beta-decay.

A powerful team of laboratory experimenters took up the challenge. Chien Shiung Wu of Columbia contributed her art in designing experiments and her experience in beta-decay work. A team at the National Bureau of Standards under Ernest Ambler undertook the task of lining up the nuclei. Ambler's job was to provide the straight line; Wu's, to look for the tip of the arrow (*i.e.*, the preferred direction of beta-emission).

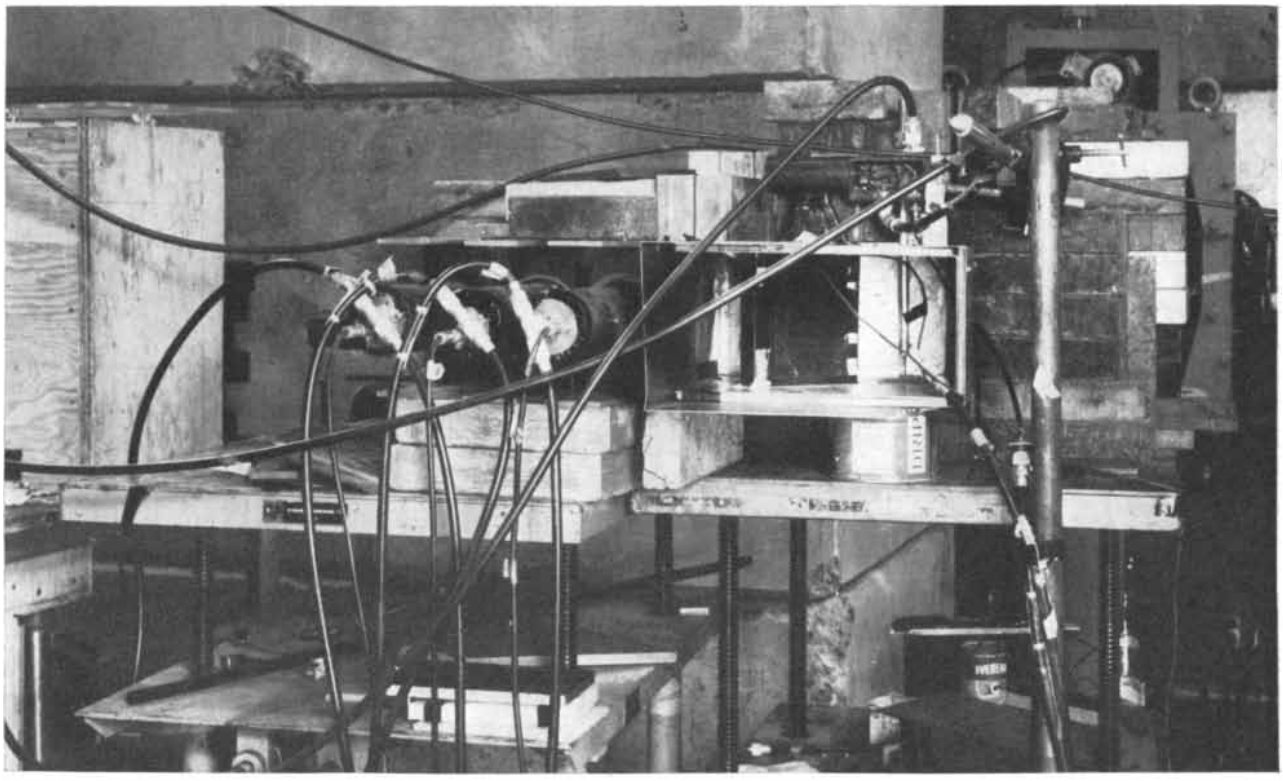
Nuclear alignment is a new art, no more than three or four years old. The sole handle by which the nuclei of atoms can be manipulated is their magnetic moment. No laboratory generator can produce magnetic fields strong enough to align these tiny moments; only within atoms themselves do sufficiently strong fields exist. So special atoms are lined up to produce a field, and their field in turn lines up the magnetic nuclei. But to make orderly alignment possible at all, thermal agitation of the atoms must be reduced to a minimum, which means cooling the system to very low temperature—considerably less than one degree above absolute zero. Shielded by the best sort of vacuum bottle, cooled by streams of liquid helium, the cobalt 60 atoms which served as the beta-emitters were kept aligned for 15 minutes or so at a time.

Six months to design, prepare and carry out the 15-minute experiments—these times proved just long enough to settle the issue beyond doubt. The beta particles emitted by the lined-up cobalt nuclei went predominantly in the direction against the magnetic field. This meant that, from the standpoint of beta-emission, the nuclei had an intrinsically left-handed spin. Left could be distinguished from right. Mirror invariance was dead. However valid it was elsewhere, in the realm of weak interactions it unambiguously failed.

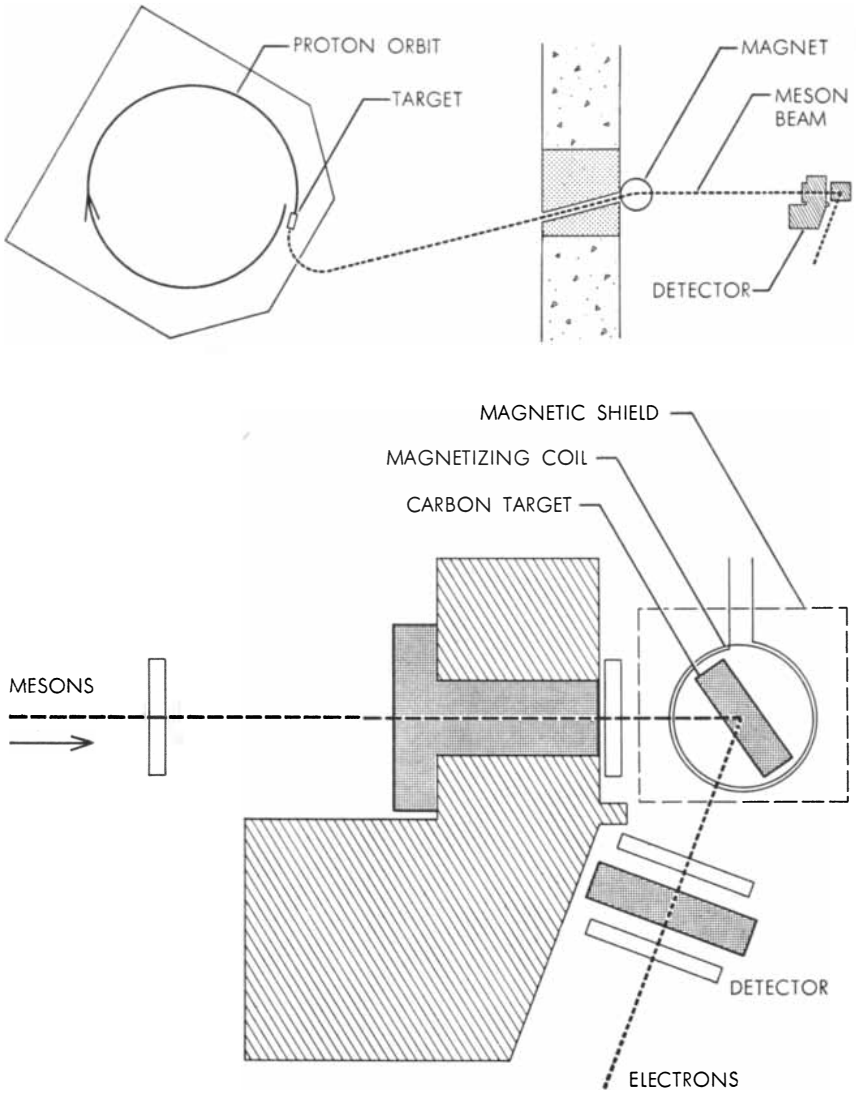
Within a few weeks after that first test in December, 1956, the conclusion was again unequivocally confirmed by another experiment. This time the weak



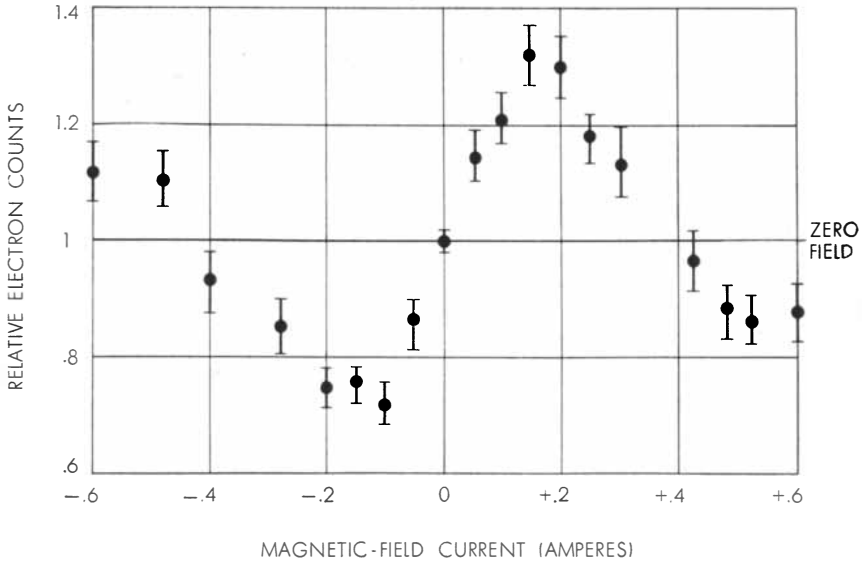
MESON DECAY EXPERIMENT, also showing lack of mirror symmetry, was done at the Columbia University cyclotron. Experimental setup is at center, between the small stepladder and the tall pile of concrete blocks. The cyclotron itself is behind shield at right.



CLOSE-UP OF EXPERIMENT shows wire-wound carbon block in which mu mesons are brought to rest. The block is in the rectangular frame supported by a brick and a coffee can. To the left of the frame is a triple counter which detects the emitted electrons.



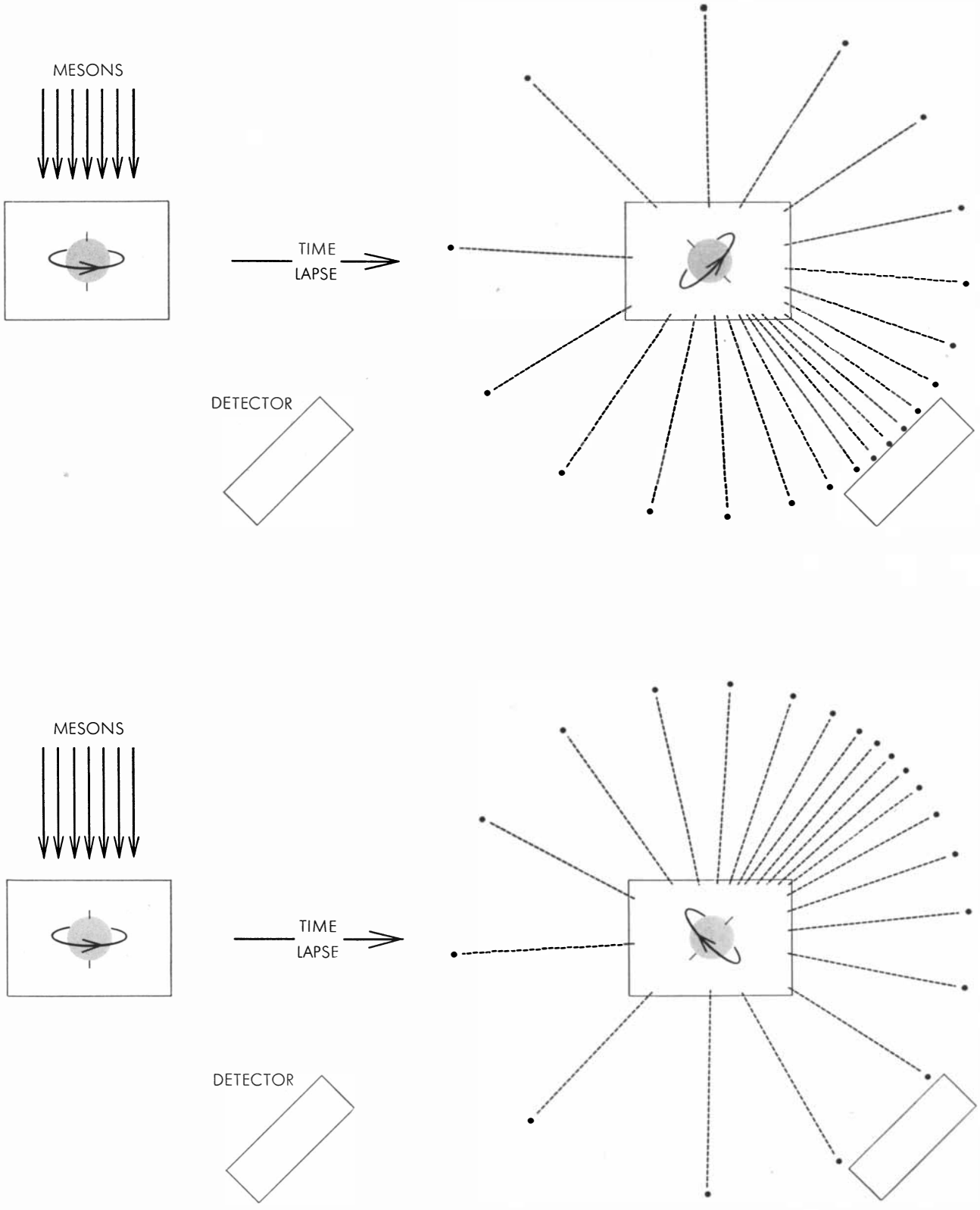
PATH OF MESONS, from accelerator to detector, is shown at top. At bottom is a detailed diagram of target and detector. T-shaped block stops pi mesons, leaving beam of mu mesons. These come to rest in carbon target and decay to electrons which are counted in the detector.



ELECTRON COUNTS are plotted on the vertical axis against the strength of the magnetic field which turns the electron-emitting mu mesons. Variation shows asymmetry of emission.

interaction tested was the decay of the mu meson. The experiment rested on a hypothesis which seeks to explain the failure of mirror invariance in beta-decay. The theory assumes that in the decay of a mu meson both a neutrino and an anti-neutrino are emitted, along with the beta particle, and that the neutrino always has a right-handed spin while the anti-neutrino's is left-handed. It was reasoned that when a pi meson decays into a mu meson and an anti-neutrino, the mu meson must be emitted with a left-handed spin to balance that of the anti-neutrino. As a consequence, when aligned mu mesons, under suitable conditions, decay with emission of electrons, the electrons should come out in a preferential direction. The theory was tested, first by a group at Columbia and later in other laboratories, and the preference for the specified screw direction was verified. The Columbia group have used the effect very ingeniously to measure the magnetic moment of the mu meson, and thus already have made a useful application of the failure of mirror invariance.

Theoretical physicists have only begun to speculate about the more general implications of this profound overthrow of a basic principle in the world of weak interactions. But there is an over-all lesson which can be put simply: The great invariance principles of nature may be relied upon within the domains of their application, but they are not *a priori* self-evident or necessarily of universal application. It is worth while to test to higher and higher precision the great foundation principles, including the conservation of energy. So far as we have gone, even in weak particle interactions, energy conservation appears to hold, but does it still hold for the weakest interactions of all, those involving the weak force of gravity? Here one thinks of the hypothesis that matter may arise spontaneously from a space containing no energy, and the possibilities are exciting. It may also be that there is some connection between the two major asymmetries we now see in the physical world—the right-left asymmetry of weak particle reactions and the fact that our world is overwhelmingly made up of one kind of matter, to the near-exclusion of anti-matter. Perhaps this lead could forge a bridge between the microphysics of the fundamental particles and the physics of the great distances—that is, cosmology. It is fair to say that the discovery of the limitations of the mirror invariance principle is not a setback but an opportunity. We have entered an exhilarating time.



ASYMMETRICAL MESON DECAY detected in the Columbia experiment is illustrated schematically. Pi mesons from the cyclotron decay into mus, and the mu mesons turn out to have their spins lined up with respect to their flight direction. They are stopped in a carbon block. Their alignment in the block is represented symbolically in the diagram by a single rotating sphere. A coil around the block produces a magnetic field which turns the spinning mu mesons. The field is allowed to act for about as long a time as it takes the average mu meson to decay into an electron. The decay electrons, shown as small dots, go off in all directions, but only those traveling in a particular direction from the block are counted. The experiment is repeated for different values of the magnetic field, which give different amounts of turning. The electron counts vary as shown in the curve at the bottom of the opposite page. This shows that more electrons are emitted along one direction of the mesons' spin axis than in any other direction.

Experiments in Hypnosis

In which experimental subjects are found to be suggestible while hypnotized or while in a light sleep, demonstrating that there is very little difference between the two states

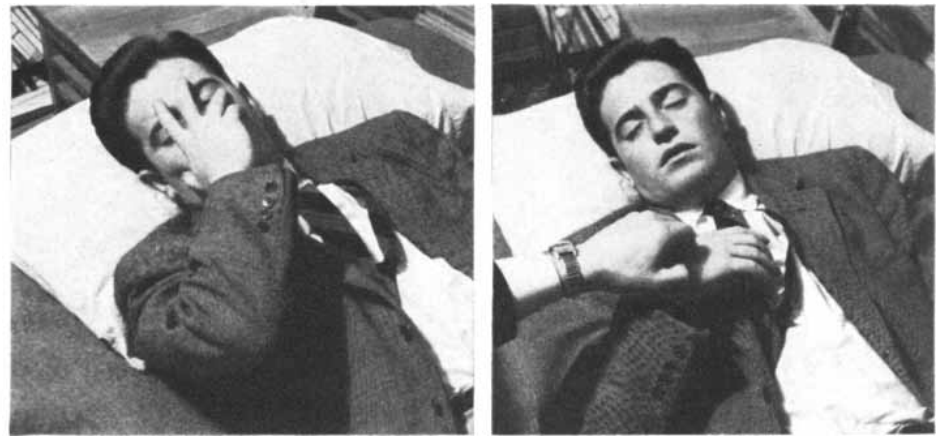
by Theodore X. Barber

There is a blare of trumpets: the great man enters, bows and calls for volunteers from the audience. A number walk up to the stage. He fixes them with his eyes and intones that they are becoming drowsy and sleepy, their eyes are closing, they are coming completely under his power. Soon one of the subjects begins to run on all fours like a dog. Another becomes a "human plank"—the hypnotist lays the body across two chairs and stands on it. A third is told that when he hears the word "now" he must sing "Auld Lang Syne"—obediently he sings.

What is the real meaning of this performance? Is the hypnotist endowed with some strange power? Hardly. Are his subjects stooges? Sometimes they are. But there can be no doubt that hypnosis is a genuine phenomenon. The prime question is: What, exactly, is the hypnotic state?

Hypnosis has been known for thousands of years, but scientific attempts to understand it have begun only within the last century. In the 19th century students of the phenomenon, principally James Braid in England and Hyppolyte Bernheim and A.-A. Liébault in France, found that the tricks and hocus-pocus of the stage hypnotist—such as the piercing eye, the hand-waving and the commanding manner—were not at all necessary to induce a trance. Basically all that is needed is to repeat a certain relaxing patter over and over. In fact, even a phonograph record of the patter will induce hypnosis, and it is possible for a person to learn to hypnotize himself. (Among the Balinese, self-hypnosis is a common accomplishment.)

About 30 years ago a group of young men under the leadership of Clark L. Hull at the University of Wisconsin began a systematic investigation of hypnosis with controlled experiments. They found that practically everyone is suggestible to some extent—"suggestible" in this sense meaning not gullible but responsive to the hypnotic type of suggestion. For example, if a group of people on their feet are asked to close their eyes and are told over and over that they are falling forward, practically all will sway at least a few inches, and many will lose their balance. Hypnosis increases this normal suggestibility, but not as much as is usually supposed. If a subject is very suggestible during hypnosis, the odds are pretty good that he will also be found to be very suggestible when awake.



ANESTHESIA under hypnosis is shown in the first three of these pictures made in collaboration with the author. The experimenter suggests to the subject: "Your right hand is becom-

UNBREAKABLE HAND CLASP in hypnosis is brought about by the experimenter's suggestion: "Clasp your hands together. The hands are as solid as a rock. . . . It is impossible

Moreover, it has recently been demonstrated that many of the feats performed by hypnotized subjects seem "amazing" only because we underestimate what people can do when they are fully awake. Even the "human plank" feat can be duplicated by an unhypnotized subject if he is properly motivated. Offer a subject a hundred dollars to make his body rigid, and he will be surprised to find that he can keep it rigid enough to support your weight; in fact, you will seem to weigh no more than a few pounds. The investigator A. M. Weitzenhoffer of the University of Michigan, who has himself performed this demonstration, believes that from the physical standpoint it "is nowhere near the feat it appears to be."

The same thing holds true for the seemingly "amazing" physiological effects under hypnosis. Some years ago A. B. Luckhardt and R. L. Johnston of the University of Chicago suggested to a hypnotized subject the hallucination of eating a meal. The subject responded as if he were eating. The investigators found that the volume and acidity of his stomach secretions increased just as if he had actually eaten a meal. But when they in effect repeated the experiment with an unhypnotized subject, speaking to him about appetizing foods, this conversation also was sufficient to cause a similar rise in the volume and acidity of the gastric secretions.

In the department of psychology at American University in Washington, D.C., we carried out a series of experiments to explore the relationship of the hypnotic state to ordinary sleep and the suggestibility of individuals under various circumstances. Our first step was to select a group of "normal" subjects who were not unusually suggestible and who had never been hypnotized before. In a short time we rounded up 22 suitable subjects—14 men and 8 women. Eight were Federal Government employees and the rest university students. Their average age was 24. Examination by a well-known personality test, the Guilford-Zimmerman Temperament Survey, showed that they were a more or less typical group of young Americans, of average sociability and emotional stability. We also determined, by several simple tests, that they were no more than normally suggestible. (In one such test the subject holds a Chevreul pendulum—a small metal bob hanging on a thread—and the examiner keeps suggesting that the bob is swinging, faster and faster. The subject's suggestibility is measured by the amount of actual swing, in inches, at the end of three minutes.)

Our first experiment attempted to answer the much disputed question whether the hypnotic state resembles ordinary sleep. With the subjects' advance consent, I tested their suggestibility during their sleep at night. After a subject had been asleep for about three hours, I would approach him and, speaking softly, make a suggestion of the kind usually given under hypnosis. Each subject was tested on seven such instructions. Of the 22 subjects three opened their eyes when I spoke to them and told me that they were awake. But the other 19 remained

ing dead and dull and numb." If the subject can feel the pinch, he is to move his fingers. His failure to do so indicates that his right hand is devoid of sensation. In the last two pictures the subject's right hand is being made rigid by further hypnotic suggestion.

to unclasp your hands. Try it." This subject could not break the clasp, though he struggled for one minute. At the end of the minute the experimenter said, "Your hands . . . are easy to open now." His response is typical of half the subjects in this test.

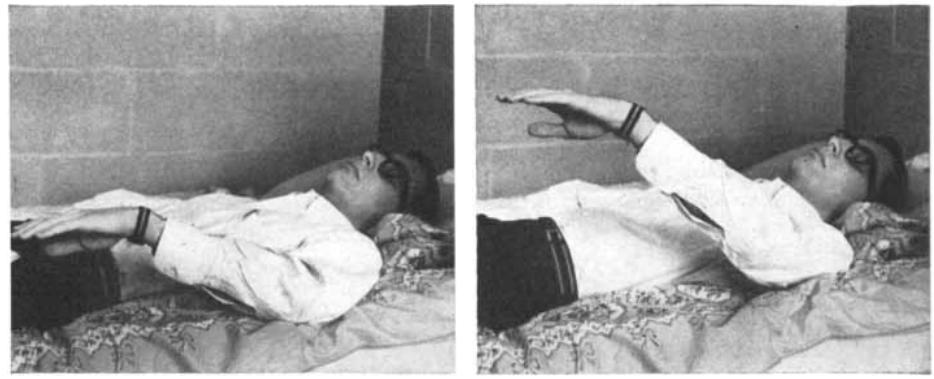
either asleep or in a drowsy state. Seven showed some sign of partial awakening: for example, they moved or changed their breathing rate, and afterward they reported that they were awake but drowsy. The remaining 12 subjects gave no indication of disturbance of their sleep, continued their slow, somnolent breathing rate and after they awoke did not remember or only vaguely remembered that I had spoken to them.

Let us follow the responses of one sleeping subject on these seven tests. He is a 34-year-old Federal employee. He went to bed about 12:45 a.m. and I entered his room at 3:15 a.m. He appeared to stay asleep throughout the experiment. First I touched his left hand and whispered, "Notice how light this hand feels and how it's beginning to rise and come up and up." His hand began rising slowly as I kept repeating these phrases. At the end of one minute I said, "Your hand is now coming back down again to its original position." It came down slowly and touched the bed. Next I said, "Clasp your hands together." There was no response. Again I said, a little louder this time, "Clasp your hands together." His hands began moving toward each other, and in a few seconds they were clasped together. I then said, "Notice how your hands are becoming hard and solid and rigid. They're as solid as a rock and as rigid as a piece of steel. It's impossible to unclasp those hands." After repeating these and similar phrases for one minute I said, "Try and open them now." He tried to unclasp them but failed. After a minute I said, "They are not hard anymore. They are very easy to open now. Try it and see." This time he unclasped his hands in two seconds.

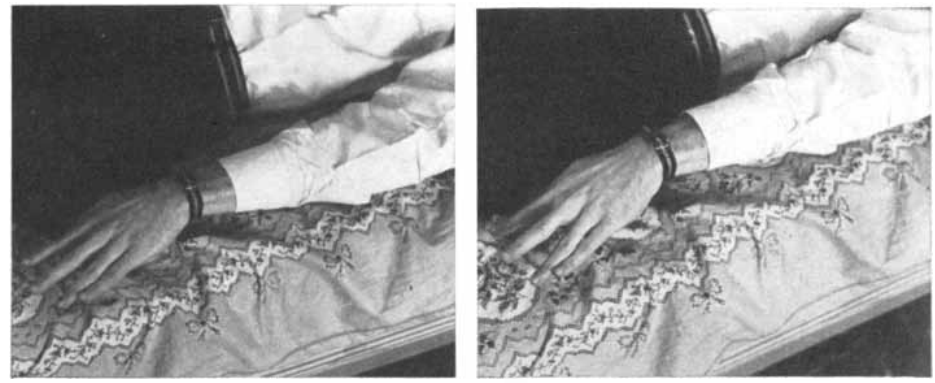
I then went to the third test: "Notice how your fingers are as solid and hard as a piece of iron. It is impossible to move those fingers." Again, as in the hand-clasp test, he was unable to move his fingers until after I said, "They are not hard any more. They are easy to open now."

Next I made an "anesthesia" test: "Notice how this hand is becoming dead and dull and numb. It has become completely insensitive. When I pinch your hand, you will not be able to feel it. Move the fingers if you feel me pinch it—but you will not be able to feel anything at all." As in the preceding tests, he did not move any of the fingers until I said, "The sensitivity is back now. You can feel very well now with that hand."

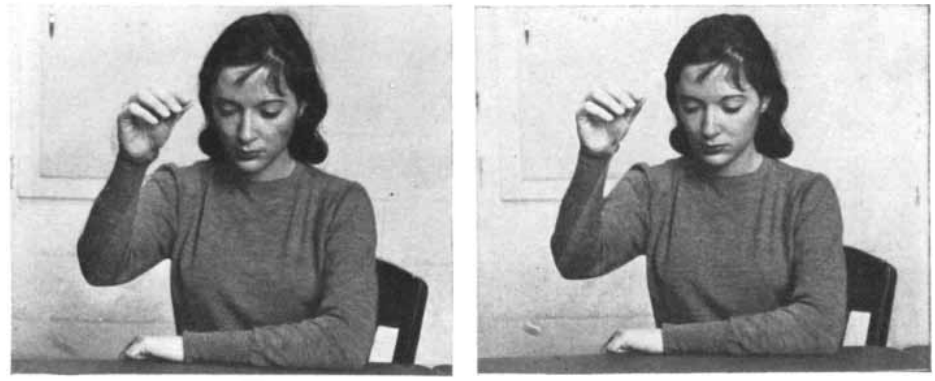
Finally I gave him the last three tests together. For one minute I repeated over and over, "Your lips are very dry. You



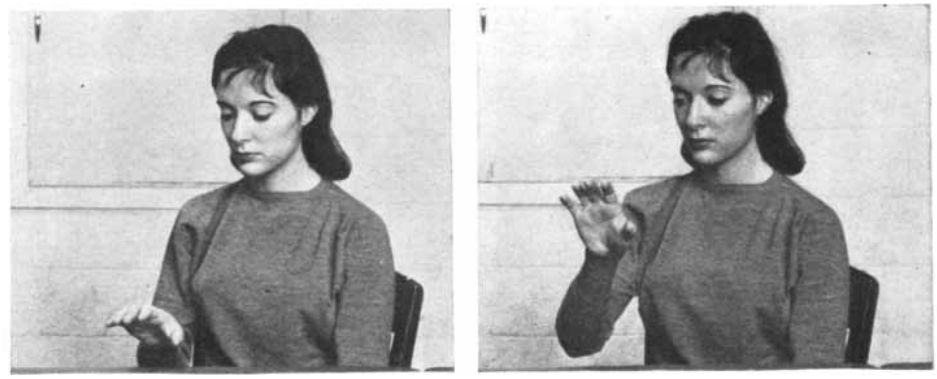
HAND LEVITATION occurs during hypnosis when the experimenter suggests: "Your left hand is becoming lighter and lighter. . . . It is rising up and up . . . faster and faster." When



FINGER RIGIDITY occurs in the subject during hypnosis when the experimenter tells him: "The fingers are becoming hard and solid like pieces of metal. . . . It is impossible to



WAKING SUGGESTIBILITY is measured with a Chevreul pendulum in these pictures. Without hypnotizing the subject the experimenter tells her to hold the pendulum and



HAND LEVITATION test for waking suggestibility is administered in this set of pictures. Starting in repose, the subject gradually responds to the experimenter's suggestion: "Notice

the subject's hand reaches the limit of levitation, the experimenter must bring it down by saying, "Notice how the hand is coming back down now . . . coming down to its original position." Some subjects raise their hands higher when awake than under hypnosis.

bend those fingers. . . . Try it." In the middle picture the subject's fingers have reached maximum rigidity. Relaxation begins (*fourth picture*) as the experimenter says: "The fingers are not hard anymore. They are easy to move now." Subject's fingers finally move.

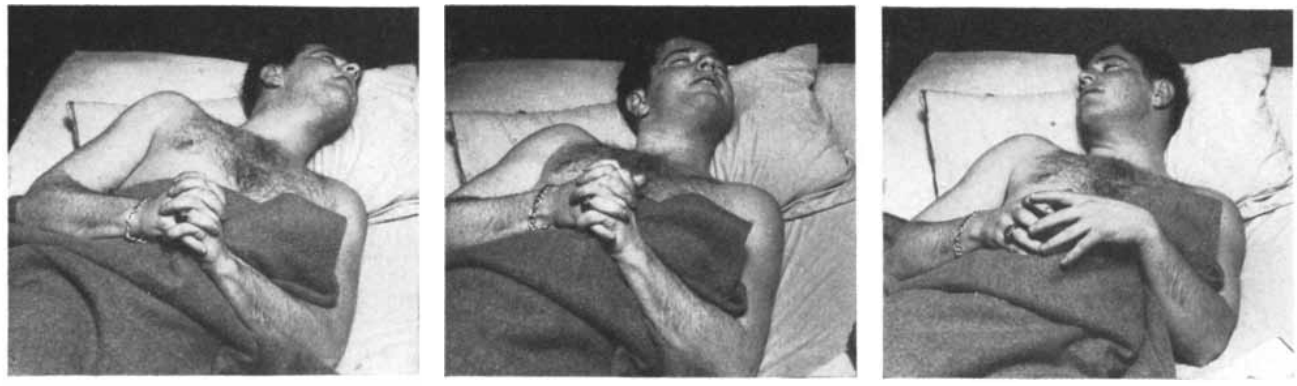
". . . notice how the metal bob is beginning to swing all by itself, right along the ruler . . . faster . . . back and forth." As the experimenter talks the swing actually increases without conscious effort on her part. The response shown here is greater than average.

how your right hand is becoming lighter and lighter . . . coming up and up . . . rising and lifting as if it were a balloon." This subject's response is again greater than the average one: the experimenter is able to conclude that she would make a good hypnotic subject.

ANESTHESIA DURING SLEEP is brought on as in hypnosis. The subject's fingers do not respond to the pinch until he is told, "The sensitivity is back now." The subject wore glasses because he thought he might awake during the experiment.

SUGGESTION is made by the experimenter to a sleeping subject that he will get up in five minutes for a drink. Though the subject cannot recall upon waking having heard any instructions, he follows them. This parallels the post-hypnotic suggestion response.

FINGER RIGIDITY DURING SLEEP, as in hypnosis, occurs when the subject is told: "Your fingers are hard and solid and rigid. It is impossible to bend your fingers. Try it and see." In the last two pictures the subject tries vainly to move his fingers.



ANGUISHED SLEEPER struggles to unclasp his hands, but cannot do so until the experimenter tells him he can. As in the three other experiments pictured on this page, the sleeper's response to suggestion does not differ from those observed in hypnotic subjects.

are becoming thirstier and thirstier." Then for another minute, "You will have to get up in exactly five minutes after I finish talking and have a cool, wonderful, refreshing drink of water." Finally, "You can't remember anything that I said or anything that you did. Everything is fading away like a dream." I went into another room and waited. He did not get up in five minutes, as suggested, but at precisely eight minutes he rose from his bed, went to the bathroom and drank two glasses of water. The only thing of all these events that he recalled after he awoke in the morning was that he had got up to get a drink of water.

Like this subject, all except the three who woke up responded to the seven tests as if they were in some stage of hypnosis. (The depth of hypnosis is conventionally measured on what is known as the Davis and Husband Scale—*see table on this page*). The seven drowsy subjects behaved as under very light hypnosis: for example, they had difficulty unclasping their hands and moving their fingers in the rigidity tests and became thirsty in response to the suggestion. Of the sleeping subjects, half responded as in a light trance: *e.g.*, they could not unclasp their hands or move their fingers at all and could not recall much of what had happened. The other sleeping subjects were in at least the medium trance: they obeyed the suggestion to get up to take a drink and remembered little or nothing of the experiment. One subject said: "I was just sleepy enough to believe that what you were saying is true. I couldn't oppose what you wanted with anything else." Another said: "I remember you talking but I don't remember what you said. I remember your voice—that's about all." These are similar to comments subjects often make after hypnosis.

About a week after the sleep experiment, the subjects went through the same tests under hypnosis. I hypnotized each subject with these words: "Lie down. Relax. Make yourself as comfortable as possible. You are going to feel more relaxed than you have ever felt in your life. Imagine yourself floating on a soft, warm, comfortable cloud. You are sinking easily and gently into a soft, smooth, relaxing cloud. So relaxed . . . so comfortable . . . so drowsy and comfortable. Breathing easily and gently and softly as you sink into the soft, comfortable cloud. . . Becoming more relaxed every moment . . . drowsy . . . so drowsy. . . . So very tired and drowsy and comfortable and sleepy. . . . As I count to five you will get drowsier and drowsier . . . sleepier and sleepier. One. You are becoming more and more drowsy. . . . Two. Getting sleepier and sleepier. . . . Three. Going sound, sound asleep," etc.

Immediately after this procedure I gave them the seven tests of suggestibility. Their responses were indistinguishable from those during their normal night sleep. Whatever suggestions a subject accepted during drowsiness or "sleep," he also accepted during hypnosis, and likewise he resisted the same ones in both cases. For example, if a subject did not get thirsty during the sleep experiment, he also did not do so during hypnosis. One subject commented after hypnosis: "I felt like going to sleep. I guess I was asleep. I can't remember much. I kind of remember you saying I'd get thirsty." Another said: "I felt about the same as when I was asleep. I felt like I was floating on a cloud."

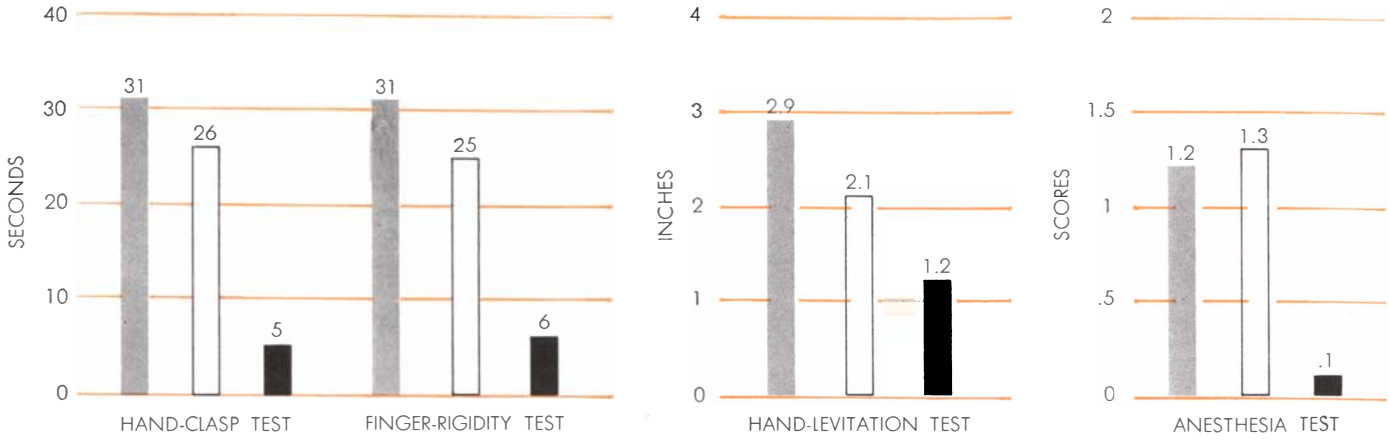
An interesting question remained to be answered. How does a subject's suggestibility when he is wide awake relate to his suggestibility during sleep and hypnosis? As we noted earlier, Hull and other investigators had found that under the proper conditions practically everyone gives some response to suggestions even when he is fully awake. Everyday observation confirms this: you may have noticed, for instance, that you have a tendency to yawn when others around you are constantly yawning.

Our 22 subjects submitted to the same seven tests of suggestibility in the normal waking state. This time they were less responsive to the suggestions, but they did respond in greater or less degree [*see charts on next two pages*]. For example, on the average the subjects kept their hands clasped for 26 seconds when hypnotized and for five seconds when awake. As a rule there was a close relation between an individual's normal waking suggestibility and his suggestibility during sleep or hypnosis. The subjects who were most suggestible when awake were also the most suggestible during the sleep experiment and were also the best hypnotic subjects. Indeed, a few subjects were more suggestible on some tests (*e.g.*, hand levitation) when awake than under hypnosis!

One subject during the tests of suggestibility while awake raised his hand 16 inches, could not move his fingers and became thirsty. Afterward he said: "My throat was killing me. My lips got dry and tight. I had a hard time opening my hands. Did I open them? You told

DEPTH	SCORE	OBJECTIVE SYMPTOMS
INSUSCEPTIBLE	0	
HYPNOIDAL	2	RELAXATION
	3	FLUTTERING OF LIDS
	4	CLOSING OF EYES
	5	COMPLETE PHYSICAL RELAXATION
LIGHT TRANCE	6	CATALEPSY OF EYES
	7	LIMB CATALEPSIES
	10	RIGID CATALEPSY
	11	ANESTHESIA (GLOVE)
MEDIUM TRANCE	13	PARTIAL AMNESIA
	15	POSTHYPNOTIC ANESTHESIA
	17	PERSONALITY CHANGES
	18	SIMPLE POSTHYPNOTIC SUGGESTIONS
	20	KINESTHETIC DELUSIONS; COMPLETE AMNESIA
SOMNAMBULISTIC TRANCE	21	ABILITY TO OPEN EYES WITHOUT AFFECTING TRANCE
	23	BIZARRE POSTHYPNOTIC SUGGESTIONS
	25	COMPLETE SOMNAMBULISM
	26	POSITIVE VISUAL HALLUCINATIONS, POSTHYPNOTIC
	27	POSITIVE AUDITORY HALLUCINATIONS, POSTHYPNOTIC
	28	SYSTEMATIZED POSTHYPNOTIC AMNESIAS
	29	NEGATIVE AUDITORY HALLUCINATIONS
	30	NEGATIVE VISUAL HALLUCINATIONS; HYPERESTHESIAS

STAGES OF HYPNOSIS are measured on the Davis and Husband Scale in this chart. The experimenters found that half of their sleeping subjects reached the medium-trance stage.



SUGGESTIBILITY in the sleeping, hypnotic and waking stages is compared in these charts. In the hand-clasp and finger-rigidity tests half of the sleep and hypnosis subjects were so responsive that they could not relax their hands until they were told to do so. The figures in the charts for these tests give the average length of time the other

me I'd forget everything. I vaguely forgot for a second. I couldn't think right away." It is this type of hypersuggestible subject that a hypnotist likes to choose for his stage performance; usually such a subject is still more suggestible when hypnotized.

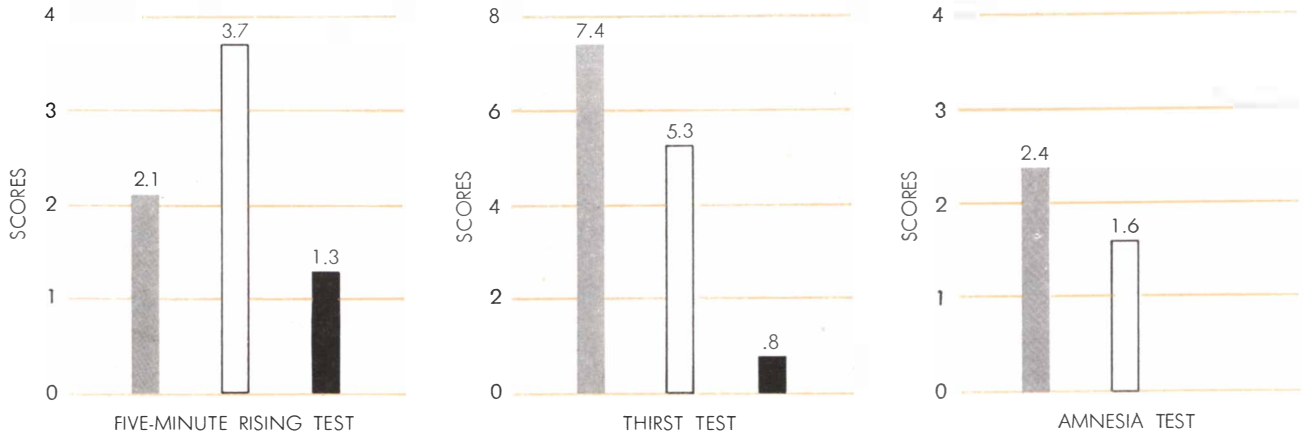
When we looked back at the subject's personality tests, we made a surprising discovery. It was the persons with the most attractive personality traits who were the most suggestible. The more suggestible and hypnotizable a subject, the more he tended to be a leader and to be sociable, emotionally stable, happy-go-lucky, not self-centered or hypersensitive. It seems that the best hypnotic subjects are the ones who are secure enough to remain unafraid, relaxed and cooperative during the hypnotic procedure.

The results also indicate that the good hypnotic subject may be the individual who is both willing and able to go to sleep easily and quickly. To check this idea Martin T. Orne of the Boston Psychopathic Hospital, Ronald Shor of Brandeis University and I hypnotized 34 psychology students who were very willing to be hypnotized. Before the hypnosis we asked them: "Can you fall asleep easily during the day if you lie down and close your eyes?" We found that we could predict whether a subject could be hypnotized deeply by his answer to this question.

In our three-part experiments on the

THIRST TEST in conjunction with the five-minute rising test is given to a hypnotized subject. The experimenter suggests: "Your lips are becoming dry. . . . You are becoming very thirsty. . . ." Having established a sensation of thirst the experimenter continues,

POSTHYPNOTIC AMNESIA is shown in these photographs. While under hypnosis the subject is told that he is becoming very thirsty, and during this part of the experiment he shows signs of thirst. Next the experimenter tells him: "You will not remember anything

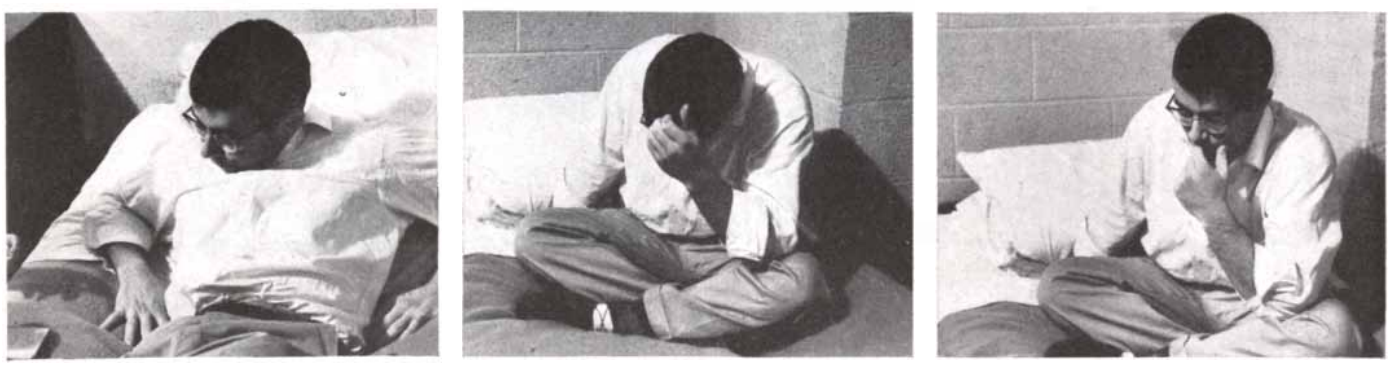


subjects took to regain control of their hands. The height of hand levitation was nearly the same in each of the three states. The scores for the remaining four tests are based on arbitrary numbers representing the maximum and minimum levels of response to suggestion. On the whole, a response closer to the maximum was reached by the sleeping, rather than hypnotized, subjects.

effects of suggestion during sleep, hypnosis and wakefulness, the subjects had no difficulty remembering everything that had occurred in the waking tests, although they were told, as in the sleep and hypnosis tests, that "you will not remember anything that I said or anything that you did." In the sleep tests and the hypnosis tests, equal numbers of subjects were unable to recall what had happened afterward. This seems to indicate that in part the amnesia after hypnosis is similar to the amnesia of sleep.

We are now planning experiments at the Laboratory of Social Relations at Harvard University to look further into comparisons between hypnosis and sleep and also to learn what makes some individuals hypersuggestible. The findings I have discussed open up what promises to be a fruitful area of research. Most promising are further studies in the psychology of sleep. We expect to learn much more about the meaning and function of dreams by suggesting to sleeping subjects that they will dream about some particular subject. We would also like to give tests of suggestibility to sleepwalkers, find out more about people who sleep with their eyes open and see if we can carry on a conversation with people who continually talk in their sleep. At the therapeutic level it is possible that suggestions given to people while they are asleep may help obese persons to reduce, heavy smokers to cut down their smoking and timid persons to gain in confidence. We look forward to many interesting studies.

"You will wake up in exactly five minutes and be so thirsty . . . you will have to have a cool . . . drink of water." The measure of suggestibility in these tests is based on how close to the five-minute mark the subject actually rises and how much water he drinks.



that I said or anything that you did. . . . Everything is fading away like a dream." When the subject awakes he is asked what he remembers about the experiment. Though he tries hard to remember, he finally answers: "I don't seem to be able to recall anything."

SKIN TRANSPLANTS

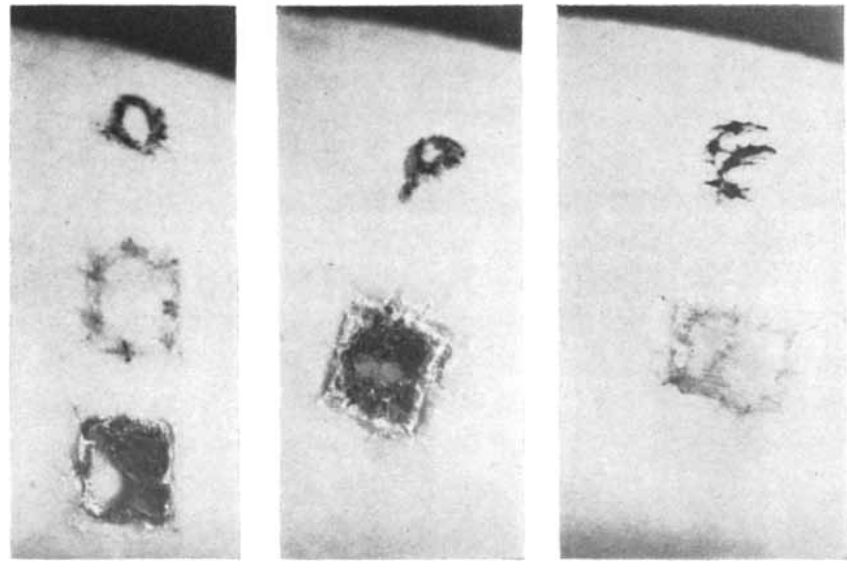
When skin from one man is grafted onto someone other than his identical twin, it soon drops off. The chemical mechanism which interferes with the graft is illuminated by animal experiments

by P. B. Medawar

Skin-grafting was introduced into medical practice by Jacques Louis Reverdin, a surgeon in Paris, about 90 years ago. In principle it is quite a simple operation. The skin has two layers: an outer epidermis, consisting of tiers of cells which are constantly replaced from the inside outward, and an inner dermis, or corium, consisting mainly of a latticework of tough connective-tissue fibers, to which skin owes its great strength [*see diagram on page 66*]. The portion sliced off for grafting is made up of the epidermis and the upper part of the dermis. Its transplantation amounts to little more than laying it in place over the area to be repaired and holding it there under light but firm pressure until the dermis becomes knitted to the graft bed below.

The early plastic surgeons supposed that skin could be grafted from one person to another; some of them—victims of heaven-knows-what enormities of self-deception—convinced themselves that even the skin of frogs and rabbits could be transplanted to man. It was not until 1911 that Erich Lexer, in a masterly address before a conference of German surgeons, showed conclusively that skin grafts exchanged between different persons, even between parents and their children, were invariably unsuccessful. The truth of what Lexer said was slowly and grudgingly conceded. Nowadays everyone agrees that skin transplanted from one individual to another will not survive permanently. After a week or so the transplanted skin becomes puffy and inflamed, and soon the graft is sloughed off or drops away. Ordinarily the only kind of graft that will work is an autograft—that is, a transplant of an individual's own skin from one part of his body to another.

One exception to this rule is that skin can be exchanged between identical twins. This test has provided crucial evidence in cases of disputed or uncertain parentage, as two stories will illustrate. The first story, which has the makings of an operatic libretto, is about three six-year-old boys called Victor, Pierre and Eric. Victor and Pierre were supposedly twin brothers, and would still be so regarded if their father (as he imagined himself to be) had not had his attention called to a third boy, Eric, who was the very image of his Victor. Inquiry showed that Eric had been born in the same maternity clinic and on the same night as Victor and Pierre. It seemed likely that Eric was Victor's real twin and that Pierre had been substituted for Eric by mistake. A very careful physical comparison (including a study of fingerprints, eardrum patterns and X-rays of the hands) made it virtually certain that Eric and Victor were identical twins. However, the mother to whom Eric had been allotted did not take kindly to the view that the boy whom she had brought up to the age of six was not in fact her son. Blood-group tests failed to exclude the possibility that Eric might be her son (though they did prove that Pierre could not be Victor's mother's son). It was agreed that a skin-grafting test would be decisive. A surgeon, Sir Archibald McIndoe, transplanted small squares of skin between Eric and Victor and between Victor and Pierre. The grafts exchanged between Pierre and Victor were sloughed off. But Eric and Victor accepted the grafts from each other, a result which proved that they



SKIN GRAFTS were made to determine whether two Swiss boys who closely resembled each other had been accidentally interchanged at birth. At left is the arm of Victor; on it are two square skin grafts, one from Eric (*top*) and the other from Pierre (*bottom*). The graft from Pierre has begun to slough off; the graft from Eric has "taken," indicating that Eric and Pierre are twins. In the middle is the arm of Pierre with a graft from Victor; the graft has not taken. At right is the arm of Eric with a graft from Victor; the graft has taken. The study was made by A. Franceschetti, F. Bamatter and D. Klein.

must be identical twins. So Eric and Pierre were restored to their rightful and now satisfied parents, and the story ends happily (which makes it unsuitable for an operatic libretto after all).

The second story is about a mother and daughter and a question of "virgin birth." Members of the staff at University College in London often give lunch-hour lectures which may be attended by the press and the public, and in the course of one such lecture a geneticist gave certain reasons for supposing that parthenogenesis (development of the egg without fertilization) occurred in guppies and might not inconceivably occur in man. (Later evidence indicated that the guppy births were probably a case of self-fertilization.) A section of the press, no doubt animated by a sense of public duty, instituted a campaign to find an authentic example of virgin birth in human beings. In response to an appeal 19 mothers presented themselves with daughters—daughters they must be, for genetic reasons—of allegedly parthenogenetic birth. Eleven who had not quite grasped the import of the idea of virgin birth were at once eliminated; seven more were disqualified by differences between the mother's and daughter's blood types. But there remained one mother whose daughter qualified on blood grouping and certain other grounds. To clear the matter up, skin grafts were transplanted from the mother to the daughter and vice versa. Both grafts broke down and were sloughed away in a matter of weeks. The failure of the graft transplanted from the daughter to the mother proved that the child must have had a father.

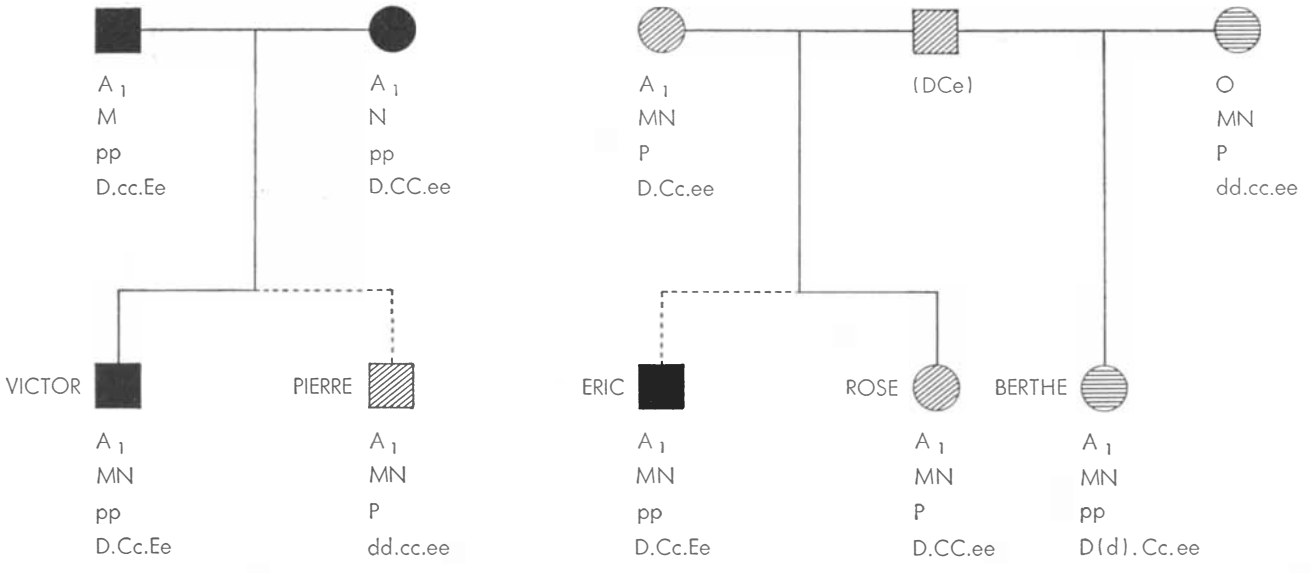
The reaction which causes one individual to reject a graft from another is not a peculiarity of human beings. With the mysterious exception of the hamster, every species of vertebrate so far tested has exhibited this reaction against homografts (*i.e.*, transplants between different individuals of the same species). Nor is the reaction confined to skin, though no other tissue shows it so clearly. W. J. Dempster of the Postgraduate Medical School of London has shown that it applies to a graft of a whole kidney, and it has also been shown to apply to the heart, the lung and even to grafts of tumor tissue. Some parts of the body will accept homografts—for example, the cornea of the eye and the brain—but in these cases special factors are at work.

Plainly the reaction against a graft is an immunological one; *i.e.*, a reaction of the same general kind as that provoked in the body by foreign proteins, foreign red blood cells, or bacteria. This is easily demonstrated by experiments. After a mouse has received and rejected a transplant from another mouse, it will destroy a second graft from the same donor more than twice as rapidly, and in a way which shows that it has been immunologically forearmed. This heightened sensitivity is conferred upon a mouse even when it merely receives an injection of lymph-node cells from a mouse that has rejected a graft.

In most immunological reactions the body employs antibodies as the destroying agent—*e.g.*, in attacking foreign proteins, germs and so on. Antibodies are formed in response to a homograft, but there are reasons to doubt that these are normally the instruments of the reaction against such a graft. Paradoxically enough, a high concentration of circulating antibodies seems if anything to weaken the reaction: it allows the graft to enjoy a certain extra lease of life.

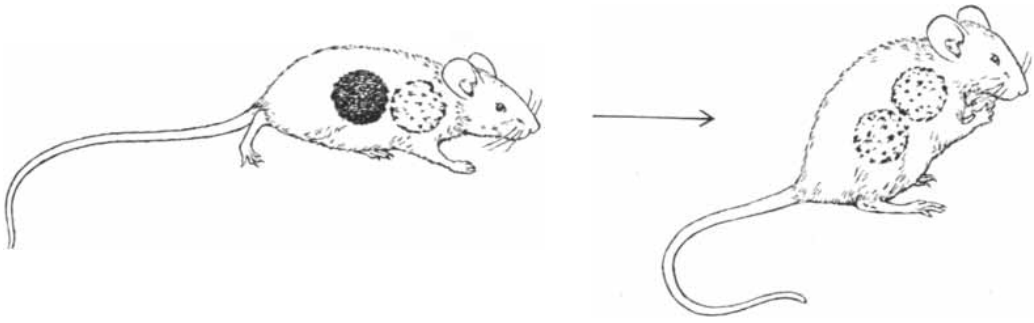
The actual agents of attack on the graft seem to be not antibodies but cells produced by the lymph glands. Some skillfully designed experiments by G. H. Algire, J. M. Weaver and R. T. Prehn at the National Cancer Institute in Bethesda certainly point in that direction. In one experiment they enclosed a homograft in a porous capsule before planting it in a mouse which had been sensitized by an earlier homograft from the same donor. When the pores of the capsule were large enough to let cells through, the mouse destroyed the graft. But when the experimenters used membranes with pores so fine that they kept out cells and let through only fluid, the graft survived.

The hypothesis that the action against a graft is carried out by cells explains why grafts in the cornea are mercifully exempted from attack. The cornea



DIAGRAMS OF FAMILIES of the interchanged boys show the blood types of each person involved. The four major blood groupings (*A, B, O; M, N; P, pp;* and the Rh factors *D, d, C, c, E, e*) are indicated, with capital letters for dominant traits and small letters for recessive. Pierre could not have inherited dominant trait *P* from his supposed parents who both show the recessive *pp*, nor could he have the *cc* factor if he were the son of the mother (*black circle*) with two genes for the *C* trait. Pierre's blood groups are consistent with those of Eric's supposed mother (*shaded circle, top center*) and with what is known of the father. Eric's father had died, but certain of his blood factors were deduced from those of Berthe, his daughter by a previous marriage. Eric's factors fit with what is known of his supposed parents, but his blood groups are the same as Victor's and fit as well with those of Victor's parents.

NORMAL WHITE MOUSE (*left*) which receives a skin graft from a brown mouse will reject it. The foreign skin disintegrates in about 10 days' time and falls off (*right*). Grafted skin from any other animal not an extremely close relative will also be rejected.



MOUSE WHICH HAS HAD A GRAFT will also reject a second one from the same donor. The second transplant and subsequent ones will disintegrate even more rapidly than the first. This occurs even when many months have passed between grafts.

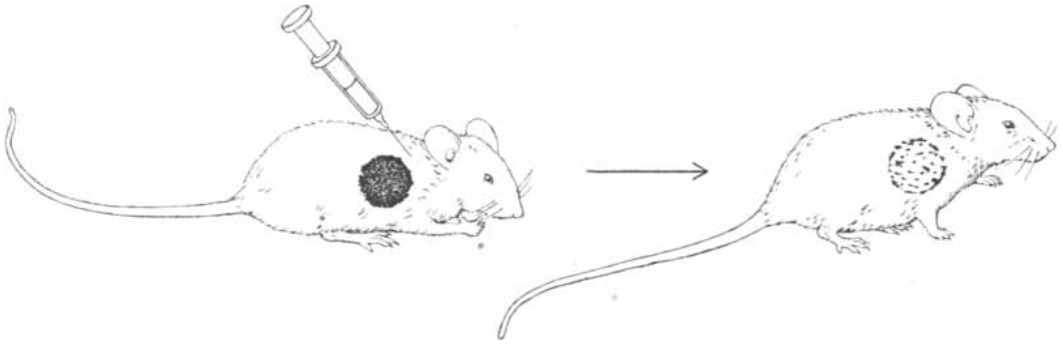
INJECTION OF LYMPH CELLS obtained from mouse which had earlier rejected a graft is administered to a normal mouse. If this mouse later receives a graft from a brown mouse, it will reject the graft as rapidly as the mouse which had had two grafts.

has no blood vessels; consequently blood-borne cells cannot reach the graft. In the brain, on the other hand, the converse of this situation obtains: the brain lacks a lymphatic drainage system, so that any antigens released by a graft there may not be able to travel to centers where they can stir up an immunological response. This probably explains why homografts can often be transplanted successfully into the brain.

For some years past at University College in London R. E. Billingham, L. Brent and I have been studying the cause of the reaction against homografts and steps that can be taken to prevent it. Following up a clue provided by the work of R. D. Owen at the California Institute of Technology, we discovered that the power to react against homografts could be prevented from developing if we injected an animal at a very early age with cells from the donor strain —most conveniently cells of the spleen. In adult mice the injection of such cells increases the mouse's resistance to a graft from the donor. But if the spleen cells are injected in a mouse in the fetal stage or very shortly after its birth, the opposite happens: the mouse becomes tolerant of grafts from the strain that provided the spleen cells, though it remains intolerant of homografts from mice of other strains. A tolerant mouse can be recalled to a sense of the fitness of things by injecting it with lymph-node cells from a normal mouse of its own strain. Its tolerance then slowly disappears. The operation seems to equip the tolerant mouse with cells which are competent to recognize and react against foreign substances issuing from the previously tolerated homograft.

This experiment, among others, shows that the tolerance of a homograft is due to absence of specific reactivity in the host, rather than to any change in the properties of the grafted tissue. The antigens are present in the graft, but the animal cannot react to them. The

NEWBORN WHITE MOUSE is injected with spleen cells obtained from a brown mouse. If it is grafted later with skin from a brown mouse, the graft will "take" and remain intact for weeks or months just as if it had been taken from another part of the same mouse.



TOLERANT MOUSE, *i.e.*, a mouse which has accepted a graft after having been injected with spleen cells very shortly after birth, is injected with spleen cells from a normal mouse of its own strain. The mouse now rejects the graft it had accepted earlier.

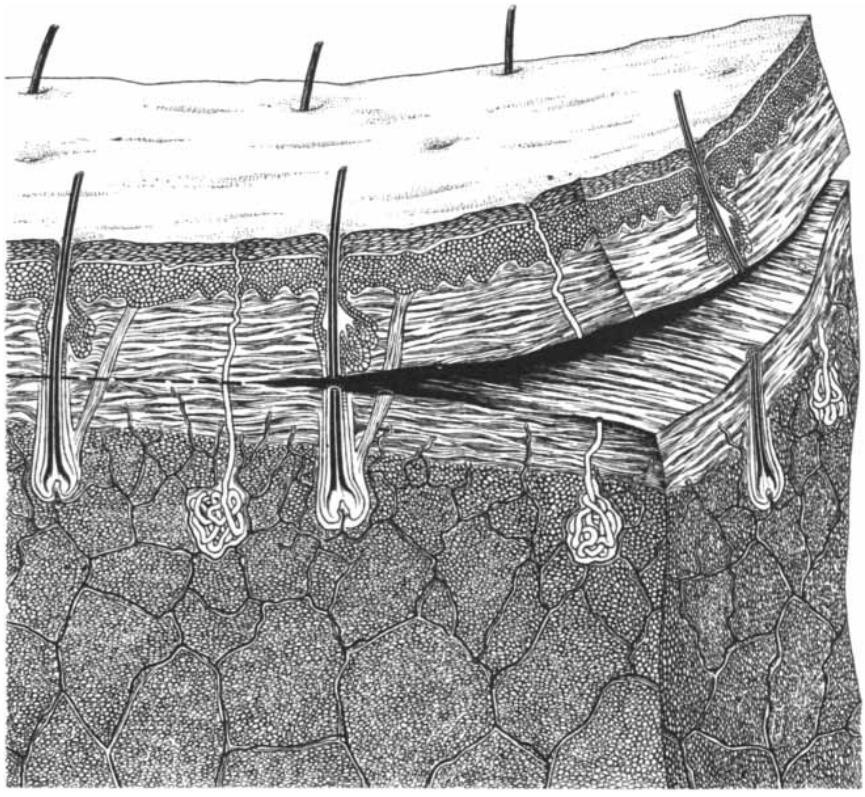
SEVEN-DAY-OLD MOUSE does not become tolerant when injected with spleen cells from a brown mouse. On the contrary, it rejects grafts from the brown mouse more rapidly than usual. Adult white mice react in the same way to the injection.

phenomenon of tolerance of antigens cannot yet be explained by any chemical theory of the immunological reaction. No future theory will be acceptable unless it can take tolerance in its stride.

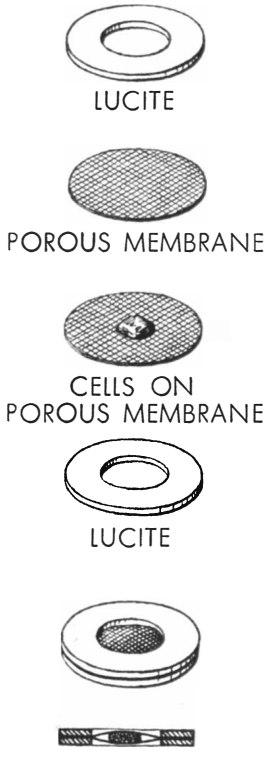
What are the tissue antigens that cause an animal to reject a homograft? When we began our work, it was known only that they are very numerous and that they are under the most exact genetic control. While the antigens could not be identified chemically, they could be separated by genetic methods, *i.e.*, by a combination of breeding and grafting tests. E. J. Eichwald and C. R. Silmser at the Deaconess Hospital in Montana have just made the remarkable discovery that, within certain inbred strains of mice, a female will accept a skin homograft from a female, a male from a male and a male from a female, but a female will not take a graft from a male. The discovery raises the possibility that the Y chromosome of male mice, hitherto thought to be concerned only with sexual differentiation, may actually control the formation of an antigen.

The study of the nature of the antigens that cause the homograft reaction is difficult and laborious. Their action cannot be investigated in the test tube but only by effects on living animals. Moreover, the antigens are highly unstable. Cells which have been frozen and thawed or dried in the frozen state or heated to about 120 degrees Fahrenheit are no longer capable of eliciting a homograft reaction. Fortunately we have discovered ways of disintegrating cells without destroying their antigenic power. For example, with judicious use of ultrasonic radiation we have broken down cells into nuclear and cytoplasmic fractions and found that the antigenic power lies only in the nuclear material.

The antigenic substances in the nucleus are not soluble in water of the same salinity as the body fluid (*i.e.*, about 1 per cent sodium chloride). But they can be coaxed into solution in dis-



SKIN FOR GRAFTING is sliced off above the root of the hair, through the elastic fibrous tissue of the dermis. The graft then consists of the horny protective epidermis, the layer of growing cells and part of the connective tissue. The main portion of the sweat glands, the hair follicle and fatty tissue remain, and missing parts regenerate from them.



PERMEABILITY CHAMBER to test the size of graft-rejecting substances is essentially a three-layered sandwich. Cells are placed between membranes of known pore size. Glue made of lucite and acetone holds the membranes together and fastens them to lucite rings. Cross section is shown at bottom left. The chamber is placed in the mouse's abdomen. If antagonistic substances in the mouse pass the membranes, the cells in the chamber are destroyed.

tilled water. After we learned the trick of dissolving them, we found by centrifuging tests that the active substances either were very large molecules or very small particles or were firmly attached to a large molecule or particle. The active matter can be precipitated from the water solution by adding a very small amount of magnesium chloride to the solution. It can be partly redissolved by raising the concentration of magnesium chloride and can then be precipitated again simply by adding water to dilute the solution. I mention these reactions because they have the crispness and clarity that one usually associates with schoolroom chemistry, and because of the commendable frugality of the reagents which we use—water and a number of simple salts.

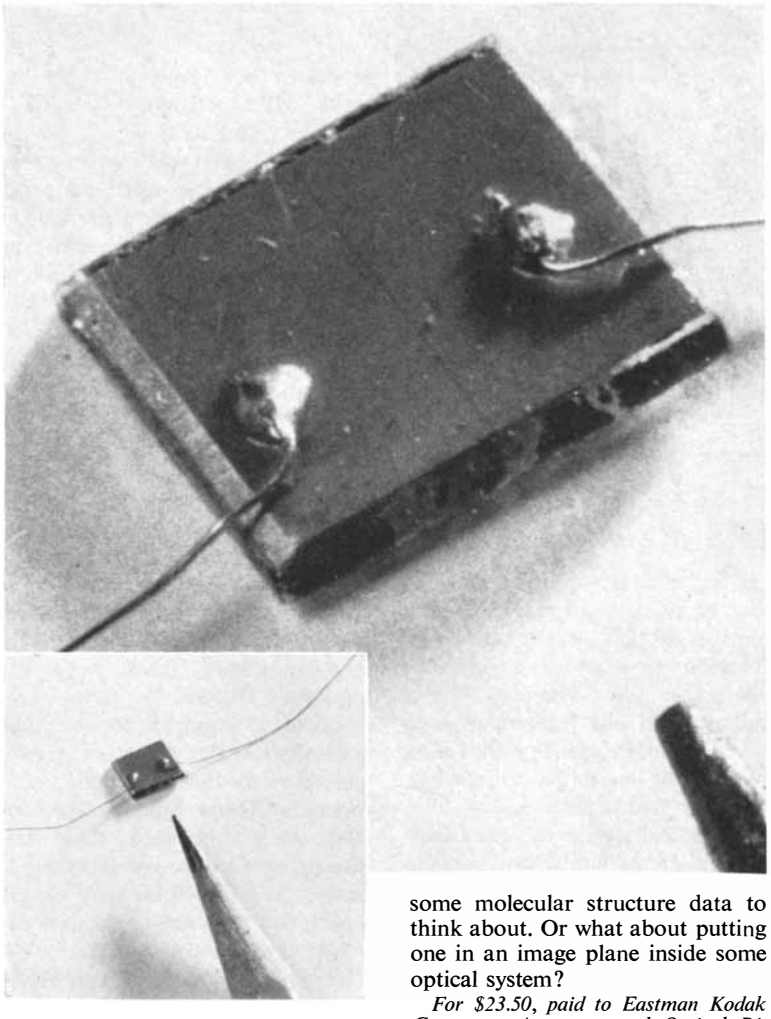
Our experiments suggest, but do not yet prove, that the antigens responsible for the homograft reaction are compounds of desoxyribonucleic acid and protein—that is, chromosomal matter. Tests on the breakdown of the antigenic substances by specific enzymes support this interpretation. Furthermore, the idea that these antigens are chromosomal matter fits well with evidence that the antigens are present in all the tissues of the body, in embryos and (so it has been said) even in sperm.

Desoxyribonucleic acid itself does not act as an antigen. It is active only in combination with protein. Perhaps the protein part, like the protein coat of a bacterial virus, simply helps the nucleic acid to get into the cells from which it elicits a reaction—in this case, the lymphoid cells of the host. If that is so, the nucleic acid may be the part of the antigen that is specifically responsible for its power to sensitize an animal against the cells of a foreign graft. We have not yet proved this, but the evidence that desoxyribonucleic acid is the chemical embodiment of heredity makes it a plausible guess.

If our interpretation turns out to be true, the study of the antigens that cause the homograft reaction could be of decisive importance in working out the chemical structure of chromosomes, for it would provide a test to determine whether a chromosomal extract has been damaged by the process of extraction. At present no one can be sure, for only in microorganisms do we have biological tests that can guarantee that the nucleic acids are in working order. Our hypothesis has many other deeper and more exciting implications also, but there will be time enough to consider these when we have assured ourselves that the hypothesis is correct.

Kodak reports to laboratories on:

a photoresistor 20μ wide . . . a hydrocarbon among hydrocarbons



Thin receptor

The thin black line is 20μ wide and 0.2 mm long. In the dark, d-c resistance across the .0008″ of lead sulfide is a few hundred ohms. When radiant energy shines on the line, the resistance drops. A manifestation, obviously, of the celebrated *Kodak Ektron Detector*. The wavelength of the energy can be from 3.5μ in the infrared,* right through the visible and on to at least 250mμ in the ultraviolet. Imagine an infrared spectrometer that could afford to image its exit slit down to .0008″! Might provide some molecular structure data to think about. Or what about putting one in an image plane inside some optical system?

For $23.50, paid to Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y., anybody can have one. If the eloquence of these words gets us swamped, delivery may be a bit delayed. If you wanted to wait, it's not unlikely the price will drop. But then you might not be first on your block.

*That would make a receptor less than 6 wavelengths wide, wouldn't it?

That ol' shark oil

$$\left[\mathrm{CH_3CH(CH_2)_3CH(CH_2)_3CH(CH_2)_2}\right]$$
$$\qquad\quad\mathrm{CH_3}\qquad\quad\mathrm{CH_3}\qquad\quad\mathrm{CH_3}$$

This looks like a tedious concatenation of 30 carbon atoms and 62 hydrogen atoms, but oh, how wrong you would be to say that!

This is *Squalane*. (Note the "a.") We hereby announce our readiness to sell it as Eastman 7311 at $15.60 per 100 grams. *Squalane* is hydrogenated *Squalene* (Eastman P6966). We can distill squalene (Note the "e.") in our unique molecular stills from the oil found in the gigantic, oily liver of the mighty but leisure-loving basking shark. Squalene is being added to at least one brand of cattle feed on the strength of certain findings by the manufacturer about cholesterol and sex hormones. The merest *soupçon* of it in dog food is said to bring utter bliss to the canine palate.

The latest is that *Squalane* has a contribution to make to gas chromatography, which is booming. This is an analytical technique whereby a volatile sample mixture is swept by an inert gas through an adsorbing column and resolved by virtue of the different times it takes each component to make its way through against the adsorption forces. *Squalane* is reported (*Anal. Chem. 28*,303, March '56) to modify the adsorbing characteristics of a commercial carbon black in a manner that shuffles the order of emergence from what it is with other adsorbents, thus providing a good fix on the proportions of each different C_5, C_6, and C_7 saturated hydrocarbon present. One of our own plants tried it out and forthwith contributed further to the burgeoning art by discovering that *Squalane* is very good at separating hydrocarbons from oxygen-bearing compounds close to them in physical properties. They found, for example, that n-heptane emerges later than n-butanol, even though n-butanol is the higher boiling substance.

Will we reveal more about this? Will other experiments now in progress with Squalane *turn out to be as interesting as the preliminary results promise? Don't wait for the next gripping chapter, if any. We sell* Squalane *with which you can go to work yourself. (You won't find it in our Eastman Organic Chemicals List, No. 40. It's too new. You will find some 3500 other organic compounds, though. If you haven't a copy, drop us a note.) Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

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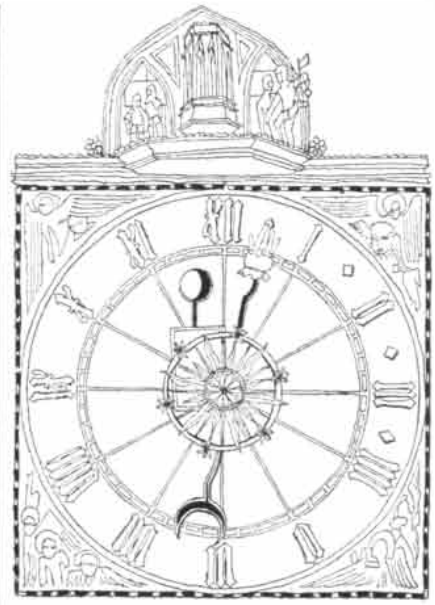


Euratom

In 10 years a cooperative group of six nations of Western Europe may be the world's largest producer of atomic power. These countries—Belgium, France, West Germany, Italy, Luxembourg and The Netherlands—are setting up an international pool, called Euratom, for the development of nuclear power. Their goal is three million kilowatts of atomically generated electricity by 1963 and 15 million by 1967. Of the other potentially major producers, the U.S.S.R. has announced plans for 2.5 million kilowatts by 1960, Great Britain for six million by 1965. The U. S. has no formal goal, but the estimate is about one million kilowatts by the early 1960s.

Under an agreement concluded last month by the heads of state of the Euratom countries, an agency of the union will own all the fissionable material to be used in power reactors. Individual countries retain the right to withdraw material for military purposes, in which case they will assume ownership. Most of the fuel, at least in the early years, will be purchased from the U. S., which has indicated that it can supply the necessary amounts. This country has also promised technical assistance.

Von Neumann

Few scientists have left as wide an imprint on their time as did John Von Neumann, who died of cancer last month at the age of 53. The Hungarian-born mathematician made timely contributions to fundamental knowledge in several fields. His great energy and breadth of interests, together with his prodigious mental speed, enabled him to tackle a wide range of scientific and practical problems.

His first major achievement was the treatise *Mathematical Foundations of Quantum Mechanics,* written when he was a 23-year-old lecturer in Germany. In it he proved that Erwin Schrödinger's wave mechanics and Werner Heisenberg's matrix mechanics, both of which had just been developed, were mathematically equivalent. He thus helped put modern physics on a firm mathematical foundation.

A few years later Von Neumann came to the U. S. as a visiting professor at Princeton University. In 1933 he joined the Institute for Advanced Study. While still in Europe he had turned his attention from quantum mechanics to an apparently less imposing problem—finding a rational strategy for the penny-matching game. This led him to the development of a powerful new branch of mathematics: the theory of games. He worked on the theory with the Princeton economist Oskar Morgenstern, and in 1944 they published their famous *Theory of Games and Economic Behavior.* The principles they developed have found extensive application in economics and military strategy.

During World War II Von Neumann played a major part in the development of the atomic bomb. He was also a roving consultant on ordnance, submarine warfare, bombing objectives, economic intelligence and similar matters. After the war he continued his service as a military adviser and in 1955 was appointed to the Atomic Energy Commission.

Von Neumann's chief interest in the postwar years was high-speed computing machines. He designed one of the biggest and fastest, the MANIAC (Mathematical Analyzer, Numerical Integrator and Computer), at the Institute for Advanced Study. As he had foreseen, it played an indispensable part in research on the hydrogen bomb. He also showed the value of computers for long-range weather forecasting and for chemical and biological research.

There are countless stories of Von Neumann's power of mind. Problems that had stumped competent mathematicians for days, he often solved in minutes. He could talk to physicists, mathematicians, engineers and economists

about their specialized problems and penetrate swiftly to the central point, often suggesting a fruitful new approach. When he was appointed to the AEC, a brilliant young physicist who had known him at the Institute remarked: "Johnny will do all right, because he's probably the smartest man in the world."

The Scratcher Scratched

The axiom that only a diamond can scratch a diamond was made obsolete last month. The General Electric Research Laboratory announced that it had synthesized a new substance which is just as hard as the hardest thing found in nature. It is called borazon—"bor" for boron, "azo" for nitrogen. Atoms of boron and nitrogen are arranged in a cubic crystal similar to the arrangement of carbon atoms in a diamond. The new crystals are much more resistant to heat than the glorified coal. Borazon can withstand heat above 3,500 degrees Fahrenheit, while diamond burns up in air at about 1,600 degrees F. It may therefore be superior for jobs requiring high-speed cutting or polishing.

Borazon was made by subjecting boron nitride to pressures above one million pounds per square inch and temperatures exceeding 3,000 degrees F. Boron nitride, a white compound, is physically similar to graphite: like graphite, it is soft and slippery because it is composed of layers of atoms which slide over one another easily. Graphite can be converted to diamond by subjecting it to very high pressure and temperature, which causes the free electrons to form bonds between the atomic layers. After its success in synthesizing tiny diamonds from graphite, the G. E. Laboratory undertook to apply the same method to make a completely new crystal with boron nitride.

Boron and nitrogen lie beside carbon in the periodic table, and a combination might be expected to react somewhat like carbon. The main problem was that boron nitride lacks free electrons to serve as bonds for the layers. Robert H. Wentorf, Jr., who achieved the synthesis of borazon, believes that each nitrogen atom in the crystal must donate one of its electrons to supply a bond to the adjacent layer. Despite the fact that the crystal of borazon contains two different

kinds of atoms, the alternate boron and nitrogen atoms are packed together almost as closely as the carbon atoms in diamond.

Safety Car

Engineers at the Cornell Aeronautical Laboratory have lowered their sights to consider a terranautical problem. They are studying methods for reducing injury in automobile collisions. To demonstrate and dramatize their findings, they have designed a model "safety car" which should make smash-ups as painless as possible.

The outside of the car has a minimum of protuberances on which to impale pedestrians. The bumper goes all around the body and is attached directly to the chassis through shock-absorbing mounts. Steel bars above the front and rear seats brace the roof against overturns.

Inside, the vehicle has individual bucket seats for six passengers. The driver sits in the center of the front row. He controls the car with a set of levers and buttons mounted on an adjustable padded panel which rests in his lap and also serves as a seat belt. The windshield bulges so that his head cannot possibly hit it when the lap panel is in place. The instrument panel is just below the driver's normal line of sight, so that he can see it with a minimum deflection of his gaze. All the dials except the speedometer have automatic alarm lights. If they are not lit, the instruments do not require the driver's attention.

Two other front-seat passengers sit slightly aft of the driver on either side. They also are held by lapboards, which double as desks or arm rests. Behind the driver is a seat facing backward, and in the rear are two more that face front. They all have seat belts. Among the other safety features are accordion-type doors which fold back like those in a telephone booth and bolt closed, and a ventilating system which maintains the inside air pressure slightly above that outside to prevent carbon monoxide from seeping in.

Six Billion Years to Go

The sun, now about six billion years old, will shine on steadily for another six billion and then flare up and burn everything on the earth to a crisp, according to a considered prediction by Allan R. Sandage, astronomer at the Mount Wilson and Palomar Observatories. Sandage summarizes the latest views on the evolution of stars in *Engineering and Science,* the magazine of

DOW CORNING

SILICONE NEWS

Silicones Ease the "Profit Squeeze"

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

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

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

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

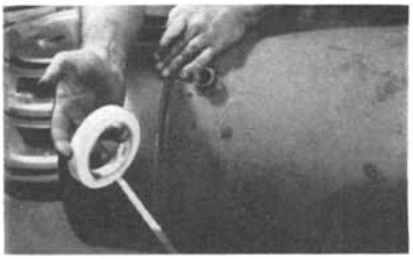
Unlike many oils, this silicone fluid is an excellent lubricant for plastic or rubber parts in contact with metal . . . an essential factor here. And silicones don't thicken when temperatures head for the deep freeze: another essential. In all, Kelvinator has added a pleasing new sales feature at practically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

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

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

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

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



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

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the California Institute of Technology.

A star of our sun's type, he says, remains stable from the time it is formed until about 12 per cent of its hydrogen is converted to helium by thermonuclear reactions. He calculates that our sun is halfway through this period of equilibrium. During the past six billion years it has heated up very slightly, so slightly as to cause a rise of only about 36 degrees Fahrenheit in the average temperature on the earth. In the next six billion years it may raise the temperature by about the same amount—a change to which living forms should be able to adapt. But when 12 per cent of the sun's hydrogen is gone, it will abruptly heat up and swell to about 30 times its present diameter. It will begin to burn its remaining hydrogen faster, and in a few hundred million years the earth's temperature will rise to 1,500 degrees—well above the boiling point of lead. After the sun has consumed its hydrogen, it will shrink to a white dwarf.

The more massive a star, the faster its evolutionary course. If the sun were only 10 per cent heavier than it is, Sandage says, it would already be in the heating-up stage. Since there are presumably countless stars of that larger size in the universe, life on any planets attached to them must already have suffered the fate that faces the earth six billion years hence, when, Sandage says: "Life will have ceased, the oceans will have boiled away and conditions will be miserable."

Green Solar Battery

Students of photosynthesis have begun to suspect that the process cannot be explained entirely in terms of chemical reactions in solutions. Some of the steps, they believe, belong in the realm of solid-state physics and semiconductors. William Arnold and Helen K. Sherwood of the Oak Ridge National Laboratory have made a discovery which supports this view. They find that chloroplasts, the chlorophyll-containing bodies in plants, behave like semiconductors.

Melvin Calvin and his colleagues at the University of California recently proposed a hypothesis that chloroplasts are built like semiconducting solar batteries and function in the same way. They are composed of tiny, stacked protein disks called "grana," which are glued together by layers of fatty molecules. Calvin suggests that the energy of sunlight has the same effect on chlorophyll in the disks as it has on certain crystals: it knocks out a few electrons from the lattice and leaves positive

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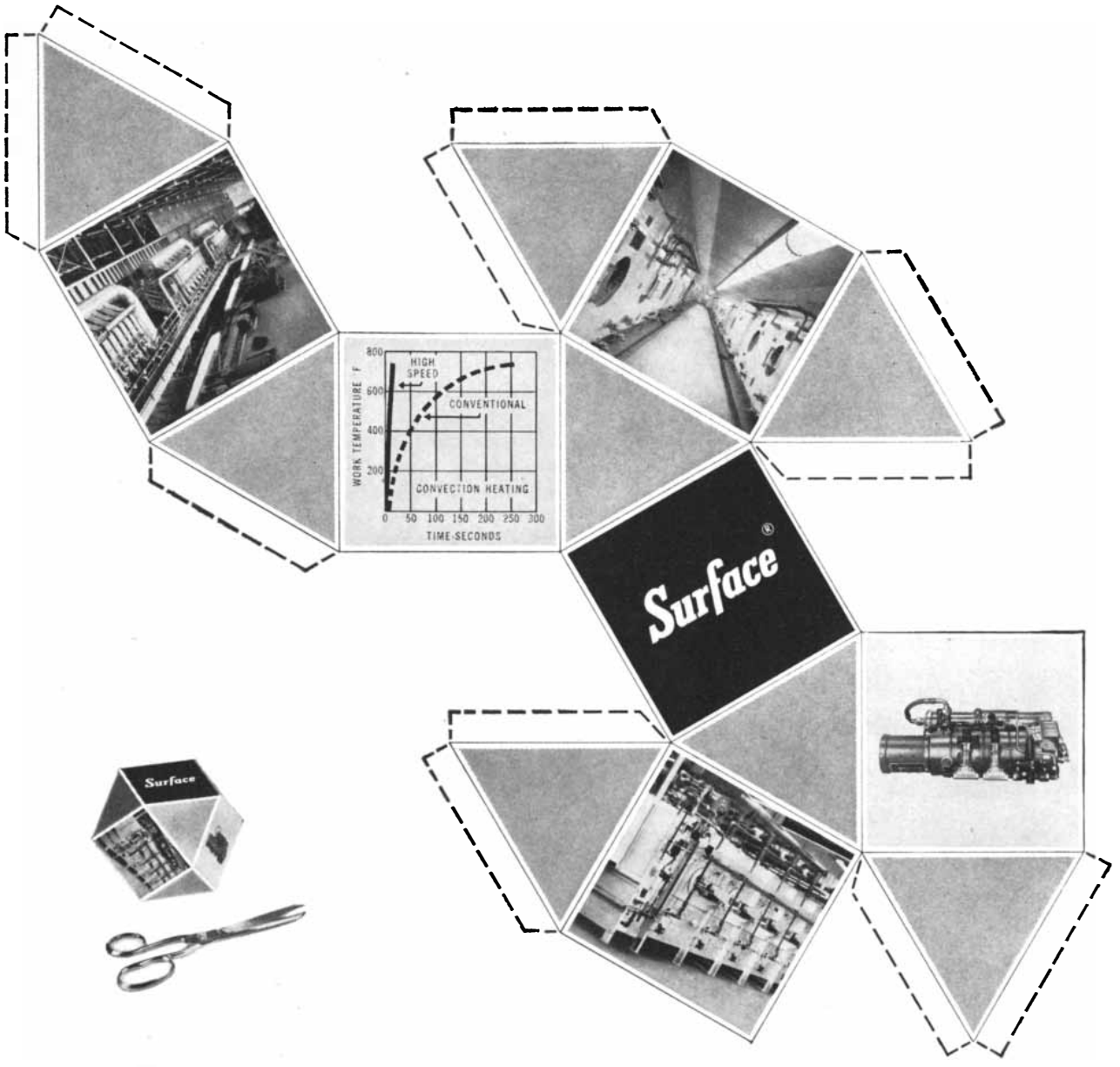
"holes." These mobile charges migrate into the fatty layers, which act as semiconductors of two types, one type conducting the electrons and the other the positive holes. Thus the charges are separated and light energy becomes the electrical energy of a battery. The positive charges then begin the job of decomposing water molecules, and the electrons are supplied to the reducing agent which eventually converts carbon dioxide to sugar.

To test the semiconductor hypothesis, the Oak Ridge biologists studied the effect of heat on a layer of dried chloroplasts. The chloroplasts absorbed heat energy and reradiated it in the form of light, a characteristic of semiconducting crystals. Also, the electrical resistance of the layer decreased with increasing temperature, in the typical pattern of semiconductors. Arnold and Sherwood reported their work in the *Proceedings of the National Academy of Sciences.*

Rust-Proof Wheat

A new strain of wheat which is resistant to the 22 known varieties of rust disease has been developed by E. R. Sears of the U. S. Department of Agriculture's Missouri Experiment Station. The hybrid is a triumph of genetic juggling and legerdemain with X-rays. Sears lifted a single gene or constellation of genes out of a grass distantly related to wheat and installed it in the germ plasm of common wheat by a long, roundabout process.

The plant with which he started was *Aegilops umbellulata,* a wild grass practically immune to leaf rust. Aegilops has only seven pairs of chromosomes and wheat has 21, so they could not be crossed directly. Sears first mated the grass to emmer, a 14-chromosome wheat, and got a sterile hybrid with 21 unpaired chromosomes. A dash of the drug colchicine then converted this into a fertile plant with 21 paired chromosomes. Sears now crossed the hybrid with common (Chinese spring) wheat. The offspring had 14 pairs of chromosomes and 14 chromosomes which did not pair—seven from Aegilops and seven from Chinese spring. A series of backcrosses to Chinese spring successively eliminated Aegilops chromosomes until only one was left—the one that contained the rust resistance. This chromosome, however, also contained a number of undesirable characteristics. So Sears proceeded to expose the seeds to X-rays with the hope of breaking off the piece of the Aegilops chromosome containing the rust resistance. In 6,091 tries at this



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Surface

shot in the dark he got one hit on the bull's-eye: the target fragment was separated and recombined with a wheat chromosome. His product is a rust-proof wheat that breeds true.

Strontium 90 in Bones

Strontium 90, the radioactive product of atomic explosions, is now present in the bones of all human beings on the earth, "regardless of age or geographic location," says a group of scientists at the Lamont Geological Observatory of Columbia University. They are conducting a world-wide survey of the strontium hazards, and base their conclusion on more than 500 samples of human bones from five continents already analyzed.

The average amount of strontium 90 in each person's bones is tiny—only about one 10,000th of what radiation authorities have set up as the maximum safe dose of this bone-cancer-producing radioisotope.

So far as is known, atomic explosions are the only appreciable source of strontium 90 on the earth. The tests of the very large bombs have sprayed the material into the stratosphere, where winds carry it all over the earth. It is washed down by rain and picked up by plants, which pass it on to animals and man.

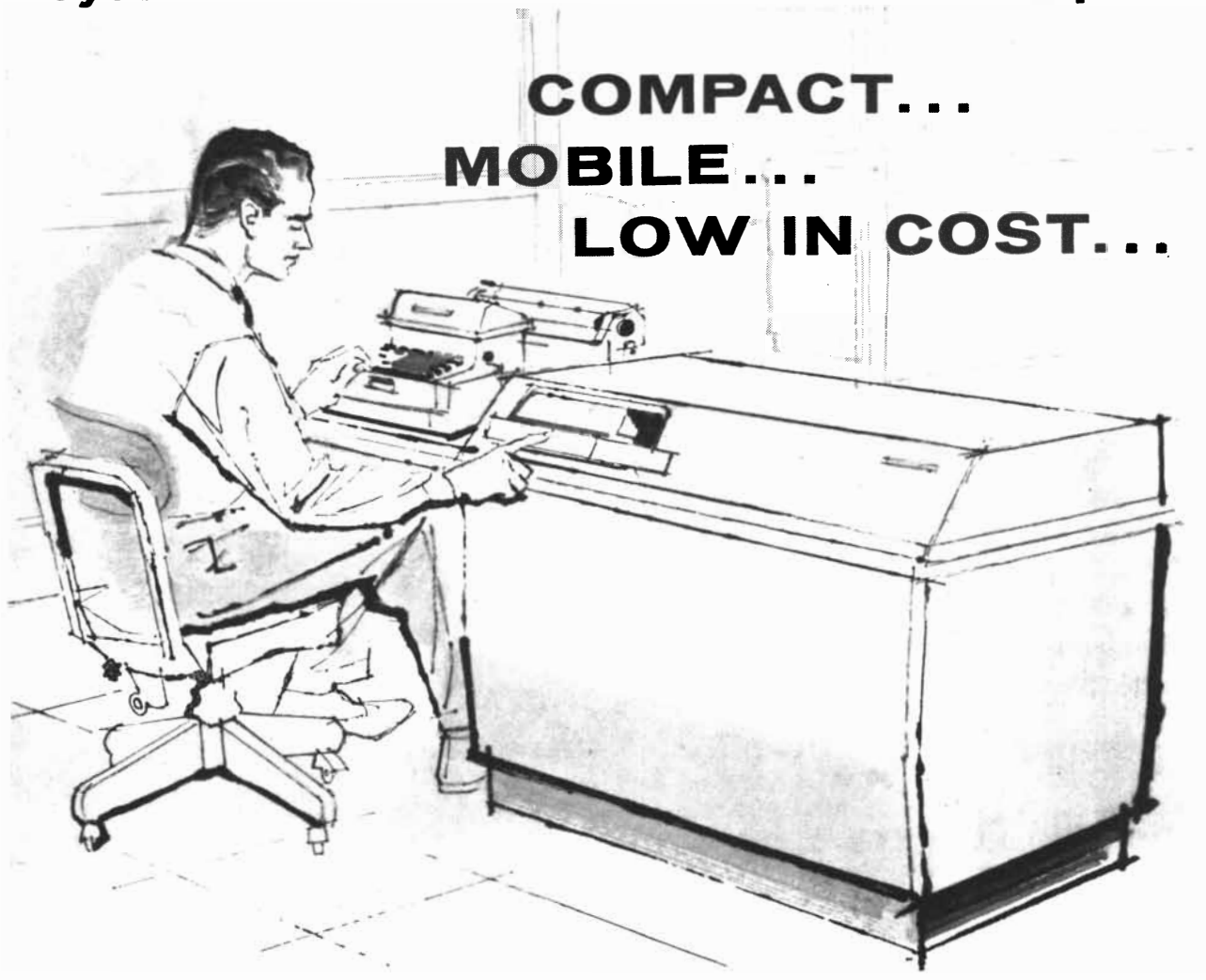
The fallout of strontium 90 seems to have been fairly uniform over the earth, but it is slightly greater in the Northern Hemisphere than in the Southern. The young age groups, particularly those in the rapid growth period under four years of age, have more of the substance in their bones than the older ones.

The Lamont scientists estimate that there is still enough strontium 90 in the atmosphere from the 50 megatons of bombs exploded so far to increase the average absorbed by human bones to 10 times the present amount by the year 1970. The world-wide average would then be about 1.3 micromicrocuries per gram of calcium in the bones, and the average in the U. S. a little higher. But the investigators say it would take 35,000 megatons of atomic explosions to raise the concentration above the present standard of safety.

Mongooses, Go Home!

When, for his own purposes, man moves animals from continent to continent, he usually gets more than he bargained for. Three American naturalists, Antoon de Vos, R. H. Manville and R. G. Van Gelder, have taken a historical look at these interferences with nature by man, and they find an appalling rec-

Royal Precision LGP-30 Electronic Computer



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ord of biological havoc in countries where such experiments have been tried.

In 1931 the Netherlands imported nine ermines and 102 other weasels to control rats and rabbits. The ermines survived and did a job on the rats, but in 20 years they had themselves become such a menace, preying on wild birds and poultry, that the Dutch Government had to put a bounty on them.

In 1872 Jamaica took in four male and five female mongooses to go after rats devouring the sugar cane. Ten years later the mongooses were estimated to be saving sugar planters 45,000 pounds a year. But then, having decimated the rat population, the mongooses turned to other small creatures, and they have now all but exterminated several species of mammals, birds and reptiles.

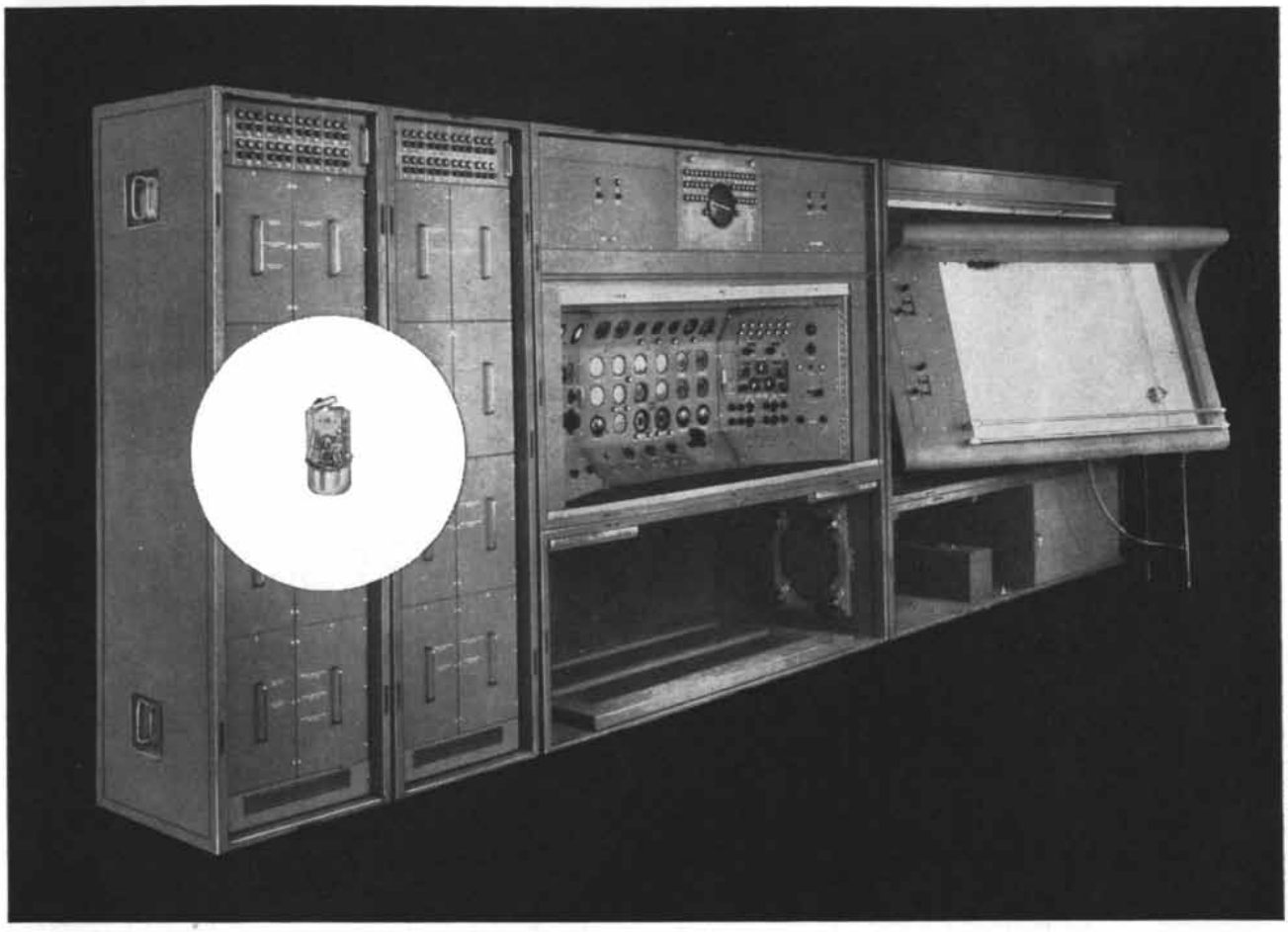
Early in the 1940s a local zoo on the Japanese island of Oshima put a few squirrels from Formosa on exhibition. Within a few years the squirrels had overrun the island and all but destroyed its major industry, camellia oil, by chasing the birds that distribute pollen among the camellia flowers.

About 50 years ago some deer were brought from Siberia to what is now Czechoslovakia. The Siberian males mated with the Czech species of deer, which is smaller, with the result that the females bore fetuses too large to deliver.

Perhaps the most disastrous import was the European rabbit introduced in Australia. In 1859 Thomas Austin, the culprit in this affair, brought in 24 rabbits in the interests of happy hunting. Six years later he counted more than 30,000 rabbits on his estate. The rabbit population grew to an estimated half billion, and the Australians have had to tamper with nature again by importing a virus to control the rabbits [see "The Rabbit Plague," by Frank Fenner; SCIENTIFIC AMERICAN, February, 1954]. The red fox, another import to Australia for hunters, is a menace to the beloved kangaroo, because it chases kangaroo mothers so that they drop the young from their pouch.

The naturalists sum up by pointing to a number of hazardous consequences that may befall heedless nations which allow such tinkering with nature: the foreign animals may kill or outstrip desirable native animals; they may grow out of control because there are no natural enemies in their new habitat; they may introduce new diseases.

In their report in *Zoologica*, a publication of the New York Zoological Society, the authors suggest that an international board of scientists be set up to control man's urge to transplant mammals.



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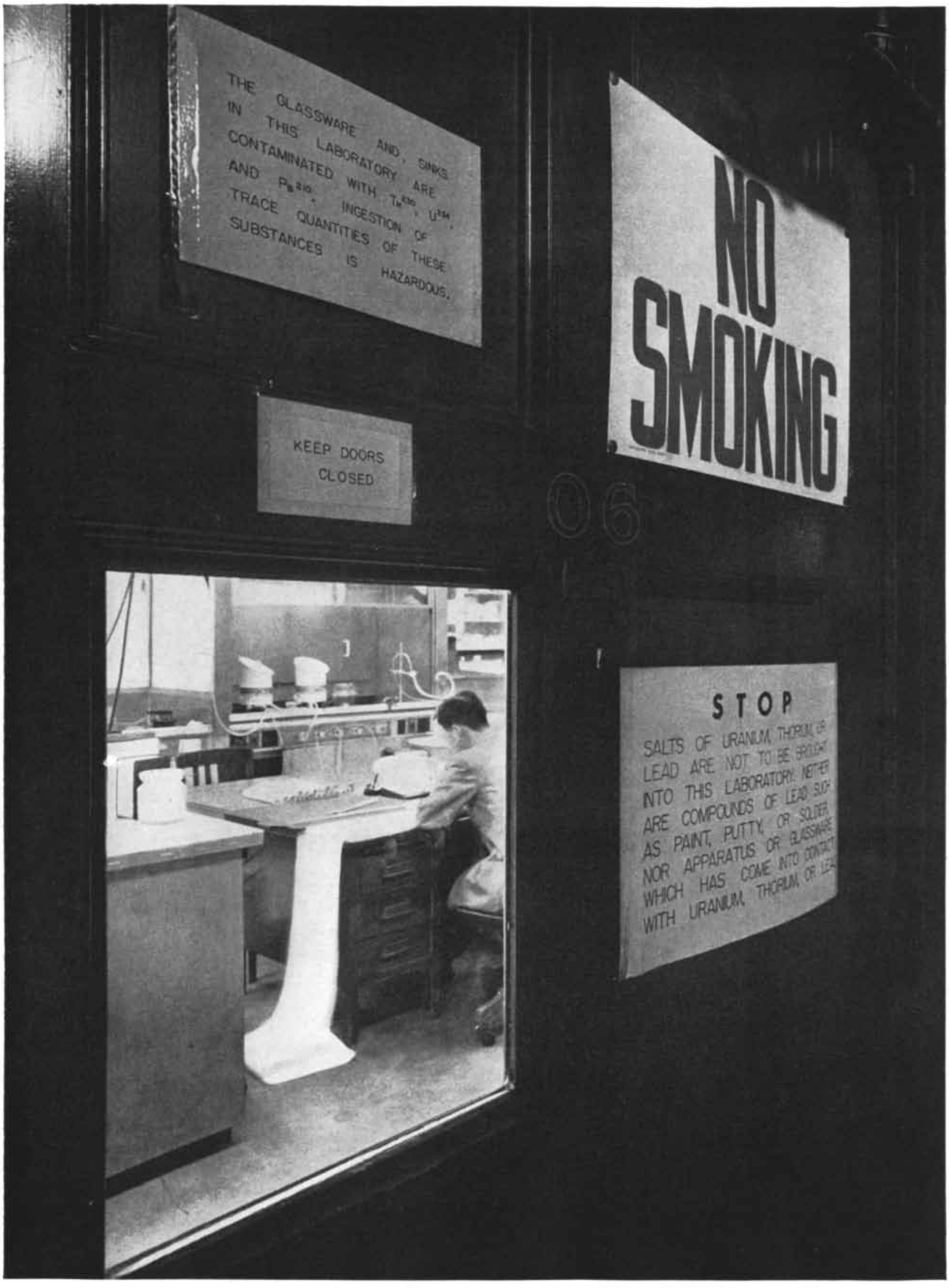


AIR-CONDITIONED LABORATORY at the California Institute of Technology is used for the chemical processes involved in establishing the age of minerals. Here the laboratory is seen through a door festooned with signs reflecting the delicate nature of its work.

THE AGE OF THE SOLAR SYSTEM

Rocks and meteorites contain radioactive elements and the products of their decay, the laborious analysis of which presently indicates that the earth and its neighbors were formed 4.5 billion years ago

by Harrison Brown

Before the discovery of radioactivity, estimates of the age of the earth and of the solar system were little better than guesses. The classic studies of the earth's rocks by James Hutton and by Sir Charles Lyell in the 18th and 19th centuries had freed geologists of the time-scale restrictions long imposed by theology, and they had begun to speak in terms of 10 million, 100 million and even a billion years. But they could only conjecture about the date of formation of our planet. In the year 1907 came the suggestion that its age might be measured by a clock ticking off the eons of time in the rocks.

Lord Rutherford's group in Cambridge had proved that the radioactive elements uranium and thorium decay ultimately into helium and lead. Bertram Boltwood, a U. S. radiochemist working with Rutherford, proposed that this phenomenon could be used to calculate the ages of minerals bearing uranium and thorium. Measurement of the amount of lead or of helium in such a mineral, together with the data on its remaining content of uranium and thorium and the known rates of decay of those elements, should make it possible to tell how long ago the mineral had been formed. By 1913 one ancient rock had been dated by the helium method to be at least 700 million years old and others tested by the lead method were estimated to be as old as 1.5 billion years.

It was recognized that these determinations were subject to certain possible errors. If helium had escaped from the rock, the estimate of its age would be too low. If the mineral contained "ordinary" lead—lead which was not a decay product but had been present from the beginning—the age estimate would be too high. But the lead technique was later made more accurate by precise measurement of the ratios of lead isotopes present, which allowed "ordinary" lead to be distinguished from radiogenic lead. This placed the dating of uranium minerals upon a truly firm foundation. The accurate new determinations confirmed that the geological time scale must be reckoned in billions of years.

The radioactive isotopes in nature fall into three main categories. Two of these consist of products which are continually being formed: (1) products of the breakdown of uranium and thorium (*e.g.*, radium), and (2) products of nuclear reactions in the earth's crust or the atmosphere (*e.g.*, carbon 14, formed by transmutation of nitrogen by cosmic rays). The other category, the most important from the point of view of dating, are the primary radioisotopes such as uranium 238, uranium 235, thorium 232, potassium 40 and rubidium 87. These isotopes were apparently made at the time the elements originated and are not

NATURALLY OCCURRING SPECIES	HALF-LIFE (MILLIONS OF YEARS)	DECAY PRODUCTS
URANIUM 238	4,510	LEAD 206, HELIUM
URANIUM 235	710	LEAD 207, HELIUM
THORIUM 232	13,900	LEAD 208, HELIUM
POTASSIUM 40	1,310	CALCIUM 40, ARGON 40
RUBIDIUM 87	50,000	STRONTIUM 87

SPECIES NOT OBSERVED IN NATURE	HALF-LIFE (MILLIONS OF YEARS)	DECAY PRODUCTS
URANIUM 236	24	THORIUM 232, HELIUM
IODINE 129	17	XENON 129
CESIUM 135	3	BARIUM 135
BERYLLIUM 10	2.7	BORON 10

RADIOACTIVE SPECIES OF THE ELEMENTS used to determine the age of minerals are listed in the table at the top. Radioactive species not found in nature, but which may be prepared in the laboratory, are listed at the bottom. The fact that these latter elements are not found in certain minerals is evidence that the minerals are at least a billion years old.

being formed to any significant extent on the earth today. All of them have very long half-lives: the shortest (for U-235) is 710 million years. Shorter-lived species (*e.g.*, uranium 236, with a half-life of 24 million years) have been made artificially in the laboratory, but these are not found in nature. Presumably they, too, were formed at the beginning and have long since disappeared because of their comparatively short lifetimes. For example, if uranium 236 was just as abundant as uranium 238 originally, within one billion years it would have declined to an undetectable amount. The fact that uranium 236 is not found in nature now has been taken as confirming evidence that the earth is at least a billion years old.

The laws of radioactive decay tell us that in a uranium mineral of a given age we should expect to find decay products in certain specific ratios to uranium itself. For example, in a mineral 500 million years old, for every 1,000 atoms of uranium 238 there should be 80 atoms of lead 206 (the end product of the decay of U-238), 4.5 atoms of lead 207 (the decay product of U-235) and 670 atoms of helium. This assumes that no "ordinary" lead was present when the mineral was formed and that no lead or helium has been added to or lost from the mineral during its 500-million-year lifetime. Now there are four different ways we can compute the age of the mineral; namely, from (1) the ratio of lead 206 to uranium 238, (2) the ratio of lead 207 to uranium 235, (3) the ratio of lead 206 to lead 207, and (4) the ratio of helium to uranium. Ideally all four of these ages should agree, and no age estimate can be considered trustworthy unless at least two independent methods (*i.e.*, two of the first three here) agree. But, unfortunately, complicating factors often produce discrepancies in evaluating a given sample. And helium does leak out of minerals, so that the helium age is generally lower than the others.

The method based on the ratio of lead 206 to lead 207 is the simplest and in many ways the most satisfactory, because it depends on only one analysis—measurement of the ratio of the two lead isotopes. The methods based on uranium-to-lead ratios are apt to be somewhat more uncertain because they involve three measurements—the chemical concentrations of uranium and lead and the ratios of two lead isotopes. It is important to remember that fundamentally the measurement of the ages of rocks depends only upon the *ratios* of elements and isotopes. Often the ratio can be determined without measuring the absolute amounts of the two substances in question.

The concentrations or quantities of material to be measured may be extremely small, and the measurements have to

AGE DETERMINATION METHOD	RATIO	AGE (MILLIONS OF YEARS)	ELEMENT	QUANTITY TODAY (ATOMS)	QUANTITY INITIALLY (ATOMS)
LEAD 206 : URANIUM 238	.08	500	URANIUM 238	1,000	1,080
LEAD 207 : URANIUM 235	.62		URANIUM 235	7.2	11.7
LEAD 206 : LEAD 207	17.8		LEAD 206	80	0
HELIUM : URANIUM	.67		LEAD 207	4.5	0
			HELIUM 4	670	0
LEAD 206 : URANIUM 238	.166	1,000	URANIUM 238	1,000	1,166
LEAD 207 : URANIUM 235	1.65		URANIUM 235	7.2	19.1
LEAD 206 : LEAD 207	14		LEAD 206	166	0
HELIUM : URANIUM	1.4		LEAD 207	11.9	0
			HELIUM 4	1,410	0
LEAD 206 : URANIUM 238	.36	2,000	URANIUM 238	1,000	1,360
LEAD 207 : URANIUM 235	6.07		URANIUM 235	7.2	50.9
LEAD 206 : LEAD 207	8.2		LEAD 206	360	0
HELIUM : URANIUM	3.2		LEAD 207	43.7	0
			HELIUM 4	3,190	0

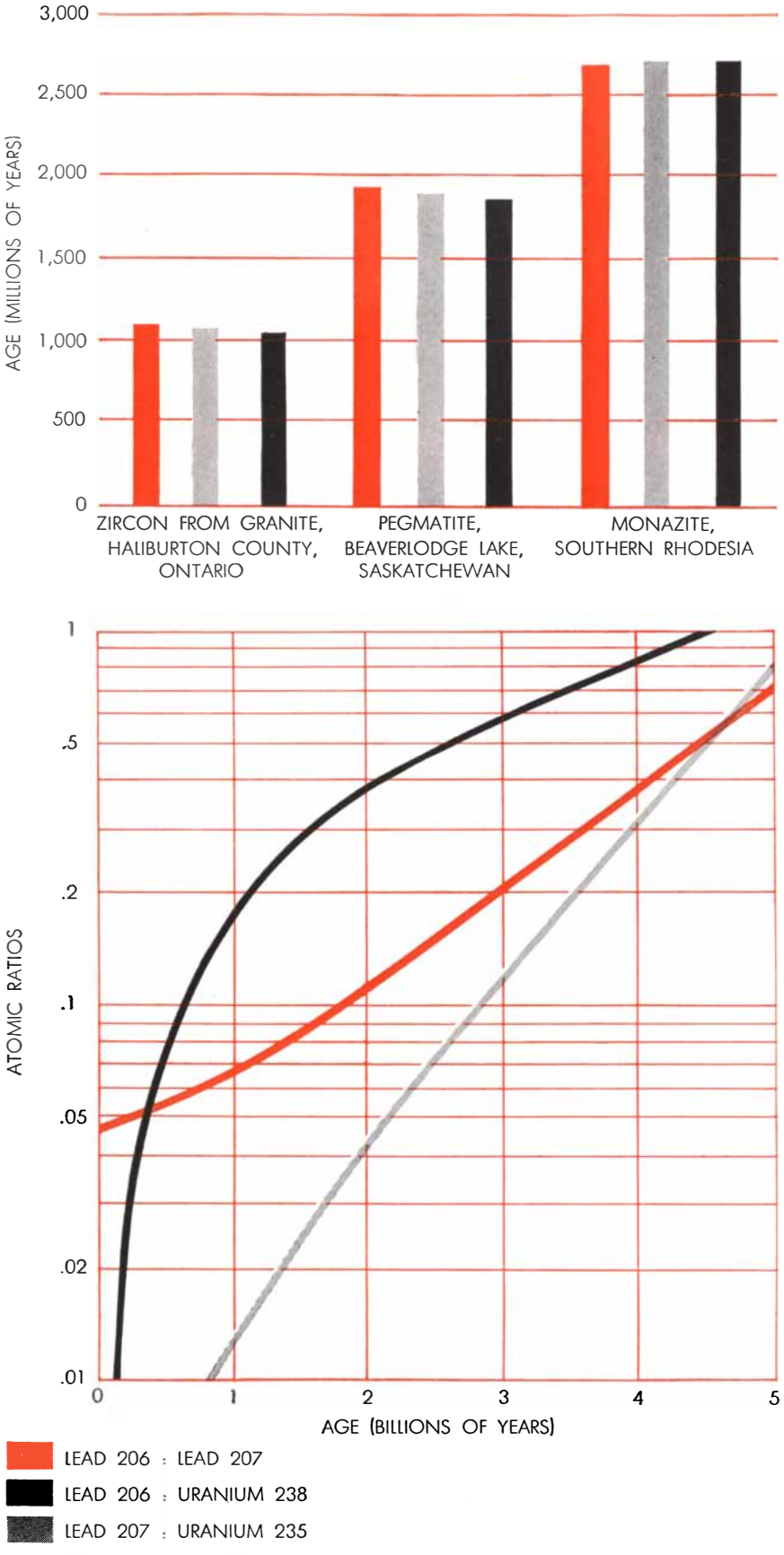
RATIOS OF SPECIES OF THE ELEMENTS are used to determine the age of minerals according to the decay of uranium. In a sample 500 million years old, for example, the four ratios at the upper left would obtain. For each 1,000 atoms of uranium 238 in the sample today, the sample would have originally contained 1,080 atoms of uranium 238 and 11.7 atoms of uranium 235. The number of atoms in the sample today would add up to the same number, with the exception of helium atoms. Because helium atoms, or alpha particles, are emitted in the decay of uranium 238, uranium 235 and various daughter species, the helium atoms may be regarded as "new."

be made with high accuracy. The measurement of a minute sample of lead may be thrown awry by contamination with "ordinary" lead from the reagents or even from the air (particularly in cities, where the air contains lead from gasoline). Measurement techniques have been greatly refined, however, by an extensive program of cooperative research by scientists at several institutions. It is now possible to determine the ages of some samples containing less than one part per million of uranium. Isotope ratios can be measured in samples of lead weighing as little as one millionth of one gram. In our special laboratories at the California Institute of Technology, by improvements in chemical techniques, Claire C. Patterson has succeeded in isolating lead from a meteorite which contains only one part per three million. Common rocks such as granites, where the lead content averages only between one and 10 parts per million, can be dated successfully.

Unfortunately most minerals in nature possess some "ordinary" lead, and the proportions of the lead isotopes vary widely in various samples. This makes correction for the primeval lead difficult and in many cases impossible. We can, however, use lead 204 as an index. This isotope (the least abundant form of lead found) is nonradiogenic, so its presence in a sample is a clear indication of the presence of primeval lead. The concentration of radiogenic lead in a sample is now conventionally expressed in terms of the ratios of the other isotopes to lead 204: the higher this ratio, the more radiogenic is the sample. Thus we have a scale for measuring the radiogenic "purity" of samples. Most of the precise age determinations have been made on rocks whose lead content is almost purely radiogenic. But there are certain cases in which accurate corrections can be made for nonradiogenic lead, because the lead and the uranium were sharply separated from each other when the rock originally crystallized. This is the case in some granites; it is actually possible to determine what proportions of the various isotopes of lead were present when the granite was formed.

Ancient Rocks

The data on three purely radiogenic rocks whose ages have been measured particularly precisely are presented in accompanying charts [*shown at right*]. The oldest, a monazite from Southern Rhodesia, is calculated to be about 2.7 billion years old. It gives us a rather



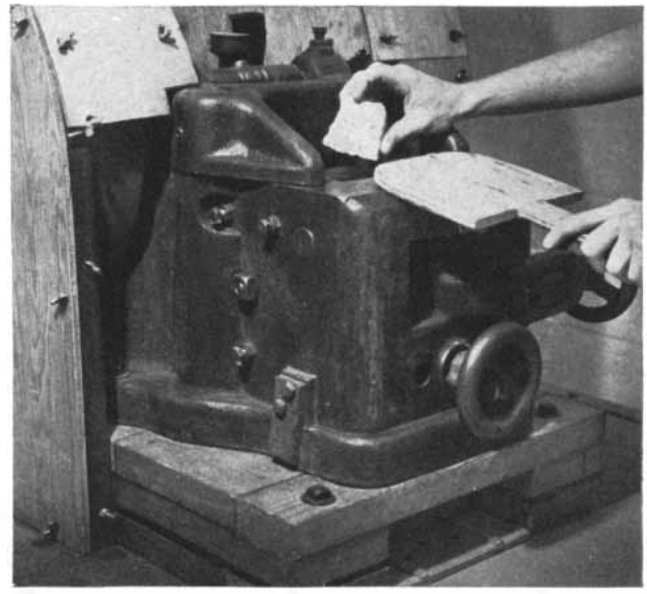
RATIOS OF LEAD SPECIES to uranium and to each other in three mineral samples yielded the ages indicated in the chart at the top of the page. The change in the ratios over a period of five billion years is given in the chart at the bottom. The key applies to both charts.

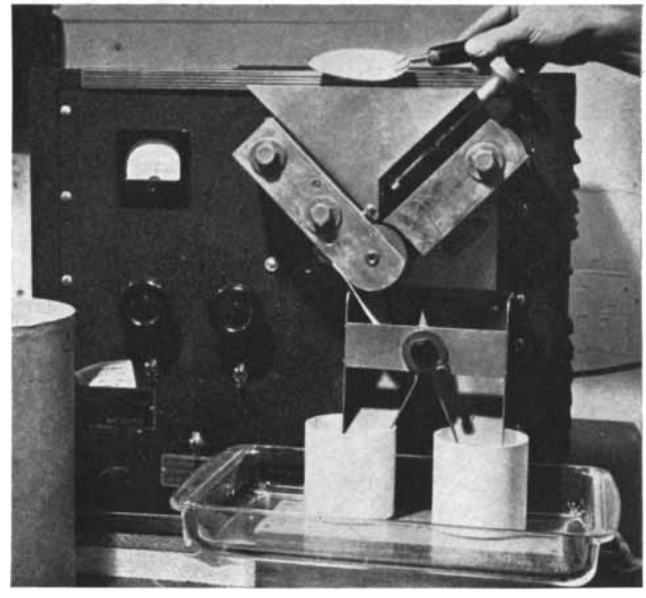
clear-cut figure for the minimum age of the earth.

We get similar figures when we date rocks on the basis of the decay of radioactive potassium to argon. These determinations are more open to question, because the values of the decay constants are still uncertain and argon, like helium, can escape from rocks. But it is encouraging to find that this method also indicates some South African rocks to be at least 2.7 billion and possibly 3.2 billion years old. Dating of rocks by the method based on decay of rubidium to strontium likewise yields estimates consistent with these results.

Can we find some indication of an outside limit for the age of the earth? Let us examine lead deposits found in various parts of the world. Generally speaking the oldest deposits have the smallest proportion of radiogenic lead, presumably because the decay of uranium and thorium has steadily been adding radiogenic lead to the earth's supply, so that a higher proportion of such lead is incorporated in the more recent deposits. In other words, there has apparently been a progressive evolution of the isotopic composition of lead in the earth. It has been acquiring a higher ratio of radiogenic lead (*e.g.*, lead 206) with respect to the primeval isotope lead 204. The variations in ratios are illustrated in the accompanying table listing a number of lead specimens from various places [*see page 92*]. The ratio of 206 to 204 averages about 18 to 1, but it ranges up to higher than 90 to 1, in rocks with a rather high concentration of uranium.

The lowest ratio that has been found on the earth so far is 12.65 to 1. This sample of lead came from an ancient deposit in the Rosetta Mine in South Africa. We can estimate (on the basis of the ratios of lead 206 to lead 207) how long it must have taken for this ancient composition of lead to have evolved to that of



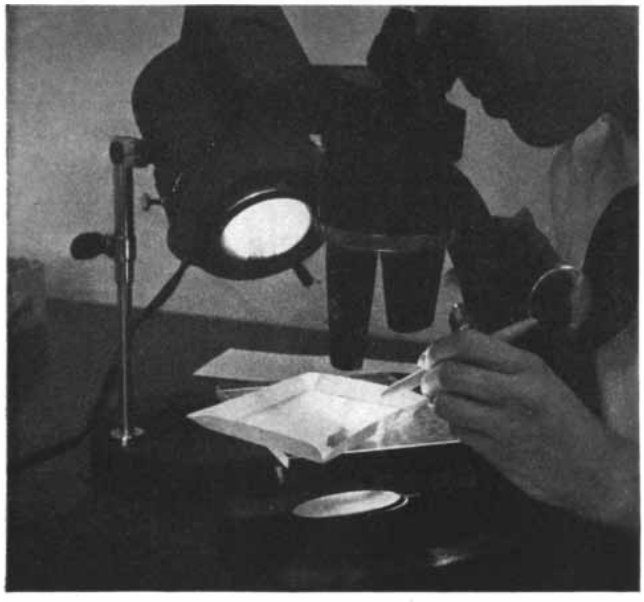


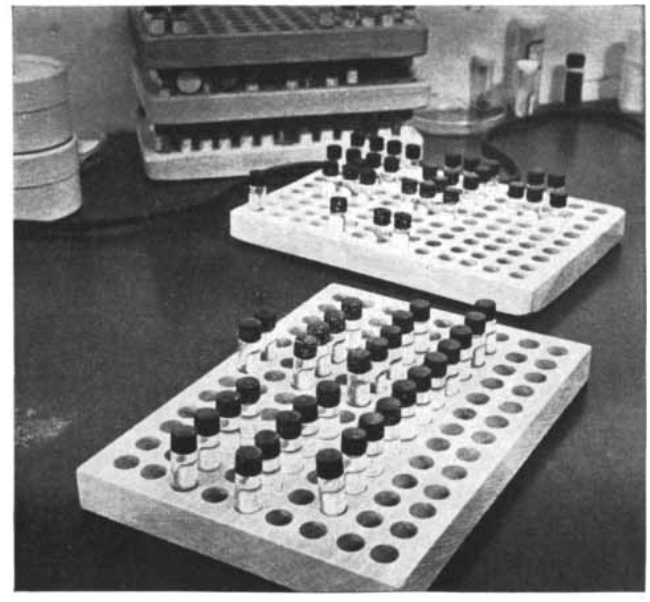
PREPARATION OF A SAMPLE for the determination of its age is depicted in the photographs on this and the next six pages. The photograph at upper left shows samples stored in barrels at the California Institute of Technology. The open barrel contains diabase rocks from the region of Great Bear Lake in northwestern Canada. In the photograph at upper right a rock is crushed. After the rock is ground to sand, the sand is sorted by a sieve (*lower left*). The sand is further sorted magnetically (*lower right*).

modern lead, such as is found in the red clay at the bottom of the Pacific Ocean. The calculation puts the figure at about 3.1 billion years. Now suppose that the heavy isotopes of lead are entirely radiogenic—for example, that all the lead 207 has come from the decay of uranium 235. (Actually some lead 207 probably was formed when the element came into being, but for the purpose of finding an upper time limit let us assume it is all radiogenic.) How much time would have been required to produce the present concentration of lead 207 entirely by uranium decay? It turns out to be about 5.6 billion years. Thus solely on the basis of the isotopic compositions of common leads we can say that the age of the earth probably lies somewhere between 3.1 and 5.6 billion years.

Meteorites

We could be a good deal more definite about the date if we but knew what the actual isotopic composition of lead was when the earth was formed. Comparing that with the present average isotopic composition of lead, we could readily calculate the time required for the original lead to have been suitably modified. Unfortunately we have no lead samples from that early time. The Rosetta Mine lead is the oldest specimen thus far uncovered in the earth. But about 10 years ago the author proposed that we might find samples of the original lead of the solar system in meteorites. The theory is that meteorites may contain some lead which has been segregated from uranium and thorium ever since the formation of the planets. In meteorites the elements are found in certain associations, called phases, depending on their chemical properties. Uranium and thorium, because they are easily oxidized, are concentrated almost exclusively in the silicate phase; *i.e.*, in association with





SEPARATION IS CONTINUED by flotation (*upper left*). In this process the sand is mixed with a very heavy brominated hydrocarbon liquid; the lighter sand particles float and the heavier particles sink. The particles are then further sorted by a device which distinguishes between their characteristic magnetic properties and weight (*upper right*). The particles are finally sorted visually under low-power microscope (*lower left*). The sorted samples are then stored in labeled bottles (*lower right*).

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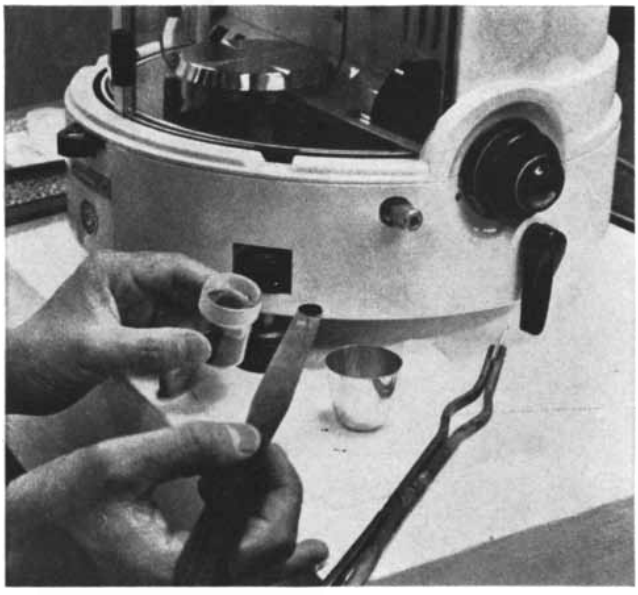
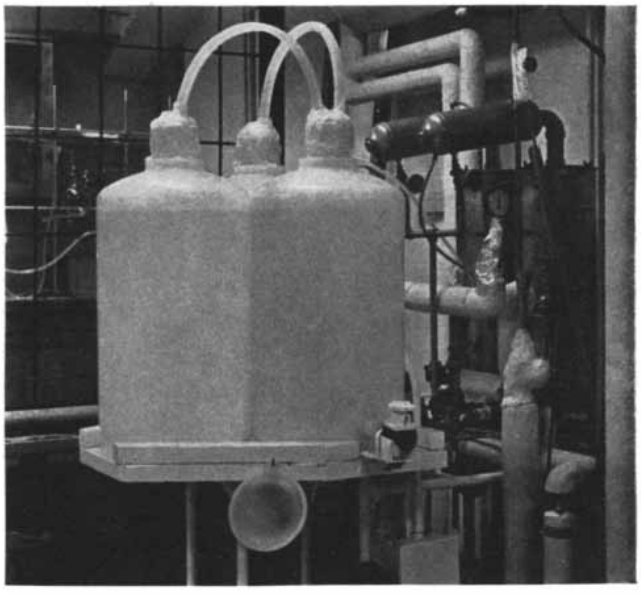
silica. Lead, on the other hand, is found not only in this phase but also in the metallic phase (in association with iron and nickel) and in the sulfide phase (in association with sulfur). Thus some lead is isolated from contact with uranium or thorium. If this lead has been so segregated since the time of the formation of the solar system—an assumption which appears reasonable from several points of view—then its isotopic composition should represent that of the original lead.

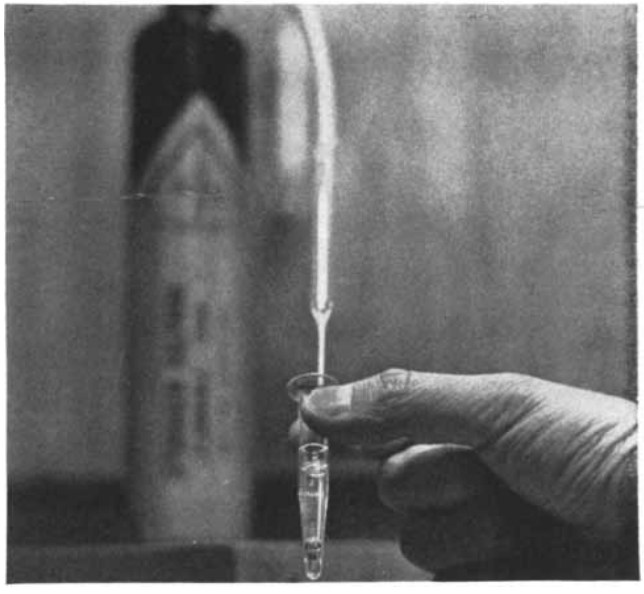
The author, and independently the chemist Hans E. Suess of Germany (who is now at the Scripps Institution of Oceanography), attempted to isolate lead from the metallic phase of a meteorite. Unfortunately the amount of lead in the material turned out to be so small that the only lead actually detected was that which was present in the chemical reagents used! Finally, six years later, after our lead-free laboratory was constructed at the California Institute of Technology, Patterson succeeded in isolating lead from the Canyon Diablo meteorite, which blasted the famous Meteor Crater in Arizona. This was a masterful chemical achievement on Patterson's part, for the lead in the metallic phase of that meteorite amounted to only one part in three million. Later he isolated lead from the sulfide phase of the same meteorite and of one found in Henbury, Australia.

All three of these lead samples had about the same isotopic composition. It was evident that this lead was far less radiogenic—and therefore probably much older—than any previously found on the earth. The ratio of lead 206 to lead 204 in one sample was only 9.41 to 1. Assuming that the samples really represent original lead, we calculate the age of the earth to be 4.5 billion years.

More than a decade ago F. A. Paneth and his group at the University of Durham attempted to estimate the ages of





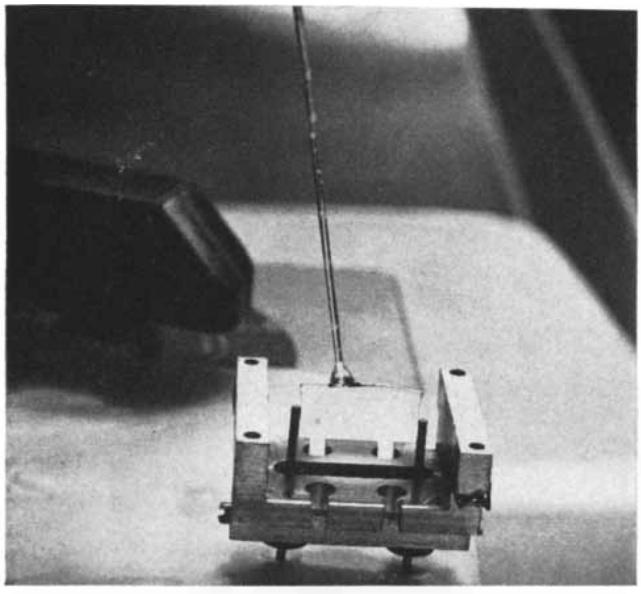


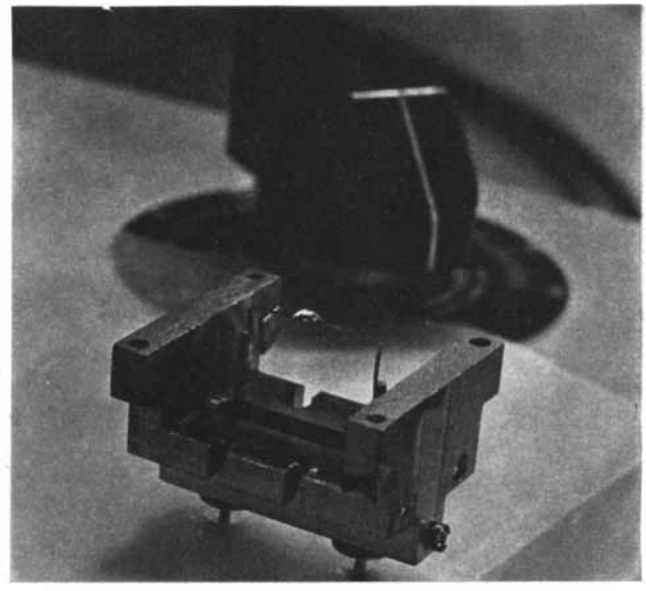
SAMPLE IS WEIGHED (*upper left*) **before it is chemically broken down into its constituent elements. Pure water for the chemical manipulations is made by quadruple distillation** (*upper right*). **The sample is then heated and dissolved in water** (*lower left*). **Hydrogen sulfide is then bubbled through it to precipitate uranium** (*lower right*). **The sample is now ready for the final separation.**

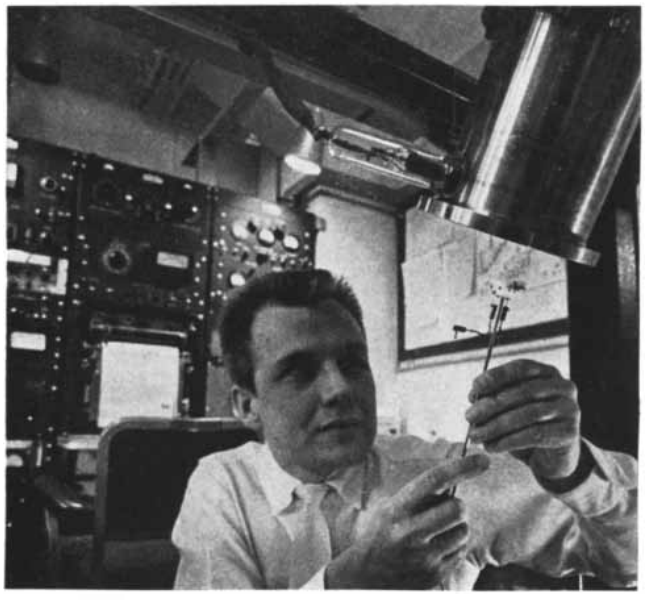
a number of iron meteorites by the uranium-thorium-helium method. Using ingenious devices for measurement of the tiny amounts of these elements, they arrived at ages ranging from a few million to several billion years [see "The Origin of Meteorites," by S. Fred Singer; SCIENTIFIC AMERICAN, November, 1954]. They realized that the escape of helium might account in part for this great variation in the results, and two other misleading factors have been discovered: a substantial fraction of the helium in meteorites has been produced by cosmic rays rather than by uranium decay, and iron meteorites probably start with considerably less uranium than had been supposed. Attempts have been made to calculate corrections for these factors, but there is a considerable margin of possible error. Thus estimates of the ages of iron meteorites, on the basis of the uranium-thorium-helium method, cannot be trusted at the present time.

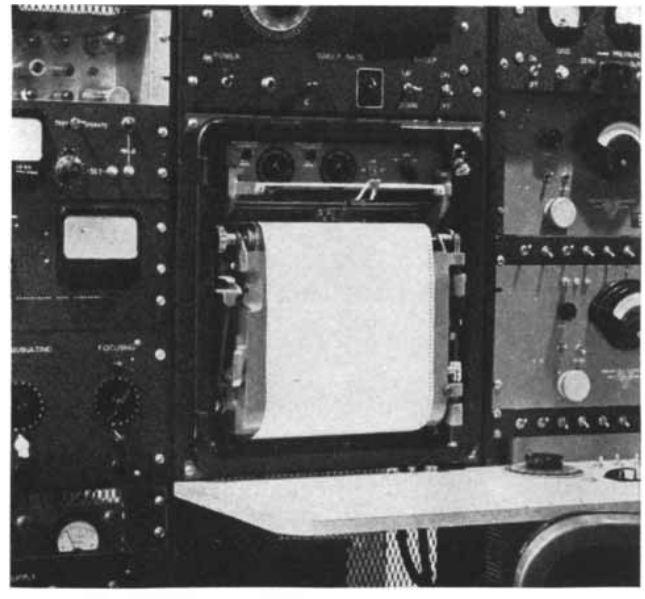
Patterson undertook to apply the lead method to date stony meteorites, which contain substantial amounts of uranium in the silicate phase. These meteorites should possess a high proportion of radiogenic lead. Patterson isolated the lead from three stony meteorites and found that it was indeed highly radiogenic. Comparing the isotopic composition of these leads with that of "original" lead, we find that the ages of the meteorites are of the order of 4.5 billion years.

The time scale also seems to be confirmed by estimates of the ages of meteorites on the basis of the decay of potassium to argon. These estimates, made by investigators in the U. S. and in the U.S.S.R., range from 600 million to 4.8 billion years. Considering that the decay constants of potassium are somewhat uncertain and that argon, like helium, can escape from rocks, the argon results appear to be compatible with the lead results. An estimate of the age of a stony









DROP OF SOLUTION containing the uranium precipitate is placed on the filament of a mass spectrometer (*upper left*), which electromagnetically separates species of the elements according to their mass. The filament assembly is gently heated to dry the precipitate (*upper right*). The filament bearing the sample is placed in the spectrometer (*lower left*). Finally the species of elements present in the sample, and their proportion to one another, are recorded on a tape at the control panel of the spectrometer (*lower right*).

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SPECIES OF LEAD found in rocks (*top*) and in meteorites (*bottom*) are listed. On the basis of these ratios it can be shown that the earth is between 3.1 and 5.6 billion years old.

meteorite based on the decay of rubidium to strontium also is consistent with an age of 4.5 billion years for the earth.

The problem of the age of meteorites would appear to be solved with a fair degree of certainty were it not for one unfortunate difficulty. If our assumptions are correct, the silicate phase of meteorites should contain uranium in certain calculable proportions, but, in the meteorites analyzed so far, uranium seems to be present in only from one sixth to one half of the required concentration. It is too early to say whether the discrepancy is real or the result of a combination of analytical and sampling errors. If the discrepancy is real, we shall have to conclude that either there is something seriously wrong with the lead data or that we are dealing with a situation which is far more complicated than we have suspected.

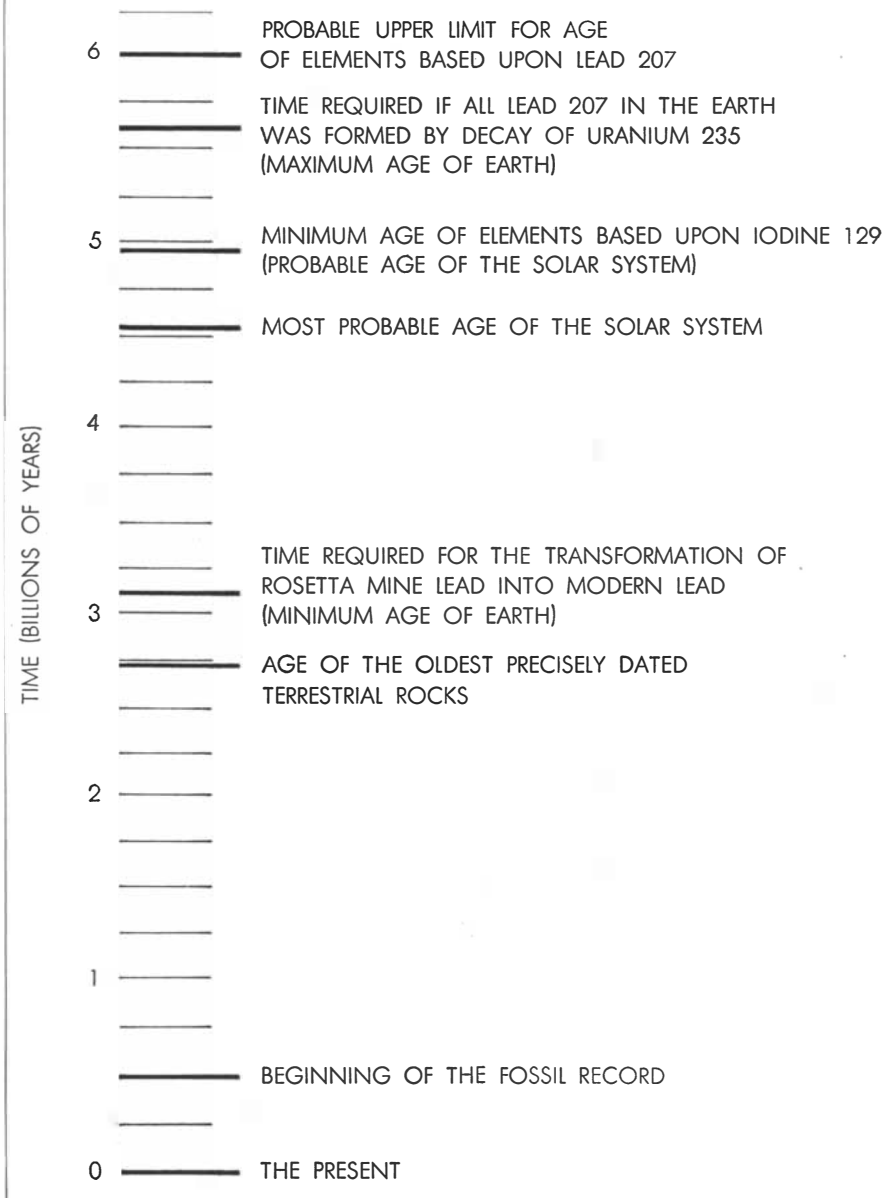
Age of the Elements

Practically all of the evidence now available points to an age for the solar system of about 4.5 billion years. How much older is the matter that formed the solar system—that is, the chemical elements? We know that the elements must have a finite age which is not too much longer than the half-lives of the radioactive species, else they would have

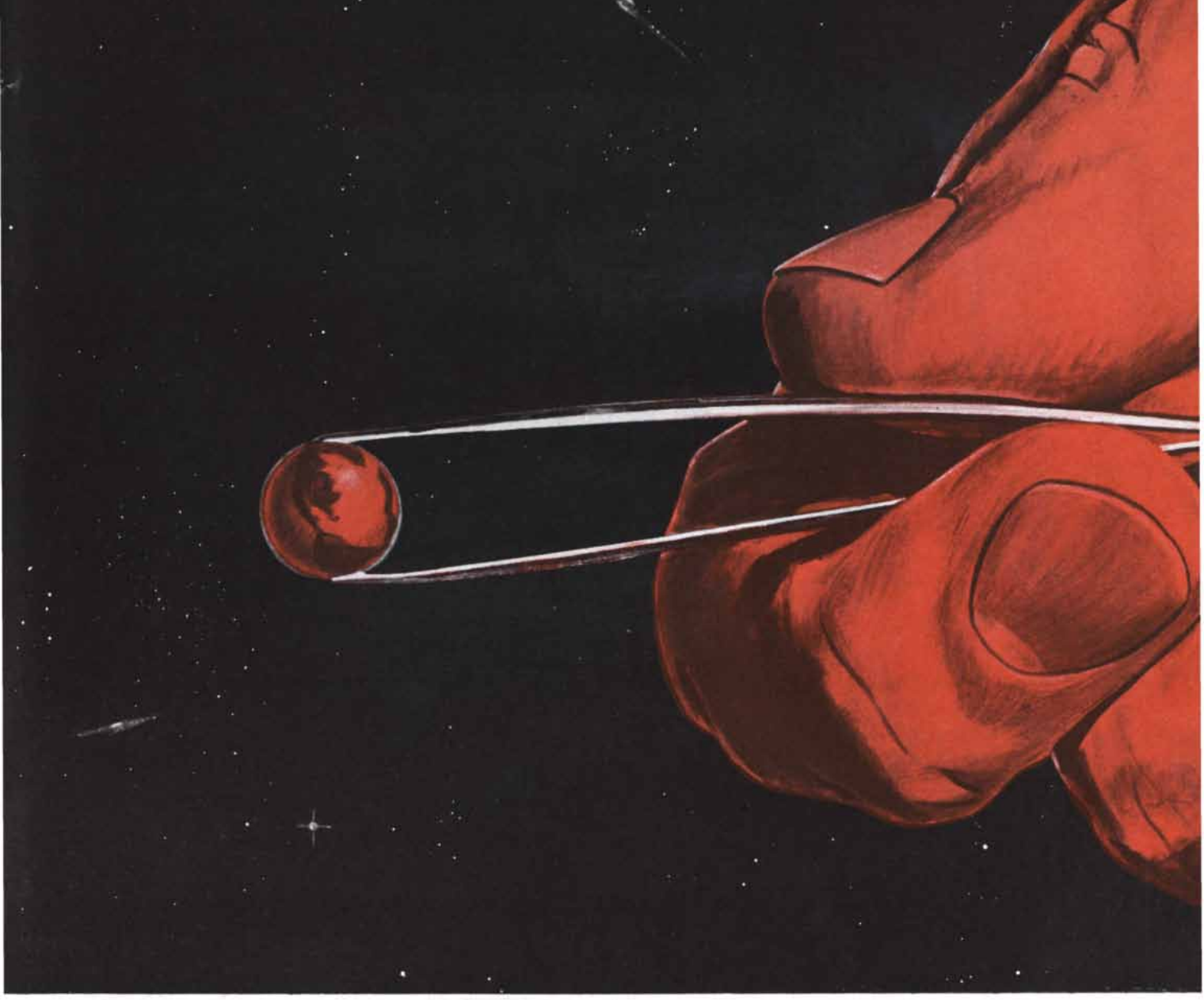
disappeared by now. On the basis of the present relative abundances of uranium and lead, we can estimate that the elements cannot be much older than six billion years. This would make them at most about 1.5 billion years older than the solar system.

We can also fix a minimum limit for their age. The element iodine, for example, provides a clue. There are reasons to believe that when the elements were formed, there were about equal amounts of nonradioactive iodine 127 and the radioactive isotope iodine 129 (half-life 17 million years). Iodine 129 is no longer found in the earth. Was any still in existence when the meteorites were formed? If so, the meteorites should now contain detectable amounts of xenon 129, the product of the decay of iodine 129. But a meteorite was analyzed and no xenon 129 was found. In view of this, and if our assumptions concerning the original abundance of iodine 129 are correct, we must conclude that the iodine 129 had virtually disappeared by the time the meteorites came into existence. This means that at least 400 million years elapsed between the formation of the elements and the onset of the phase segregations which led to the formation of the earth and the other planets of the solar system.

Assuming that the earth is about 4.5 billion years old, we can say that in our region of the universe the elements probably came into being some time between 4.9 and 6 billion years ago.



SUMMARY OF KNOWLEDGE of the age of the solar system and the elements, based on the study of the ratios of elements in rocks and meteorites, is presented in this chart.



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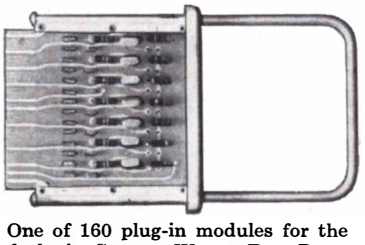

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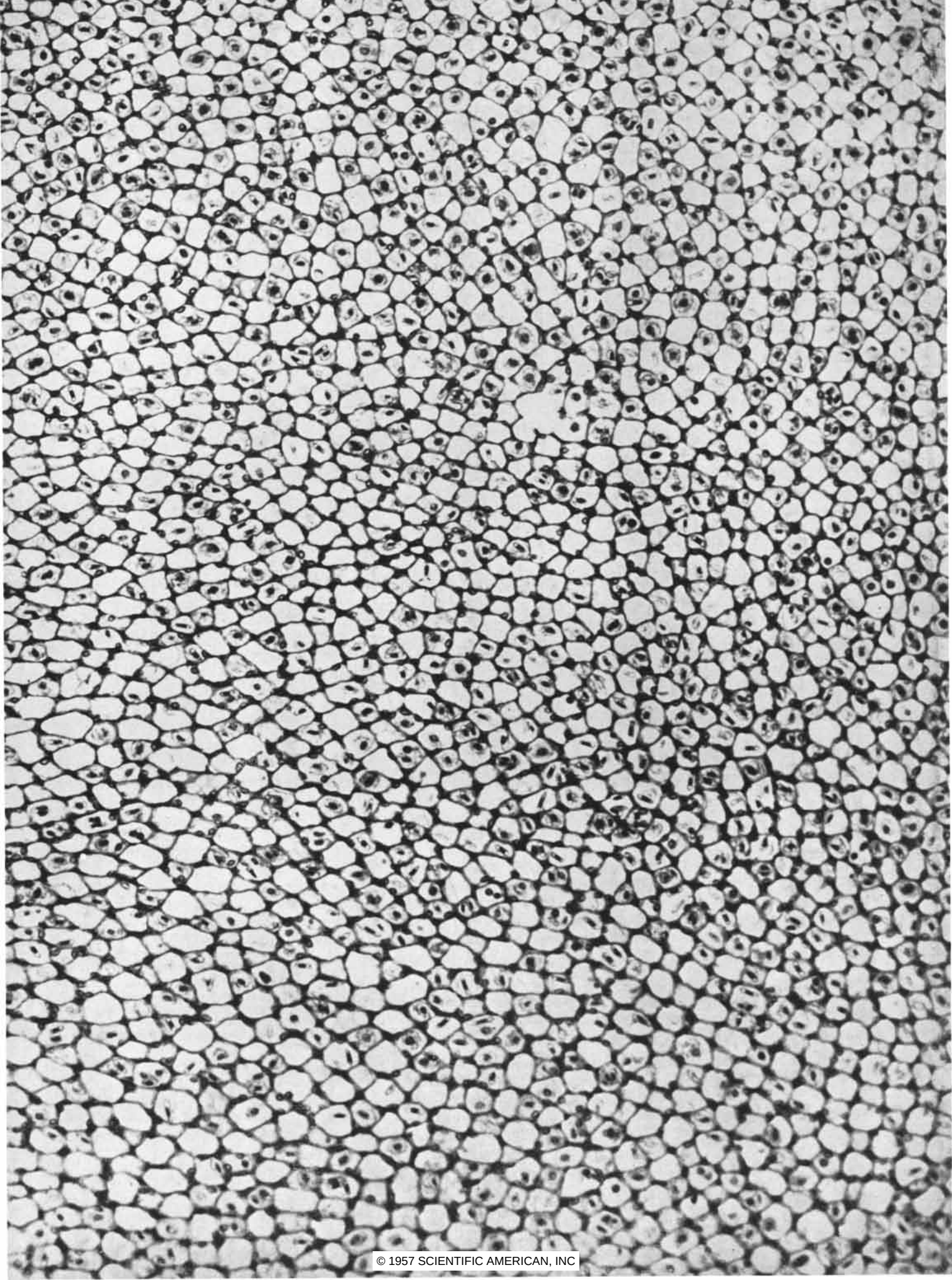


"The Wonderful Net"

These words are a translation of rete mirabile, an arrangement of blood vessels in which animals can conserve heat and oxygen pressure by applying the principle of counter-current exchange

by P. F. Scholander

A man standing barefoot in a tub of ice water would not survive very long. But a wading bird may stand about in cold water all day, and the whale and the seal swim in the arctic with naked fins and flippers continually bathed in freezing water. These are warm-blooded animals, like man, and have to maintain a steady body temperature. How do they avoid losing their body heat through their thinly insulated extremities? The question brings to light a truly remarkable piece of biological engineering. It seems that such animals block the loss of heat by means of an elementary physical mechanism, familiar enough to engineers, which nature puts to use in a most effective way. In fact, the same principle is employed for several very different purposes by many members of the animal kingdom from fishes to man.

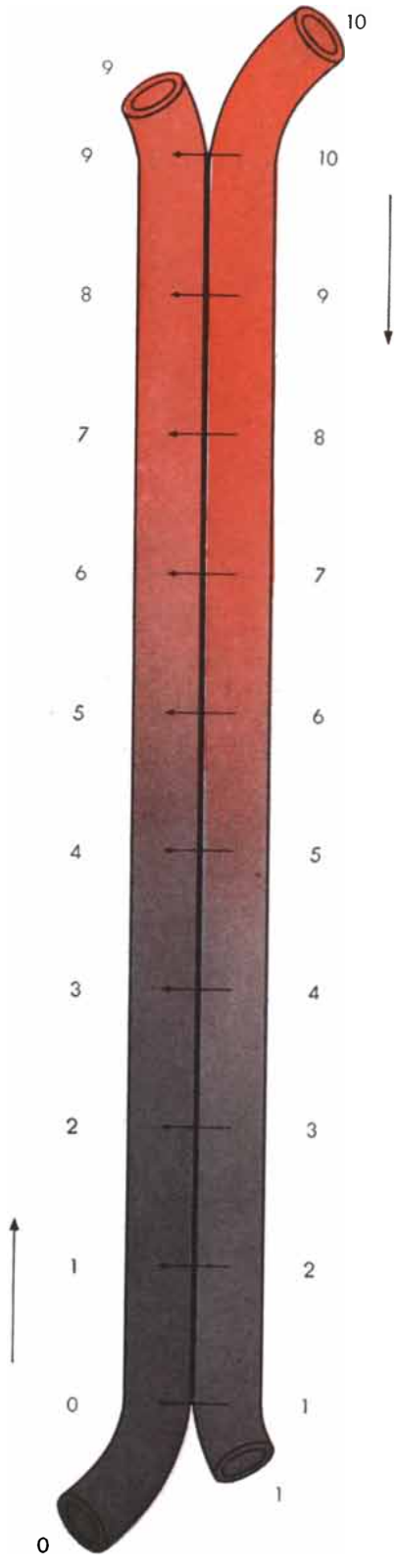
The principle is known as counter-current exchange. Consider two pipes lying side by side so that heat is easily transmitted from one to the other. Suppose that fluids at different temperatures start flowing in opposite directions in the two pipes: that is, a cold stream flowing counter to a warm [*see diagram on next page*]. The warmer stream will lose heat to the colder one, and if the transfer is efficient and the pipes long enough, the warm stream will have passed most of its heat to the counter current by the time it leaves the system. In other words, the counter current acts as a barrier to escape of heat in the direction of the warm current's flow. This method of heat exchange is, of course, a common practice in industry: the counter-flow system is used, for example, to tap the heat of exhaust gases from a furnace for preheating the air flowing into the furnace. And the same method apparently serves to conserve body heat for whales, seals, cranes, herons and other animals with chilly extremities.

RETE MIRABILE in the wall of the swim bladder of the deep-sea eel is enlarged 100 times in this photomicrograph. The rete is a bundle of small blood vessels; each of the small light areas in the photomicrograph is a blood vessel seen in cross section. The veins and arteries in the bundle are arranged in such a way that the blood in one vessel flows in a direction opposite that of the blood in an adjacent vessel.

Claude Bernard, the great 19th-century physiologist, suggested many years ago that veins lying next to arteries in the limbs must take up heat from the arteries, thus intercepting some of the body heat before it reaches the extremities. Recent measurements have proved that there is in fact some artery-to-vein transfer of heat in the human body. But this heat exchange in man is minor compared to that in animals adapted to severe exposure of the extremities. In those animals we find special networks of blood vessels which act as heat traps. This type of network, called *rete mirabile* (wonderful net), is a bundle of small arteries and veins, all mixed together, with the counter-flowing arteries and veins lying next to each other. The retes are generally situated at the places where the trunk of the animal deploys into extremities—limbs, fins, tail and so on. There the retes trap most of the blood heat and return it to the trunk. The blood circulating through the extremities is therefore considerably cooler than in the trunk, but the limbs can function perfectly well at the lower temperature. It has been found that many arctic animals have a leg temperature as low as 50 degrees Fahrenheit or even less.

Anatomists have confirmed that the whale, the seal and the long-legged wading birds possess such retes. However, these networks have also been discovered in the extremities of many tropical animals. It is not surprising to find heat-trapping retes in a water-dwelling animal such as the Florida manatee, for even tropical waters are chilling to a constantly immersed body, but why should the retes appear in tropical land animals like the sloth, the anteater and the armadillo? The answer may be that these animals are hypersensitive to cool air. The sloth, for instance, begins to shiver when the air temperature drops below 80 degrees F. It has to adjust to this situation almost every night, and the retes may well be the means by which it makes the adjustment: that is, the sloth may let its long arms and legs cool to the temperature of the night air, as a reptile does, to preserve its body heat. Recent measurements have shown that it takes a sloth two hours to rewarm a chilled arm from 59 to 77 degrees, whereas an animal without retes, such as a monkey, accomplishes this in 10 minutes.

There is another finding, however, which at first sight is more puzzling. Many animals that spend a great deal of time in cold water or live in the arctic snow seem to lack retes to sidetrack body heat from their poorly insulated legs or feet. Among them are ducks, geese, sea gulls, the fox and the husky (the Eskimo dog). The absence of retes in these animals is not difficult to explain, however, when we consider that all of them are heavily insulated over most of their bodies. Their principal problem lies in getting rid of body heat rather than in conserving it. Consider, for instance, the situation of a husky. It is so well insulated that it can sleep on the snow at 40



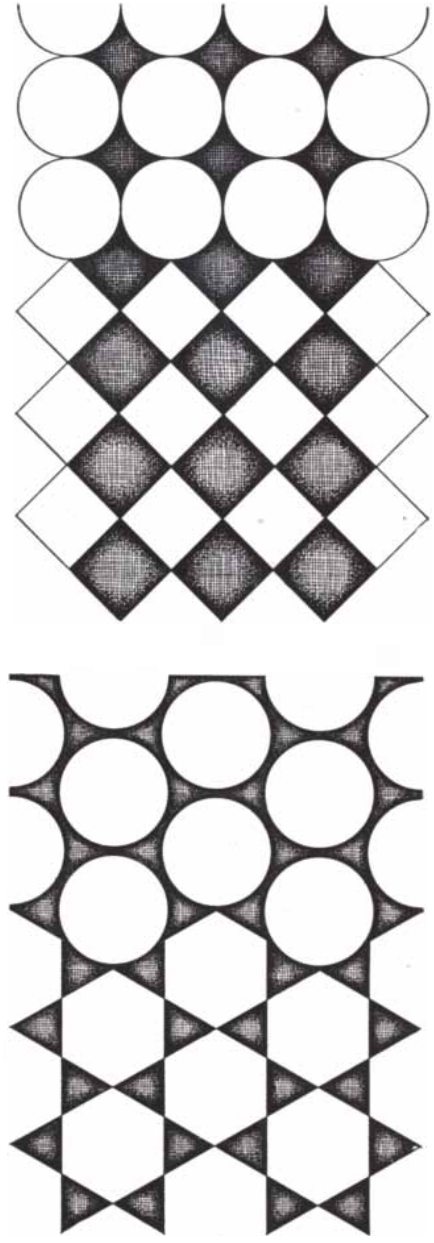
THE PRINCIPLE of counter-current exchange is demonstrated in two pipes lying side by side. Hot water enters one pipe (*top right*); cold water enters the other (*bottom left*). The fluids flow in opposite directions. Under ideal conditions heat will diffuse almost completely from one to the other.

degrees below zero without raising its normal rate of metabolism at rest. When this animal gets up after a cold night and begins to run in the warm sun, increasing its metabolic rate 10- or 20-fold because of the exercise, it is immediately faced with the problem of dissipating a good deal of excess heat. Because of its thick fur covering, it can lose heat only through exposed surfaces such as its tongue, face and legs. An arteriovenous network impeding the transport of heat to its legs would be a severe handicap. The same is true of the duck and other extremely well-insulated birds, which probably depend upon their webbed feet for heat dissipation.

As I mentioned at the beginning, heat conservation is only one of the functions performed by counter-current networks such as I have described. Indeed, there are more dramatic manifestations of this sort of system in the animal world. Nowhere in nature is counter-current exchange more strikingly developed nor more clearly illustrated than in the swim-bladder wall of deep-sea fishes. Here the function of the "wonderful network" is to prevent the loss of oxygen from the fish's air bladder.

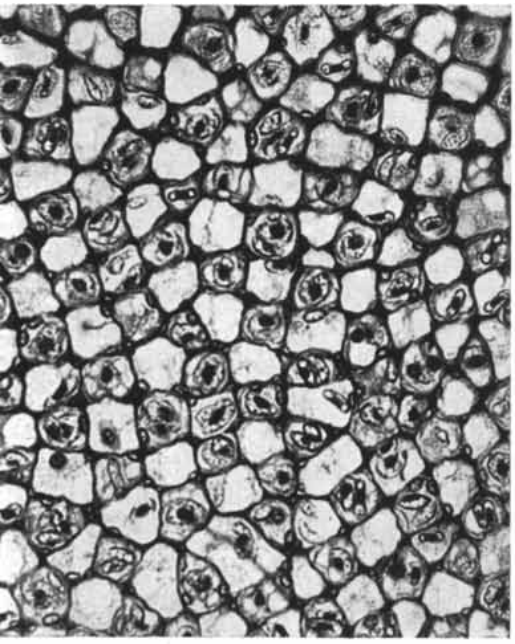
A deep-sea fish keeps its swim bladder filled with gas which is more than 90 per cent oxygen. At depths of 9,000 feet or so it must maintain an oxygen pressure amounting to 200 to 300 atmospheres—nearly double the pressure in a fully charged steel oxygen cylinder. On the other hand, the oxygen pressure in the bladder's surroundings—in the fish's bloodstream and in the sea water outside—is no more than a fifth of an atmosphere. So the oxygen pressure difference across the thin swim-bladder wall is some 200 atmospheres. What is more, blood is constantly streaming along this wall through myriads of blood vessels embedded in it. Oxygen from the bladder, under the enormous pressure of 200 atmospheres, must diffuse into these blood vessels. How is it, then, that the streaming blood does not quickly drain the oxygen from the bladder? The answer, of course, is a counter-current exchange system. Very little oxygen escapes from the swim-bladder wall to the rest of the fish's body, because the outgoing veins, highly charged with oxygen, give it up to adjacent incoming arteries. There is a network of thousands of looping capillaries, so closely intermingled that diffusion of oxygen from veins to arteries goes on at a high rate.

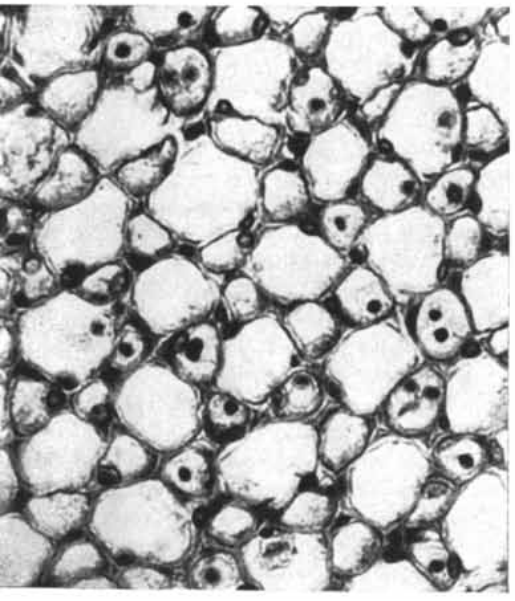
What would be the most efficient arrangement of veins and arteries to give the maximum surface for transfer from



THE APPLICATION of counter-current exchange reaches the ultimate in the swim-bladder retes of deep-sea fishes. Drawings at left show two ways in which veins (*white*) and arteries (*black*) might be arranged to gain the greatest possible area of exchange.

one type of vessel to the other? We can treat this as a problem in topology and ask: How can we arrange black and white polygons (representing the cross sections of the blood vessels) so that black always borders white? If we allow only four polygons to meet at each corner, there are two different possible solutions: a checkerboard of squares or a pattern of hexagons with triangles filling the open corners [*see diagrams above*]. Under the microscope we observe that evolution has produced precisely these

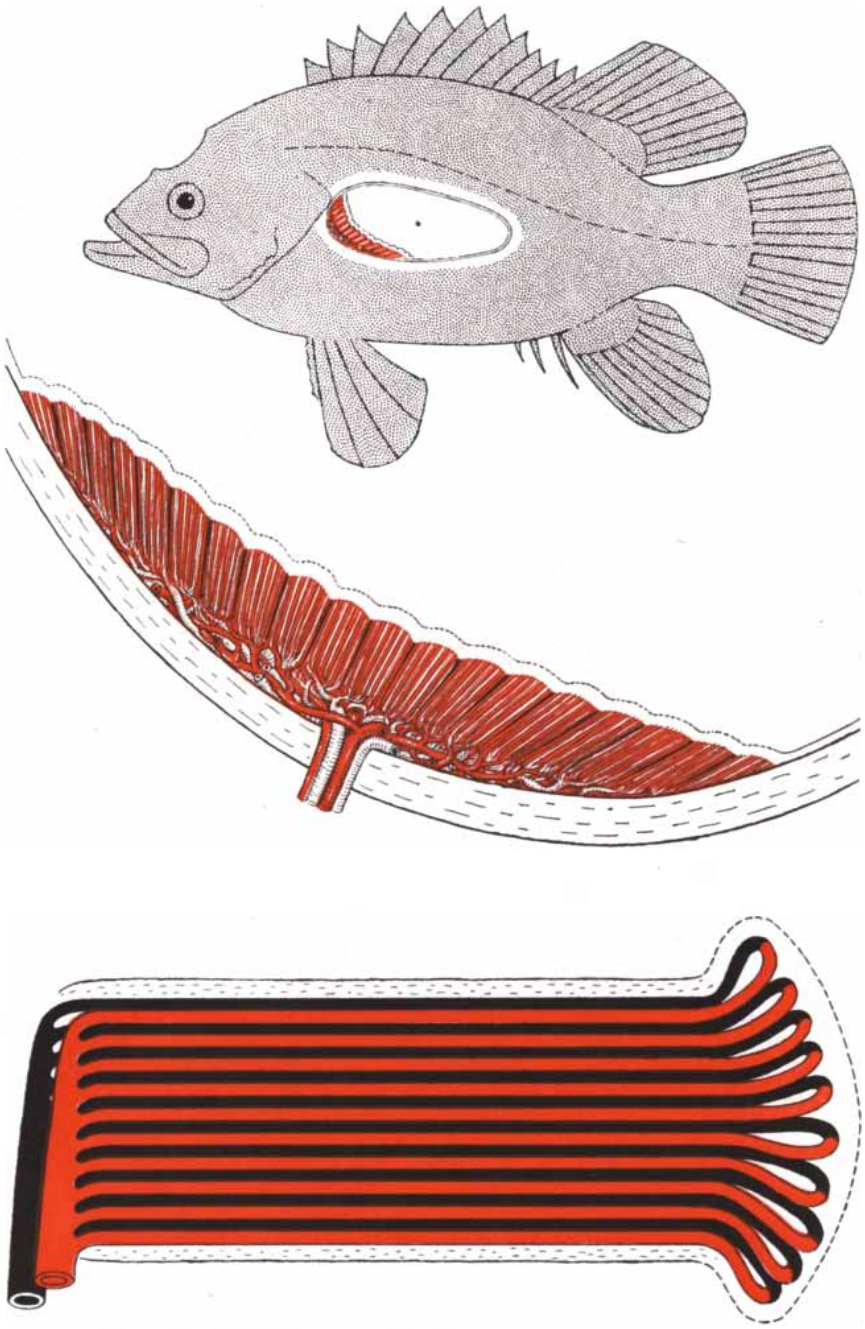


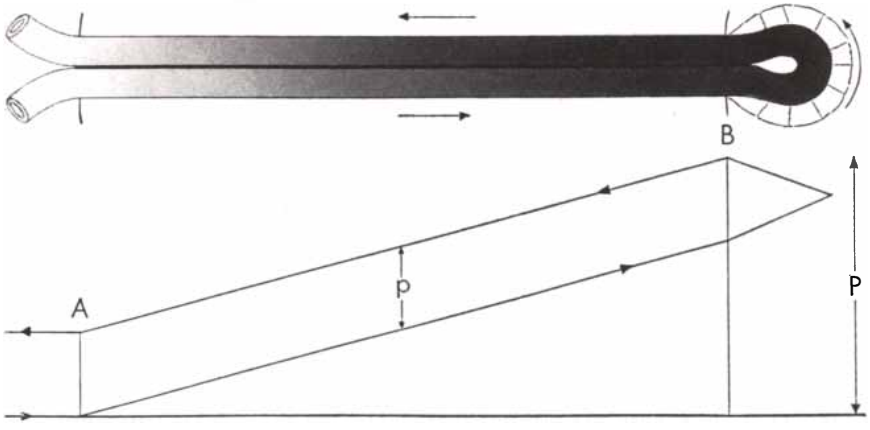


One pattern is non-staggered; it gives rise to a checkerboard (*top left*). The other is staggered; it gives rise to stars (*bottom left*). Photomicrographs show the checkerboard in the deep-sea eel (*top right*) and the star pattern in the rosefish (*bottom right*).

two patterns in the swim-bladder retes of deep-sea fishes [*see photographs above*].

From the number and dimensions of the capillaries, the speed of the blood flow and other information we can calculate the amount of the oxygen-pressure drop across the rete, or, in other words, how effectively the rete traps oxygen. The calculation indicates that across a rete only one centimeter long, the oxygen pressure is reduced by a factor of more than 3,000. That is to say, the leak





RETE GRADIENTS

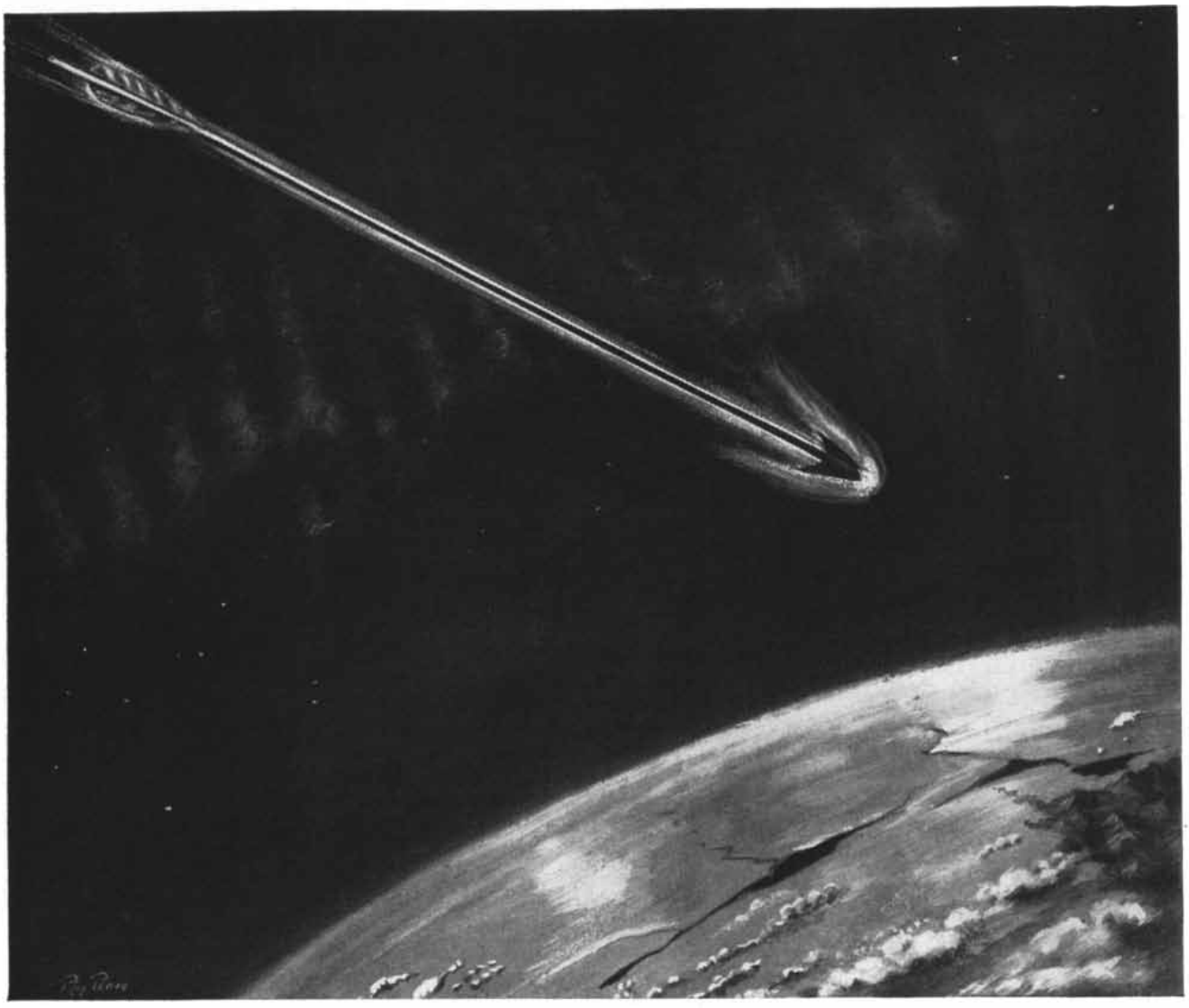
of oxygen through the rete is insignificant: translating the situation into terms of heat, if boiling water were to enter such a rete from one end and ice water from the other, the exchange of heat would be all but complete—to within one 10,000th of a degree!

To put it another way, the counter-current exchange in the swim-bladder rete is so efficient that in a single pass a rete one centimeter long is capable of raising a given concentration 3,000-fold, which leaves industrial engineering far behind. In speaking of concentration we include several different kinds: heat, gas pressure, the concentration of a solution and so on. A counter-current exchange system can establish a steep gradient in any of these quantities.

It has recently been suggested that counter-current exchange may be involved in the process whereby the kidneys filter the blood and produce urine. During the process of conversion of blood fluid to urine, the concentration of salts and urea in the fluid may be increased three- or four-fold. Just how is this concentration carried out?

The machines that perform the transformation are the units called nephrons, of which a kidney contains several millions. A nephron consists of a glomerulus capsule (a small ball of capillaries), a long, twisting tubule and a collecting duct [*see diagram on page 105*]. From the blood in the glomerulus capillaries a filtered fluid passes through the capsule wall into the tubule. The fluid travels along the tortuous course of the tubule, doubles back at the loop of Henle [*see diagram*], and by the time it leaves the collecting duct it has become concentrated urine. The conversion does not take place in the glomerulus capsule; it has been established that the fluid emerging from the capsule has essentially the same salt concentration as the

THE WRECKFISH swims at great depths and must therefore keep its swim bladder filled with oxygen at tremendous pressures. It does this by means of counter-current bundles (*solid red*) in the swim-bladder wall (*first and second drawings*). One of these bundles (*third drawing*) and a single counter-current capillary (*fourth drawing*) are schematically depicted. Very little oxygen (*red shading*) escapes beyond the swim-bladder wall because it diffuses (*small arrows*) from the outgoing vein into the adjacent incoming artery. The diagram (*bottom*) represents build-up of pressure (*P*) by means of a pressure difference (*p*) between the counter-current artery and vein.



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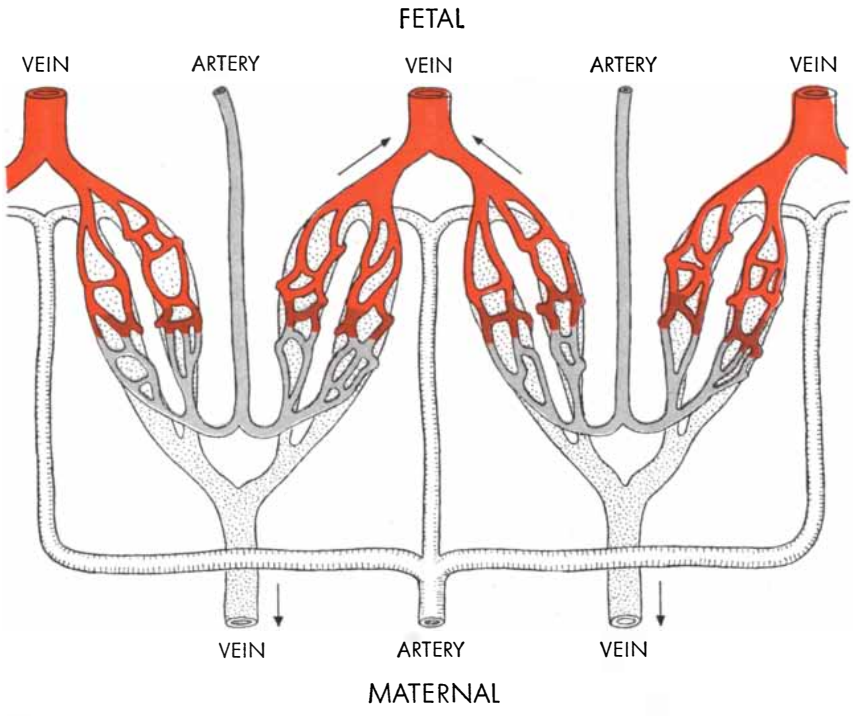
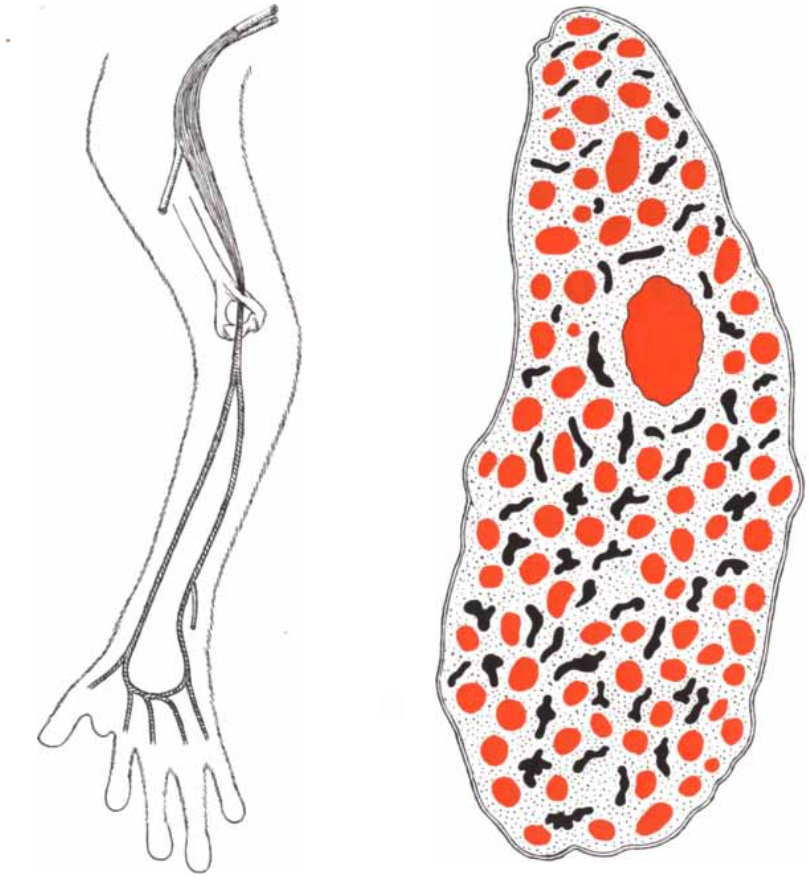


OXYGEN IS EXCHANGED by counter-current flow in the placenta of the ground squirrel. Oxygen-rich maternal blood (*white*) enters the arteries (*bottom*) and flows counter to the oxygen-poor fetal blood (*gray*). The fetal blood picks up oxygen (*red*) and leaves through the fetal vein (*top*). Oxygen-poor maternal blood (*stippled*) returns to the maternal heart.



HEAT IS CONSERVED by rete bundles in the loris. They occur where the limbs join the body (*upper left*). Arterial blood enters the upper end of the rete and flows counter to the venous blood. Heat diffuses from the arteries to the veins and is returned to the body. A cross section of the rete (*right*) shows the arrangement of arteries (*red*) and veins (*black*).

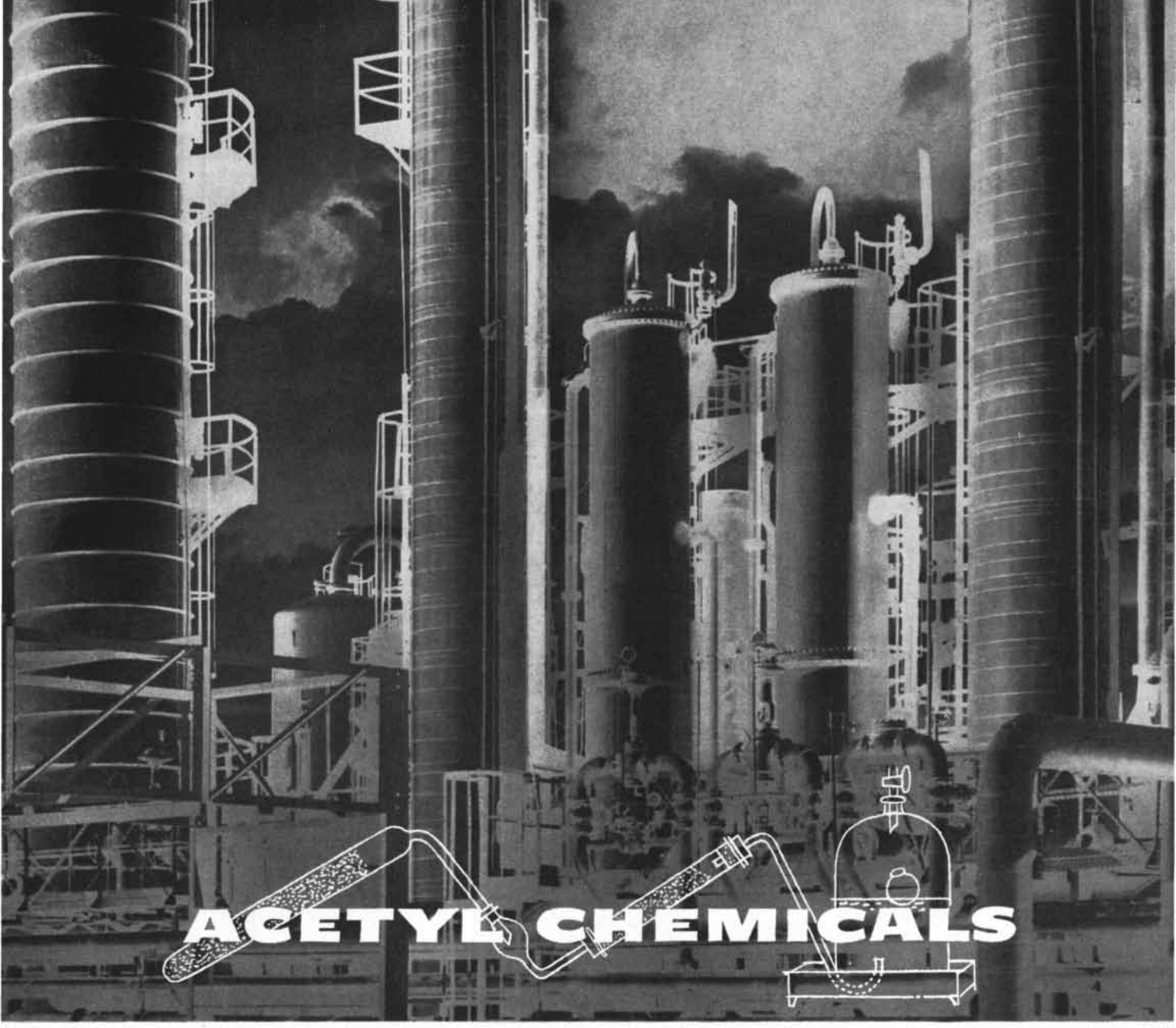
blood. The problem is to determine exactly where in the system the change in concentration is produced.

B. Hargitay and Werner Kuhn of the University of Basel recently proposed that it takes place primarily in the loop of Henle. They pointed out that only animals with a Henle loop in the kidney nephron—namely, mammals and birds—can produce a concentrated urine.

The loop of Henle, with its two arms running parallel and fairly close together, is a structure which reminds us of the arteriovenous capillary loops that make up the rete of a fish [*see diagram on page 100*]. Hargitay and Kuhn reasoned that salts or water might migrate from one arm of Henle's loop to the other, and that as a result salts might be concentrated in the bend of the loop. This part of the loop is situated in an internal structure of the kidney called the papilla, which also contains the collecting ducts and adjacent blood capillaries. The investigators assumed that the fluid concentrated in the loop would be transmitted to the ducts and capillaries and become concentrated urine. To test their idea, they first froze rat kidneys and examined small sections of the tissue under a microscope. The sections of tissue in the papilla, around the loop of Henle, proved to have the same melting point as the rats' urine, while the tissue in the cortex (outer part) of the kidney had the same melting point as frozen blood. Since the melting point depends on the salt concentration this finding tended to confirm the idea that the primary site for the concentration of urine is located in the bend of Henle's loop. But it was possible that the brutal freezing process had damaged the tissues so that urine escaped from the collecting ducts and diffused to the area around the loop. To make a clearer test, H. Wirz, a colleague of Hargitay and Kuhn, developed a technique for drawing samples of blood from the capillaries around Henle's loop. This blood proved to have the same melting point as the urine, *i.e.*, its salt concentration was as much as three times higher than that of blood in other parts of the animal's body.

Thus Hargitay and Kuhn seem to have strong support for their thesis that a counter-current exchange in Henle's loop plays a part in the formation of urine by the kidney. But the question still needs further research.

Various other examples of counter-current exchange in animals have been discovered. One of them concerns the breathing of fishes. A fish requires a far more efficient and resourceful



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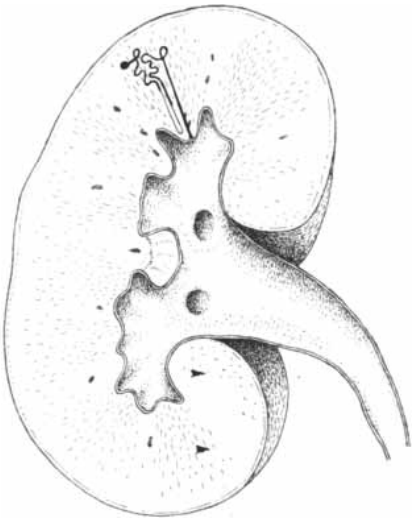
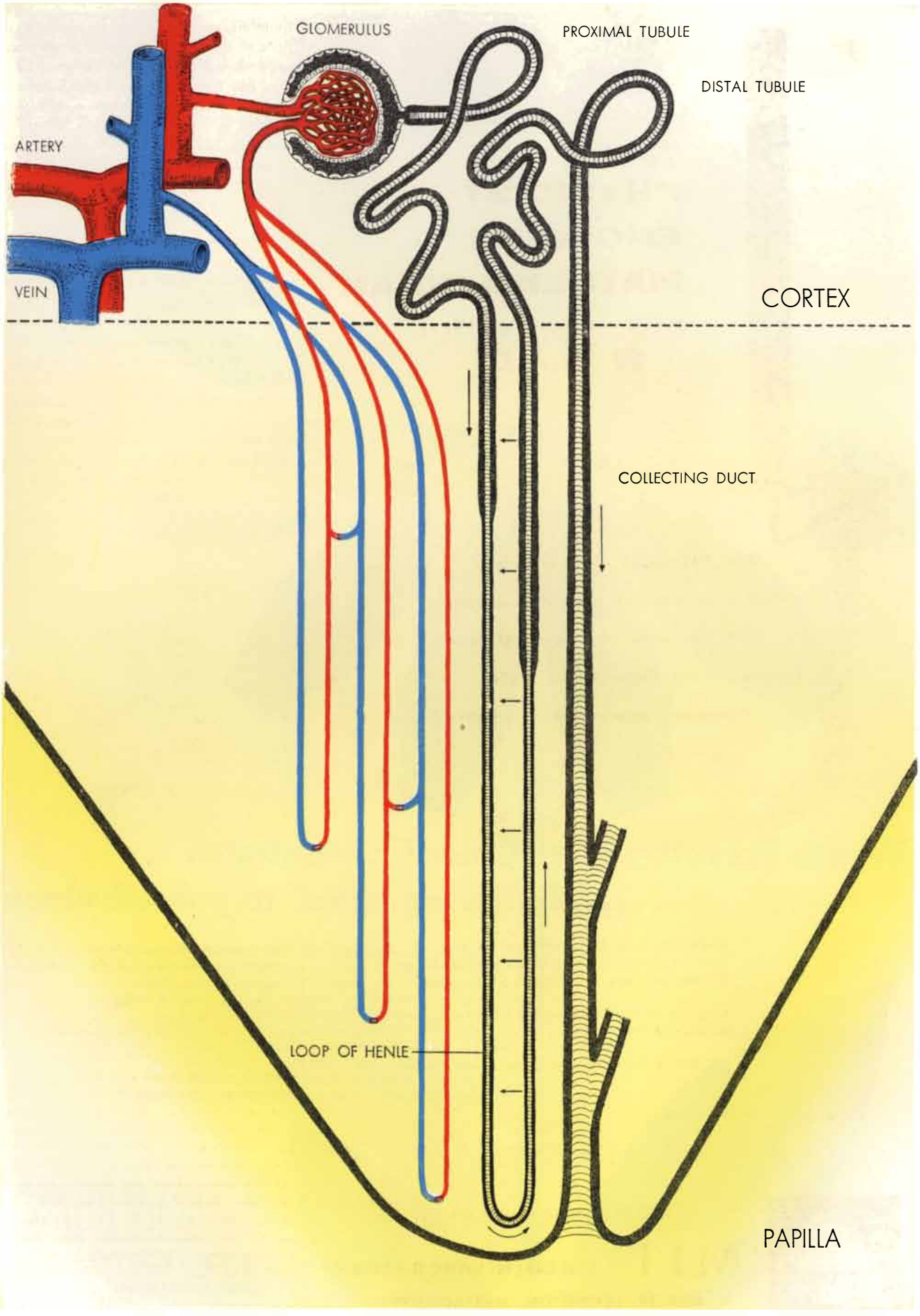
breathing apparatus than an animal that lives in the air. Each quart of air contains some 200 cubic centimeters of oxygen, but a quart of sea water has only about five cubic centimeters, and oxygen diffuses through water slowly. The fish therefore has to be remarkably efficient in extracting oxygen from the water that flows over its gills. It can, in fact, take up as much as 80 per cent of the oxygen in the water. Anatomical studies and experiments have proved that fishes employ a counter-current system in this process. The blood in the capillaries of the fish's gill plates flows in the direction counter to the flow of water over its gills. When experimenters reversed the direction of the water current over the gills, fishes extracted only one fifth as much oxygen as they did normally!

In many species of animals the mother and the fetus she is carrying share their blood substances by means of a counter-current exchange system. This apparently is not true of the human animal, for



THE NEPHRON filters urea and other dissolved substances out of the blood and concentrates them in the urine. It may accomplish this with counter-current exchange. The drawing above is a cross section of the human kidney. At its upper left is a schematic representation of one of the kidney's several million nephrons. On the opposite page the nephron is enlarged. Arterial blood (*red*) is depicted entering the capillaries of the glomerulus. The dissolved substances filter out of the glomerulus into the proximal tubule. The solution then travels down the tubule and doubles back at the loop of Henle. If the dissolved substances diffused from the ascending tubule into the descending tubule, the urine would be concentrated (*yellow shading*) near the bend of the loop. The concentration might then be transmitted to the portion of the collecting ducts located in the papilla.



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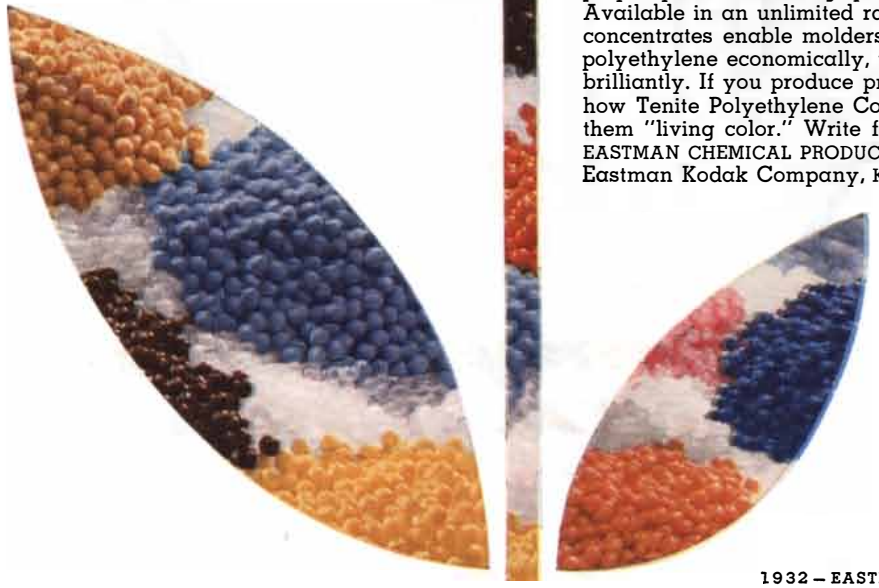

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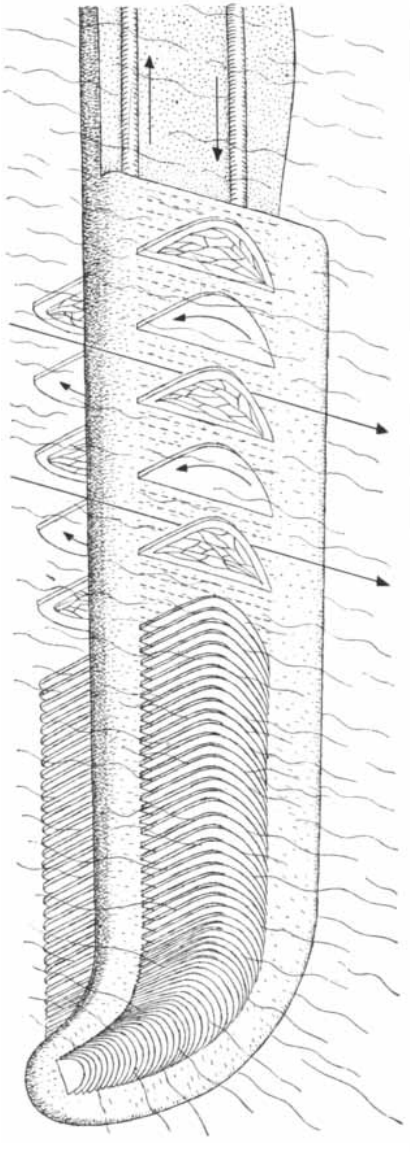
the fetus's capillaries are bathed directly by the mother's blood. But in the rabbit, the sheep, the squirrel, the cow, the cat, the dog and other animals, the mother's blood vessels are intermingled with the fetus's in the placenta, and by counter-current flow they exchange oxygen, nutrients, heat and wastes.

In sum, the principle of counter-current exchange is employed in many and various ways in the world of living things. We cannot fail to be impressed by the marvels of bio-engineering that nature has achieved in its development of "the wonderful net."



GILL OF A FISH is a counter-current system which efficiently extracts the small amounts of oxygen dissolved in water. In this schematic drawing of a single gill filament, water flows between the gill plates from left to right (*straight arrows*). Blood flows through the capillaries of the gill plates in the opposite direction (*curved arrows*).

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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.

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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.

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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.

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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.

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NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

OMR a promising approach to meet world's need for small to large power plants

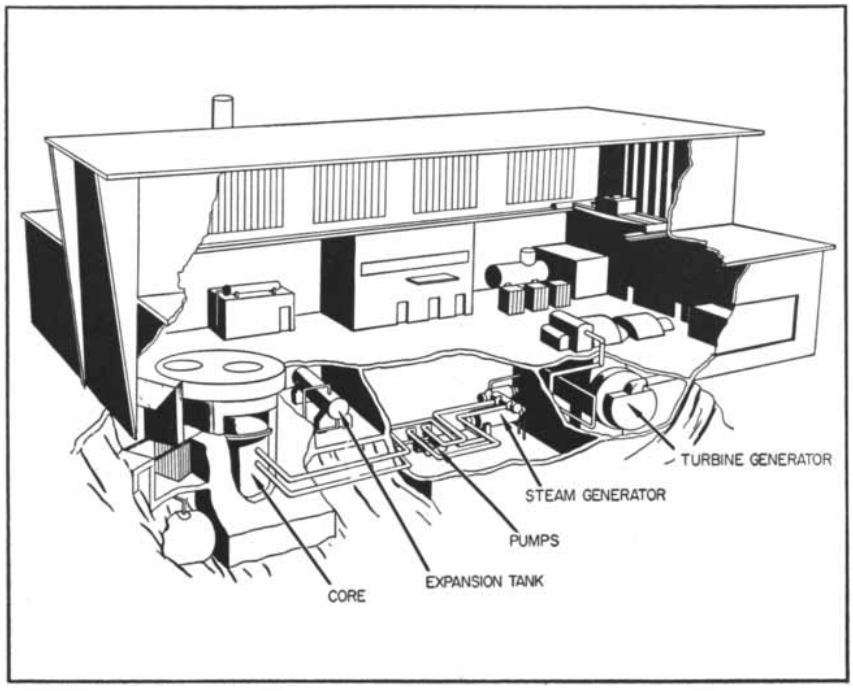
An important goal of the Atomic Energy Commission's program to develop electric power from the atom is a low-cost reactor for plants with gross outputs of 10 megawatts or more. Such plants are particularly suited to areas that need relatively small increments of additional power, and to those parts of the world where coal, oil, and water-power are scarce or costly.

The OMRE (Organic Moderated Reactor Experiment), which ATOMICS INTERNATIONAL is now building at the National Reactor Testing Station in Idaho, is one of the more promising types for this purpose. The new experimental reactor was pioneered by ATOMICS INTERNATIONAL — from preliminary design to prototype.

It will be used to investigate the rate of degradation of organic fluids, the properties and compositions of the equilibrium mixture in the reactor, and the effect of organic fluids on heat-transfer surfaces. Results of these experiments will be incorporated into the nuclear power plants ATOMICS INTERNATIONAL is planning for Piqua, Ohio and a Latin American country.

Basic advantages of the OMR are small size, compact core with good neutron economy, and elimination of problems with high-pressure primary coolant circuits and uranium-coolant reaction hazards. Its safety features are outstanding. The high boiling point of the organic moderator-coolant fluid permits a low-pressure system. There are no chemical incompatibilities between coolant and uranium or coolant and water, and no unusual corrosion problems. Because of its fluid moderator—an isomeric terphenyl—the OMR has a negative temperature coefficient of reactivity, which acts as a governor in case of power surges or excess power levels. The organic fluid becomes only slightly radioactive, which makes the entire heat-transfer system relatively accessible.

A typical power plant, such as the one proposed for Piqua, Ohio, has a gross electric output of 12,500 kilowatts and a heat output of 45,500 thermal kilowatts. It produces steam at a pressure of 415 psig (29 kg/cm^2) and a temperature of 550°F (288°C).



Typical OMR Central Station Nuclear Power Plant

The reactor core is heterogeneous, with fuel elements and control rods immersed in the moderator-coolant fluid and contained in a thin-walled core tank. The fuel is uranium slightly enriched in U^{235}.

Power costs for this reactor, including both capital and operating charges, are estimated at 18 mills per kilowatt-hour. Power costs will be significantly lower in larger OMR plants. Lower power costs are also expected to result from advances in OMR technology.

Atomic power for supertankers. The AEC has assigned ATOMICS INTERNATIONAL the challenging design study to adapt the OMR for maritime use. The OMR, considered a promising possibility for ship propulsion, is expected to be particularly suitable for supertankers. The OMR offers the safety of a low-pressure system, low construction costs (because it can be built of aluminum and mild steel instead of more expensive zirconium and stainless steel), and low maintenance costs.

ATOMICS INTERNATIONAL is staffed and equipped to help you with any phase of reactor development. Please write: Director of Technical Sales, Dept. SA-72, ATOMICS INTERNATIONAL, P. O. Box 309, Canoga Park, California. Cable address: ATOMICS.

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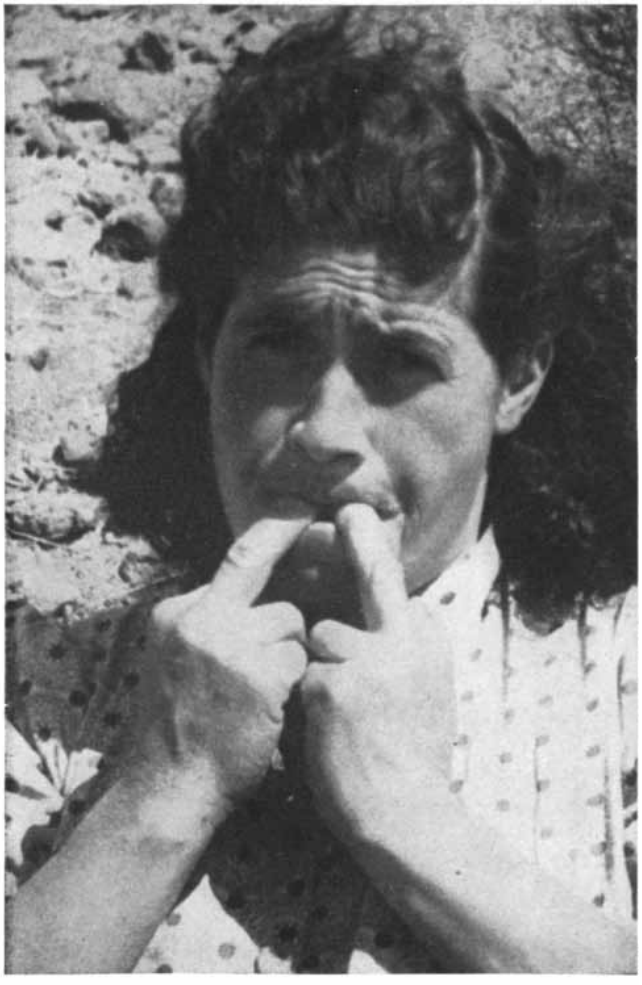
The Whistled Language of La Gomera

The harsh terrain of this island in the Canaries has led its people to develop an extraordinary form of telephonic speech. Its clear tones may be understood at a distance of three miles

by André Classe

La Gomera is one of the Canary Islands, lying in the Atlantic off the west coast of North Africa. It is inhabited by some 30,000 Spanish-speaking people, scattered over the island in many tiny hamlets and four little towns. The island, volcanic in origin, is distinguished by a rugged and peculiar topography. It has the general shape of a big tent: from a central peak some 4,500 feet high it slopes down on all sides to sheer cliffs at the sea's edge [*see drawing on page 115*]. Deep gorges radiating from the center cut up the terrain. It is a difficult, mountainous country where two points only 500 yards apart as the crow flies may be as much as an hour apart in walking time. Aside from a single road, built comparatively recently, which links San Sebastián, the capital, with the other three towns, the only means of travel between most points on the island is by very rough paths which are little better than goat tracks. Clearly com-

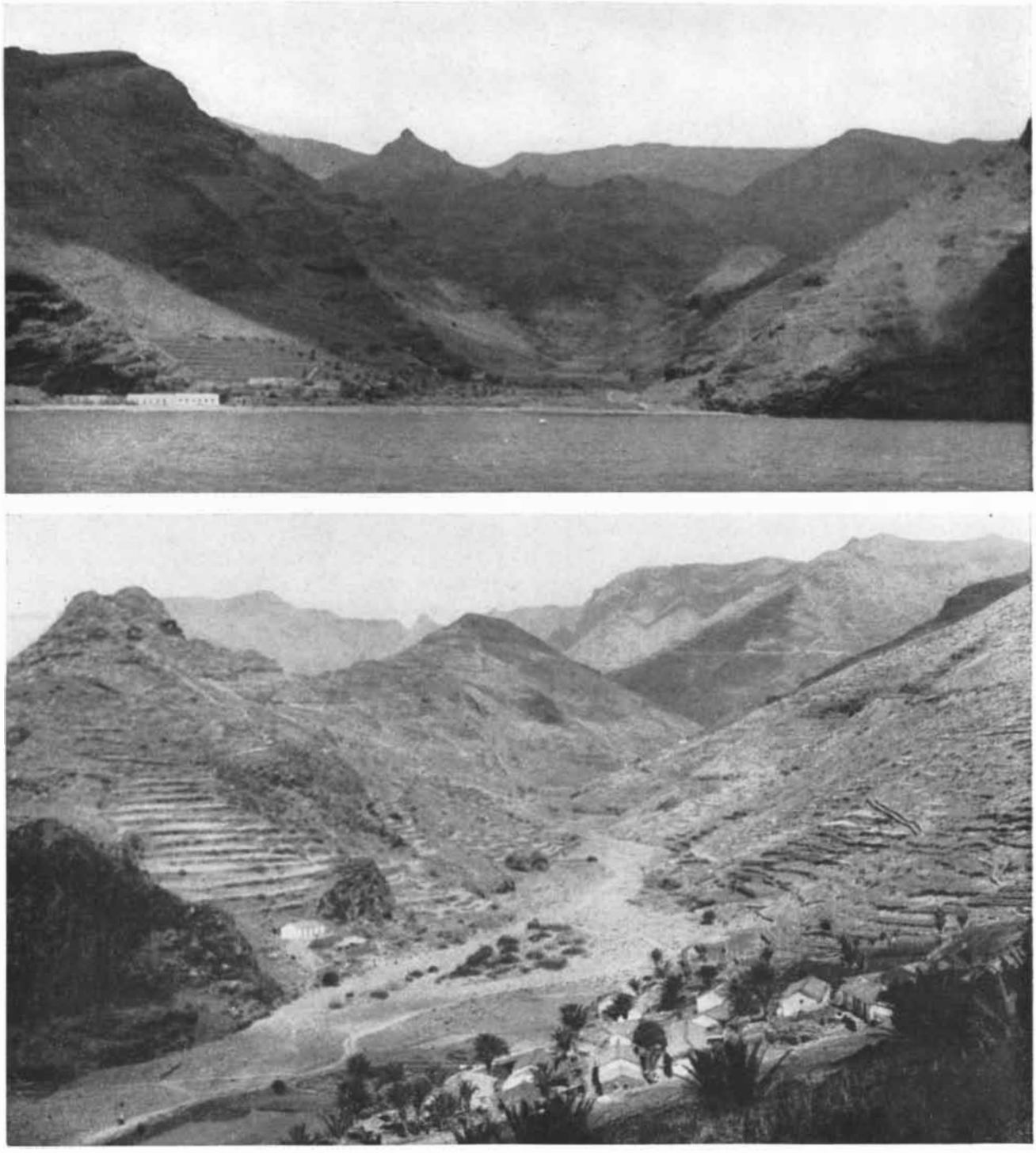


TYPES OF WHISTLE are demonstrated by a woman of La Gomera. Finger-in-mouth variety (*left*) is common. Position of the fingers does not affect the sound of the whistled language, whose articulation is provided by the tongue, as in ordinary speech.

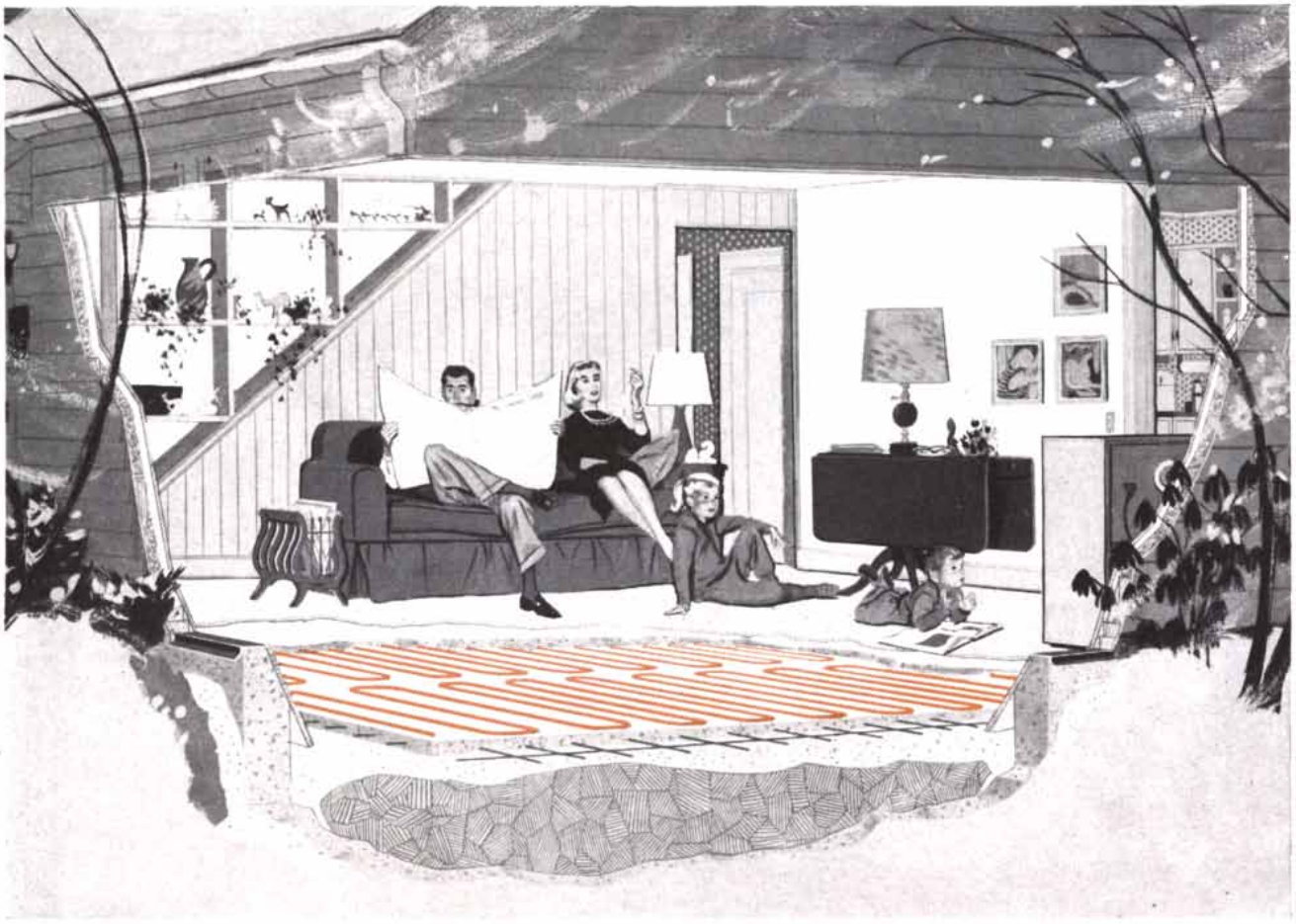
munication on this island is no small problem.

But the Gomeros do communicate freely, from hamlet to hamlet, across their ravines and from the valleys to the mountaintops. Long ago they contrived an elegant solution to their problem: namely, a whistled language by which they speak to each other across miles of disjoined terrain. The *silbo* (Spanish for "whistle"), as this language is called, is not a mere code or signal system but a version of Spanish. And it has extraordinary carrying power: it can be heard and understood clearly over far greater distances than shouted talk. On a windless day any practiced silbador can be heard more than a mile away. A good performer can whistle messages three miles or more, and I was told that the record is more than eight miles. This may be an exaggeration, but, considering the astounding volume of sound a really first-class silbador can produce, the acuteness of hearing most of the Gomeros seem to enjoy and the great carrying power of sound in the gorges of the island, the eight-mile figure does not strike me as outrageously improbable.

On La Gomera goatherds on widely



RUGGED LANDSCAPE of La Gomera is shown in these two photographs. Shoreline of the island (*top*) is indented by one of the many gorges which make ordinary communication difficult. Farther inland (*bottom*) is a tiny village at the edge of a cultivated valley.



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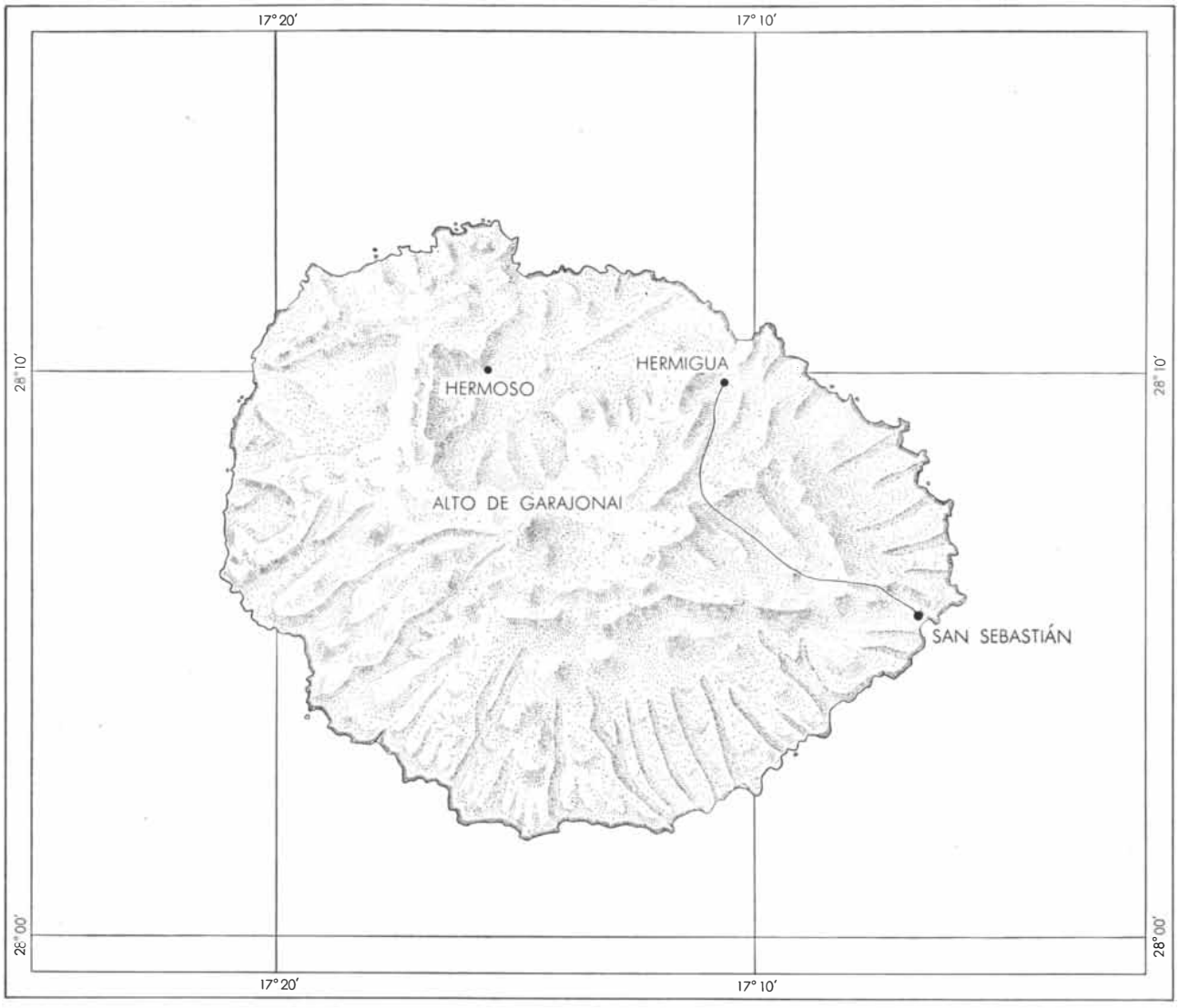
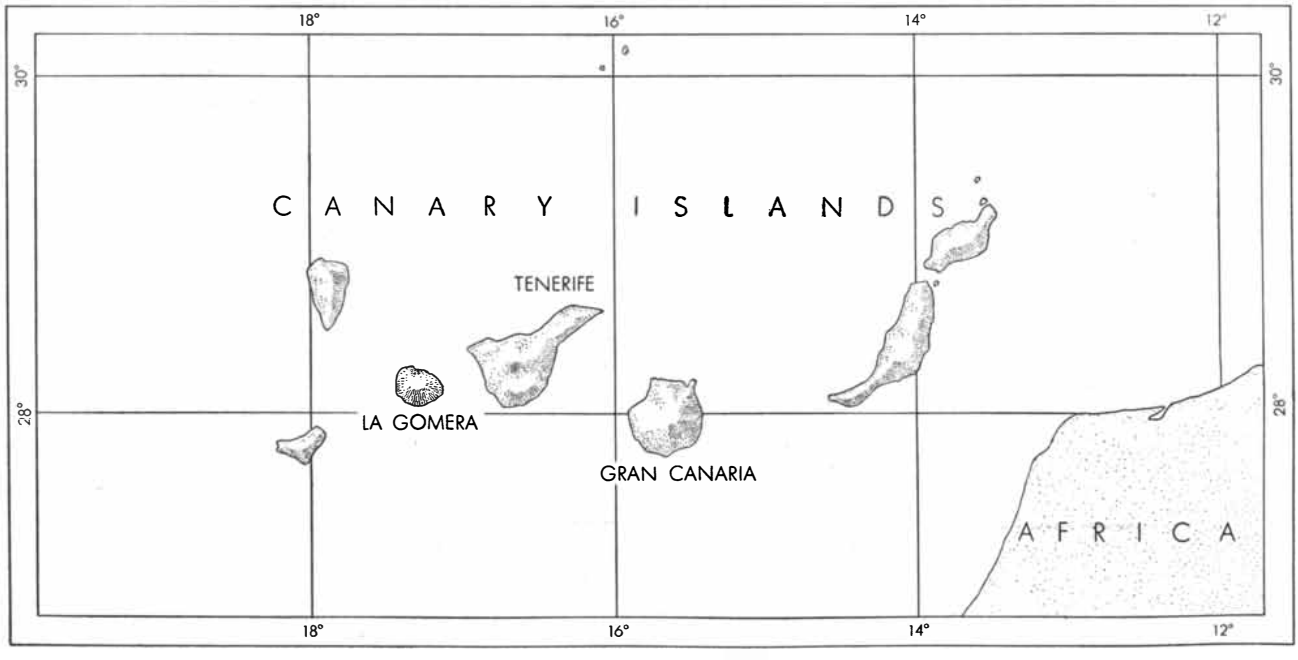


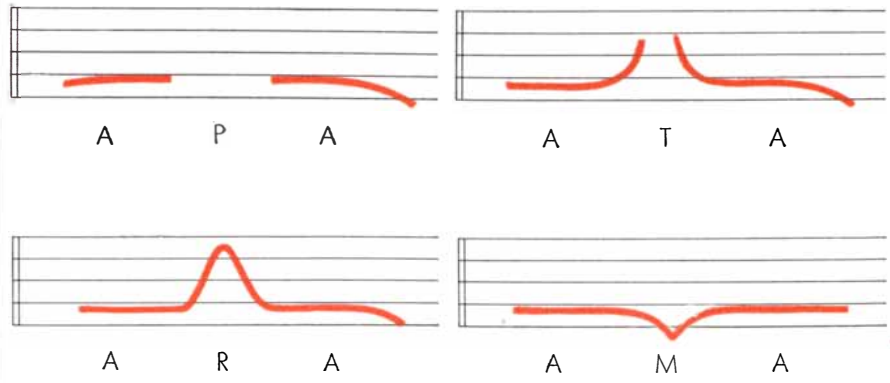


separated hills carry on silbo conversations just to pass the time. They whistle long sentences and even make jokes. An instructor who was teaching me the language whistled a facetious sentence which was immediately translated by a Gomero at my side as: "Rineo, will you lend me your donkey because I want to ride to Santa Cruz tomorrow?" (Santa Cruz being on the island of Tenerife, seven hours away by sea). During the Spanish Civil War in 1936-39 Gomeros were used occasionally for communication at the front, but the practice was discontinued when it was discovered that there were silbadores on both sides, so that the degree of secrecy was not high.

This curious medium of communication quite clearly owes its existence to the geography of La Gomera. It goes back to the aborigines who inhabited it before the Spanish came in the 15th century. The aboriginal residents in the Canary Islands, called the Guanches, had developed a whistled form of their language for communication in their territory, then so thickly wooded that whistles were the only kind of "talk" which could be transmitted for any distance. Whistled speech has disappeared from the other Canaries, but it is still going strong on La Gomera because that is the only island where moving about is really difficult.

The silbo is based directly on the Spanish language and is learned effortlessly and as a matter of course by most Gomeros. This may seem, from more than one point of view, a strange statement. In the first place, many writers on the subject have declared that the whistled language is a difficult technique and must be taught to young Gomeros laboriously, as if it were a foreign language. Nothing could be further from the truth. Children on La Gomera pick up silbo as naturally as they pick

LA GOMERA is depicted above in a simplified profile that shows its tentlike form. In the topographical map (*top of opposite page*) gorges can be seen radiating from the island's mountainous interior. The Canary Islands (*bottom of opposite page*) lie west of the African coast in the Atlantic Ocean.



FOUR CONSONANTS of the whistled language are shown as colored lines on these musical staves. Each consonant is heard as a modification of the vowel sounds coming before and after it. The consonant *p* (*upper left*) appears as a break in the steadily low-pitched *a* vowels of its environment. This corresponds to the break in voicing caused by lip closure when *p* is spoken in ordinary language. Pronunciation of the other consonants requires articulation by the tongue. Since tongue movements enlarge or contract the resonance chamber of the mouth, they vary the pitch of the whistled language. When the *t* sound is whistled (*upper right*) the rising of the tongue as it approaches contact with the upper gum ridge causes a rise in pitch. This is followed by silence when the contact is made, then a falling pitch as the next vowel begins. The consonant *r* (*lower left*) resembles *t* but has no break, since the tongue does not complete contact. The consonant *m* resembles an inverted *r*.

up spoken Spanish in their parents' talk: they often begin to recognize their own name in silbo before they are a year old. One Gomero said to me of the whistled language: "It's so easy that if I didn't know it I could learn it in one morning." My wife and I, though handicapped by the fact that our Spanish is very different from the peculiar dialect of La Gomera, learned to whistle sentences efficiently in less than three months. It is doubtful that we could learn as much of a difficult new language, say Finnish, in that time.

What may strike linguists as more questionable is the statement that the silbo is accurately modeled on the Spanish language itself. How can whistling, which uses only one tone quality, replace normal speech, which is based primarily on variations of tone quality? Our phonetic studies of the silbo answered this question and showed that previous descriptions of it were quite inaccurate.

In ordinary speech we use an assortment of organs to produce a great variety of sounds. To begin with, the larynx generates the voice-tone, which may vary in pitch, loudness and duration. This sound is modified by the lips, tongue, teeth, lower jaw and soft palate. All these combine to produce vowels, semivowels and consonants.

A whistle, in contrast, is a simple sound. The only active organ is the tongue, or rather two thirds of it. The lips and front part of the tongue are immobilized, but the rear part may move to vary the pitch. The only variables you have at your disposal are pitch, loudness and duration. For articulating words, variations in duration and loudness are unimportant in the silbo, because duration has little significance in Spanish and you always whistle "at the top of your voice" in order to be heard at a distance. So the only element available for whistled "speech" is variation of the pitch.

Most students of the silbo have failed to appreciate this fact, and as a consequence have attributed mysterious properties and qualities to the Gomeros whistle. Some have asserted that the whistlers vary the timbre of the whistle with the use of their fingers and hands. Actually it should be obvious that nothing can significantly modify the quality of a whistle, for the sound is always a simple oscillation—to all intents and purposes a sine wave with no audible harmonics. And one look at a silbador's performance is enough to settle the point beyond question. Some Gomeros whistle with the tongue alone; some stick one or two fingers in the mouth; some use their hands as a megaphone; but neither the fingers nor the lips ever move.

Other writers have declared that the phonetic elements of the silbo are discrete musical notes. Actually notations by these authors, purporting to reproduce silbo sentences, bear no resem-

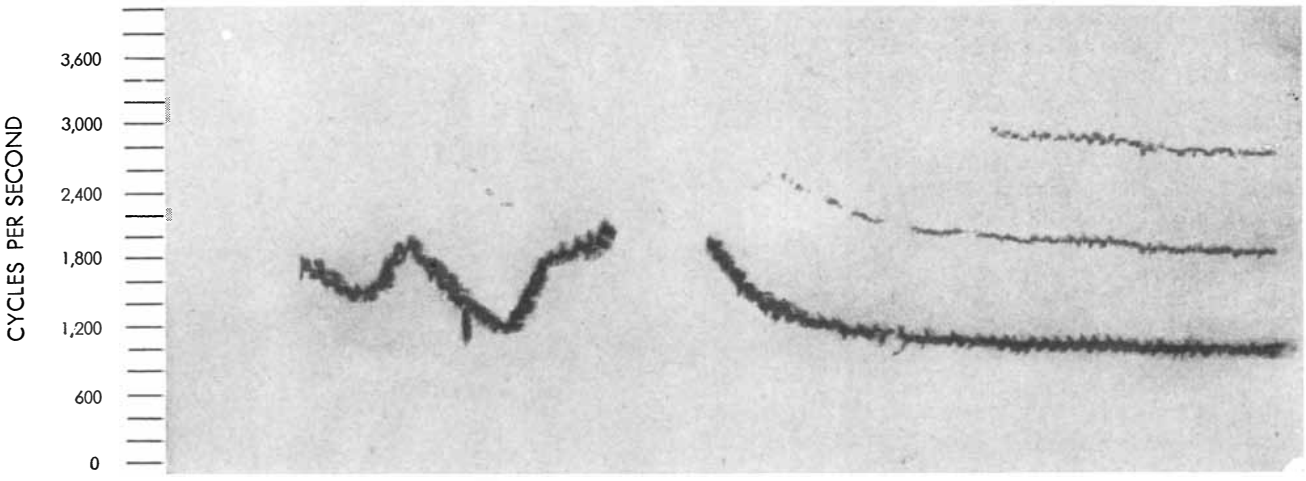
blance to the way the silbadors whistle the same sentences, and the natives cannot understand these renderings of their language. Analyses of tape recordings of their whistled speech clearly show the difference.

The fact that the whistled language depends only on pitch makes plain why it can be understood at much greater distances than ordinary shouted speech. The sounds of ordinary speech, as we have noted, are complex waves containing a number of harmonics. What makes such speech unintelligible at a distance is the loss of the weak harmonics and transients. On the other hand, a whistled signal, whose meaning does not depend on timbre but is determined solely by pitch, will be understood perfectly so long as it is heard at all.

The question now is: How does the silbo, using only variations in the pitch of a whistle, express the sounds of Spanish? We can say at once that it is fortunate the language is Spanish. It would be vastly more difficult to whistle English, for English has a very complex phonetic system. The Spanish phonetic system, especially in the Gomero dialect, is almost the simplest possible: it has comparatively few different vowel and consonant sounds, and relatively little contribution to meaning is made by stress, rhythm or intonation.

There is nothing the least bit mysterious about the way the Gomeros produce their silbo. All the silbador has to do is to stick the tip of his tongue against his teeth, start whistling and at the same time try to articulate words as if he were speaking normally! Anyone capable of whistling can demonstrate to himself what will happen. Suppose you emit a whistle and simultaneously attempt to articulate the sound *e*, as in Pete. The back of your tongue will move upward, reducing the volume of the mouth cavity. If you attempt to articulate the sound *ah* (as in calm) while whistling, your tongue will assume a different position, which makes the mouth cavity larger than in the other case. Since the mouth acts as a resonator, the difference in size of the mouth cavity must make the pitch of the whistled *e* a good deal higher than that of *ah*.

What will transpire if you try to whistle two syllables, consisting of vowels separated by a consonant? Let us take the word fragment *apa*. In speech, to articulate the *p* the lips close. In the silbo they do not, but the glottis does and stops the breath. The tongue does not change its position during the whistling of these two syllables. The result is



SIMPLE ACOUSTICS of the whistled language is evident from this sound spectrogram. The weak harmonics (*lines at upper right*) are almost inaudible. Since the whistle is virtually lacking in timbre, it relies entirely on changes in pitch to convey meaning.

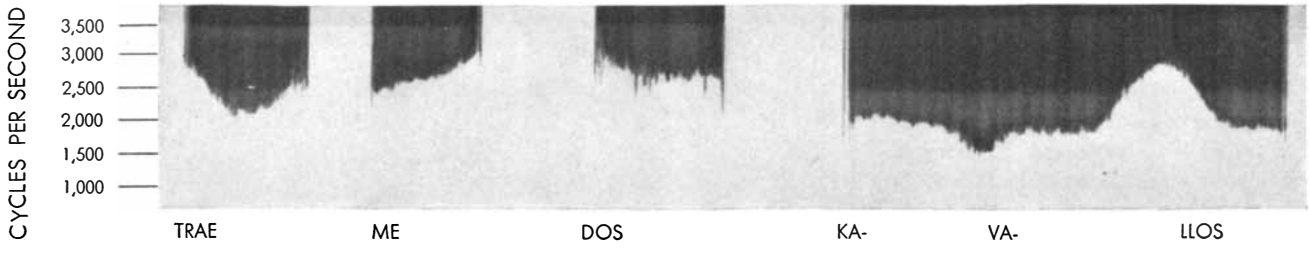
a whistle of unchanging pitch, interrupted by a gap while the vocal cords are closed to form *p*. If, on the other hand, you try to whistle *ata*, the pitch varies. To form the *t* the tongue moves up and makes contact with the palate. While doing so, it is reducing the size of the mouth cavity, so that the pitch of the whistled *a* rises; as the tongue moves down again for the second *a*, the pitch falls. So the whistling of *ata* produces a sound of rapidly rising pitch, a momentary interruption (while the tongue is against the palate) and then a rapid down-glide. When you whistle *ara*, the pitch-curve is quite different, because this time the tongue does not touch the palate and the tone is continuous [*see charts on page 116*].

These few examples should suffice to give an idea of the way the silbo works. A practiced silbador can whistle intelligibly everything he can say in the Spanish language. The whistle does not differentiate all the consonants in the spoken language, but when the silbador whistles words and sentences, the context makes his meaning unambiguous. The situation indeed is no different from the case of ordinary speech. In conversation we do not ordinarily give attention to every sound; we recognize patterns through long familiarity with them, and we grasp the thought though we may miss and have to guess at a high proportion of the individual sounds. This explains why it is so difficult to understand people speaking a foreign language of which we have only an imperfect knowledge—we cannot supply the unheard elements.

There is nothing esoteric about the silbo. Most Gomeros, particularly in the peasant class, understand it and many of them use it regularly. They do not use it at close quarters, except to show off to admiring strangers. But even in the towns people usually call to each other in the street by whistling rather than speaking their names. Children, as I have said, pick up the silbo naturally and often understand it quite well by the time they are eight or nine. It seems to be very much easier for them to learn the silbo than it is for us to learn to read a system of shorthand. Given a good set of teeth, they have no trouble developing a good loud whistle. One exceptional performer was described to me as having cultivated a whistle that sounded like a ship siren. I heard him later, and the description seemed to fit well enough, although a locomotive whistle would have been nearer the mark. All the silbadores we met looked upon the silbo as a perfectly normal activity, quite as natural as speech. Most young Gomeros can converse in the silbo by the age of 12 or so. One of the best subjects we recorded was a 12-year-old girl whose father was a shepherd. She had learned from him. Another subject, also first class, was exceptional in having learned to whistle at the comparatively late age of 19.

Like ordinary speech, the silbo is differentiated into dialects and even individual styles. Each silbador has his own delivery. When we played back recordings, the whistlers would invariably recognize and claim their own performances, saying something like: "Ah, that's *my* silbo"—implying that it was much better and clearer than anybody else's.

Nothing better illustrates how commonly the Gomeros use the silbo than an experience we had one day in the wilds of the middle of the island. We were climbing the central mountain, and all



PITCH CONTOURS are shown in electronic transcription of sentence given also in phonetic spelling. The meaning ("Bring me two horses") is conveyed by continuous sound curves rather than by successions of individual notes, as some authors have suggested.

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a report by LINDSAY

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For a long time, as you may know, the rare earths were simply a by-product of our regular business of producing thorium nitrate for gas mantles. Up to 35 years ago, rare earths were little more than scientific curiosities. Industry had not yet discovered them as a practical scientific tool.

But, as time sped by, we learned more about these unusual elements and how to produce them in larger quantities, in higher purities and at lower cost. And with their increasing availability, industry began to find ways to use them profitably in their operations. In the last ten years, we've seen a sharply increasing rise in the demand for rare earths from a rather amazing variety of industries.

WHY THIS DEMAND? Well, as we see it, it's due largely to the enormous technological strides made since World War II. Industry itself sparked much of this interest by its own explorations of the rare earth group in a search for materials to improve products and processes. Their studies in relation to specific problems often uncovered totally unsuspected applications. It was a sort of chain reaction that is still increasing in velocity.

LINDSAY BUILT NEW PLANT. We saw what an industrial revolution the rare earths were creating. And anticipating heavy demands, we constructed our modern plant in 1953. The Lindsay plant facilities, including more recently developed and improved separation processes (such as our ion exchange systems), increased our production capacity manyfold.

WHAT ARE THE RARE EARTHS? Rare earths are *not* rare—nor are they earths. This group of 15 elements (atomic numbers 57 through 71) are trivalent metals found together with thorium and yttrium primarily in monazite ore. In chemical properties they are almost identical, a fact which makes them difficult to separate and at the same time makes them valuable tools for research and industry.

HOW THEY ARE USED. The fascinating description of industrial applications of the rare earths would fill many books. We work with these materials every day and we're constantly amazed at the variety of ways in which they're used. Here are only a few. Glass polishing. Steel additives. Catalysts. Colorizer and decolorizer for glass. Medications. Ultra-violet light absorber. Arc carbon electrode cores. Aluminum and magnesium alloys. Lighter flints. Radiation-proof glass. Waterproofing. Textile production. Color TV tubes . . . and the list goes on and on.

RARE EARTH SALTS. Lindsay produces rare earth salts in large tonnages and in varying purities. Most of them are surprisingly low in cost. Rare earth chloride—for example—a mixture of several of these elements—is only about 25¢ a pound and available in virtually unlimited quantities. High purity separated rare earths are, of course, more expensive, but economical in relation to the wonders they perform.

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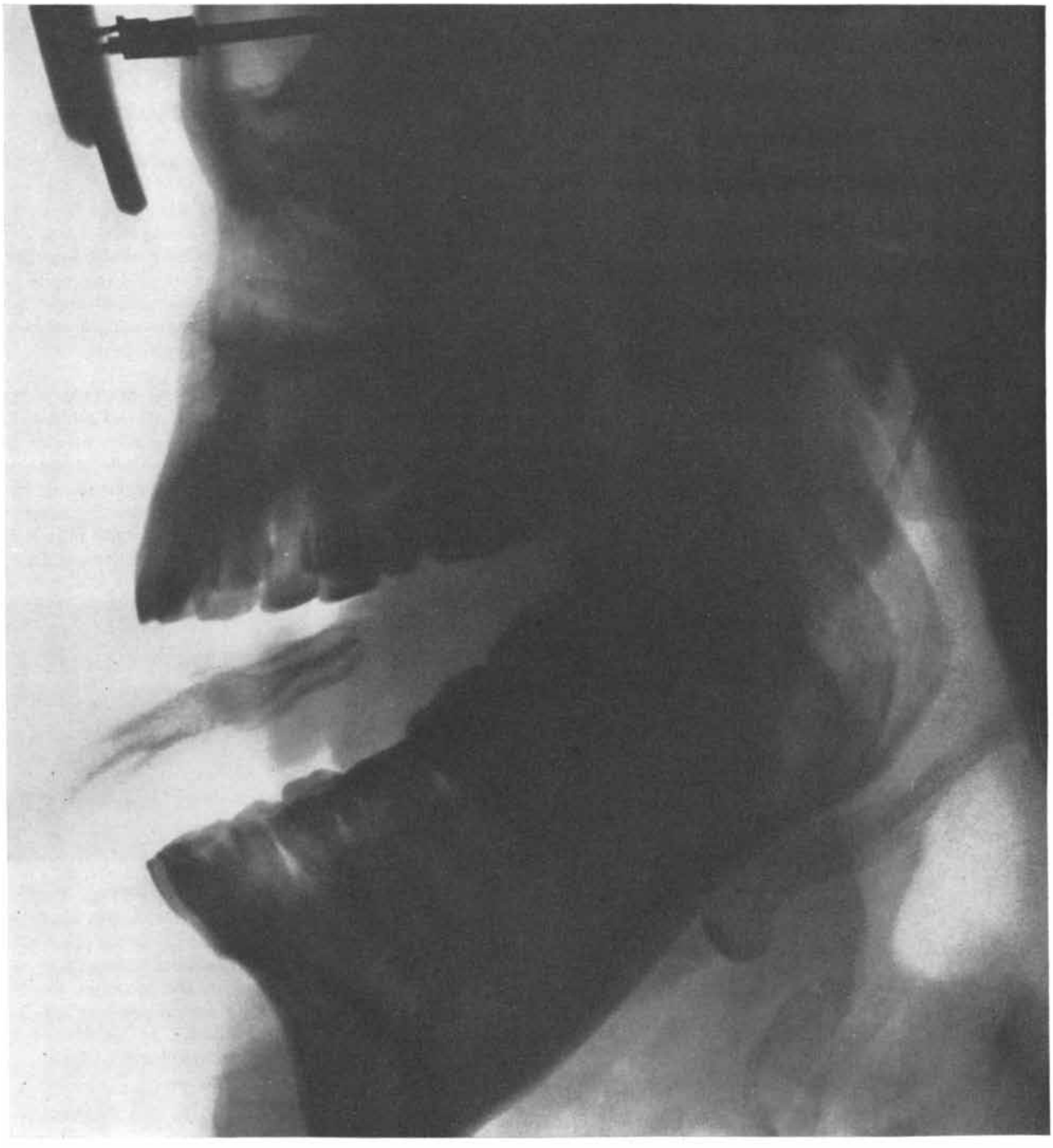
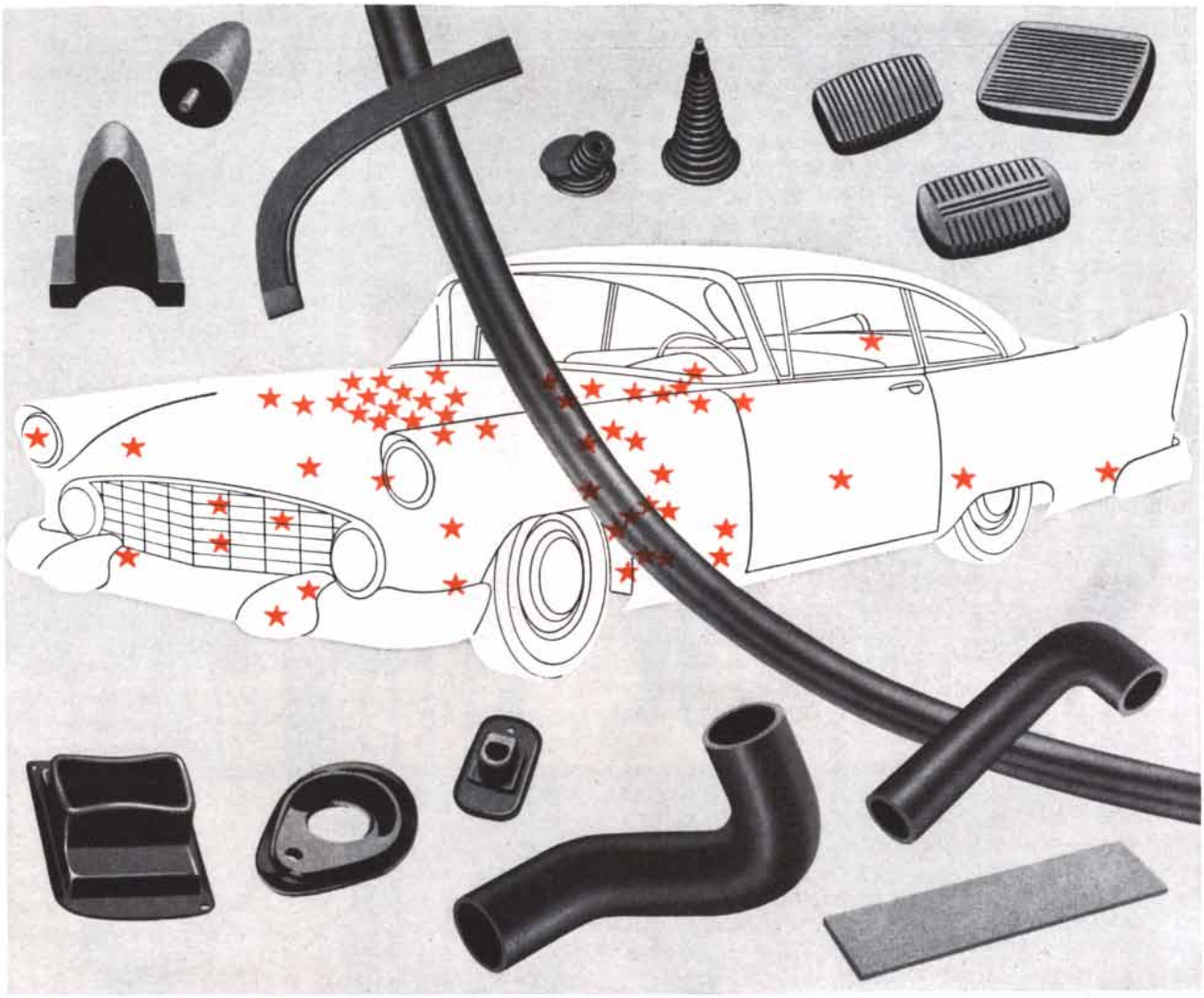
around us in the woods we heard blackbirds whistling, not their own bird songs but, unmistakably and with excellent articulation, the silbo for the names "Felipe," "Alfonso," "Frederico" and so on. In each case the bird prefixed the name with the attention-calling sound "ah," which invariably precedes a call in the silbo. Our guide told us that he had had a tame blackbird which was in the habit of whistling his daughter's name: "Ah, Maria de los Angeles"!

The silbo of La Gomera is by no means the only whistled language in the world, but it is the most explicit. Other whistled forms of communication, found in Mexico and some parts of Africa, are made up of the tones, isolated from the other elements of speech, and convey meaning by a kind of musical accent (as Chinese languages do). Generally speaking these other whistled languages are far less accurate, less explicit and more limited in power of expression than the silbo. The silbo is of great interest to a linguist because it does without what is commonly thought to be the one indispensable feature of normal speech: namely, variation of tone quality.



X-RAY PICTURE of a whistler shows a typical mouth position. This subject (who is wearing a pair of glasses) uses his fingers to depress the tip of his tongue; others employ a knuckle for this purpose or keep tip of the tongue tensed against the lower teeth.



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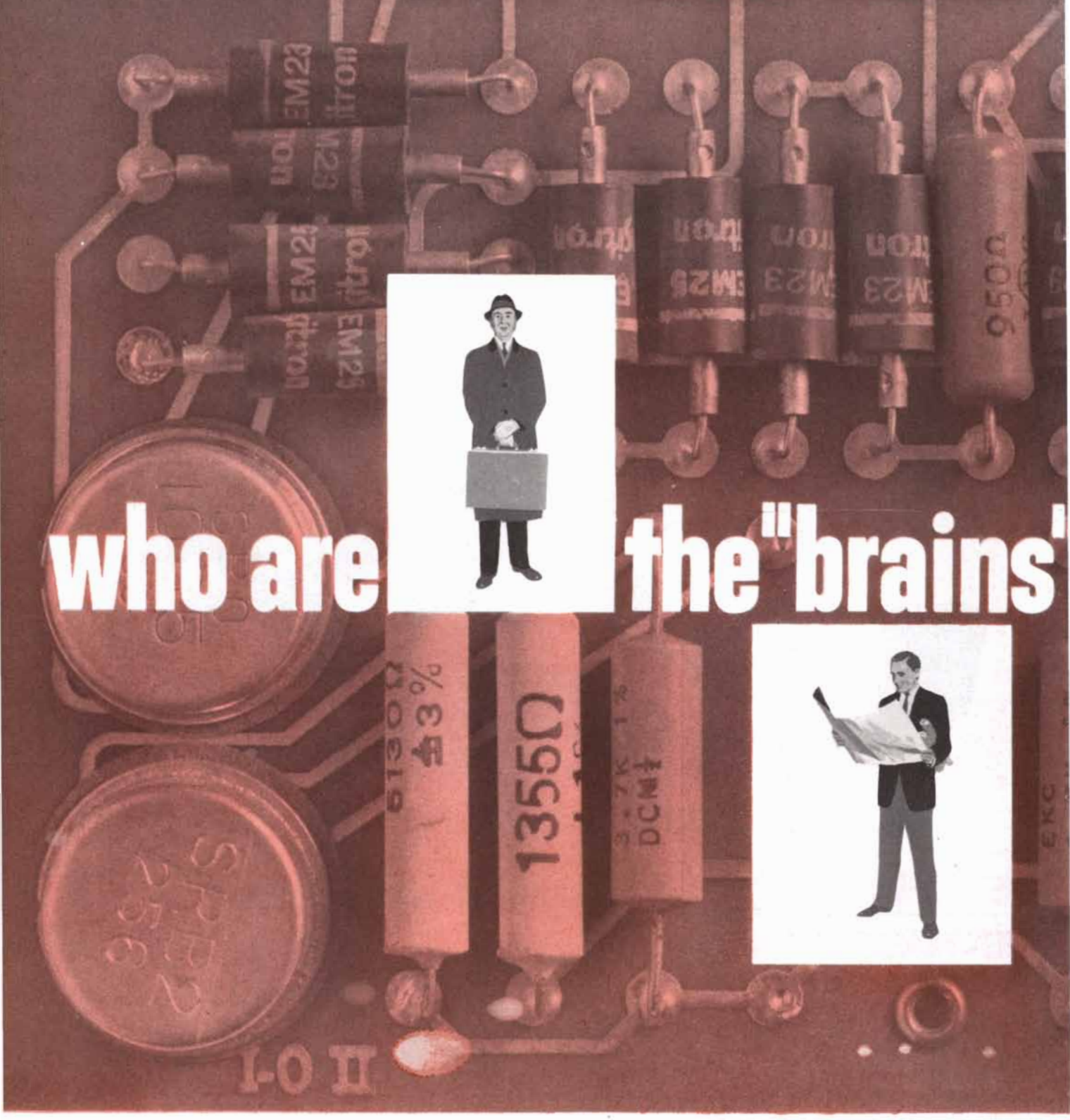

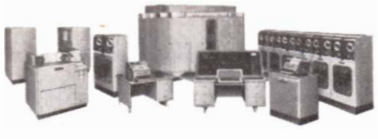

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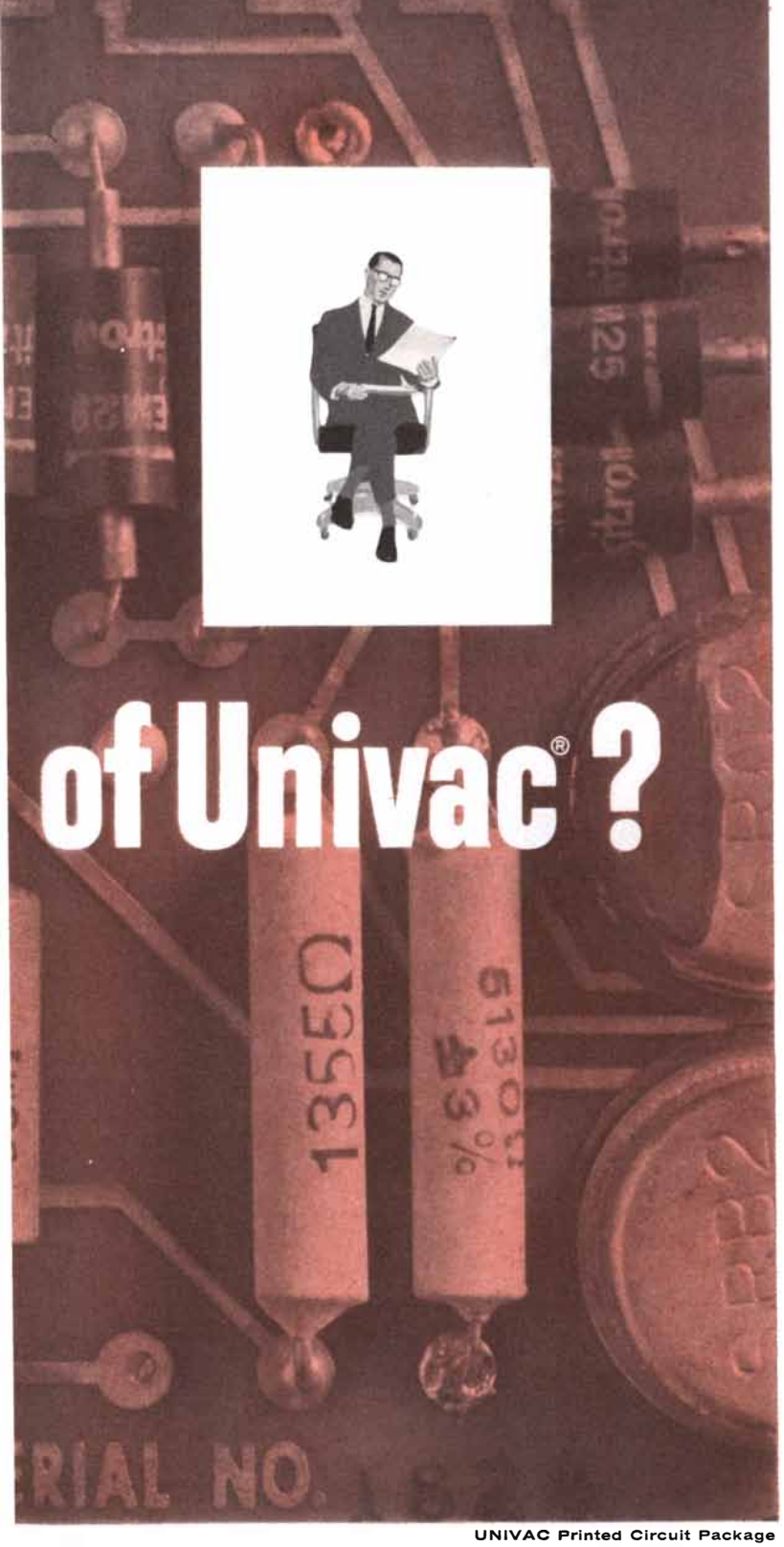

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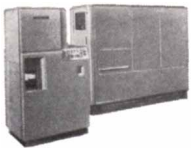

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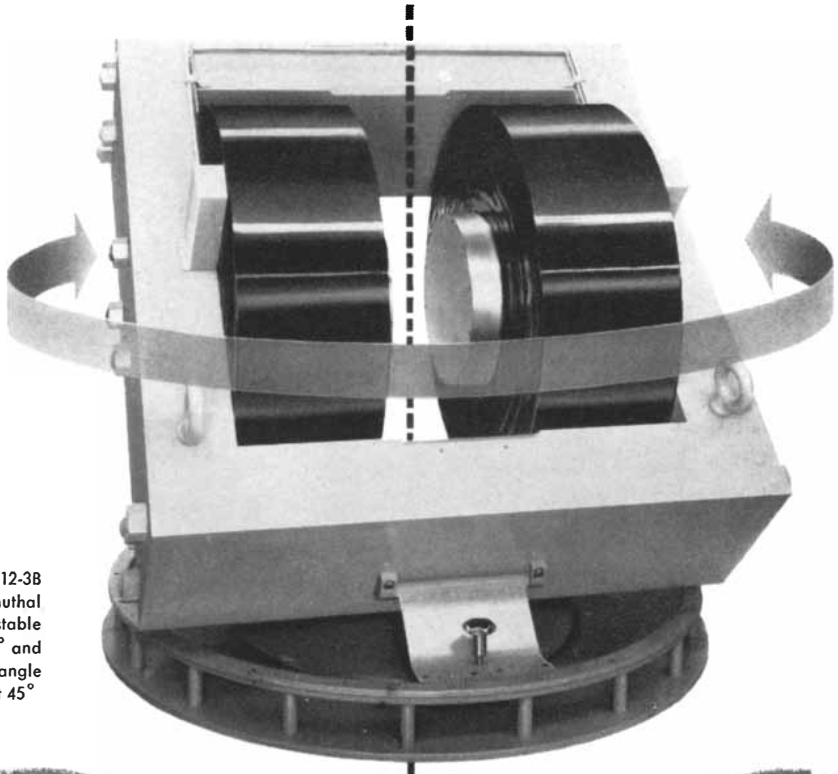

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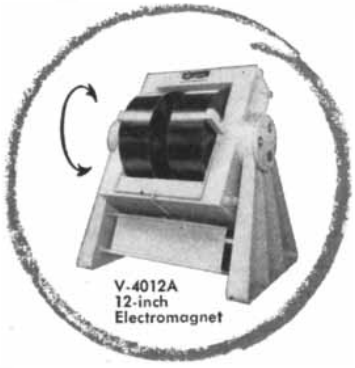

V-4012A
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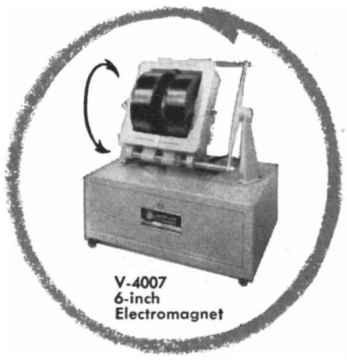

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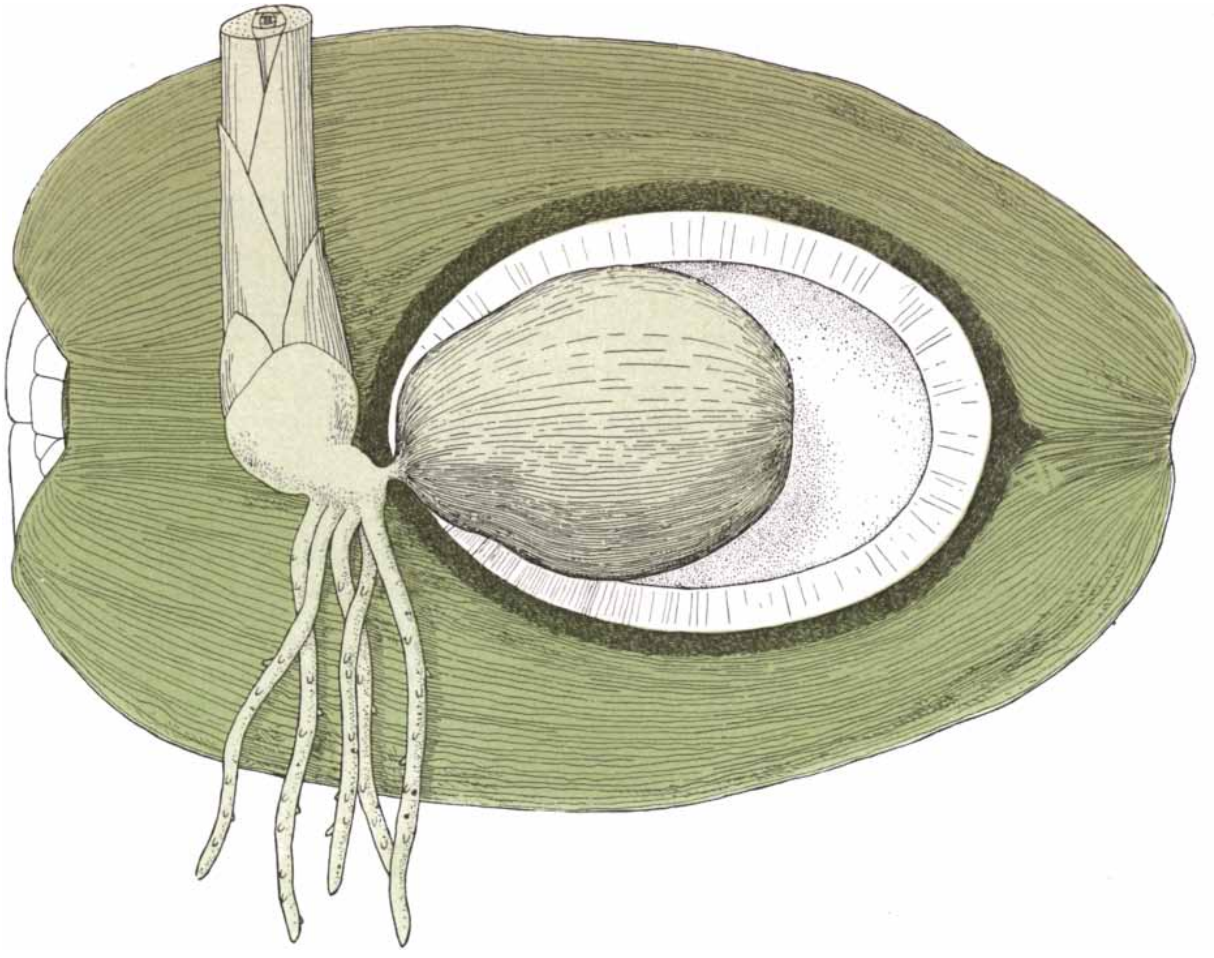
PLANT GROWTH SUBSTANCES

It has long been known that auxin stimulates the growth of plants. Now it has been discovered that some other substances do the same thing, opening up new horizons in plant physiology and agriculture

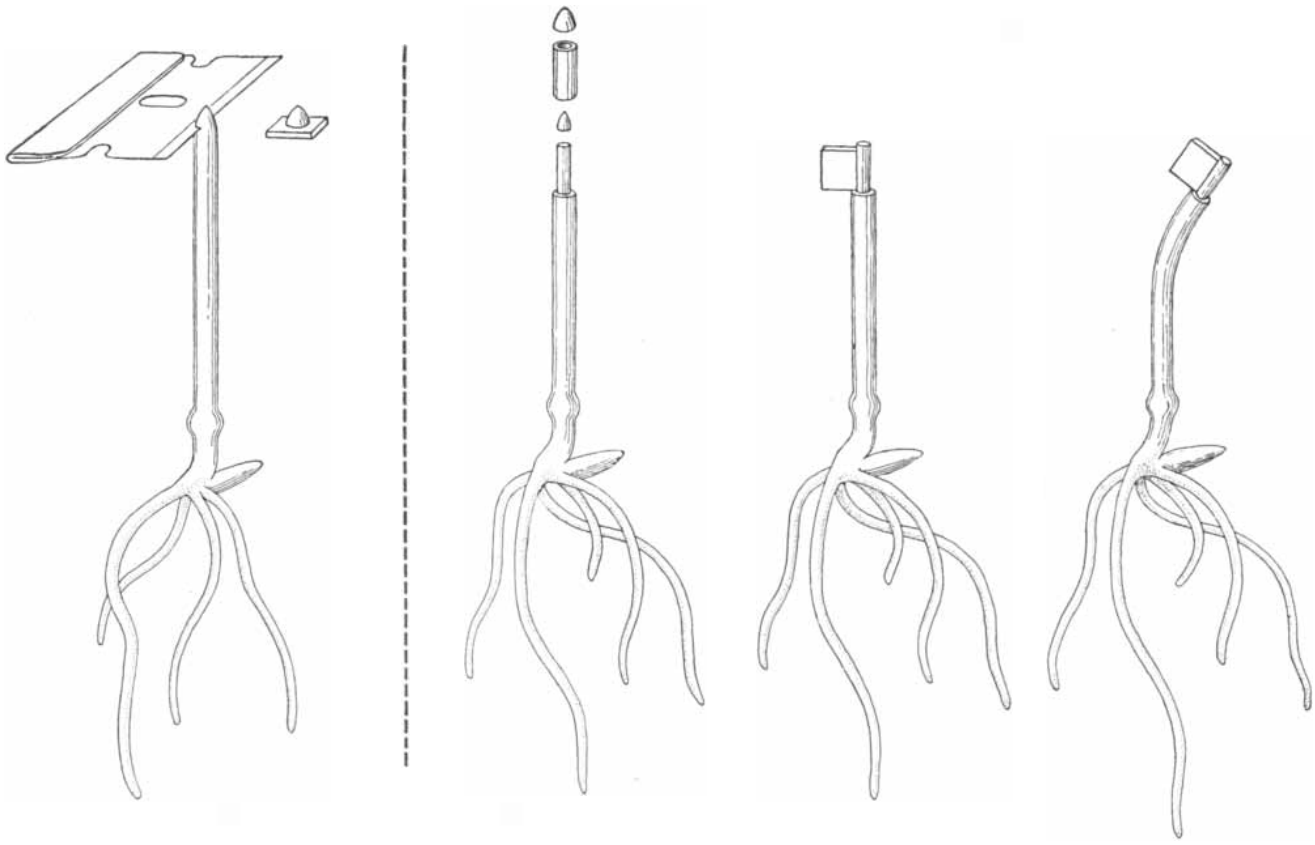
by Frank B. Salisbury

In the year 1926 a young Dutch botany student in Utrecht performed a simple but historic little experiment with oat seedlings. By day Frits Went was serving in the Dutch Army, working in the gas warfare division, but at night he would repair to his father's plant-physiology laboratory at the university to keep up his graduate studies in botany. Went and his fellow students were intensely interested in certain experimental investigations of the growth of plants that had been started by several European botanists, and they spent many a midnight hour arguing about the meaning of these curious experiments. Various tests of the effects of removing and replacing the tip of an oat seedling had indicated that the tip produced some substance which controlled growth of the sheath (coleoptile) covering the stem.

Went thought of a test which might settle the issue as to whether there really was such a substance. He cut off the tip of an oat seedling, laid it on a small block of gelatin and let the tip stand on the gelatin for several hours. Then he discarded the tip and attached the block of gelatin alone to the side of a decapitated seedling. If the hypothetical



GERMINATING COCONUT is depicted in cross section to show how its cotyledon (*pear-shaped object in center*) grows to fill the central cavity of the nut. The central cavity contains coconut milk, which has been found to stimulate the growth of other plants.



OAT-SEEDLING experiment was performed by Frits Went to demonstrate the presence of auxin. In the first drawing the tip of the seedling is cut off and placed on a block of gelatin. In the second drawing another oat seedling is prepared as shown. In the third drawing the block of gelatin on which the tip of the first seedling had rested is attached to the side of the second. In the last drawing the seedling has bent to the right, indicating that auxin which had been present in the tip of the first seedling has stimulated the growth of cells on the left side of the second. The angle at which the seedling is bent is a measure of the amount of auxin.

growth substance had diffused from the tip into the gelatin, his experiment should show an effect on the growth of the decapitated stem. And so it turned out. The side of the stem to which the gelatin was attached grew faster than the other side, so that the stem bent.

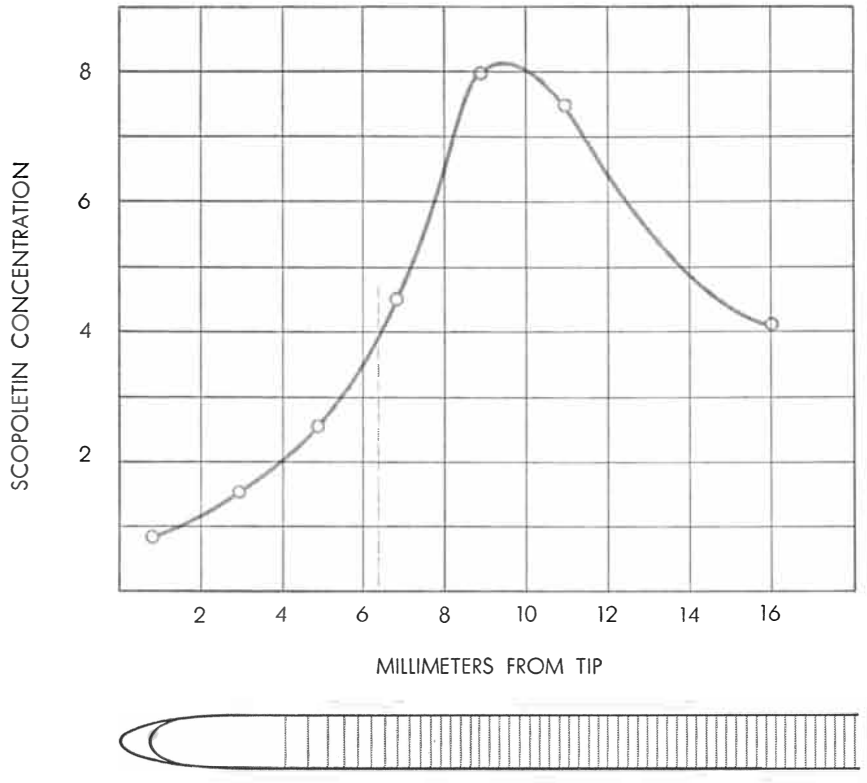
It was at 3 a.m. on the morning of April 17, 1926 that Went saw the successful result of his experiment. That moment is a milestone in the history of the study of how living things grow. Went's ingenious demonstration led to the isolation and identification of the plant growth hormones now known as auxins—substances which play a key role in the growth of roots, stems and buds; the development of fruit, and the falling of fruits and leaves. The auxins have become an immensely useful tool in plant culture, serving many purposes from the propagation of cuttings to the killing of weeds. Besides this, Went's experiments laid the foundation for most of what is now known about the mechanism of plant growth.

In 1956, just 30 years after Went's discovery of auxin, there came another milestone of a similar kind. On the afternoon of August 28, 1956, plant scientists assembled at Storrs, Conn., to hear the first collective report on exciting new developments in the investigation of plant growth. The subject of this conference, sponsored by the American Institute of Biological Sciences, was "Growth Regulators Other than Auxins." The new field opened up by the work reported at that meeting may well turn out to be even more important than the studies that grew from Went's discovery. Certainly the "growth regulators other than auxins" are going to touch the lives of all of us—not only in the classroom but on the farm and at the dinner table as well.

To show why I believe this to be true, I am going to review briefly some of the highlights of the talks given that day. Five men summarized work which is going on in many laboratories in the U. S., England, Japan and elsewhere.

F. C. Steward of Cornell University told about a group of substances which have become known as the "coconut milk factors." In most species of plants the new seedling starts its growth on food stored in the seed. In the coconut this food is contained in the milk. When a coconut germinates, the embryonic seed leaf (cotyledon) within the shell feeds on the milk and grows rapidly by cell division until it fills the cavity of the nut. In 1941 J. Van Overbeek, while working at the Cold Spring Harbor Laboratory on Long Island, discovered that coconut milk could also stimulate the growth of embryos of the Jimson weed, a member of the potato family. Steward's group at Cornell has followed up this finding and sought to identify the growth-promoting substances in coconut milk.

They found that when the milk is added to a test-tube culture of carrot tissue, it produces a remarkable speed-up of the growth and division of the carrot cells. This technique therefore provides a means of testing the activity of the various ingredients of coconut milk. Identification of the active components has been an arduous and time-consuming task. From about 660 gallons of coconut milk the Cornell workers extracted about 26 pounds of a dark, heavy syrup which they then fractionated into a number of substances, many of which were identified as amino acids or other nutrients. They have so far isolated four substances which show growth-stimulating activity. One of these has been definitely



OAT ROOT was used by R. H. Goodwin to determine the concentration in the root of scopoletin, a substance which inhibits plant growth. The root is depicted at the bottom. The closely spaced gray lines indicate the section of the root which has stopped growing. The curve shows the concentration of scopoletin at various points along the root. The broken line shows the point at which the inhibiting concentration of scopoletin is reached.

identified as diphenylurea—though urea is usually thought of as an animal product. It is the first compound of this type that has been found in a plant extract. Synthetic analogues of this compound are known, however, to be powerful weed killers—which may be more than a coincidence.

The Cornell group finds that the growth-stimulating factors in coconut milk interact in significant ways with other substances. For instance, the activity of some of them is greatly enhanced when amino acids from the milk protein casein are added to the culture. On the other hand, coconut milk is counteracted by certain other materials, including extracts from the potato tuber. Yet potato tissue itself can be made to grow on a simple culture medium if coconut milk and a small amount of the weed-killing auxin 2,4-D are added!

Steward pointed out that all this suggests the normal growth of a plant is a balance between stimulators (*e.g.*, the coconut milk factors) and inhibitors (*e.g.*, the inhibiting substances in potato tubers). As the plant matures, the inhibitors may accumulate so that cell division slows down and finally stops. The unrestrained growth of tumors in plants (and possibly in animals?) may be the result of a disturbance of the balance between stimulators and inhibitors.

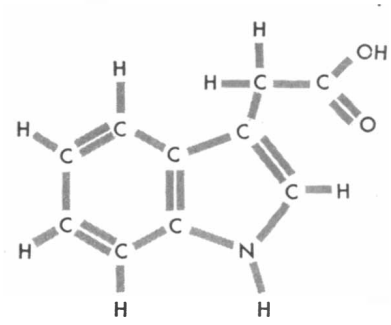
By means of the test-tube carrot culture the Cornell group has discovered growth promoters in other plants besides the coconut. They have extracted stimulating material from immature bananas, ginkgo fruit, walnuts, horse chestnuts, corn (in the milky stage) and from certain plant tumors. A stimulator in immature horse chestnuts has been identified as a colorless relative of the pigments in flower petals.

After Steward's report, R. H. Goodwin of Connecticut College reviewed the work of various laboratories on another group of plant substances known as unsaturated lactones. In contrast to the coconut factors, the lactones have long been recognized as plant substances and are well known chemically. But their significance to plant growth is just beginning to be understood.

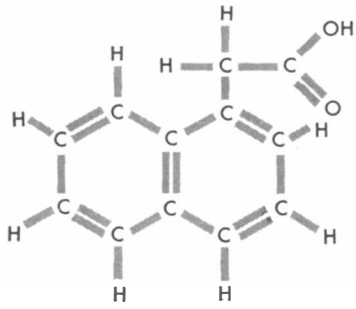
In general, they seem to be inhibitors. The effects upon root growth are especially interesting. Goodwin and his students have shown that the concentration

of certain lactones and their derivatives in some plant roots increases as the growth of the root cells decreases. A number of workers have been interested in just how the unsaturated lactones inhibit cell growth. Among other things, these lactones are known to interfere with certain enzyme systems. Since the systems in question are of a common type, the unsaturated lactones may turn out to be important in a number of phases of the growth process. This seems especially likely because they are so widely distributed in plants. One can't help but think of Steward's suggestion that growth is a balance between coconut factors and unknown inhibitors. Will those inhibitors turn out to be unsaturated lactones?

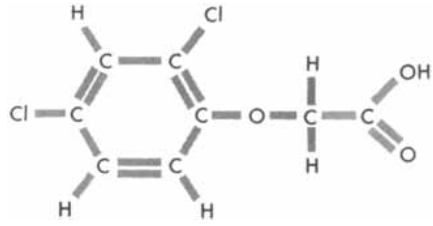
The lactones may also be highly important in plant ecology. Some of them (*e.g.*, coumarin, found in the tonka bean and certain other plants) are known to inhibit the germination of seeds, and anything that prevents seeds from sprouting must have a powerful influence on the make-up of a plant community. Went, who has been at the California Institute of Technology since 1933, has found that desert plants carry



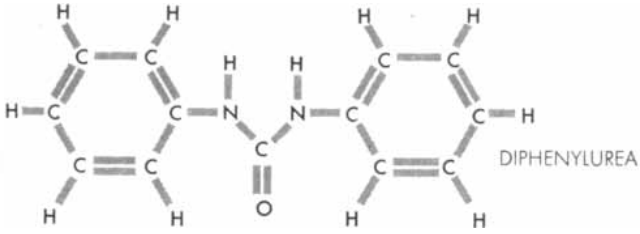
IAA



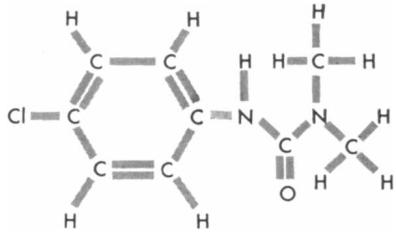
NAA



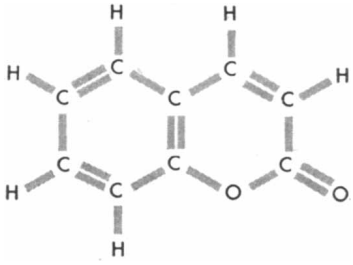
2,4-D



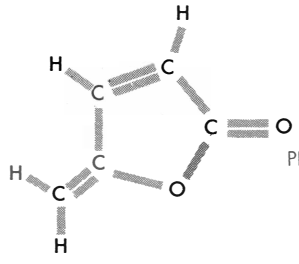
DIPHENYLUREA



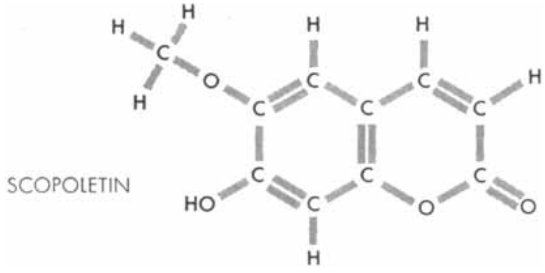
CMU (DU PONT)



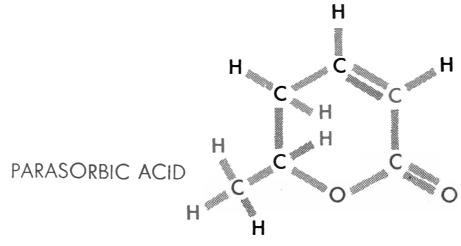
COUMARIN



PROTOÃNEMONIN



SCOPOLETIN

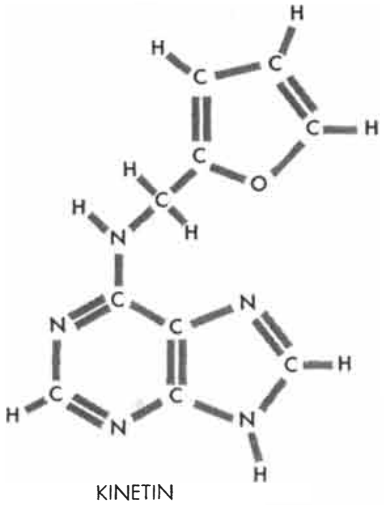


PARASORBIC ACID

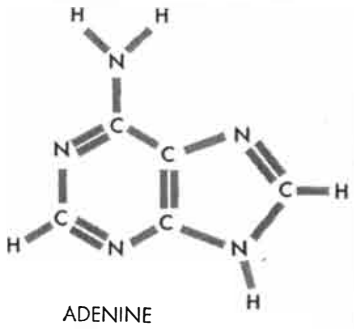
MOLECULAR STRUCTURE of various plant growth substances is depicted by these diagrams. The three structures at upper left are auxins. Indoleacetic acid (IAA) is probably the native auxin of higher plants. Alpha-naphthalenacetic acid (NAA) and 2,4-dichlorophenoxyacetic acid (2,4-D) are not found naturally in plant tissue. At certain concentrations 2,4-D is a powerful weed-killer. Diphenylurea, a substance isolated from coconut milk, is compared with CMU, a Du Pont herbicide. Coumarin, protoanemonin, scopoletin and parasorbic acid are unsaturated lactones. An unsaturated lactone has a ring structure with an oxygen atom (O)

on a continual chemical warfare by means of inhibitors against rivals [see "The Ecology of Desert Plants," by Frits W. Went; SCIENTIFIC AMERICAN, April, 1955]. James Bonner and some of his students at Cal Tech have isolated and identified compounds produced by some desert plants which are toxic to other plants. Three of these are unsaturated lactones. Thus a study of these substances might open up whole new vistas of understanding to the plant ecologist.

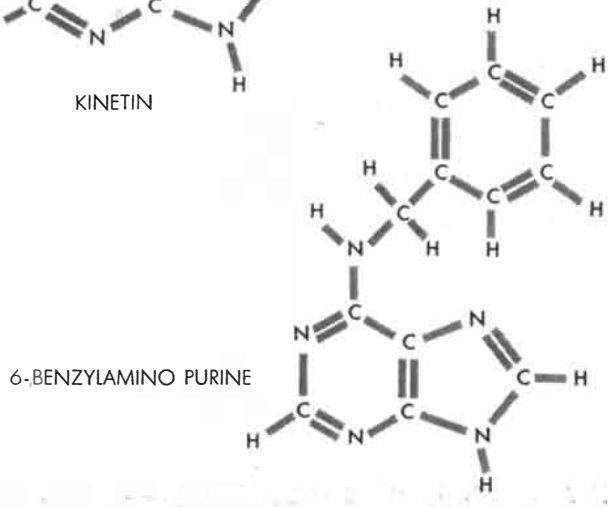
Kenneth V. Thimann of Harvard University, the chairman of the conference, next reported on work on another group of substances in which the leaders have been Folke Skoog, Carlos O. Miller and F. M. Strong of the University of Wisconsin, who were unable to attend



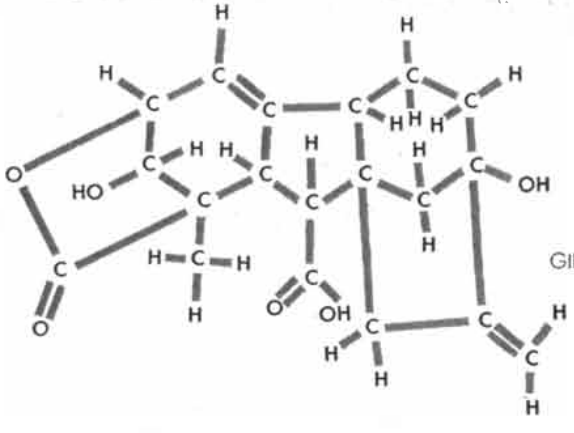
KINETIN



ADENINE



6-BENZYLAMINO PURINE



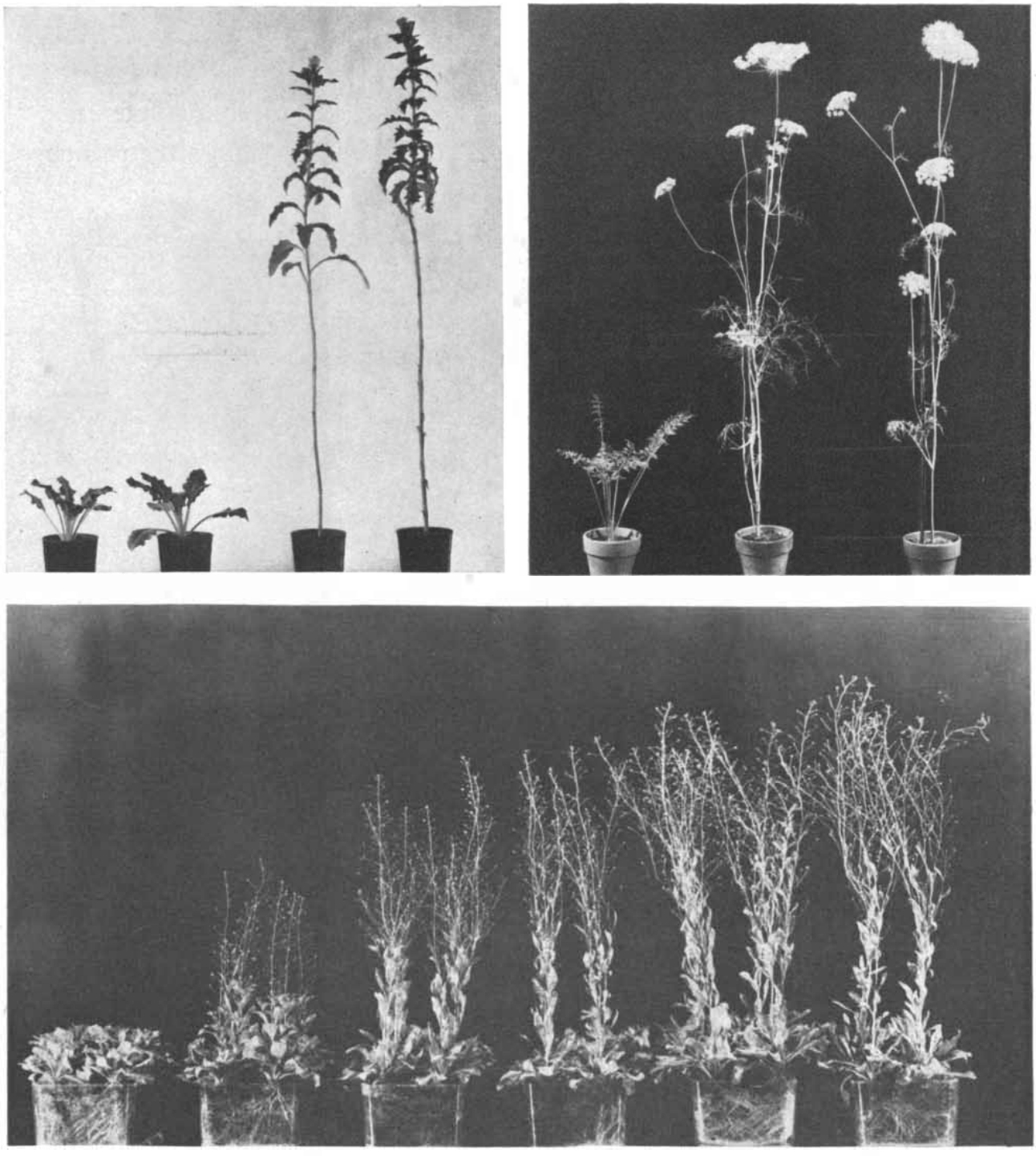
GIBBERELLIC ACID (TENTATIVE)

in the ring, another oxygen atom attached to the carbon atom (C) next to the ring oxygen, and a double chemical bond (*double lines*) between the two carbon atoms next to the carbon attached to the two oxygens. Protoanemonin slows root growth. Parasorbic acid inhibits germination. Kinetin and 6-benzylamino purine cause tobacco pith cells to divide. The structure of gibberellic acid has been proposed by J. F. Grove and his associates.

the symposium. The principal substance in this group is a compound called kinetin, which is a derivative of adenine, one of the building blocks of the nucleic acids, the vitally important components of all cells. The Wisconsin group has found that kinetin will stimulate cells of the tobacco plant to divide in a culture in which they would not do so otherwise.

Kinetin has been extracted from the sperm of the herring and from other organisms. A substance with similar activity has been found in yeast extract and other plant products. Various other adenine derivatives active in causing cell division have been synthesized.

Kinetin or its relatives will cause a tobacco stem grown on a culture medium to form a greatly increased number of buds. There is an interplay between auxin and kinetin: the more auxin in the culture medium, the more roots are formed; the more kinetin, the more buds. Kinetin and its relatives will promote ex-



GIBBERELLIC ACID produced these effects in experimental plants. At upper left are four henbane plants, which require a period of cold and long days to flower. The two henbane plants at the right flowered without these conditions after treatment with gibberellic acid. At upper right are three carrot plants, which require a cold period to flower. The two carrot plants at the right were treated with gibberellic acid. At the bottom are six primrose plants, which require long days to flower. The first plant is untreated; the second plant was treated with gibberellic acid; the remaining plants, with increasing amounts of the growth substance.

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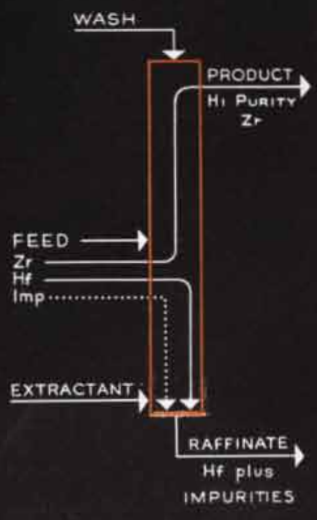

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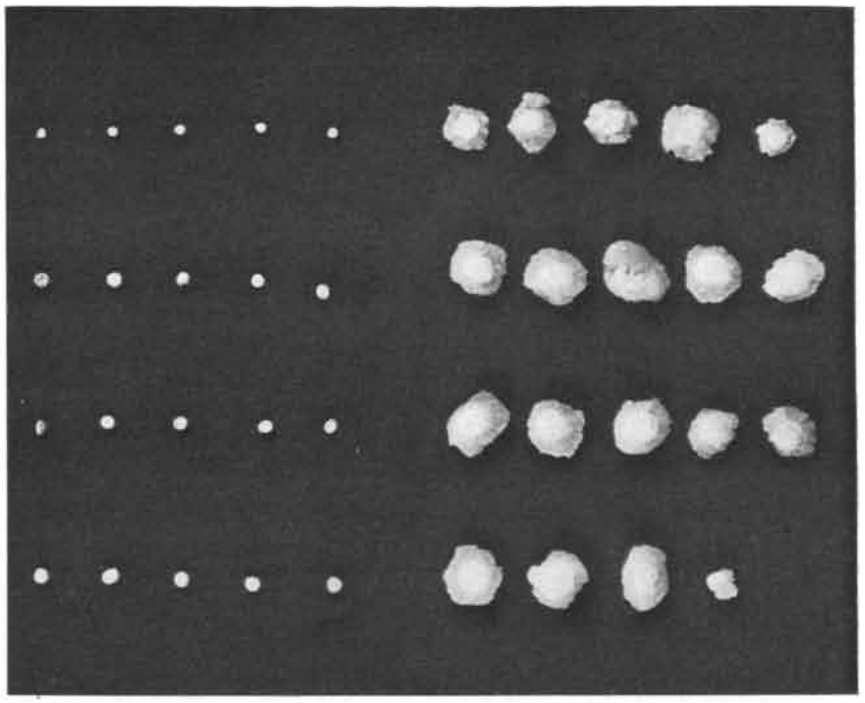

COCONUT MILK stimulated the growth of bits of carrot tissue implanted on a culture medium. The five bits of tissue in the horizontal row at upper left were implanted on a medium containing the auxin indoleacetic acid. The five bits of tissue in the row at upper right were implanted on the same medium to which coconut milk had been added. The bits of tissue in the second row were grown on a medium containing more indoleacetic acid; the bits in the third and fourth rows, on mediums containing still more of the auxin.

pansion of leaf disks and germination of lettuce seed. Further, kinetin and auxin will imitate exactly the effects of certain bacteria in producing plant tumors.

Very likely many problems of both normal and abnormal plant growth will be illuminated by future work with kinetin. Among other things, it may tell a great deal about why plants take the shapes they do.

Probably the report that many of us at the symposium looked forward to most eagerly was the one on the gibberellins. F. H. Stodola, a chemist at the Northern Regional Research Laboratory in Illinois, reviewed the history of the gibberellin research and told about recent work on their chemistry.

It is a striking commentary on the poverty of international communication that the Western world has only just begun to pay attention to these important substances, although they were discovered in Japan as early as 1926—even before Went's discovery of the auxins! The Japanese knew that a fungus, *Gibberella fujikuroi*, caused a disease of rice, called "foolish seedling" disease because it made young rice plants grow ridiculously tall. A plant pathologist found that extracts of the fungus could produce the disease, and, after 12 years of concerted effort, workers at the University of Tokyo isolated an active substance which they named gibberellin A. By the time of Pearl Harbor the Japanese had published seven papers on the substance, and six of these had been abstracted in the U. S. Twelve more Japanese papers appeared during the war. Yet it was not until 1950 that anyone outside Japan began to study gibberellin. Among the first were Stodola and his group in Illinois and P. W. Brian and his associates at the Imperial Chemical Industries in England. Since 1955 U. S. interest in the gibberellins has risen to a feverish high.

At least three gibberellins have now been isolated from the culture liquor of the fungus. All of these are acids with a complex structure [*see formula on page 129*]. It is interesting to note that part of the structure is that of a lactone, which makes the gibberellins technically members of the lactone group.

Plant physiologists have been eagerly investigating the growth-regulating properties of these compounds. B. O. Phinney of the University of California at Los Angeles was chosen to tell the symposium about some of this work. The gibberellins have been applied to a large number of plants, and have produced quite a variety of responses. The most consistent and striking response is a

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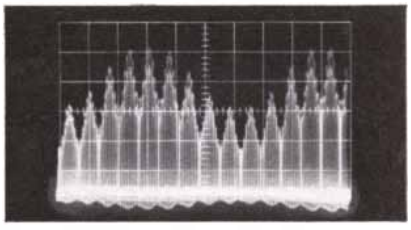

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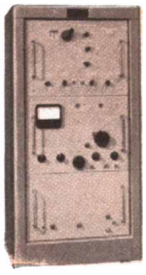

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Taming Rocket Powerplants

by Walter O. Borcherdt

In charge of the Engineering Development Laboratory as well as the Valves and Controls Section at RMI, Mr. Borcherdt has over a decade of rocket experience. Before coming to RMI in 1951, he was senior project engineer on controls in the rocket department of Curtiss-Wright Corporation. Mr. Borcherdt received his degree in mechanical engineering from Stevens Institute of Technology in 1938.

Reliability of a rocket powerplant is the direct result of the simultaneously correct operation of all of its elements. Generally, this is assured by overcoming each element's own peculiar development problems. Among these elements is one type which has the interesting property of being composed of specific components, yet whose operational characteristics are significant only in the performance of the entire powerplant system. This element is the control system.

Present powerplant controls requirements are based on these straightforward, simple considerations:

1. Prepare the powerplant for firing
2. Sequence and control the system to rated thrust
3. Vary thrust rapidly and safely as required
4. Shut down smoothly

Step one may require the use of gas pressure regulators and relief valves to push the propellants safely from tankage to pumps. There must be switches and relays to indicate or control the valves which admit propellants to the gas generators and combustion chambers, and time delay cutouts to insure against unsafe accumulation of propellants.

In step two, ignition and combustion may be monitored to insure correct use of the high energy release rates. Turbines may be safely brought up to speed by throttling the propellants. Safety devices may be added to limit over-speed and avoid the danger of structural failure.

In step three, a controller (it may be hydraulic, electric, pneumatic, or a combination) is used to vary thrust. Here multiple loop servo systems are sometimes used to insure that thrust change rates, turbine speeds, vehicle acceleration or terminal velocity, and other parameters vary in a coordinated manner.

Finally, in multiple stage powerplants or piloted vehicles, the rocket engine must be shut down safely and the system automatically purged of propellant accumulations.

The successful implementation of these four steps involves the application of many devices of unique characteristics whose individual selection is intimately tied to the following question:

"What is the actual control system problem to be solved?"

Once this question is clearly and consistently defined, a tight performance envelope results. This makes the few possible solutions fairly obvious. The final stage is to apply the knowledge of a team of control specialists and proceed through the usual component development stages. At RMI, this team of specialists in controls engineering is made up of highly qualified mechanical, electrical and chemical engineers. These professional men have wide experience in the creation of control units and systems for rocket powerplants as well as other types of propulsion systems. However, there is a continuing need for qualified graduate engineers, able to participate in working closely with other groups of specialists, integrating the control system into the overall engine performance envelope.

The systems approach is of extreme importance to successful rocket powerplant control efforts. It is a standard approach of the RMI Controls Section. Sequence system design, switching circuit analysis, human engineering, feedback control methods, statistical procedures, information theory and latest research data on fluid flow control are among the techniques used. They are applied along with practical design concepts which result in the development of simple but effective controls systems.

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

marked elongation of the plant's stems. In citrus trees gibberellin causes the stems to lengthen more than sixfold! In a survey of 42 plant species, including grasses, trees, beets, beans, peanuts and so on, only three—the white pine, the onion and the gladiolus—failed to respond by stem elongation.

The gibberellins have a very interesting effect upon some dwarf plants. Brian has found that they cause a dwarf ("bush") pea to grow as tall as a "pole" pea plant, and Phinney has made five out of nine dwarf mutants of corn grow to normal height by treatment with gibberellin. Eleven other growth stimulators, including auxin, failed in this test. Is it possible that normal corn or peas produce gibberellin or gibberellin-like substances? There is now reason to believe that they may, for the U.C.L.A. workers have discovered that the five dwarf mutants of corn can be stimulated to grow to normal height by extracts taken from young seeds of a number of different plants.

So it appears that great things await plant physiologists as they begin to examine the substances discussed above. The auxins alone have kept students of plant growth busy for 30 years. Now there are four new groups of growth substances to explore—though it seems possible that the four may merge into a smaller number, for the coconut factors resemble kinetin in action, and the gibberellins appear related to the unsaturated lactones in chemistry.

It seems significant that within each group of compounds the individual members display considerable variation in behavior. These variations may be important. Physiologists have hitherto emphasized the similarities in basic processes (*e.g.*, respiration) among all living organisms, but it is time to ask the question: How do species of plants and animals *differ* in their physiological functions? Concrete, meaningful answers may be forthcoming from studies of the plant-growth regulators. The stimulating factors obtained from horse chestnuts seem to be clearly different from those obtained from coconuts. How many of the higher plants have gibberellin-like substances? In what amounts and to what ends? These are new and exciting questions.

All the textbook notions of plant growth will have to be re-examined in the light of the new research. Some of them will stand and some will fall. Fascinating new problems beckon. Will this new understanding of normal growth help us to solve the problem of cancer?

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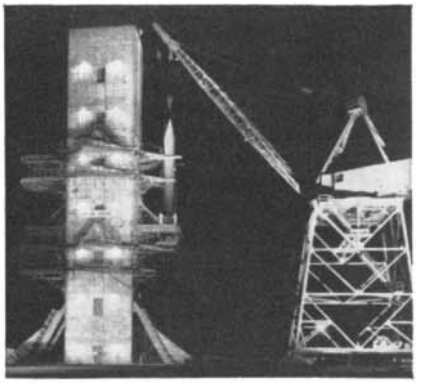

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Sun Clouds and Rain Clouds

Once a month, on the average, the earth intercepts a mighty swarm of corpuscles ejected by the sun. There is new evidence that these corpuscles, impinging on the earth's atmosphere, affect the weather

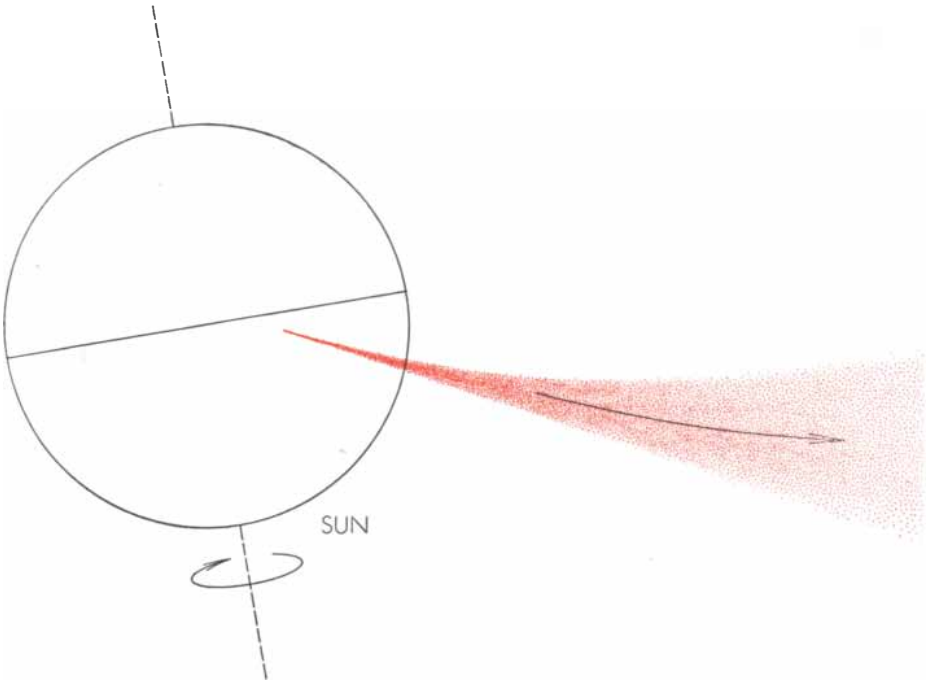
by Walter Orr Roberts

On January 21 the earth, sailing through space in its orbit around the sun, ran into a great cloud of electrified particles that had been blasted out of the sun. Most of the world's population went about its day's business unaware of the event. But in the Arctic the northern lights put on a brilliant show; radar operators in northern regions saw brilliant blobs on their fluorescent screens; workers at magnetic observatories found that their delicate compasses quivered erratically for a day or two, and radio operators on both sides of the Atlantic had trouble transmitting their messages for some hours.

Collisions of the earth with clouds of corpuscles from the sun are not unusual: on the average we encounter such a cloud about once a month. But they have recently taken on a new interest because of evidence that the corpuscular blasts have an impact on our weather. Students of the phenomenon are now hopeful of interpreting it to improve weather forecasting and perhaps to predict weather trends over the earth for months or even years ahead.

Astronomers have tried for many years to understand these electrified solar clouds and their earth effects. In 1896 a Norwegian observer, Olaf K. Birkeland, first suggested that such clouds, attacking our atmosphere, were responsible for the mysterious auroras. Later Sydney Chapman of the University of Oxford and others traced fluctuations of the magnetism of the earth to these clouds. And about a decade ago Richard A. Craig, a young astronomer-turned-meteorologist who was working for the Air Force Research Center in Cambridge, Mass., looked into the possibility that they might affect the weather. With painstaking care he examined barometer readings at points scattered over the entire Northern Hemisphere to see whether magnetic storms produced pressure changes. His results looked promising. Meanwhile Harry Wexler of the U. S. Weather Bureau and others were trying to find a connection between year-to-year variations in the sun's activity and world-wide weather patterns. However, the pieces of the jigsaw could not be fitted together in any consistent way.

In the spring of 1953 came new clues. That spring the sun emitted a series of unusually strong and well-defined



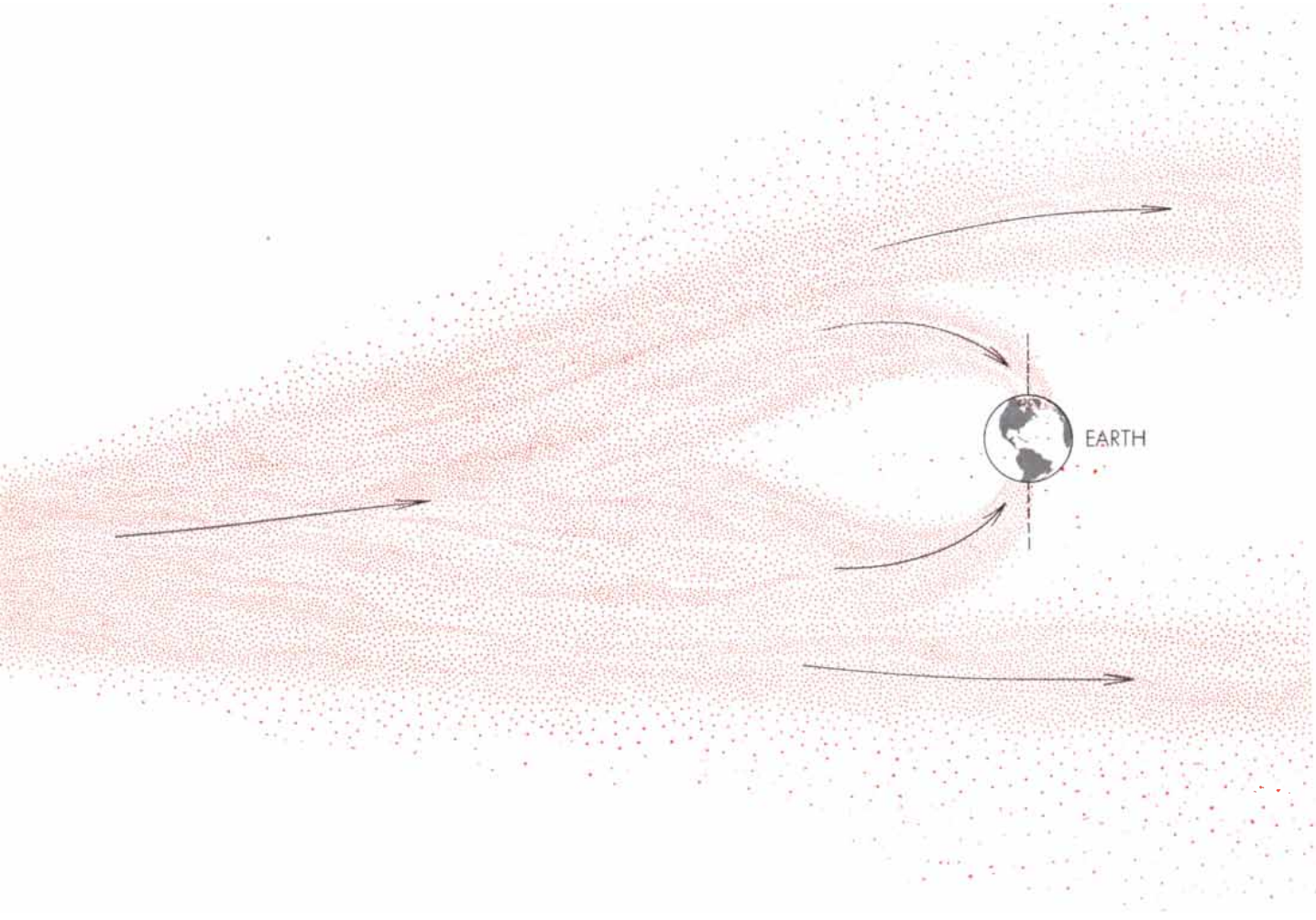
STREAM OF CORPUSCLES (*colored dots*) expelled by the sun is intercepted by the earth. Because the corpuscles are electrically charged, their paths are bent by the earth's

corpuscular clouds. Great streams of solar particles gushed from the sun like water from a giant hose, spraying the earth every 27 days as the sun turned in space. Late in the spring I talked at some length with Ralph Shapiro, a Cambridge colleague of Craig, about the possible weather effects of the clouds. It seemed to both of us an ideal occasion to investigate such effects. A few weeks later Shapiro wrote me about a baffling turn of events which provided a handle for the investigation. The Cambridge Research Center was experimenting with an electronic weather-forecasting machine. Forecasts by the computer were based on orderly trends in weather patterns. But every once in a while the forecast was thrown off by a sudden "bust" in the persistence of the trends. Shapiro noticed that these busts seemed to follow about two weeks after a corpuscular cloud from the sun swept the earth.

He made a systematic survey of weather patterns over North America (a region, by the way, of unusually complex and variable weather) and discovered that the persistence of trends broke down noticeably about 10 to 14 days after the earth's encounter with a corpuscular cloud. Three years of hard work on more than 40 years of weather records have now established convincingly that the sudden breaks (*i.e.*, large-scale changes in the weather picture) are related to the solar corpuscular streams. We have no guide yet for predicting which way the weather will jump after an encounter with a solar cloud. Moreover, these encounters do not always lead to weather changes, so we cannot be sure that something will happen in any specific instance. Scientists must not, however, be too impatient in attempting to force secrets from nature; they are intricately woven, or else they would have been unraveled long ago.

In mid-April of 1955 I spent a morning with Henry T. Harrison, director of meteorology for United Air Lines. We looked at weather maps of the dust bowl area in the Southwest for the first few months of 1955 to see if there was any relationship between solar outbreaks and the occasional periods of scattered rainfall. To our delight we found a pattern in Colorado which fitted Shapiro's work perfectly. Thirteen days after each of the four largest sun-cloud collisions with the earth, there was a sudden break in the drought pattern, and rain or snow fell for a few days in eastern Colorado.

On the 27th of April came a powerful, abrupt, magnetic storm from a solar corpuscular cloud. I called Harrison and predicted that, according to our previous experience, we could expect a sudden break in the normal westerly wind flow, and rainfall, on the 10th of May. The next few days were nervous ones for me. The weather grew hotter and the westerly winds stronger. While we were waiting I happened to receive a letter from a scientific rancher of Greeley, Col., asking what the prospects were for a break in the drought. Our research was too speculative for me to dare tell him my

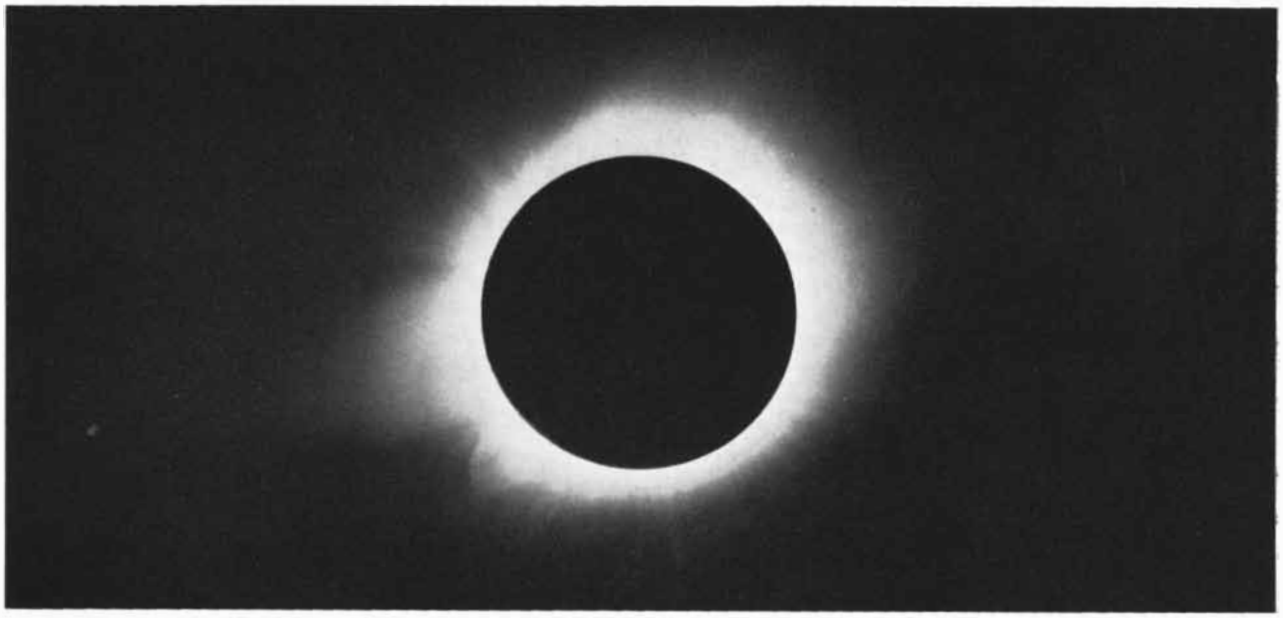


magnetic field. Thus they tend to plunge into the earth's atmosphere over the magnetic poles. In this drawing the earth and the sun are seen along the plane of the earth's orbit around the sun. The two bodies and the distance between them are not represented in scale.

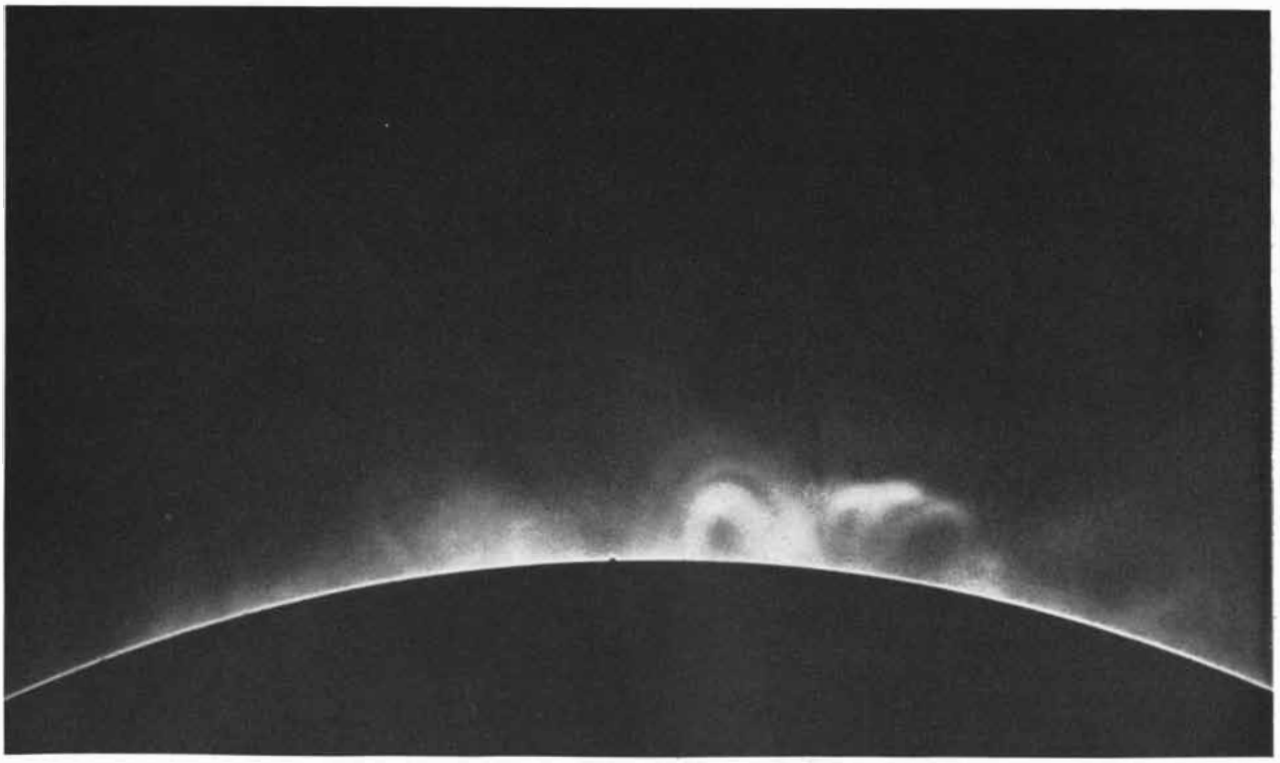
prediction. I merely ventured to say that we should have rain before too long (a drought always ends sooner or later!). And I sweated it out.

The weekend of the 7th and 8th of May there was still no sign of rain. The Denver area had been rainless for 24 straight days. On the morning of the 9th the weather forecasts still predicted no break. But by the time the late afternoon papers of May 9 hit the Denver streets, showers had begun. By 8 p.m. there was a great wind change. The west wind diminished, and cold polar air flowing southward along the east side of the Rockies met warm, moisture-laden air from the Gulf of Mexico. The result—a soaking rain which got under way during the night and fell heavily all day on the 10th of May, as predicted.

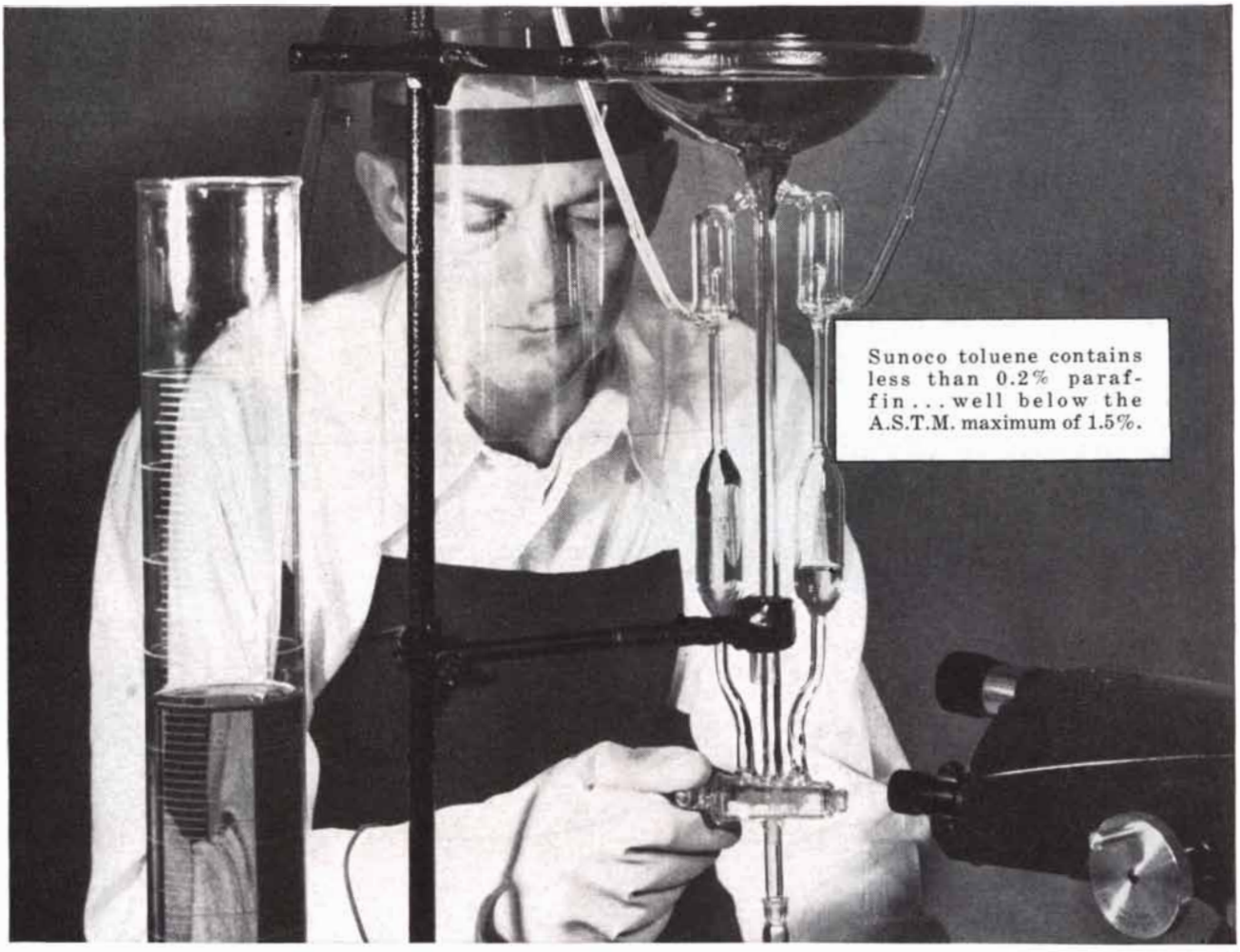
As every meteorologist knows to his sorrow, one correct forecast does not prove a method. Long, painstaking



CORPUSCLES ejected by the sun are revealed by this photograph of the solar corona, made in the Sudan during the total eclipse of 1952. The light recorded in the photograph is due to the radiation of free electrons associated with clouds of electrons and protons.



X-RAYS AND FAR ULTRAVIOLET radiation emitted by the sun may be associated with solar outbursts such as these coronal arches. The light recorded in this photograph is due not to electrons but to the green spectral line of the corona. The photograph was made with the coronagraph at the Sacramento Peak Observatory in New Mexico. The coronagraph artificially eclipses the disk of the sun.



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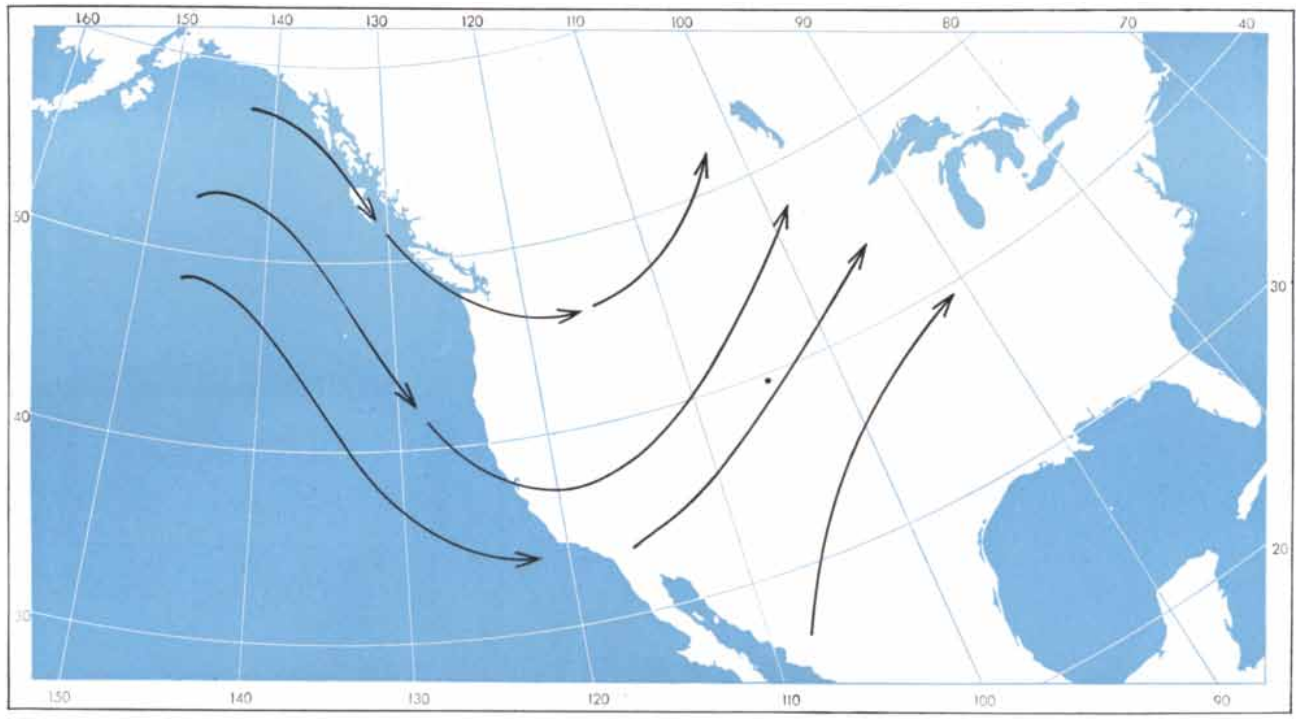
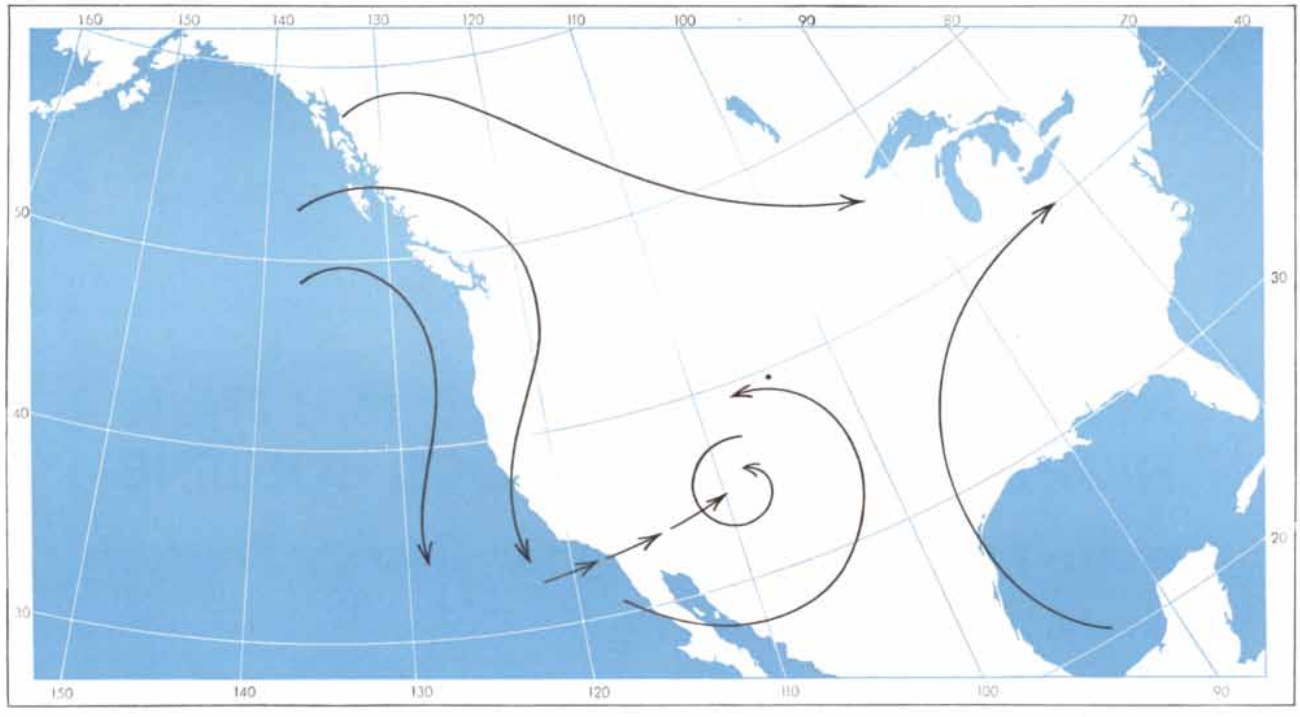
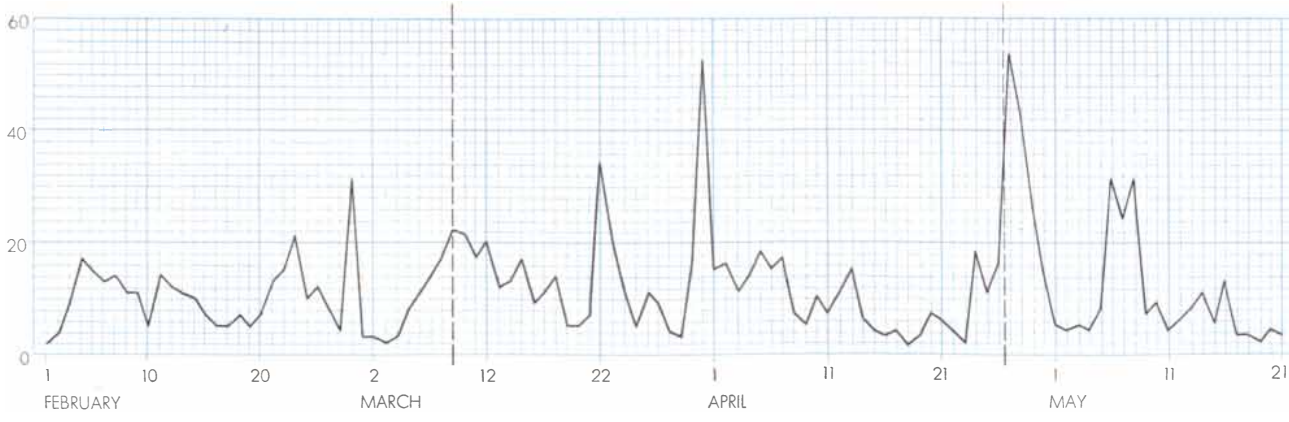






research must still be done on the corpuscular-cloud theory, and the final story will certainly not be simple. It will clearly be necessary to take into account the state of the upper and lower atmosphere before the corpuscular cloud hits, in order to be able to predict what, if anything, will happen to the weather. But one thing is sure: we have in Shapiro's work an important and specific clue which ties certain weather changes to activity on the sun. I, for one, am convinced that this is an important subject for intensive research.

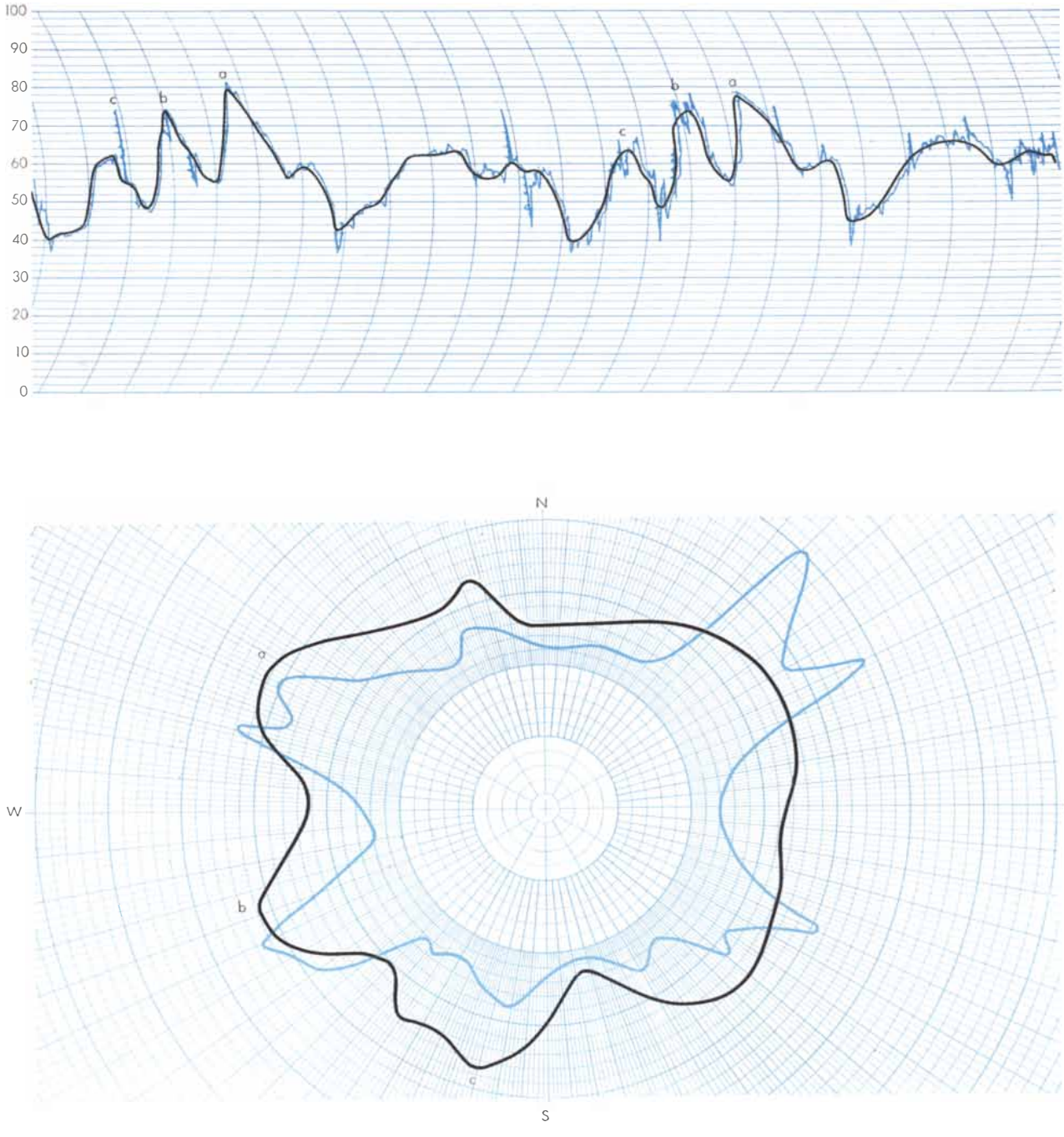
E. D. Farthing, a meteorologist with Trans World Airlines, has been investigating another possible influence of the sun on our weather. His interest is the corona—the luminous halo that surrounds the brilliant face of the sun. Thanks to coronagraphs such as ours at Climax, Col., the corona can now be studied and measured from day to day, and its earth-effects evaluated. Farthing, studying weather maps for the Kansas City area, found that the thermometer usually drops sharply when regions of the corona giving forth powerful emissions cross the center of the sun's face. His observations cover only a comparatively short period (two years) and are difficult to explain, but they are linked in tantalizing fashion to other suspected effects of the sun on weather.

The strong emissions from the corona are believed to be associated with X-rays and ultraviolet rays. In some way these radiations may strengthen our worldwide patterns of wind flow. The powerful X-rays and ultraviolet rays, fortunately for us, are stopped 50 to 100 miles above the earth's surface by our shielding atmosphere. But perhaps the satellite rockets soon to be launched will help us to test our speculations about these radiations. They will be able to circle the earth far above the protective shield,

SUDDEN BREAK in the trend of the weather came 12 days after a magnetic storm due to a solar corpuscular cloud on April 27, 1955. The map at the top of the opposite page shows the pattern of high-altitude winds over the western U. S. from April 27 to May 5. The map in the middle shows the pattern of winds from May 5 to May 10. On May 9 it rained in Denver (*dot*) because of a "cut-off" (*short arrows*) which deviated from the pattern. The curve at the bottom shows the rise and fall of an index of disturbance in the earth's magnetic field. The tall peak to the right is the magnetic storm of April 27. The broken lines indicate the sudden commencement of magnetic storms.

carrying instruments to record the day-to-day X-ray and ultraviolet changes as the sun's corona changes. The data obtained may well bring long-sought answers to important questions of upper atmosphere physics as well as long-range weather forecasting.

Various other theories about the weather effects of solar changes are under study. One is that solar outbursts cause our high-level wind systems to change their strength and direction. Another is that solar activity may influence the direction of hurricanes. Long remembered will be the hurricanes that ripped the East Coast of the U. S. in the fall of 1954 and of 1955, causing frightful damage. These particular series of storms veered west of the usual course of hurricanes as they swept northward from Florida, so that they came over the coast



BRIGHTNESS OF CORONA due to corpuscles is traced in the curve at the top, which was recorded by Gordon A. Newkirk with the coronameter at the High Altitude Observatory of the University of Colorado (*see drawing on next page*). By means of such recordings it is possible to plot the actual outline of the corona (*bottom*). The corona due to the electrons among the corpuscles is outlined in black. The corona traced by the green spectral line, which was separately measured with a coronagraph, is outlined in color.

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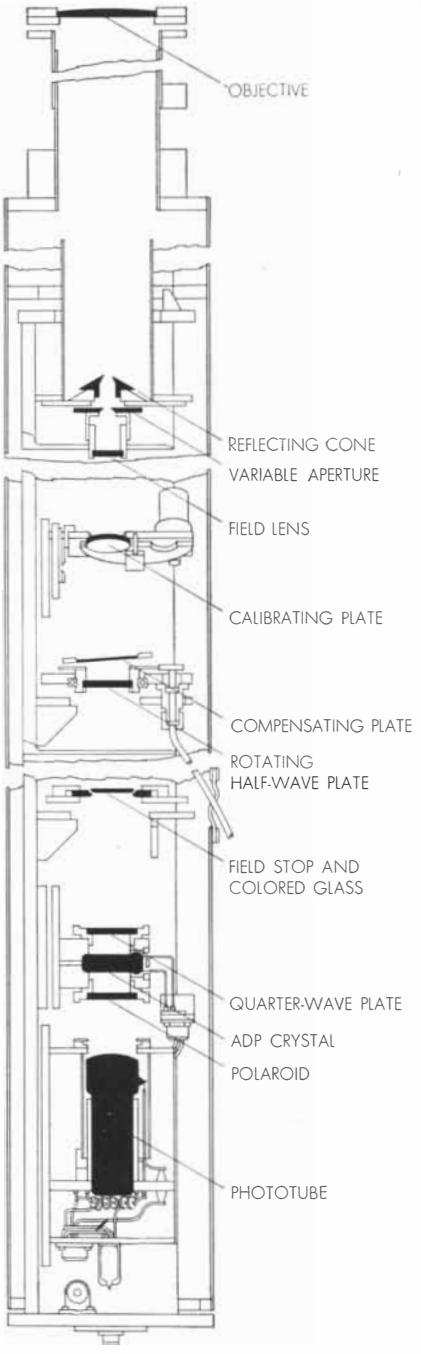
instead of blowing out to sea. Moreover, most of them, unlike usual East Coast hurricanes, intensified as they moved north. Why this unusual behavior? Jerome Namias of the Weather Bureau says that during the seasons in question the coastal low-pressure troughs were farther west than usual and drew the



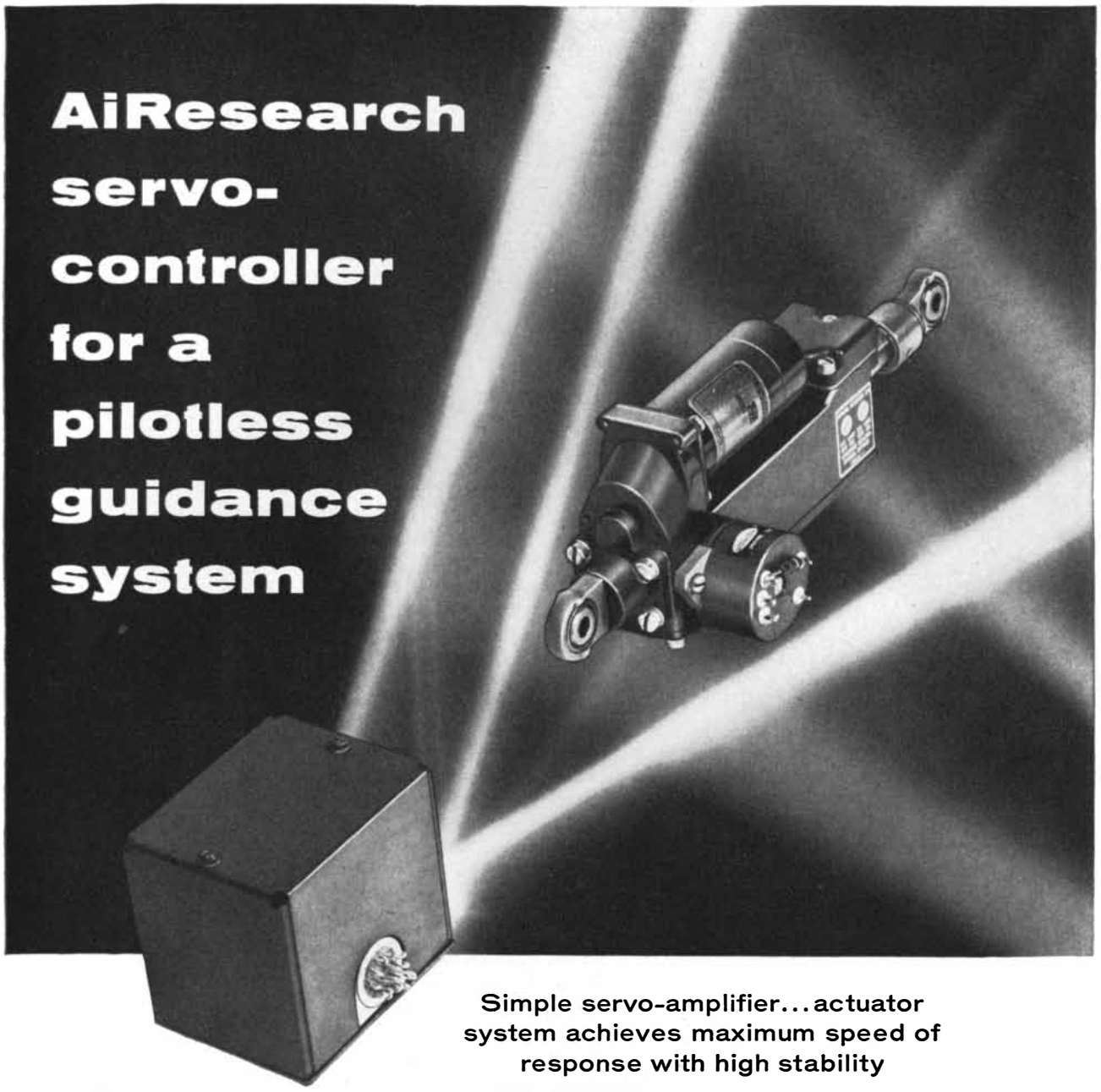
CORONAMETER of the High Altitude Observatory is shown in cross section. The reflecting cone and various filters serve to suppress the light of the sun's disk so that the much fainter light of the corona may be observed. Where the coronagraph makes direct photographs of the corona, the coronameter measures the brightness of the corona.

hurricanes inshore. Perhaps the sun was to blame. Its activity was at an extraordinarily low ebb in these years. An educated guess is that a deficiency of energy high in the earth's atmosphere (where the sun's invisible radiations are concentrated) was somehow responsible for deflection of the pressure trough. If the guess is right, conditions should change in the years immediately ahead, and the East Coast should be spared a repetition of these frequent damaging storms.

H. C. Willett of the Massachusetts Institute of Technology believes that long-term changes in solar activity are responsible for prolonged droughts. Our western prairies were once a desert, and some climatologists believe that during three out of four centuries for the past 2,000 years they have been drier than now. Meteorologists have noticed that sometimes storms in North America tend to follow a northerly path, leaving the "dust bowl" dry, hot and windy while great sections of Canada feel the change in colder and wetter weather. These anomalies persist for months or even years. Willett has collected a number of self-consistent clues, all of which point to solar changes as the cause of such long-term trends. He admits that singly these clues fall far short of being conclusive, but insists, and I agree with him, that in the aggregate they form a pretty strong case. He expects that further research will make it possible to predict rainfall and temperature trends over large areas and long periods. Long-range drought forecasts, if he is right, are in the offing, because the sun has long-term trends which the solar specialist can foretell. Willett predicts, by the way, a return to colder and stormier winters in the decade or two just ahead.

History and legend stand testimony to man's frailty before the elements of weather. Every area of earth is dependent on weather. Cycles of drought and flood govern much of the flow of history. At the level of everyday events, a change on the sun may push a jet stream of fast-moving wind 500 miles south of its usual course and thus shorten a cross-country airplane flight by an hour or more. Commerce and industry depend on weather. Farmers, sailors, fashion designers, baseball players, hot-dog vendors, resort operators—in fact, all of us have a strong economic and personal interest in the weather. So it is very much worth while to gamble more research funds on the problem. My bet is that the best chance for improving our ability to forecast the weather lies in acquiring a more detailed understanding of the vagaries of the sun.

AiResearch servo-controller for a pilotless guidance system



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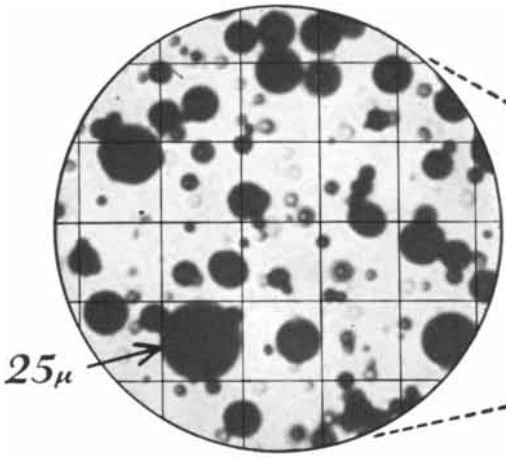

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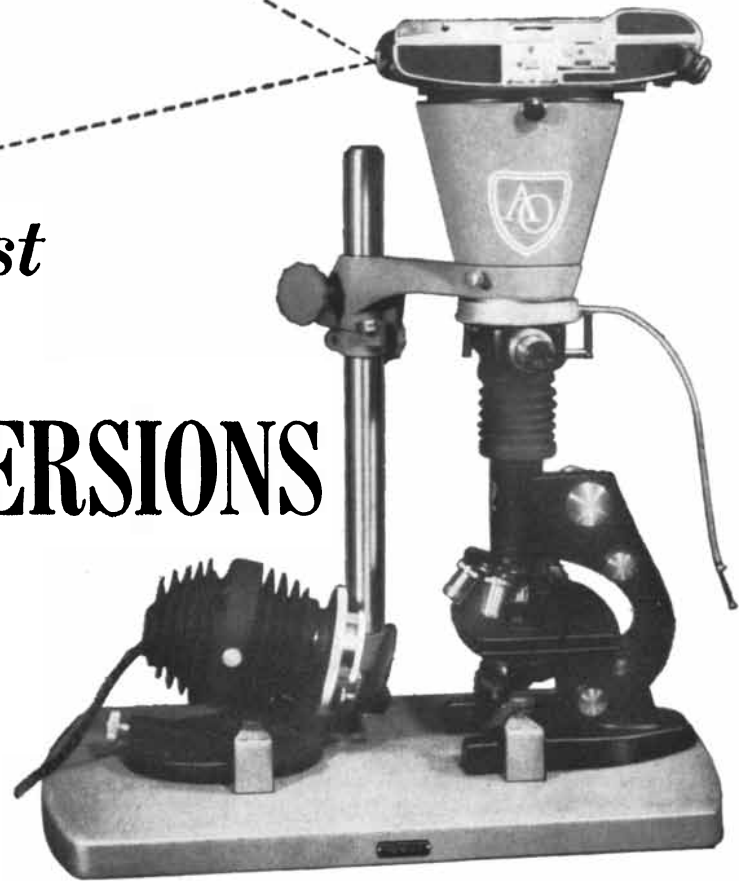

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BOOKS

Bertrand Russell's reflections on his eventful life and times

by James R. Newman

PORTRAITS FROM MEMORY AND OTHER ESSAYS, by Bertrand Russell. Simon and Schuster ($3.50).

It must be accounted remarkable that no one has yet published a biography of Earl Russell. He is the foremost living philosopher and a profound logician who with Alfred North Whitehead created *Principia Mathematica*. In the absence of a Nobel prize for philosophy or mathematics, he received the prize for literature. Two generations have been instructed by his ideas, delighted by his wit, stirred by his independence—and not infrequently spanked by him for their lack of it. Not all creative thinkers lead interesting lives. It may be there is not much more to say about Immanuel Kant than that he was punctual, and about Willard Gibbs than that he rode regularly with his sisters in a carriage around the block. Russell's case is different. He has had an eventful life. He has cared about many things: education and physics, political power and the philosophy of marriage, ethics and relativity, Bolshevism and the foundations of mathematics. He has not only thought his thoughts but lived them.

In this collection of Russell's essays, several are autobiographical. They confirm the impression that his life has been as fascinating as it has been fruitful. He has written, as I understand, a full autobiography, but by his direction it is not to be published until after his death. For the present he edifies us with glimpses and fragments. A few years ago he wrote a sparkling essay called "My Mental Development," which imparted a good deal of information about the growth of his ideas.

Russell was born on May 18, 1872, the younger son of Viscount Amberley and a grandson of Lord John Russell, a liberal statesman who introduced the famous Reform Bill of 1832. Russell's parents died before he was four years old, and he was brought up by his paternal grandmother at Pembroke Lodge in Richmond Park, the home which Queen Victoria had given to John Russell. Bertrand's grandmother was a puritan, and the habit of her home was austere. Young Russell had to practice piano every morning between 7:30 and 8 before the fires were lit. Then came prayers. "Cold baths all year round were insisted upon." Food was simple, but "if it was at all nice"—apple tart, for example—it was considered "too good for children" and the boy would be served rice pudding. The Countess herself spartanly refused to sit in an armchair except in the evening, viewed alcohol and tobacco with disfavor and prized only virtue. "She had that indifference to money which is only possible to those who have always had enough of it." She wished for her children that they live useful and decent lives, not that they achieve "success" or marry "well." Above all she believed in private judgment and the "supremacy of the individual conscience." These values were deeply implanted in Russell.

Besides this spiritual legacy, he inherited from his ancestors the genes of longevity and good health. His paternal grandmother lived to be over 80; a great grandmother lived to the age of 92 and "to her last day remained a terror to all her descendants"; his maternal grandmother had 72 grandchildren, was a founder of Girton College and, after 80, when she found difficulty in getting to sleep, used to read popular science from midnight to 3 a.m. The only one of Russell's remembered ancestors who did not live to a great age "died of a disease which is now rare, namely, having his head cut off."

The house in Richmond Park was lonely for a child. There were no other children to play with, and Russell's education until he was 18 came entirely from governesses and tutors. He became, as he describes himself, "a shy, priggish, solitary youth." There was rebellion in him, directed mainly against the theological opinions of his family. They forbade him to read the books in his grandfather's library, so he read them and became interested in history. At the age of 11 he discovered Euclid, "a great event in my life." He grew to love philosophy, which his family "profoundly disapproved." His intellectual tastes were made, one might say, by opposites. He had a disconcerting way of looking for proofs of things which grownups simply asserted. He recalls that he was told when he was five that the earth is round. He refused to believe it. Thereupon the vicar of the parish, who was Whitehead's father, was called in to persuade the boy. After listening to clerical authority, Bertrand decided to experiment by digging a hole "in the hopes of emerging at the antipodes." When they told him this was useless, his doubts revived.

At the age of 18 he went to Cambridge. A new world opened for him. He could speak his mind and ask irreverent questions. He was not "stared at as if he were a lunatic" or "denounced as if he were a criminal." The University had a number of eccentrics and a few exceptionally gifted thinkers and teachers. One of the Fellows had the amiable habit of chasing offending guests with a red-hot poker with a view to murder. No one seemed to mind this peculiarity, because, owing to a game leg, he never caught the persons he was after. Besides, he was a charming man and was roused to fury only when someone sneezed. Russell's mathematical coach went mad, "but none of his pupils noticed it" until he had to be shut up.

Russell's favorite dons at Cambridge were Sir James Frazer, author of *The Golden Bough;* Sir George Darwin, the mathematical physicist; Sir Robert Ball, another mathematician; Sir Richard Jebb, the great Greek scholar, and the philosophers Henry Sidgwick and James Ward. Sidgwick was known for having one joke in every lecture. The students waited for it, and after it was told, "they were inclined to let their attention wander." He had a stammer which he used effectively. A learned German once said to him, "You English have no word for *Gelehrte* [man of learning]." "Yes, we have," Sidgwick replied, "we call them p-p-p-p-prigs."

Whitehead, who was already a fellow

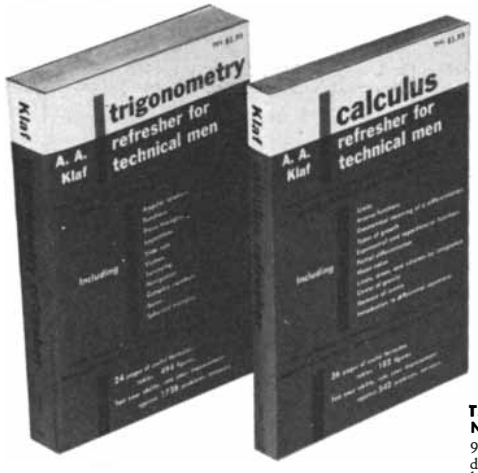
and lecturer at Cambridge and examined Russell for entrance scholarships, told the "cleverest undergraduates" to look out for him. Russell was to become a lifelong friend of many talented Cantabrigians. Among them were the Hegelian philosopher John McTaggart, the author Lowes Dickinson, the art critic Roger Fry, the novelist E. M. Forster, the essayist Lytton Strachey, the economist John Maynard Keynes and the philosopher G. E. Moore. Moore has moved everyone who ever knew him by his qualities of mind and character. He fulfilled Russell's "ideal of genius." "He was in those days," Russell writes, "beautiful and slim, with a look almost of inspiration, and with an intellect as deeply passionate as Spinoza's. He had a kind of exquisite purity. I have never but once succeeded in making him tell a lie, and that was by subterfuge. 'Moore,' I said, 'do you always speak the truth?' 'No,' he replied. I believe this to be the only lie he has ever told."

Russell spent the first three years at Cambridge studying mathematics and the fourth, philosophy. He became deeply interested in the foundations of mathematics, the subject to which he was to make his greatest contribution. He owed much of his inspiration to Whitehead, who showed him many kindnesses, guided him in his transition from a student to an independent writer and later became his collaborator "on a big book no part of which is wholly due to either."

Russell's student years probably were the happiest of his life. Afterward he debated whether to follow philosophy or politics and for a time worked for the British Embassy in Paris, but the "lure of philosophy proved irresistible." He married, spent some years traveling, and visited the U. S. in 1896. In 1898 he returned to Trinity College as a Fellow. Among his earliest writings were *German Social Democracy* (1896), *An Essay on the Foundations of Geometry* (1897) and *A Critical Exposition of the Philosophy of Leibniz* (1900). Russell marks the year 1900 as the "most important year in my intellectual life." With Whitehead he went to the International Congress of Philosophy in Paris and there heard the great Italian mathematician Giuseppe Peano lecture on his inventions in symbolic logic. The precision of his discussions and the power of his elegant notation led Russell to believe that problems in the foundations of mathematics which had been obscured in philosophical vagueness could for the first time be clearly formulated and even solved. He elaborated Peano's notation, wrote *The Principles of Mathematics* and with Whitehead worked out such matters as the definition of series, cardinals and ordinals, and the reduction of arithmetic to logic. The *Principia Mathematica*, the product of an extraordinary 10-year collaboration, was the crown of Russell and Whitehead's concerted attack on the complex questions at the base of mathematics. The complete work appeared in 1913. The effort had been so exacting that at the end, Russell says, "we both turned aside from mathematical logic with a kind of nausea."

"I grew up," writes Russell, "as an ardent believer in optimistic liberalism." His parents had been radicals and freethinkers, friends of John Stuart Mill (who was Russell's godfather). Their will said that their two sons (Bertrand and his elder brother John) must be brought up as freethinkers. But the grandparents got the Court of Chancery to set aside the will and gave Bertrand "the benefits of a Christian upbringing." His grandmother was, however, a reformer in the family tradition: she joined the Unitarian Church, supported Home Rule for Ireland and was a passionate foe of imperialism and war. Russell shared this outlook. When the *Principia* was finished, he turned to social and political affairs. The coming of the First World War plunged him into self-conflict. Love of England was "very nearly the strongest emotion I possess," and he was "tortured by patriotism," but he had no doubt what he must do. He felt as if he had heard the voice of God; he had to protest against war, however futile the protest might be. He became intensely active in the pacifist movement. On one occasion, addressing a meeting at a church, he was attacked by a mob. When two drunken ladies began to attack him with boards full of nails, a woman member of his party called on the police to defend him. They merely shrugged their shoulders. The account, as Russell tells it, continues: " 'But he is an eminent philosopher,' said the woman, and the police still shrugged. 'But he is famous all over the world as a man of learning,' she continued. The police remained unmoved. 'But he is the brother of an earl,' she finally cried. At this, the police rushed to my assistance."

In 1918 Russell was sent to prison for pacifist propaganda. The specific charge against him, though he does not mention it in this book, was that he had written a pamphlet accusing the U. S. Army of "intimidating strikes at home." Arthur Balfour intervened to ease his prison life: he was allowed to read and write as much as he liked provided he



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did not make propaganda. In four and a half months he wrote his famous *Introduction to Mathematical Philosophy,* a book which has given many students the first heady experience of Russell's thought and style. Russell also began the work for his *Analysis of Mind.* The governor of the prison found these writings perplexing but unsubversive. Similarly, a warder found nothing objectionable in Russell's reply to a question about his religion. When he said that he was an agnostic, the warder asked how to spell it, and remarked with a sigh: "Well, there are many religions, but I suppose they all worship the same God." Russell says "this remark kept me cheerful for about a week."

He was released shortly before the armistice, and in 1920 he visited Russia and met Lenin, Trotsky and Gorki. He wrote a book, *The Practice and Theory of Bolshevism,* which condemned the Soviet regime for its despotism, its narrow interpretation of Marxist philosophy, its "enormous error . . . in supposing that a good state of affairs can be brought about by a movement of which the motive force is hate." This won him few friends. Conservative opinion condemned him for his views on the war; left-wing opinion scorned him for his betrayal of Utopia.

Russell spent a happy year in China, warming to the people and finding much that was admirable in their tradition. But he feared the effects of "Western and Japanese rapacity" and foresaw the transformation of China into a modern industrial state "as fierce and militaristic as the powers that it was compelled to resist."

He returned to teaching and lecturing, and for several years became absorbed "in parenthood and attendant problems of education." He founded a school which he hoped would promote the best values of "progressive education" yet would not be deficient on the purely scholastic side. But he was a poor administrator and the school failed. Nevertheless his thinking produced several excellent books on education. In the 1920s and 1930s his literary output was immense. ("Writing books," he says, "is an innocent occupation and it keeps me out of mischief.") He published two dozen volumes and countless articles on mathematical, philosophical, scientific, political and social subjects. Among the books are *Mysticism and Logic,* in 1918; *The Prospects of Industrial Civilization,* a study of socialism written in collaboration with his second wife, Dora Black, in 1923; *The ABC of Relativity* in 1925; *The Analysis of Matter* and *An Outline*

of Philosophy in 1927; *Marriage and Morals* in 1929; *Education and the Social Order* in 1932; *Freedom and Organisation,* a history of political theory, in 1934; *Power,* a penetrating analysis of the theory of the state, in 1938; *An Inquiry into Meaning and Truth* in 1940; *A History of Western Philosophy* in 1945, and *Human Knowledge* in 1948. He has written a book for children, and a collection of short stories, *Satan in the Suburbs,* which I personally prefer to forget—though it has not wanted for admirers.

For six years, between 1938 and 1944, Russell sojourned in the U. S. He lectured at various universities and at the Barnes Foundation in Merion, Pa. In some quarters he was regarded as a "controversial" figure. This may be taken to mean he behaved like a man. Also he was guilty of changing his opinions when the evidence seemed to justify change. He had been a pacifist, but he saw no peaceful way of resisting Hitler's mad ambitions and so, for a few years at least, he condoned war. However, he could not live down some of his rational and unconventional views on society. When he was appointed a professor of philosophy at the College of the City of New York, a lady brought suit to have him barred on the ground that he believed in "free love." A justice of the New York Supreme Court, John McGeehan, denounced his appointment as an attempt to establish "a chair of indecency." Russell was barred.

We learn about Russell not only through his autobiographical essays but through his sketches of others. In this volume are reprinted his portraits of Whitehead, George Bernard Shaw, H. G. Wells, Joseph Conrad, George Santayana, Sidney and Beatrice Webb, D. H. Lawrence. With Shaw, Russell went on a bicycle tour which had a ludicrous ending. For Wells he felt affection, and admired him as an "important force toward sane and constructive thinking both as regards social systems and as regards personal relations." His contacts with Conrad were infrequent, but from their first meeting the two men were strongly drawn to each other. Conrad, like Russell, was lonely. He was courageous and felt deeply the moral shortcomings of the world, the thinness of civilization's crust. He "despised indiscipline, and hated discipline that was merely external." In all this Russell found himself in close agreement with Conrad. "His intense and passionate nobility," writes Russell, "shines in my memory like a star seen from the bottom of a well. I wish I could

make his light shine for others as it shines for me." A kindliness touches Russell's portraits even of men for whom his admiration was not unalloyed. He is not sentimental and he does not fail to recall unpleasing traits, but he has perspective and the charity of wisdom. I am struck by the fact that these set pieces, for all their charm and discernment, describe very little of the subjects' physical appearance or personal habits. Santayana was "prim" and "even in country lanes he wore patent-leather boots." But what was he like? Lawrence was full of hatred and jealousy, a cultist with "a mystical philosophy of 'blood.'" But only a part of him comes through. Russell does not always see with the storyteller's eye or the painter's. His appraisals and anecdotes are better than his pictures.

There are other essays in this book which are inimitable: "How I Write," "History as an Art," "The Cult of 'Common Usage'," "A Plea for Clear Thinking," "Mind and Matter." Russell has not lost his touch, his cutting edge, his capacity for indignation. He can still detect nonsense better than any of us. He can still strike at evil with a formidable set of claws. His eloquence in just causes is as moving as ever. And he grows old so gracefully that one takes pride in the race of men.

"An individual human existence," he says, "should be like a river—small at first, narrowly contained within its banks, and rushing passionately past boulders and over waterfalls. Gradually the river grows wider, the banks recede, the waters flow more quietly, and in the end, without any visible break, they become merged in the sea, and painlessly lose their individual being. The man who, in old age, can see his life in this way, will not suffer from the fear of death, since the things he cares for will continue. And if, with the decay of vitality, weariness increases, the thought of rest will not be unwelcome. I should wish to die while still at work, knowing that others will carry on what I can no longer do, and content in the thought that what was possible has been done."

Short Reviews

VARIETIES OF HUMAN VALUE, by Charles Morris. The University of Chicago Press ($5). A central problem of modern culture is the relation between science and ethics. Can scientific method be applied to human values? It is often said there is an unbridgeable gap between physical science and human values, because the first deals with what

is and the second with what ought to be. But the gap may not be as wide as supposed. For example, it is feasible to observe and compare the values which men profess to hold, in the same sense that one observes and compares other facts of the outside world, such as the chemical composition of different stars. Dr. Morris's book, an outgrowth of his earlier work, *Paths of Life*, deals with various professed conceptions of "the good life," as expressed by several thousand college students of various cultures. By means of a questionnaire he sounded their preferences among 13 possible ways to live. Some of them, briefly summarized, are: (1) "preserve the best that man has attained"; (2) "cultivate independence of persons and things"; (3) "constantly master changing conditions"; (4) "act and enjoy life through group participation"; (5) "integrate action, enjoyment and contemplation"; (6) "wait in quiet receptivity"; (7) "meditate on the inner life"; (8) "chance adventuresome deeds"; (9) "obey the cosmic purposes." The students were asked to scale these courses of action with numbers ranging from 7 ("I like it very much") to 1 ("I dislike it very much"). Some of the subjects were asked in interviews to explain their views of the good life and tell more about themselves, and a few were asked to state how they believed they ought to live and how they believed they did in fact live. The most extensive samples were drawn from the U. S. (2,000 men and 800 women), India (700 men and 400 women) and Nationalist China (500 men and 200 women); smaller samples came from Japan, Norway, Canada, Pakistan, England, New Zealand and Italy. All data were run through a careful statistical mill. The over-all results contain few surprises but are of considerable interest because of the comparisons of intellectual climates, standards, goals, prejudices and the like. In the U. S. the life of "integrated action, enjoyment and contemplation" is most highly favored, while ways 6, 2 and 9 are least popular. In India course 1 is most favored, followed by "controlling the self stoically." The Japanese value pattern resembles the Indian, but with "showing sympathetic concern for others" in highest place. The Chinese value most the way of life we in the U. S. value least: "Obey the cosmic impulses." Enjoyment of life through group participation is three times as popular with them as with us. And yet East and West are not in all respects in opposition, for the Chinese prize 3 as much as we do and are almost as contemptuous of "waiting in quiet receptivity" as we are. There is

much in these pages to provoke thought among those concerned with the improvement of world understanding.

SCIENCE AND CIVILISATION IN CHINA, VOL. II, by Joseph Needham. Cambridge University Press ($14.50). The second volume of this epochal survey deals with the bearing of Chinese philosophy on the development of scientific thought. Needham examines the effects of the various schools of philosophy upon the advancement of science, and he attempts to explain why science in China, despite highly promising beginnings and great achievements, has failed to attain the levels of science in the Western world. He takes us on an engrossing journey. He presents the tenets of Confucianism, of Taoism, of the Mohists and logicians, and of the legalists. He reports on the pseudo sciences, from scapulimancy (divination from cracks produced in tortoise shells or animal shoulder-blades by heating with red-hot metal) through geomancy (divination from the features of the earth), oneiromancy (prognostication by dreams) and glyphomancy (prophecy based on dissection of the ideographic characters representing names). Needham describes the rational and skeptical tradition of Chinese thought, the inhibitory effects on science of Buddhism (which spurns the study of nature as illusion), the teachings of Neo-Confucianism and the relations between Chinese philosophy and the system of Leibniz. He shows the deadening impact of bureaucratism on Chinese thinkers, and he relates in detail the lasting Chinese preoccupation with cabalistic lore, mystical diagrams, numerology and the hocus-pocus of "vital elements." Needham points out, however, the important part which mystical and magical thinking played, both in Europe and in China, in promoting science. Mystical theology, though hostile to the movement toward modern science, was hospitable to new ideas, however wild and dark, because of its faith in magic. We are apt to regard rationalism as the only progressive social force, but mysticism, as Needham's book shows, has contributed important concepts to science. Chinese thought is pervaded by the theme that the universe is ruled by an inner organizing drive and harmony, with which all things are instinct. Alfred North Whitehead and others have expressed the same point of view, and it is evidently much more in accord with modern theories of science than the crude mechanism and materialism of the 18th and 19th centuries. So we have the paradox of a people

who made a supple, sensitive philosophy which is consonant with modern science but who were unable to carry their own science within reach of it. Some critics have already found flaws and misinterpretations in Needham's book, and one does not have to be an eminent Sinologist or historian of science to see gaps in his account. But more volumes are to come, and so far he has provided an exhilarating intellectual reconnaissance.

RAUWOLFIA, by Robert E. Woodson, Jr., Heber W. Youngken, Emil Schlitter and Jurg A. Schneider. Little, Brown & Company ($5.50). Rauwolfia is a tropical genus of woody plants. The root of one species, *Rauwolfia serpentina*, was long employed by medicine men in India. Its recent clinical rediscovery (in the form of the extract reserpine), as a drug which is not only effective against high blood pressure but also makes the harsh world look a little hazier and softer, has prompted this book. Four leading students of the subject discuss the scientific and technical aspects of Rauwolfia. Its botany, chemistry and pharmaceutical features are considered in detail. Although the book is written for specialists, one of the plates can be understood by anyone. It shows the "tranquilizing" effects of reserpine on the facial expressions of a rat, rabbit, cat, dog and monkey. They all look as if they had hangovers, and the total effect on a viewer is untranquilizing.

THE BIRDS OF THE BRITISH ISLES, by David Armitage Bannerman, illustrated by George E. Lodge. Oliver and Boyd (63 shillings). The fifth volume of this excellent survey is devoted to birds of prey: various falcons, eagles, buzzards, harriers, goshawks, kites, honey buzzards, vultures, ospreys. Bird books, however valuable to professional ornithologists and amateur bird-watchers, do not often make lively reading. But this work is remarkably palatable. Bannerman gives an attractive account of each species' habits and relates many charming anecdotes about the birds. The text is beautifully supported by 34 paintings of birds in their natural surroundings by the late George Lodge. He painted most of the 384 pictures which illustrate the five volumes of this series in his 80s and early 90s; yet they are fresh and full of life.

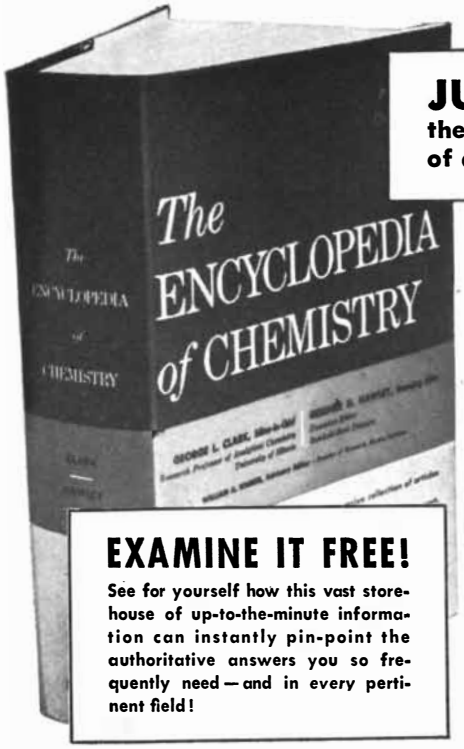
THE INTELLECTUAL LIFE OF COLONIAL NEW ENGLAND, by Samuel Eliot Morison. New York University Press ($4.95). This is a reprint of a book which appeared in 1935 under the title

The Puritan Pronaos. Morison's aim is to show that the phrase "glacial period," used by Charles Francis Adams to describe New England intellectual life in the 17th century, is altogether unjustified. He insists that interest in literature, scholarship and science in New England grew rather than diminished during this period, and that the dominant Puritan clergy "did everything possible under the circumstances in which they lived to stimulate, promote and even produce intellectual activity."

JANE'S FIGHTING SHIPS, 1956-1957, edited by Raymond V. B. Blackman. The McGraw-Hill Book Company, Inc. ($25). If it should ever be demonstrated that the seas are a bad place to fight, fighting ships, like the vertebrates of long ago, will crawl out of the water and make themselves at home on the land. Navies adapt themselves, and they have already acquired wings. The 58th edition of Jane's annual survey of the world's navies shows that they are thriving. Among its 440 new illustrations, the frontispiece features the U.S.S. *Forrestal*, the largest warship ever built and the first of a class of six giant "attack aircraft carriers." The U. S. Navy costs more than all the others combined. The British have abandoned almost all large ship construction and are concentrating on frigates, wooden coastal minesweepers, patrol boats and a few experimental guided-missile ships. The U.S.S.R.'s fleet of cruisers, destroyers, frigates and submarines is growing. France is building a helicopter carrier. Italy's fleet is swelling. Japan is greatly expanding her navy—called, initially, the Maritime Self-Defense Force. Egypt has new destroyers, as has West Germany. And even Mexico has, in addition to frigates and patrol vessels, a handsome 400-ton presidential yacht completely air-conditioned and equipped with radar.

JANE'S ALL THE WORLD'S AIRCRAFT, 1956-1957, by Leonard Bridgman. The McGraw-Hill Book Company, Inc. ($25). The latest issue of this excellent annual has hundreds of fresh illustrations and includes a new subsection on guided missiles, listing and describing no fewer than 66 species. Great Britain makes 10, France 13, Switzerland 1, and the U. S. the remainder. Soviet missiles are not included because of lack of information.

SELECTA HERMANN WEYL. Birkhauser Verlag ($12.25). This admirable volume, assembled by the Federal Institute of Technology in Zurich and the



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Institute for Advanced Study in Princeton, contains a selection of the late Hermann Weyl's notable mathematical papers, written during the period from 1910 to 1952. The selections, some in German, some in English, treat topics in pure mathematics, mathematical physics, quantum mechanics, the foundations and philosophy of mathematics. A complete bibliography is included. The only cause for regret is that the book has no biographical essay on this distinguished man, who contributed to so many departments of modern mathematics and whose broad mastery enabled him, as few others can do, to unite creatively mathematical and physical thought.

Notes

THE ART OF ARCHITECTURE, by A. E. Richardson and Hector O. Corfiato. Philosophical Library, Inc. ($25). A revised edition of a standard work on the history of architecture and the theory of design.

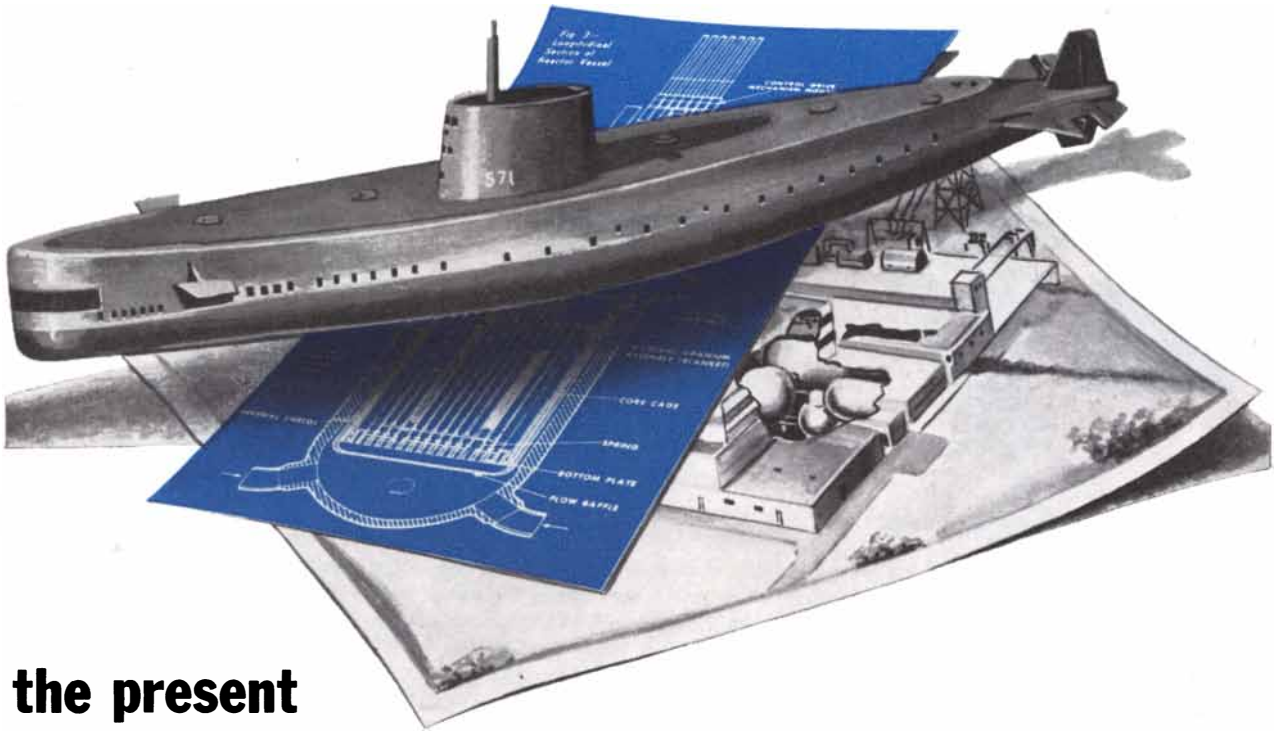
ASTRONOMICAL OPTICS AND RELATED SUBJECTS, edited by Zdeněk Kopal. Interscience Publishers, Inc. ($12.50). The proceedings of a symposium at the University of Manchester, which covered, among other topics, information theory and optics, optical images and diffraction, interferometry, resolution problems, electronic devices, filter photography and thin films.

AIR POLLUTION HANDBOOK, edited by Paul L. Magill, Francis R. Holden and Charles Ackley. The McGraw-Hill Book Company, Inc. ($15). In this large, cooperative work is collected a wide range of data on the causes, effects and control of air pollution.

THE ATOM AT WORK, by Jacob Sacks. The Ronald Press Company ($5). Revised edition of a satisfyingly clear and direct account.

FATIGUE IN AIRCRAFT STRUCTURES, edited by Alfred M. Freudenthal. Academic Press Inc. ($12). Proceedings of an international conference at Columbia University in 1956.

ANNUAL REVIEW OF NUCLEAR SCIENCE, 1956, edited by James G. Beckerley. Annual Reviews, Inc. ($7). Among the topics considered in the sixth volume of this annual are cosmic rays, polarization of fast nucleons, isotope shift in atomic spectra, nuclear radiation effects in solids, nuclear reactors for electric power generation, cellular and vertebrate radiobiology.



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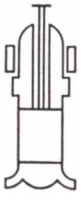

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MATHEMATICAL GAMES

Paradoxes dealing with birthdays, playing cards, coins, crows and red-haired typists

by Martin Gardner

A paradox is a truth which cuts so strongly against the grain of common sense that it is hard to believe even when you are confronted with the proof. This quality of incredibility is particularly true of paradoxes in probability—a field of mathematics especially rich in paradoxes.

Consider the paradox of birthdays. What would you estimate to be the probability that, in any group of 24 persons, two or more were born on the same day of the same month? Offhand you would say it will be very low. In fact, the probability is 27/50, or better than one half! In other words, if you were to bet even money on there being at least one coincidence of birthdays in a random collection of 24 persons, you would have a better than even chance of winning—over the long run.

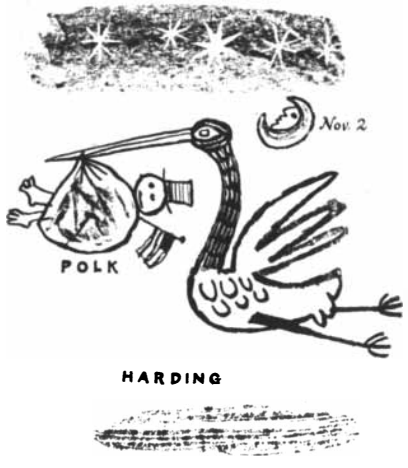
These odds are so unexpected that you can make an entertaining, as well as profitable, game of the thing at parties or other gatherings of 24 or more people. Let each person write his birthday on a slip of paper. More often than not, at least two of the birthdays will be the same—sometimes to the surprise of the parties concerned, though they may have known each other for years.

You don't need a party of 24 to play the game: you can merely take 24 names at random out of *Who's Who* or some other biographical dictionary. I looked up the birthdays of the 33 Presidents of the U. S. and am happy to report that they obeyed the law of averages. Two Presidents had the same birthday: James Polk and Warren Harding were born on November 2.

The calculation of these odds from probability principles is perfectly simple but rather tedious. One method of calculating them is given by George Gamow in his book *One Two Three . . . Infinity*. The probability that the birthdays of two persons will *not* coincide is 364/365, since there are 364 chances in 365 of their birthdays being different. The probability that a third person will have a birthday different from the first two is 363/365; for a fourth person the probability of a still different birthday is 362/365, and so on to 342/365 for the 24th person. To compute the probability that all 24 persons have different birthdays, you multiply all these probabilities together, and the result is a fraction which reduces to 23/50. This means that you would win 27 out of every 50 bets on a coincidence of birthdays in groups of 24 persons.

Even more startling is the paradox of the second ace. Suppose that a bridge player were to look at his freshly dealt hand and announce: "I have an ace." What is the probability that he also has a second ace? This can be calculated precisely, and it proves to be a little under 1/3. But suppose he announced that he had a particular ace, say the ace of spades, selected by agreement in advance of the deal. The probability that the player holding the ace of spades also had another ace would be 11,686/20,825, or slightly better than 1/2! Why should naming the ace affect the odds?

To simplify the work of computation, we can illustrate the situation with a more elementary game using only four cards—the ace of spades, the ace of hearts, the deuce of clubs and the jack of diamonds. If two cards are dealt to



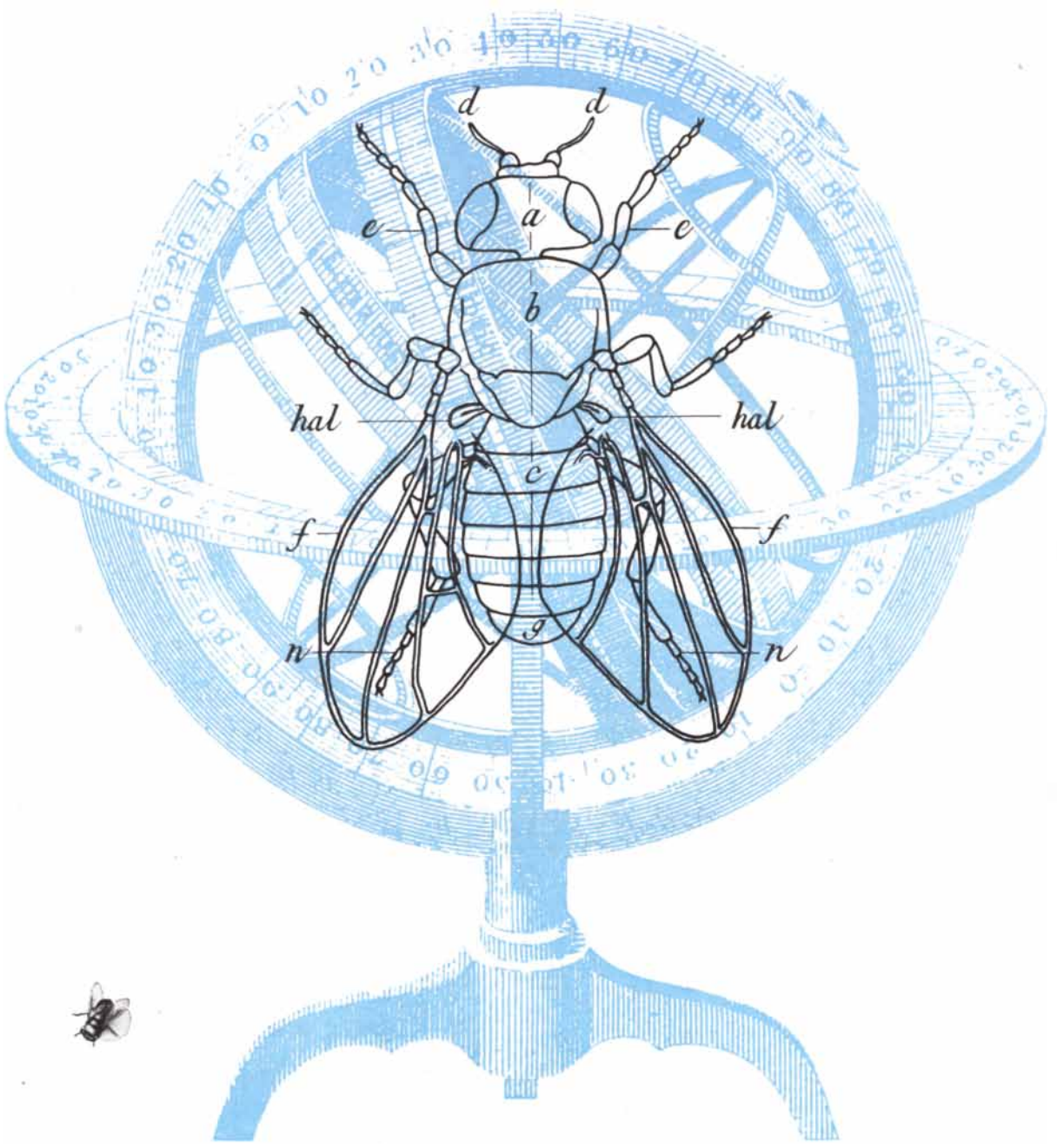
The coincident birthdays of two Presidents

The paradox of the second ace

each of two players, there are only six possible combinations that a player can hold: (1) ace of spades and ace of hearts, (2) ace of spades and jack of diamonds, (3) ace of spades and deuce of clubs, (4) ace of hearts and jack of diamonds, (5) ace of hearts and deuce of clubs, (6) jack of diamonds and deuce of clubs. Now five of these six two-card hands permit the player to say, "I have an ace," and in one of the five instances he has a second ace. Consequently in this game the probability of the second ace is 1/5. But observe that if the player is able to declare that he holds the ace of spades, the probability that the second ace is in his hand goes up to 1/3, because there are only three combinations containing the ace of spades and one includes the second ace.

The most famous of all probability paradoxes is the St. Petersburg paradox, first set forth in a paper by the famous mathematician Daniel Bernoulli before the St. Petersburg Academy. Suppose I toss a penny and agree to pay you a dollar if it falls heads. If it comes tails, I toss again, this time paying you two dollars if the coin is heads. If it is tails again, I toss a third time and pay four dollars if it falls heads. In short, I offer to double the penalty with each toss and I continue until I am obliged to pay off. What should you pay for the privilege of playing this one-sided game with me?

The unbelievable answer is that you could pay me any amount, say a million dollars, for each game and still come out ahead. In any single game there is a probability of 1/2 that you will win a dollar, 1/4 that you will win two dollars, 1/8 that you will win four dollars, and so on. Therefore the total you may expect to win is $(1 \times 1/2) + (2 \times 1/4)$



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$+ (4 \times 1/8)$. . . . The sum of this endless series is infinite. As a result, no matter what finite sum you paid me in advance per game, you would win in the end if we played enough games. You would be paid something in every game and you would also have a chance, albeit small, of winning an astronomical sum each time the game was played. This paradox is involved in every "doubling" system of gambling. Its full analysis leads into all sorts of intricate byways.

Carl G. Hempel, a leading figure in the "logical positivist" school and now a professor of philosophy at Princeton University, discovered another astonishing probability paradox. Ever since he first explained it in 1937 in the Swedish periodical *Theoria*, "Hempel's paradox" has been a subject of much pleasant and learned argument among philosophers of science, for it reaches to the very heart of scientific method.

Let us assume, Hempel began, that a scientist wishes to investigate the hypothesis "All crows are black." His research consists of examining as many crows as possible. The more black crows he finds, the more probable the hypothesis becomes. Each black crow can therefore be regarded as a "confirming instance" of the hypothesis. Hempel asserted that the existence of a brown stone also is a "confirming instance" of the hypothesis! He proved his paradox with ironclad logic.

The statement "All crows are black" can be transformed to the logically equivalent statement, "All not-black objects are not-crows." The second state-

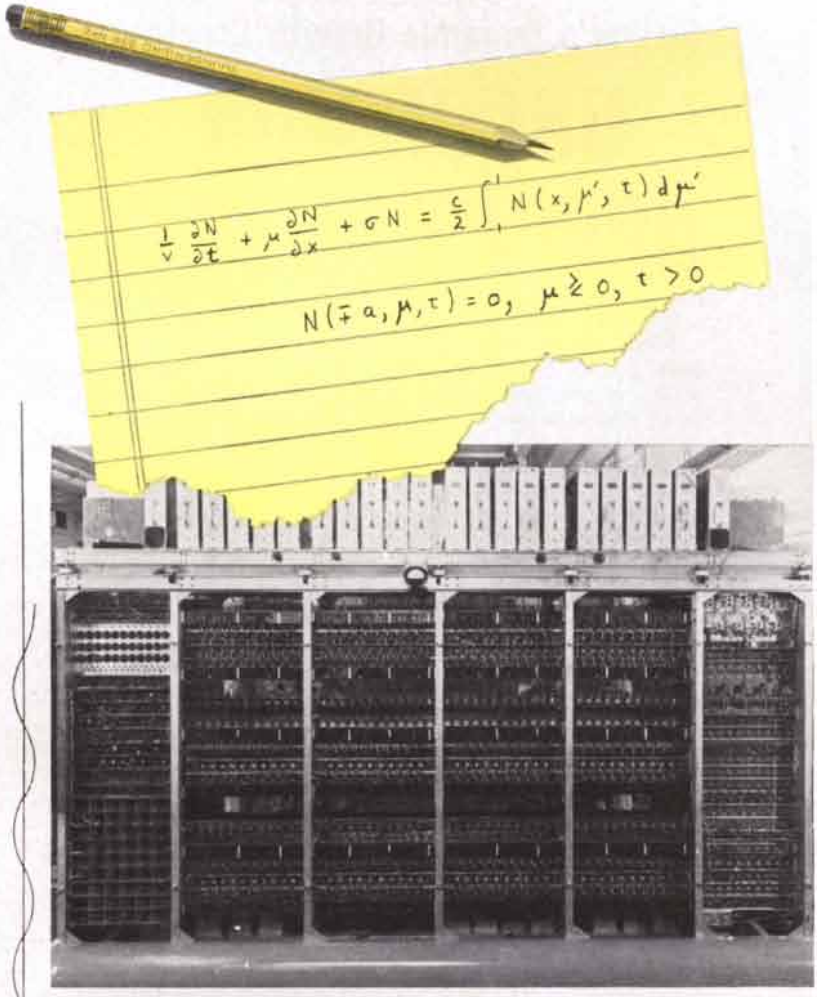
The paradox of the red-haired typists

another example of exciting work at los alamos...

BREAKING PROBLEM BARRIERS

The linearized Boltzmann equation shown at the right describes the transport of neutrons in a slab. Its mathematical structure was first completely worked out at Los Alamos. This is only one of the many fundamental problems in disciplines ranging from pure mathematics through biology that are yielding to newly developed methods of experimental and theoretical analysis.

The Laboratory has entered a new phase of scientific endeavor. Pioneering activities in the unexplored realms of nuclear power, nuclear rocket engines, and controlled thermonuclear power have been added to its weapons program; experiments are being planned and carried out at pressures and temperatures far beyond any previously created by man. These activities exemplify the imaginative approach by which the Laboratory maintains its preeminence in scientific achievement.



Mathematical support for many of the Laboratory's programs is given by the Theoretical Division, which also pursues its own investigations in hydrodynamics, magnetohydrodynamics, computer theory and design, and other fields. The vast amount of computation involved has brought about the creation at Los Alamos of the largest known computing center devoted exclusively to scientific work.

The "Maniac" (above) is one of the many advanced computers in use at the Laboratory.

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ment is identical in meaning with the original. Consequently the discovery of any object that "confirms" the second statement must also confirm the first.

Suppose, then, that the scientist, searching about for not-black objects, comes upon a brown stone. This object is a confirming instance of "All not-black objects are not-crows." It therefore must add to the probable truth of the equivalent hypothesis "All crows are black." The same applies to a white elephant, or a red herring, or the scientist's green necktie. As one philosopher recently remarked, on rainy days an ornithologist investigating the black-crow hypothesis could carry on his research without getting his feet wet. He need only explore his room and note instances of not-black objects that are not-crows!

We find it hard to accept the validity of this paradox, says Hempel, because of a "misguided intuition." But it begins to make sense when we consider a simpler problem. Let us say that we wish to test the hypothesis that all red-haired typists working for a certain large company are married. We could investigate this directly by seeking out every red-haired typist and asking her if she has a husband. But there is another test, which might actually be more efficient. We could get a list of all the unmarried typists in the company from the personnel department and then investigate whether any of the girls on this list has red hair. If it turns out that no unmarried typist has red hair, we have completely confirmed our hypothesis that all of the red-headed typists are married. And each not-married typist with not-red hair serves effectively as a confirming instance of the hypothesis. If there are fewer unmarried than married typists, we could save time by this approach.

The only real difference between the problem of the red-headed typists and the one of the black crows is in the relative sizes of the classes. There are so many not-black objects in the world that checking them would be an extremely inefficient method of testing the hypothesis that all crows are black. Nonetheless most logicians agree that Hempel's logic is unassailable. And although we may be tempted to dismiss Hempel's paradox with a smile and a shrug, we must remember that many logical paradoxes which were long regarded as mere mental exercises proved to be highly useful in the development of symbolic logic. Analyses of Hempel's paradox have already provided valuable insights into the obscure nature of inductive logic, the tool by which all scientific knowledge is obtained.

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THE AMATEUR SCIENTIST

On testing boat designs without a towing tank, and skipping stones along the beach

Since the end of the war amateur sailors have been taking to the navigable waters of the world in numbers that rival a migration of lemmings. Some of the newcomers to yachting are bringing along a strong interest in science. In consequence the aerodynamics of sails and the hydrodynamics of hulls are coming in for increased attention from amateurs. In fact, yachtsmen in England recently organized an Amateur Yacht Research Society, which has a U. S. secretary—Robert Harris of Great Neck, N.Y.

That amateurs can make experiments of great interest to boatbuilders was pointed out in this department last August by Randolph Ashton, an engineer associated with the Experimental Towing Tank at the Stephens Institute of Technology. Since a towing tank and its associated apparatus for experiments with models is expensive, he urged amateurs to undertake experiments with full-sized boats.

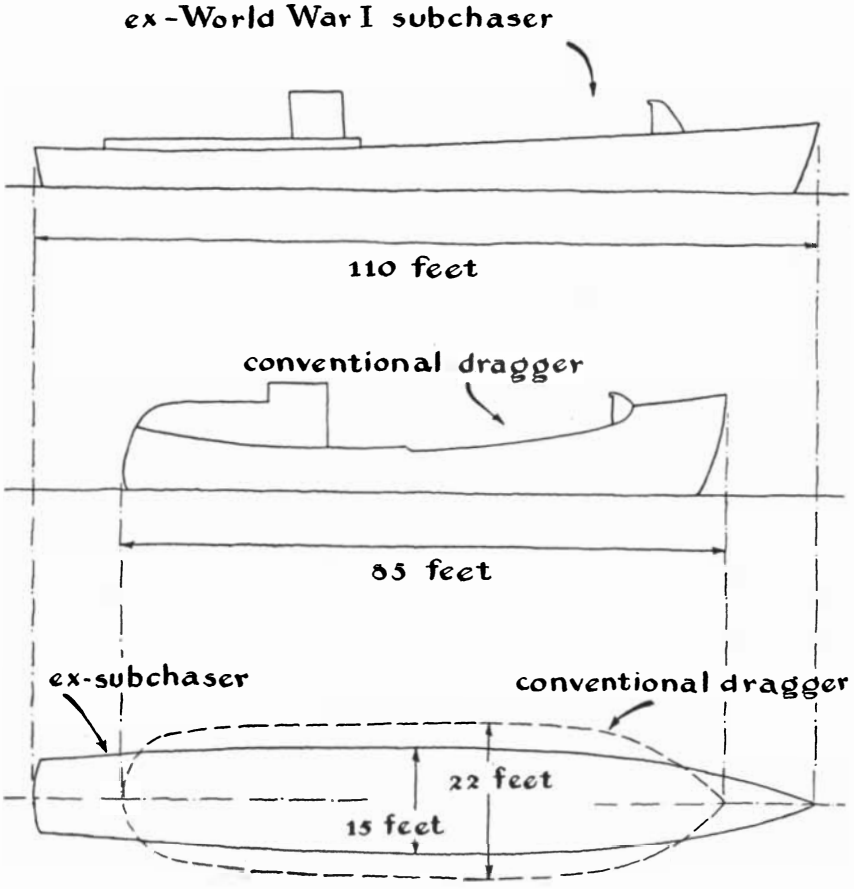
Cyrus Hamlin, a naval architect of Manset, Me., agrees that full-scale tests can provide much needed information and a lot of fun for the experimenter. He suggests, however, that interesting tests of models can be made without a towing tank.

"Naval architecture," he writes, "may be poorly endowed with funds for research, but I find it heavily endowed with fascination. For me it is a vocation, but even an amateur can, at little financial cost, make important contributions to research into the scientific design of small vessels and boats.

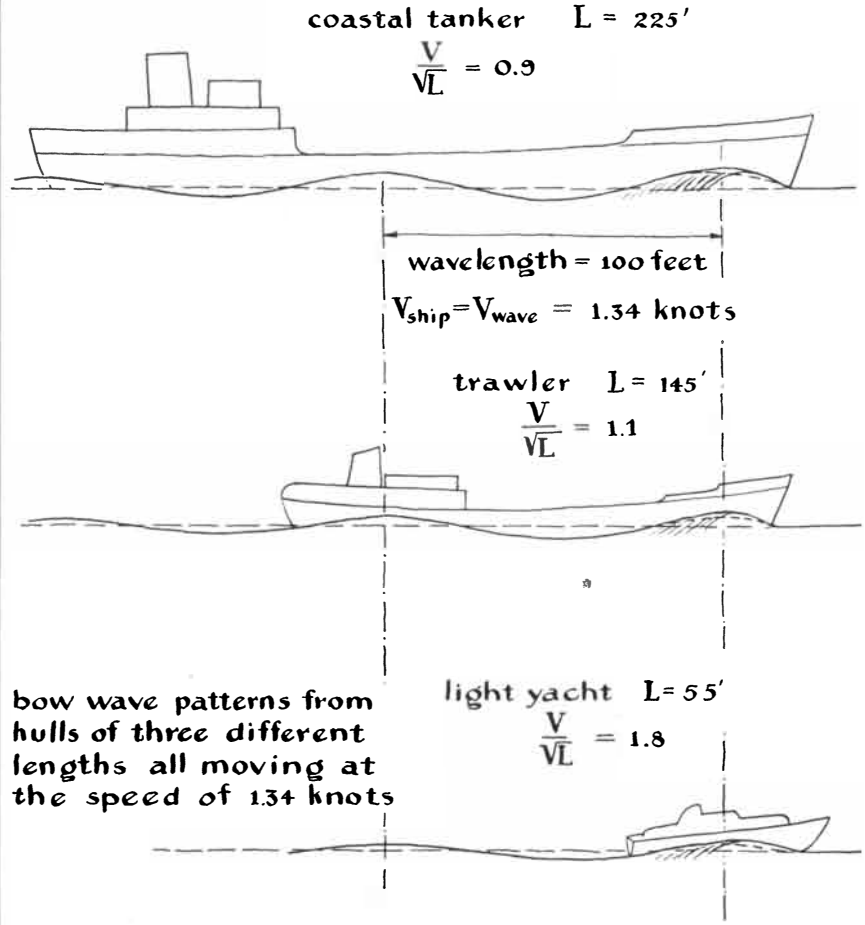
"The radical differences of vessel design and construction, found not only in widely separated areas but within the same port, indicate the sizable area of investigation open to the amateur. For instance, a conventional 85-foot Gloucester dragger (a fishing vessel exactly like a trawler but smaller) is heavily built, full-bodied, and has a beam of from 20 to 22 feet. Yet the lightly built, fine-bodied World War I subchaser, with a beam of only 15 feet on an over-all length of 110 feet, also is popular as a dragger at Gloucester. Even taking into account the personal (and frequently illogical) preferences of skippers and owners, it seems unlikely that two such widely divergent types can perform the same work equally efficiently.

"An amateur contemplating research in naval architecture might give consideration to three background thoughts. First of all he can hardly expect to compete with the formal establishments in precision of measurements of forces, angles, velocities and so on. There are so many variables involved in vessel testing and design (due largely to the fact that boats operate in two fluids of very different densities, separated by what can be a very obstreperous boundary layer) that small errors of measurement can build up a large accumulated error. Thus a beginner might better concern himself with qualitative rather than quantitative testing and content himself with examining large differences in the characteristics of the structure being tested.

"Secondly, an amateur should not concern himself with relatively slow vessels. The ratio of a boat's speed to its length (conventionally calculated as the velocity in knots divided by the square root of the waterline length) is a measure of the wave-making characteristics of a hull and is perhaps the most important and fundamental coefficient in naval archi-



The proportions of two boats used for dragging nets are compared



The effect of the ratio of speed to length on the trim of boats moving at the same speed

tecture. Slow vessels can be defined for our purposes as those whose speed-length ratio at normal travel speeds is one or less than one.

"The length of a water wave, crest to crest, is a rigid function of its speed of advance, whether it is generated by wind, an earthquake or the passage of a vessel. A body traveling through the water generates a wave system which travels with it and hence has the same velocity of advance as the moving body. At a speed-length ratio less than unity, a vessel is supported on three or more of the wave crests it is itself generating. Such a slow vessel remains essentially horizontal. A faster vessel, generating longer waves, is very sensitive to the location of the wave crests near its bow and its stern. At a speed-length ratio of about two, the vessel is trying to climb up the back of the bow wave and its stern is in the trough of the wave. This is a very difficult position for any but a very light vessel to attain and is ruinously costly to maintain. At considerably higher values of the speed-length ratio the center of gravity of a vessel may get ahead of its bow-wave crest, at which point she begins to coast down the front side of the wave and consequently requires less horsepower. For all practical purposes this condition is possible only for light planing hulls (a planing hull is one whose center of gravity rises, relative to its at-rest position, due to the hydrodynamic lift that is exerted on the hull's bottom).

"A vessel whose speed-length ratio is around one (*e.g.*, a 100-footer at 10 knots or more, or a 36-footer at six knots or more), generates waves which are about its own length. A vast number of vessels, in all kinds of service, operate in this one-wavelength speed range. These small vessels, because of the high cost of testing relative to their building cost, and the traditional and individualistic approach of their owners and operators, have not received research attention by any means proportionate to their importance.

"Thirdly, an amateur model experimenter interested in qualitative rather than quantitative results can make his tests in open water under any simulated type of weather he may choose, from flat calm to a gale. Most towing-tank

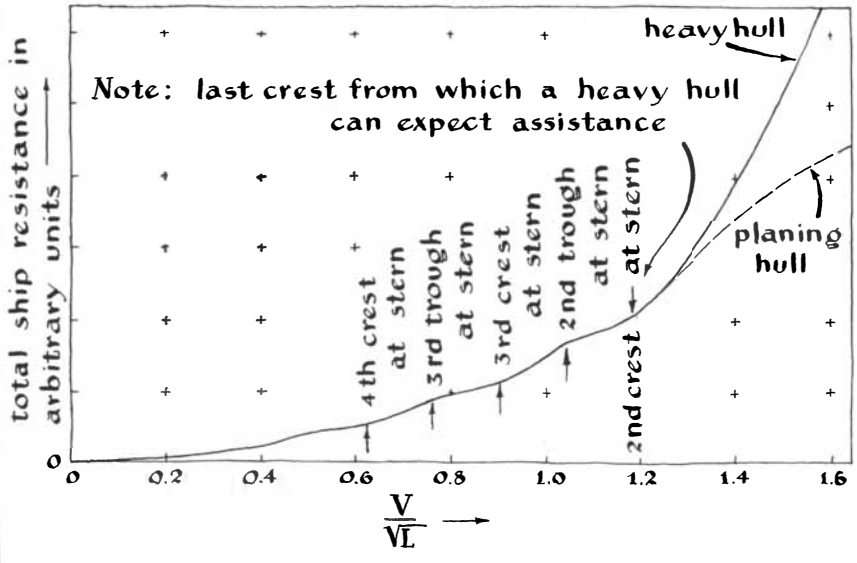
facilities are equipped with wave-making machines, but the waves generated are smooth, regular and quite unlike the breaking and confused seas met in practice. It is my opinion that tests with machine-made waves are valuable only on a rarefied theoretical level, and are of little or no practical value in investigating a particular model. In fact Randy Ashton informs me that the Stevens Towing Tank is installing equipment which will generate confused storm seas in reproducible patterns and permit testing models at various angles of attack. After all, although simple resistance to forward motion is of considerable importance, for a small vessel it is perhaps more important that she be able to operate efficiently and obediently under adverse conditions, and in the final analysis be able to carry her crew and cargo safely through the worst conditions she might possibly meet. Alan Villiers' new book, *Posted Missing*, is a moving account of a disaster which emphasizes the need for improvement in design. I recall a shocking experience that brought this home to me: a few hours after listening to the skipper of a dragger tell his wife over the radiotelephone that he was encountering rough weather but expected to be home the next day, I heard the bad news that the vessel had rolled over and was lost with all hands.

"An amateur taking up model-testing will find an endless variety of fields to tackle and ample scope for the most vivid imagination. Besides the conventional types of power-driven and sailing craft, there are now many innovations to investigate: hydrofoils which lift the hull partly or completely out of the water, boats with more than one hull (such as catamarans), jet propulsion, improved propellers, wing sails, new construction materials and methods, and so on.

"I believe that sailboats offer one of the most profitable areas of investigation. Although it may seem, as Ashton wrote, that 'the days of commercial sailing ships are gone forever,' still a return of wind-driven marine commerce is not by any means unthinkable. Nearly all present water-borne travel depends upon fossil fuels. Depletion of these fuels may make them prohibitively costly before long. Nuclear reactors are so expensive and bulky that their use will probably be limited to large or specialized vessels.

"The one source of power that will remain unchanging and always available is the sun. This power manifests itself in the form of wind, which can be used day and night. The sailing craft of the future, setting an arrangement of wingsails, or their yet-to-be-discovered counterpart, will divert the wind's force for the production of forward motion and do it without the necessity of complex machinery. Such a vessel, with a small auxiliary engine for negotiating calms and narrow waters, and a small crew assisted by power winches, should be able to compete favorably, both in speed and economy of operation, with fully powered craft. It is here, in the improvement and development of efficient sailing hulls and rigs, that I believe amateur experimenters will find the most imaginative, challenging and rewarding field for their energy.

"Model-testing procedures and instrumentation present many problems of the difficult kind that amateurs seem to delight in solving. I venture to set forth



The resistance of a boat to the water is plotted against the ratio of speed to length

τὸ πᾶν ἐστὶ τὸ κεφἄλαίωμα τῶν μέρεων

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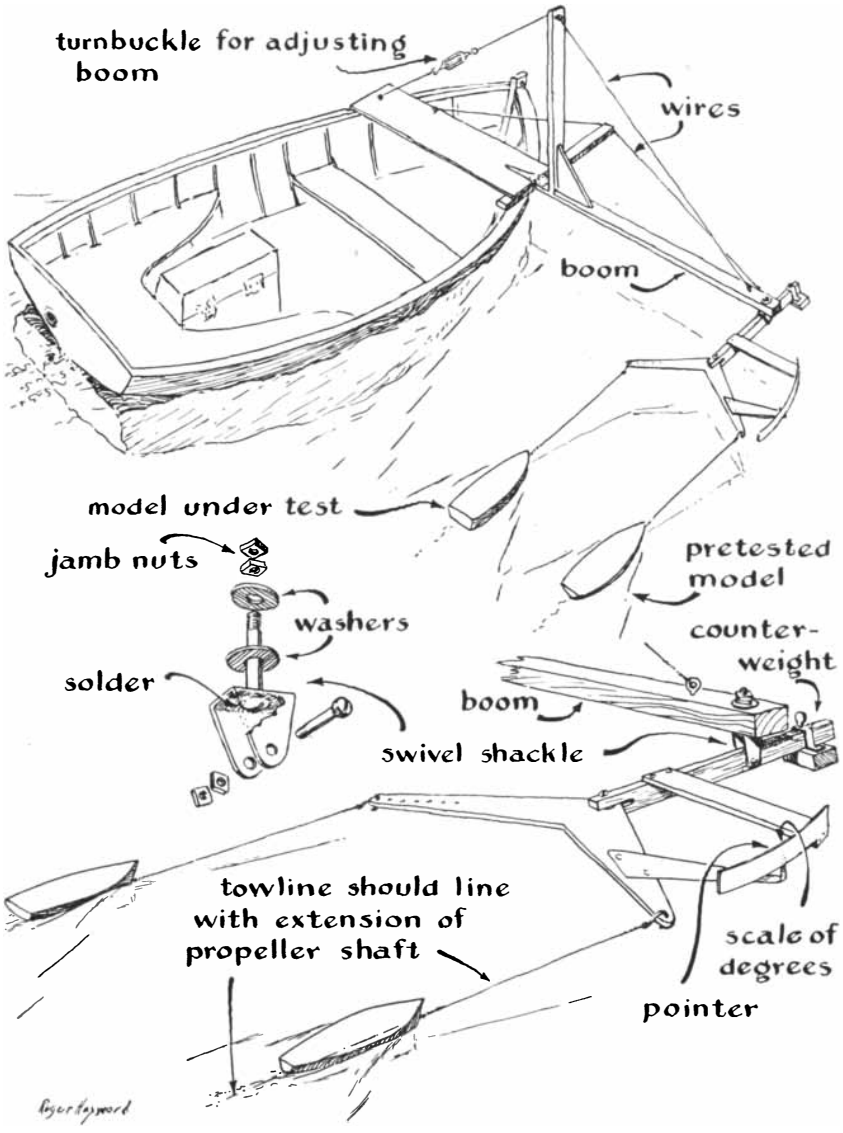
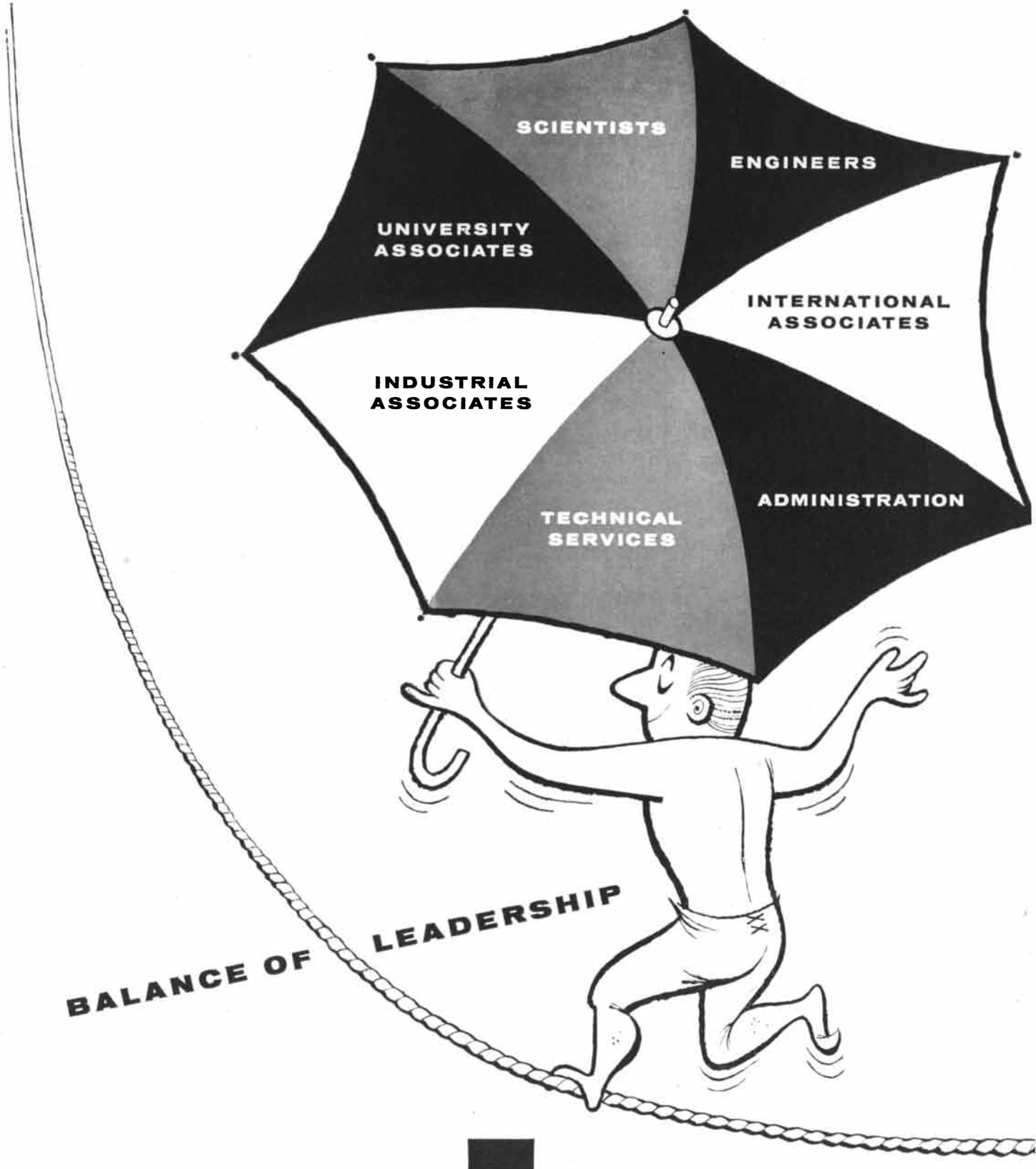


Details of an apparatus to test boat models

a few suggestions. The model should be at least three feet in length over all; and it should be finished to accurate and uniformly smooth lines, without humps or hollows. The simplest form of test is to tow a model by a string from a power boat. The towing string should represent an extension of the propeller shaft line. The towing point must be rigged out to one side so that the model is clear of the wake of the power boat. The speed of the vessel can be estimated by judging the wavelength of the wake generated by the model or the power boat: the velocity, in knots, is 1.34 times the square root of the length of the wave. Such a test can give a good indication of the qualities of the model's motion, its directional stability, the formation of waves and other properties of the motion, in smooth water and at various angles of attack to waves through a range of sizes.

"The experimenter can refine his results by incorporating a dynamometer in the tow line, and by adding a vertical turbulence-inducing wire just ahead of the model but not attached to it. The total resistance, or drag, of the model can then be measured. The precision of this measurement will depend upon the accuracy of form and finish of the model, the sensitivity of the dynamometer and the accuracy of the speed estimate. From the total resistance of the model you subtract its computed frictional resistance. You then expand the remaining figure to the dimensions of the full-sized ship and now add the computed frictional resistance of the ship. The result is the total resistance of the ship for the speed-length ratio at which the model was tested.

"A simpler test is to compare the model's performance with that of an-



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other model of the same size and type whose characteristics are known. You can do this by attaching both models to the opposite ends of a pivoted and balanced yoke and towing the two together. You should hook up a spring, or locate the pivot point ahead of the towing points, so that as the difference between the drags of the two models increases, the resistance of the yoke to turning also will increase.

"Sailing-hull testing, as Ashton made so clear, is an extremely complex and difficult problem and should be approached with some trepidation. To help clarify my own thinking, I once began to make a list of all the factors and relationships affecting sailboat performance. When my list had grown to more than 40 items, I gave up, lest I discourage myself into becoming a chicken farmer.

"The only logical plan for this method of testing sailboat models is to tow the model in the same way the wind drives it, *i.e.*, from the center of effort of the sails along the line of the resultant wind force. Although there are many unsolved practical questions connected with this method of testing, it seems reasonable.

"One area of ignorance which the amateur can help illuminate is the question of sailboat rigs. We have only spotty data on forces, pressures, effects of sail shapes, flow lines and the interrelationships of various sail combinations. I have always been intrigued by the possibilities of recording sail shapes stereoscopically by two cameras spaced on a wide baseline. Scale-model tests of rigs are good subject matter for an experimenter with access to a low-velocity wind tunnel. I would like to see some ambitious amateur look into the practicality of examining rigs, singly and in groups, in a smoke tunnel and analyzing the results by the streamline method set forth in "The Amateur Scientist" for May, 1955, and October, 1955.

"Finally, an amateur can make important contributions by experimenting with and observing full-sized boats. Ashton recently had this to say on the subject: 'Designers and model-testing establishments continually deplore the lack of full-size observations of sufficient accuracy to show definitely the refutation or verification of their ideas and predictions.' A week spent on a fishing vessel, measuring periods of pitch and roll, horsepower, steering characteristics and similar matters under various conditions of loading would be a memorable experience.

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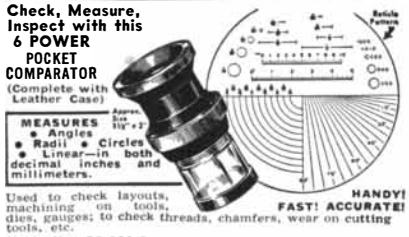

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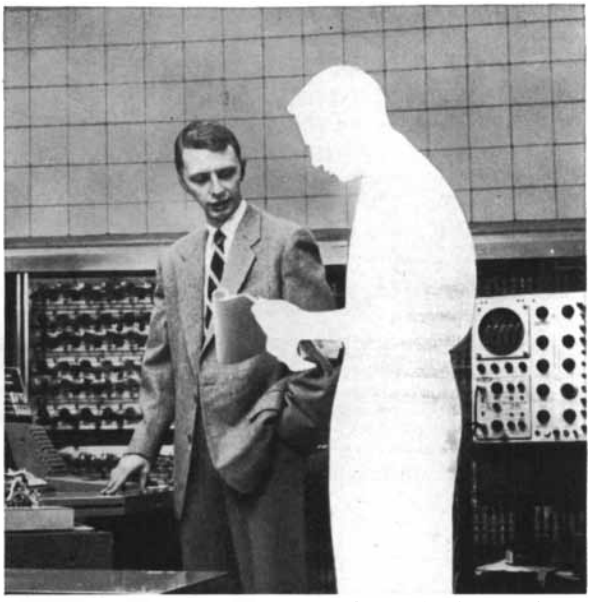

PRODUCT CONTROL ENGINEER: Promoted recently, this man formerly worked at IBM's Poughkeepsie manufacturing facilities. His job was to design information systems to insure a smooth flow of work through the plant. "It takes *creative* engineering ability to design these systems," he'll tell you, "and *administrative* ability to 'sell' a system to higher management and make it stick. If you possess this rare combination of abilities, this is the job for you!"

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testing. A beginner, towing his model with a length of butcher's string, can turn up as much provocative information as a professional, with his fine models and intricate, sensitive equipment."

Ernest Hunter Wright, the retired former head of the Department of English at Columbia University, is baffled by an odd phenomenon which came to his attention through chance observation.

"With the luck of a layman," he writes, "I have had the novel experience of seeing several of the men who plucked the heart out of the atom's mystery scratch their heads in vain for the solution of a problem which I now submit to a wider audience.

"We all think we know what happens when we skip a stone across a water surface. We believe that it bounces over the water in a series of successively shorter leaps until it finally stops and sinks. Of course the number and the length of the leaps vary with the smoothness of the water, the size and shape of the stone, the speed and skill of the throw, and other conditions, but by and large the missile seems to act about as I have said.

"I am fairly sure it does no such thing. I think a stone does not behave on water in the way described, because I *know* it does not on sand—the hard, wet sand at the water's edge. So first let me tell you what the stone does on the sand, and how I came to know it.

"I found it out in the course of a long walk along the beach. I had been skipping pebbles over the water. (By the way, I wish someone could tell me precisely why beach pebbles are always flattened rather than spherical—no geologist has given me a satisfactory answer.) Because the water rolling into the beach was too rough for good performance, I decided to see how a pebble would behave on the hard, wet sand. On this surface, of course, it would leave little marks recording its travel.

"When I saw the marks left in the sand by my first pebble, I think I must have been as astonished as old Crusoe on beholding the first footprint of his man Friday! The first bounce of the pebble was only four inches long; the next was nearly seven feet; then came another short hop of only four inches; then a leap of about five feet; then again the four-inch hop, and so on for seven big hops punctuated by the four-inch ones. Each short skip was unmistakably recorded by two neat little marks in the sand. After the seventh repetition the pebble ceased this strange behavior and merely jumped along with successively shorter strides until it stopped. The total

number of hops was about 20—my average on hard sand.

"I kept skipping pebbles all the afternoon, for mile after mile along the beach. I tried them in all shapes and sizes, over every contour of terrain that I could find, at every angle at which it was possible to launch them. I tried all the variations I could think of, and I went back a second day and tried them all again. With never an exception the result was just about the same.

"Now I fancy the same thing happens on the water, though in the water there is no imprint left to tell the story. A proper record with a camera would give us the answer. In the sand, at least, the story is quite clear, and a very pretty story it is—as pretty as the tracks of some little animal in the fresh snow.

"As yet I have no explanation for these facts. I have put the problem before several physicists of high distinction, but so far have received no answer in return. Somewhere there must be an answer for my little riddle. Who will find it?

"I may save some trouble if I say that two or three suggestions have already been tested and found wanting. One was that each of the double marks is the result of the pebble's turning over when it strikes the sand. I can imagine no reason why the pebble should turn over, and at all events I can certify from scrutiny that the stone does not turn over—and so can the companions who have watched it with me.

"Another suggestion was that the pebble, striking the sand at a tilt, might hit with its rear end first, do a little flop and strike with its front end before taking off for the long leap. But this supposes a precision of timing and a uniformity of tilt at each landing which are beyond all credence, and besides, why would a big stone make its flop within the same space (four inches) as a tiny one? As a matter of fact the marks in the sand show that the stone usually strikes the sand flat, and all the observers agree with me that there is no flop.

"The only other suggestion so far is that the pebble's spin around its vertical axis may account for its strange action. Why such a spin should make it behave the way it does is not clear to me, but we do not need to labor the question, because I have thrown pebbles without any spin (it can be done) and they all left the same mincing steps in the sand.

"So what scientist, professional or amateur, wants to go down to the beach with all the needful instruments and find the answer to my riddle? I shall be glad to go along if I am wanted; I can throw pretty well."

INDEX OF ADVERTISERS

APRIL, 1957

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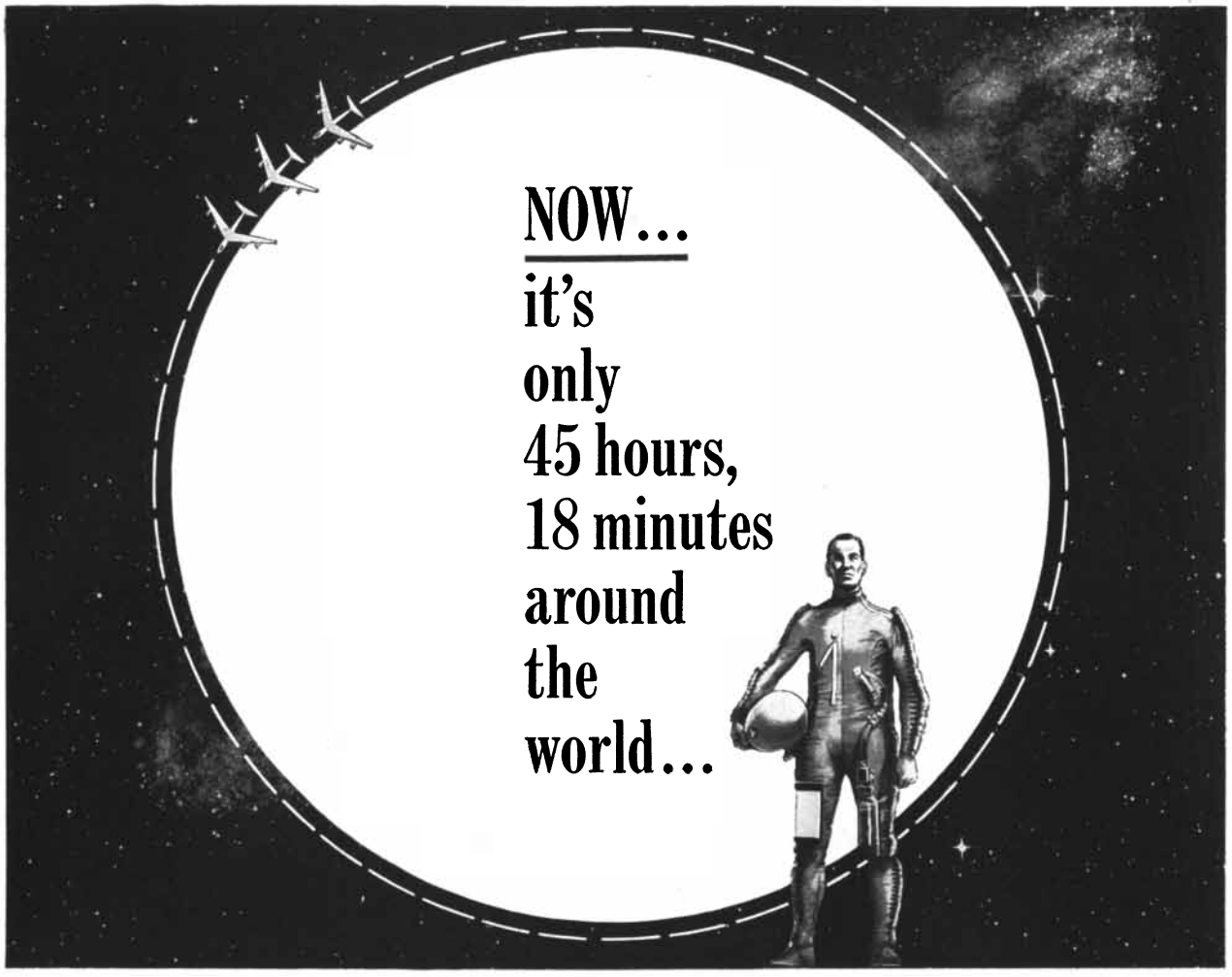

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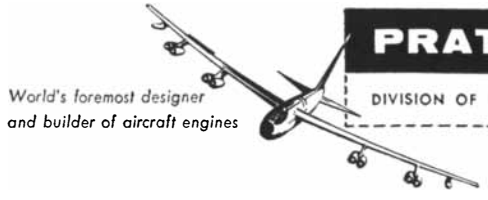

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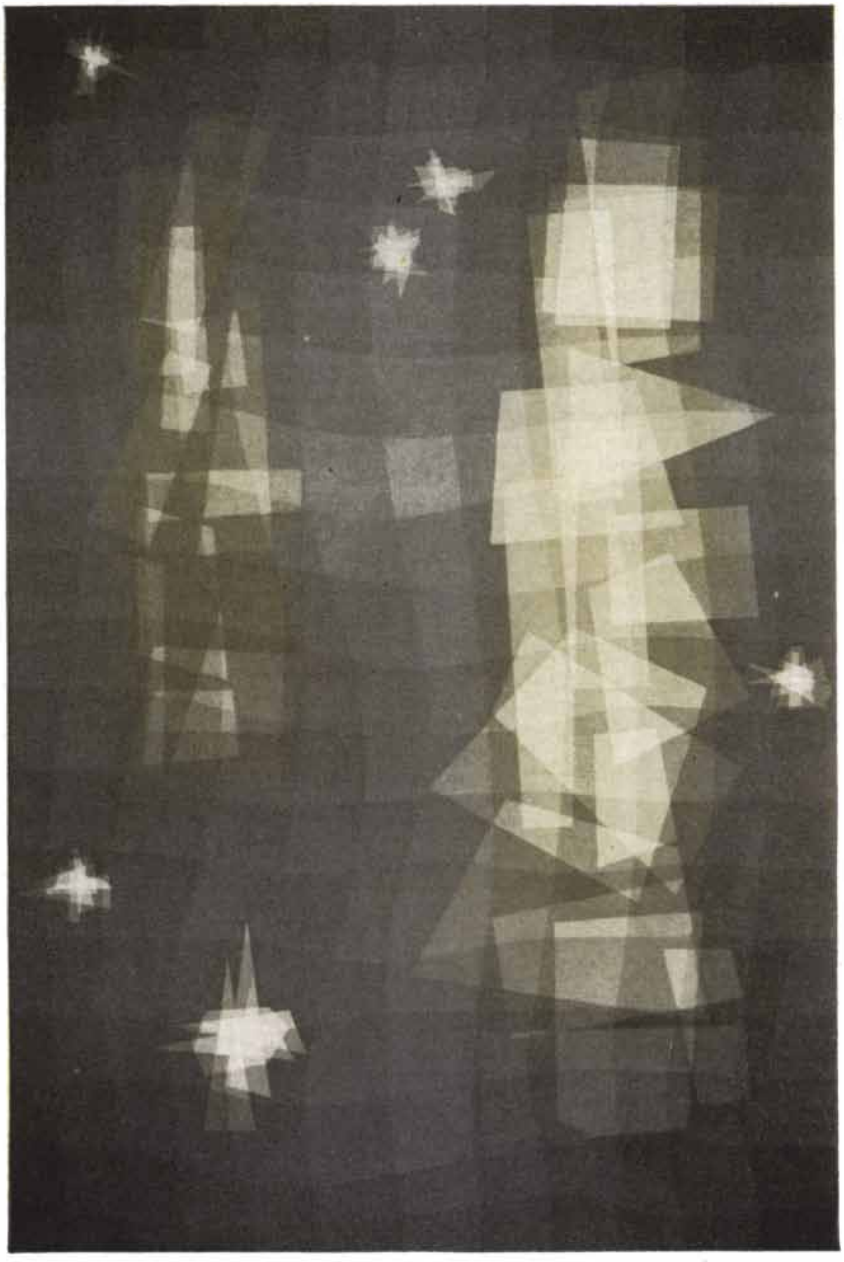

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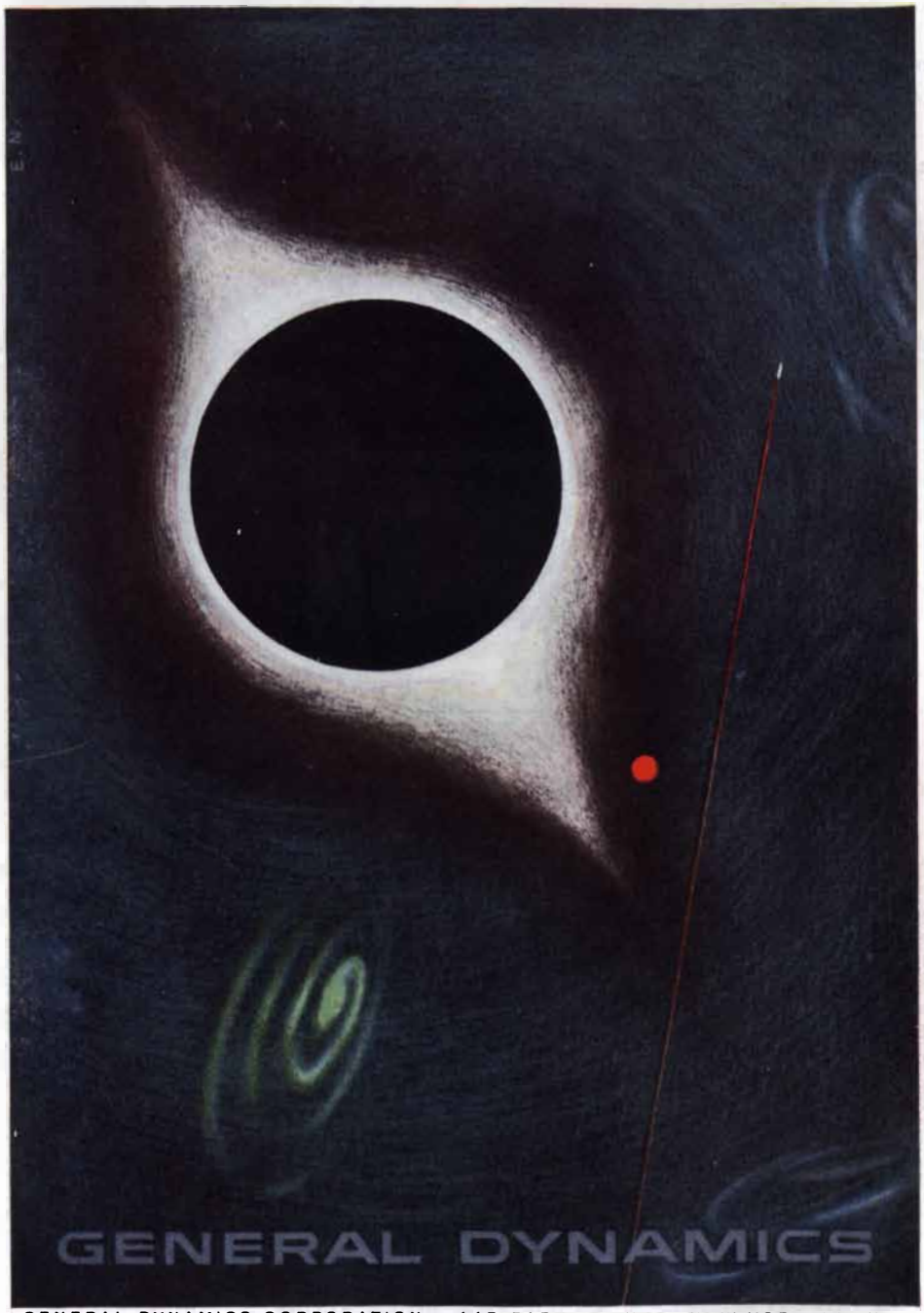

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