SCIENTIFIC AMERICAN

WEED CONTROL BY INSECT

FIFTY CENTS

July 1957

Complexion care for apples

Bigger and better fruit is yours ...with good looks that are more than skin deep

Apples, peaches, and cherries all taste best when they look best. But even before the first bud appears, fruits are constantly exposed to attack from plant diseases that can stunt growth and leave ugly blemishes on the surface.

This battle is now being won with a remarkable liquid chemical spray called CRAG Glyodin. By preventing fungus growth, it improves the overall health of the trees and stimulates the natural glowing color of the fruit.

Farmers—and home gardeners, too—use other agricultural chemicals from Union Carbide. For example, weed killers which cut down hand weeding on the farm and around the home . . . and a repellent which helps increase milk and beef production by keeping livestock free from flies.

The people of Union Carbide will continue their research to develop more of the products that help bring better foods to your table.

FREE: *Learn how research at Union Carbide helps improve many of the products you use every day. Write for the 1957 edition of "Products and Processes" booklet D. Union Carbide Corporation, 30 East 42nd St., New York 17, N. Y. In Canada, Union Carbide Canada Limited, Toronto.*

UNION CARBIDE

UCC's Trade-marked Products include

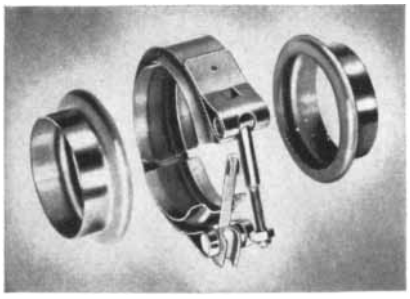
CRAG Agricultural Chemicals PREST-O-LITE Acetylene EVEREADY Flashlights and Batteries ELECTROMET Alloys and Metals SYNTHETIC ORGANIC CHEMICALS LINDE Oxygen PRESTONE Anti-Freeze HAYNES STELLITE Alloys Dynel Textile Fibers BAKELITE, VINYLITE, and KRENE Plastics PYROFAX Gas NATIONAL Carbons UNION Calcium Carbide UNION CARBIDE Silicones

Surface Reports on aircraft components

keeping "brains" alive

Whether an aircraft is piloted by a human being or a black box, the brain of the guidance system must be kept within a narrow temperature range. Sometimes an electronic brain is even more temperature sensitive than a human being.

To provide such vital protection in today's (and tomorrow's) space vehicles calls for fairly sophisticated plumbing.



Air "bled" from the engine must be conveyed through ducts, regulators, coolers, and heat exchangers—components which must combine extreme compactness and light weight with maximum reliability.

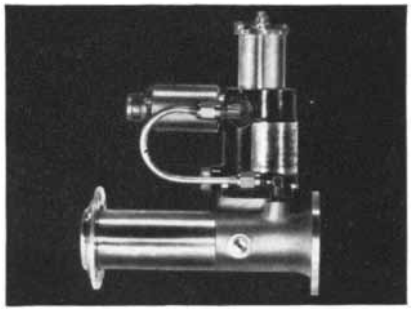
Because many strong couplings are needed for these duct systems, the weight savings recently achieved by Janitrol couplings quickly add up to significant figures. Consisting of two flanged sleeves and a clamping device, Janitrol couplings provide a metal-to-metal seal which stays pressure tight under extremes of temperature and vibration. They can be readily disconnected and reused again and again with maximum assurance of tightness. The design makes clamping and unclamping easy even in restricted spaces.

Janitrol's unique experience in welding and fabricating high temperature alloys to extremely tight physical and dimensional specifications contributed much to this advance.

If you are concerned with handling air at extreme temperatures and pressures you will do well to write for technical data on Janitrol couplings.

taming tempests

To bring high temperature compressor "bleed" air from extreme pressures down to workable levels—for use in heat exchangers, canopy sealing devices, actuators, blowers, anti-icing systems, etc.—requires even more mechanical finesse and precision than that which goes into fine watches. High temperature, high pressure air controls must be miniaturized; one valve often must be designed to do the work of several; and moving parts in these must be held to tolerances

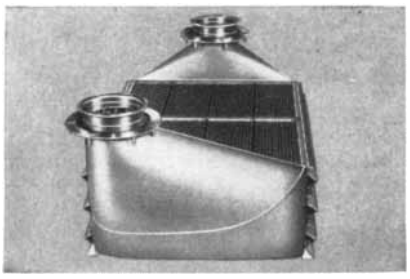


which amount to technical artistry. A considerable array of these regulators and valves bearing the Janitrol nameplate have proved themselves in service in a variety of advanced aircraft that are truly pushing out the boundries of space travel.

Specifications for Janitrol pneumatic valves and controls are available promptly on request.

hybrid heat exchangers

For many years a bundle of tubes was the best structure for light weight heat exchangers to transfer heat from air to fluid, air to air, etc. Fabrication of tubular type exchangers is difficult and expensive, particularly when leak proof performance is demanded.



To trim off weight, to improve efficiency, and to minimize pressure losses, Janitrol began a new approach about two years ago. Plates of very thin stainless steel were corrugated by a special Janitrol-developed process and assembled into highly rigid structures.

The problems of manifolding are relatively simple; and a great variety of shapes and sizes are easily assembled. Efficiency is good; weight is low; performance is excellent.

Since these heat exchangers are fabricated from plates, yet look like tubes, Janitrol coined a new word to describe them: "platular," combining the advantages of both.

For further information on Janitrol products—including combustion heaters, liquid heaters, hot fuel priming systems, and purge gas systems, write Janitrol Aircraft-Automotive Division, Surface Combustion Corporation, 402 Dublin Avenue, Columbus 16, Ohio.

Janitrol Aircraft-Automotive Division

SURFACE COMBUSTION CORPORATION

Surface® Heat Treat, Steel Mill, Glass Divisions • Kathabar® Air Conditioning & Drying Division
Janitrol® Heating & Air Conditioning Division • Webster Engineering Company: Boiler Burner Division

Highway building across the country
...is sped by an electric arc

All over the nation, you can see vast new roads being built. Rugged machines dig . . . scrape . . . haul . . . dump . . . to make your superhighway take shape.

Producing road-building machines involves special problems for their makers. Here, LINDE lends a hand. With UNIONARC welding equipment, heavy steel sections are joined with joint areas stronger than the steel itself.

Each of LINDE's different welding methods is designed for certain types of jobs. One is for joining metals that ordinarily are difficult to weld. Another gives sound seams in very thick steel. UNIONARC welding, a method recently developed by LINDE, permits welding downhand, vertically, or overhead—with savings up to 50%.

For half a century, LINDE has been engaged in research, development, and production of welding machines and methods, for both gas and electric operation. For information on UNIONARC, and a copy of the booklet, "Modern Methods of Joining Metals," write or call your nearest LINDE office.

LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y. *In Canada:* Linde Company, Division of Union Carbide Canada Limited.

For the best in electric welding—look to LINDE!

Linde
TRADE-MARK

UNION CARBIDE

Electric arc welding methods developed by LINDE are used to help make tough and durable road-building machines for building the nation's highways.

Bob Lavin

Established 1845 **SCIENTIFIC AMERICAN** July, 1957 Volume 197 Number 1

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 shows a field of Klamath weed. On the leaves of the plants are beetles of the species *Chrysolina gemellata* imported to control the weed (*see page 56*).

THE ILLUSTRATIONS

Cover painting
by Colleen Browning

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41	Harold F. Walton
42-47	Bunji Tagawa
49-52	Irving Geis
53	Mount Wilson and Palomar Observatories
54	Irving Geis
55	Naval Research Laboratory (*top*), D. S. Kennedy & Co. (*bottom*)
56-60	John Langley Howard
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125	Allan D. Cruickshank
126	Eric Hosking (*upper left*), Allan D. Cruickshank (*upper right and lower right*), Carl B. Koford (*lower left*)
127	Samuel A. Grimes (*top*), Allan D. Cruickshank (*bottom*)
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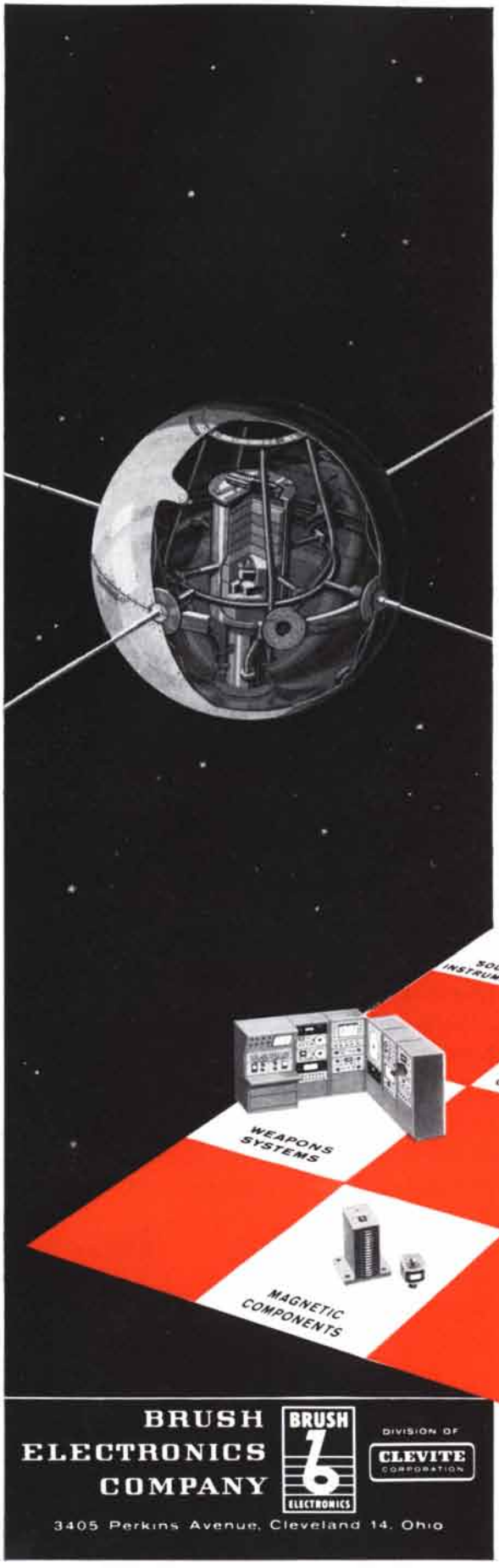


Piezoelectric ears in space

As the earth satellite cruises in space, tiny piezoelectric microphones made of a new material recently developed by Brush will "hear" collisions with microscopic meteorites. The microphones convert audible collisions into electrical signals which will be transmitted to earth.

Because of the speed of the satellite, and the sensitivity of the unique new material, collisions with particles weighing but a few billionths of a gram will be heard and reported.

Here again is Brush leadership in precision electronic products.

BRUSH ELECTRONICS COMPANY

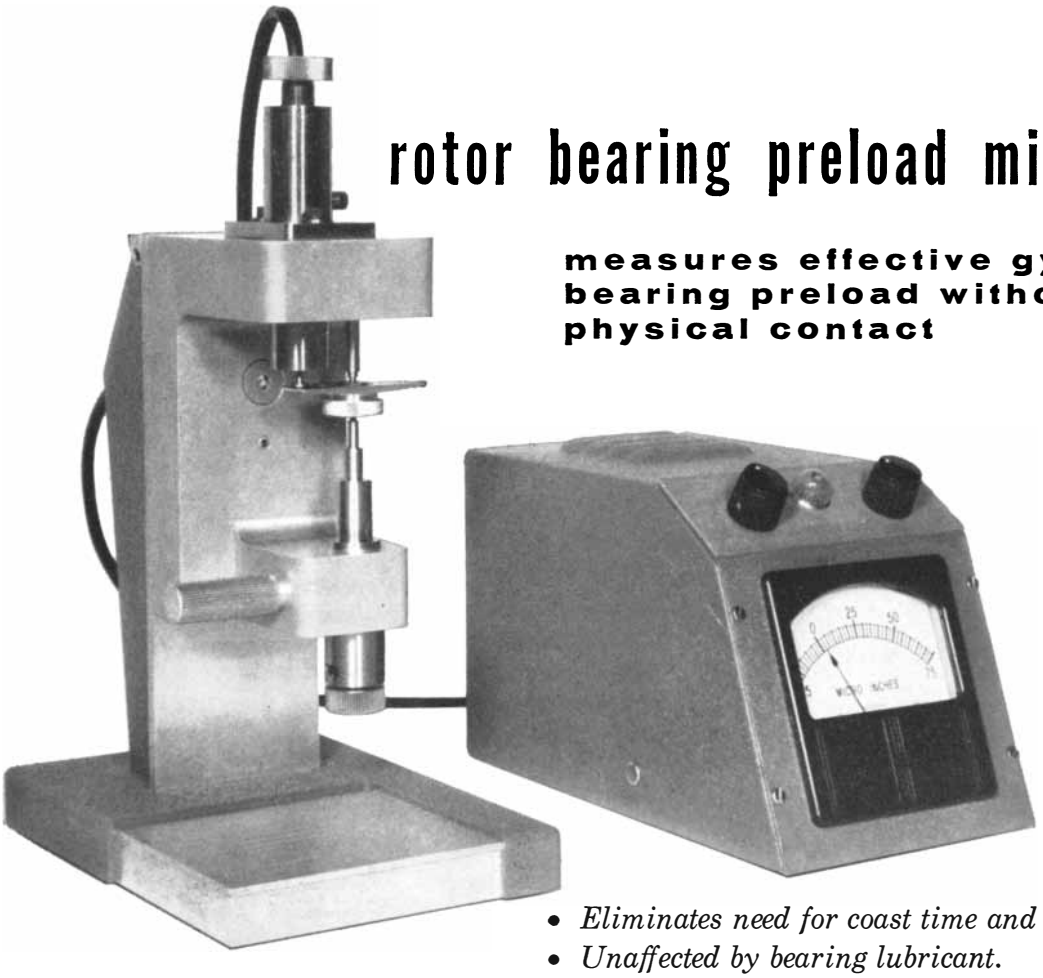
BRUSH ELECTRONICS

DIVISION OF CLEVITE CORPORATION

3405 Perkins Avenue, Cleveland 14, Ohio

rotor bearing preload micrometer

measures effective gyro rotor bearing preload without physical contact



- *Eliminates need for coast time and acceleration tests.*
- *Unaffected by bearing lubricant.*
- *Amazingly compact and portable.*
- *Rugged construction for production line service.*
- *Sensitivities as high as .000005 inch per division.*

THE DECKER MODEL 104-1 ROTOR BEARING MICROMETER provides a positive and accurate means of measuring effective bearing preload . . . a prime factor in rotor performance.

Accurately measuring axial movements to known standards, the micrometer simplifies one of the most difficult jobs in rotor assembly . . . obtaining prescribed bearing preload. Benefits gained include a reduction in rotor assembly time...less need for skilled labor . . . no chance of bearing damage during run-in . . . and fewer rejections due to improper preload.

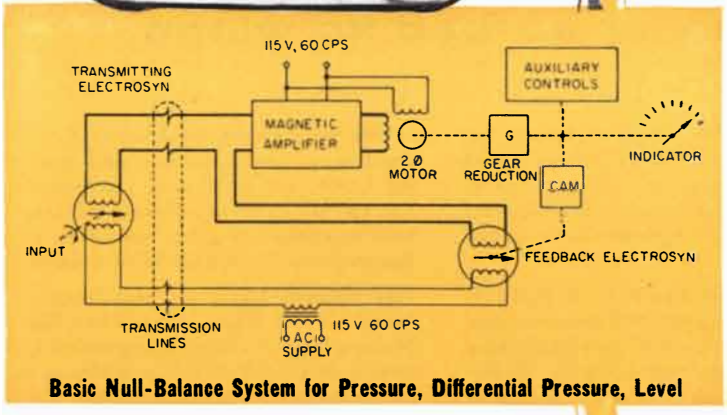
Simple adapter assemblies quickly convert the unit for handling many types of rotors, ranging in size from less than ½" diameter to 3¼" diameter.

Complete information on this unique new instrument is in Data Sheet 104-1, available upon request to the Technical Literature Section.

DECKER AVIATION CORPORATION

Philadelphia, 25

ElectroSyn Pressure Transmitter Model 501



Basic Null-Balance System for Pressure, Differential Pressure, Level

Basic system consists of signal transmitter, magnetic servo amplifier, null-balance indicator. (No electron tubes or slide wires.)

In measuring pressure the Model 501 transmitter utilizes a twisted bourdon tube as the pressure sensing element. This tube converts the pressure into shaft rotation of the ElectroSyn, a rotary differential transformer. Output from the ElectroSyn is an a-c voltage exactly proportional to the measured pressure.

HIGHer reliability
LOWer maintenance

- *pressure*
- *differential pressure*
- *flow*
- *level*
- *temperature*

ELECTROSYN SYSTEM

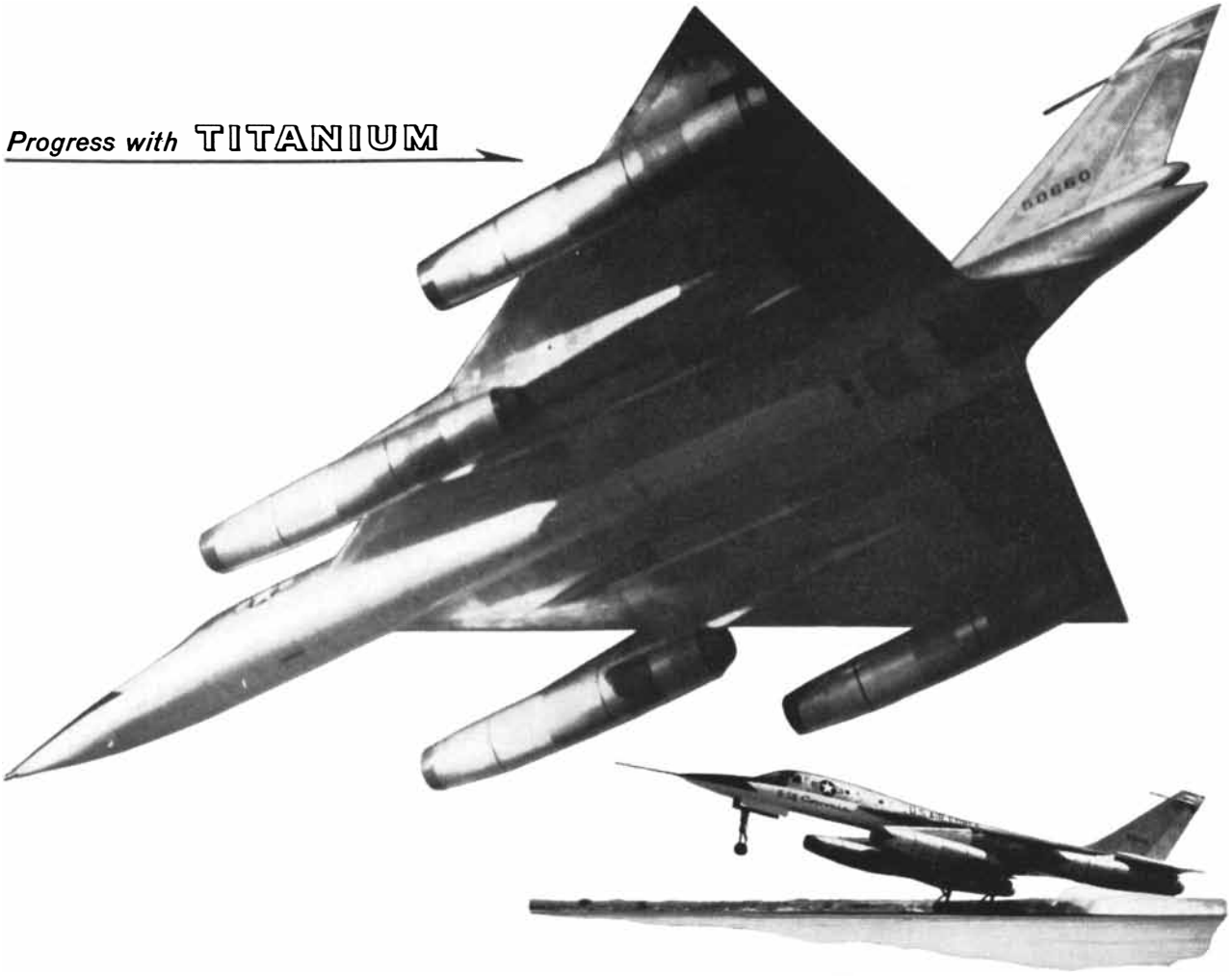
ElectroSyn is a highly flexible, extremely rugged electro-magnetic system for a wide range of applications in the chemical processing, atomic power, natural gas and petroleum transmission fields. It is designed to measure, indicate, record (including analog to digital conversions), or control pressure, differential pressure, flow, liquid level, temperature.

Leading pipeline companies are using ElectroSyn systems for remote indication and data handling of pressures and flows because of system's reliability, flexibility and the fact that it can withstand a static overload of 300% of rated pressure for a 1% zero shift. For complete information write for Technical Bulletin B257.

NORWOOD CONTROLS
UNIT OF DETROIT CONTROLS CORPORATION
933 Washington Street, Norwood, Mass.

NORWOOD CONTROLS

Progress with **TITANIUM**



HEAT TREATED TITANIUM

. . . helps the Hustler spread its wings

The Plane: The U.S. Air Force's delta-winged B-58 Hustler, made by Convair —Fort Worth. To achieve supersonic speeds, designers had to make optimum use of all materials, considering strength, weight, high temperature performance.

The Improvement: 6Al-4V titanium alloy, furnished by Mallory-Sharon, was used in certain applications as a direct substitution for steel for wing fittings bearing heavy loads. This alloy, weighing 44% less than steel, has equal or superior strength for the heat-treated conditions.

The Service Need: The Hustler is the first major application of a new technique that extends titanium usefulness —heat treating. The alloy material is supplied in a medium strength level which permits ease of rough machining. Then the part is heat treated and finished machined to the high strengths desired in service.

To help in this development, Mallory-Sharon service engineers recommended and assisted Convair in establishing qualified subcontractor sources. We furnished bar stock to these companies for evaluation, recommended furnace type, conditions, temperatures, and heating times. We performed mechanical and chemical tests before and after heat treatment, to guide this phase of the program to a successful conclusion.

The Result: Improved performance; America's first supersonic bomber. Use Mallory-Sharon's outstanding technical service on *your* applications of this new metal. For information, write Dept. C-4.

MALLORY Ti **SHARON**

MALLORY-SHARON TITANIUM CORPORATION • NILES, OHIO

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

FYI

FOR YOUR INFORMATION

Allied Chemical

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

- *Facts on food colors*
- *New aerosol mold release*
- *Chromium chemical data books*

Facts on food colors

What about those headlines on food colors? And the stories that some certified food colors are toxic? Is there anything to the Food and Drug Administration's recent delisting of three previously acceptable colors?

Here are a few facts behind the headlines.

The practice of coloring food is centuries old. Though the early colors were of natural origin, they have been replaced in the coloring of many foods by superior synthetic colors — the certified "coal-tar" colors. The Food and Drug Administration has been certifying a number of these colors for use in food since the early 1900's.

You're probably aware of some of the foods commonly colored today: ice cream, soft drinks, baked goods, candies, processed cheese, gelatin desserts, orange skins, margarine, butter.

Why then have some food colors been "delisted" and why are others being considered for delisting?

The controversy centers on the meaning of a single word in the Federal Food, Drug and Cosmetic Act: "harmless."

The Food and Drug Administration's definition: incapable of producing harm in any quantity or under any circumstances.

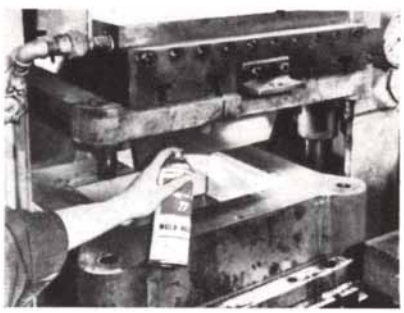
The food color industry's: incapable of producing harm under normal conditions of use.

It is the industry's view that FDA animal tests of certified colors have made use of quantities of color unrelated to — and far in excess of — quantities normally ingested by humans. A newspaper interview quoted the Commissioner of Food and Drugs as saying that he "conceded that three coal-tar dyes recently banned were harmless as used, but explained that their use was [a] technical violation of the law as now worded."

The absolute FDA standard seems to find support in the popular tendency to regard synthetics as inherently inferior to natural products. Yet, many fresh vegetables we eat every day contain small but tolerable quantities of naturally occurring poisons which, if judged as food colors are now being judged, would lead to the elimination of a large part of our vegetable diet.

What the food color industry asks is an amendment to the present law which would clearly grant power to the FDA to set quantitative limits on the use of colors in food. Such limits would safeguard public health, permit maintenance of our food color supply, and encourage research in the field.

Two articles — one supporting the industry's position, the other detailing manufacture and quality control of food colors — have been prepared by Allied's National Aniline Division, the leading food color producer. You can get them by checking the coupon at right.



Aerosol mold release

Remember the line that went, we could have some ham and eggs if we had some ham . . . and some eggs. Stretch your imagination a good deal, and it has some relevance in the business of molding.

Low-molecular weight polyethylene is a superior mold release.

There's hardly a more convenient way to dispense liquids than with an aerosol spray.

Ham and eggs: POLY-LEASE 77, a low-molecular weight polyethylene in a mixed solvent system, supplied in aerosol form. The spray's push, by the way, is from Allied's GENETRON propellants.

Here's how it works. When hot or cold mold cavities or other objects are sprayed, a smooth, relatively hard film forms quickly on the surface. This film provides efficient release with a minimum number of spray applications, resulting in faster cycle time, reduction of rejects and consequent lowering of production costs.

POLY-LEASE 77 will be of interest to molders of rubber, plastics (epoxies, polyesters, phenolics, alkyd, urea, melamine), powdered metal.

Chromium chemicals

The authoritative collection of chromium chemical technical bulletins has been published, appropriately enough, by the leading producer of chromium chemicals.

The books describe Allied's MUTUAL chromium chemicals and their applications in leather tanning, corrosion control, and anodizing of aluminum.

We'd be pleased to send either a brochure describing 49 bulletins available, or the bulletins in your field of interest.

POLY-LEASE 77, GENETRON and MUTUAL are Allied Chemical trademarks

Allied Chemical

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

Please send me further information:

- ☐ Facts on food colors
- ☐ New aerosol mold release
- ☐ Chromium chemical data books

Name_____

Company_____

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Position_____

Remarks_____

No embrittlement! Lowest cost! ASME Code approved!

In the subzero operating range . . . Specify Alcoa Aluminum equipment and piping

The flow chart details a tonnage oxygen plant now in actual operation where process temperatures average below minus 300° F. Notice that virtually all of the equipment and process piping are ALCOA® Aluminum. There's a good reason: aluminum is the lowest cost metal able to perform satisfactorily at low temperatures.

At subzero temperatures, ASME code approved aluminum alloys suitable for welded construction display improved yield and tensile strengths with no reduction in ductility or resistance to shock loading (see graphs). There is no embrittlement!

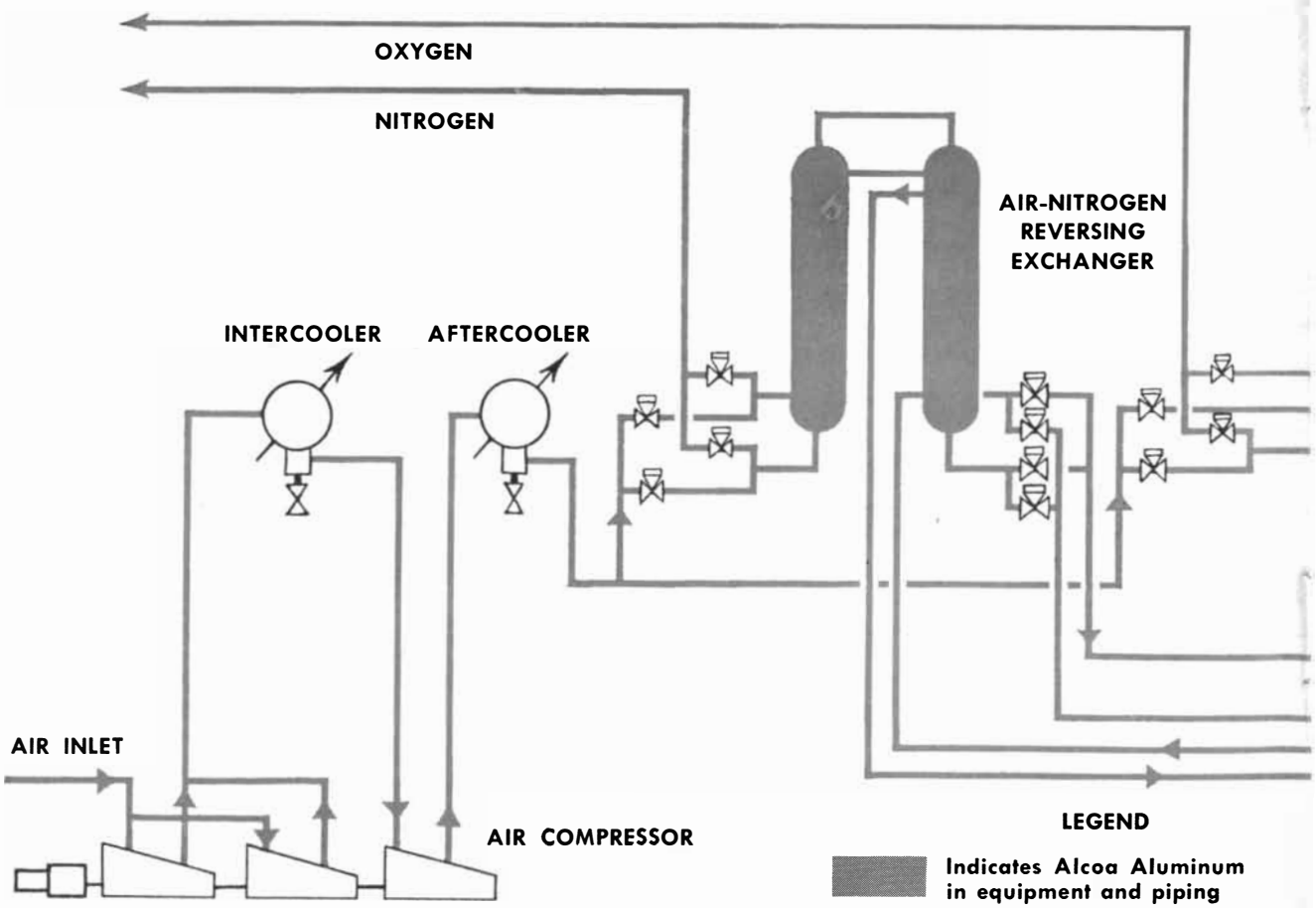
And in these operating temperature ranges, aluminum offers other valuable benefits . . . light weight . . . excellent resistance to corrosion . . . great strength in alloys . . . high thermal conductivity . . . nonmagnetic, nonsparking characteristics . . . nontoxicity . . . and excellent reflectivity. It is highly workable and lends itself readily to a variety of welding or brazing techniques for easy fabrication.

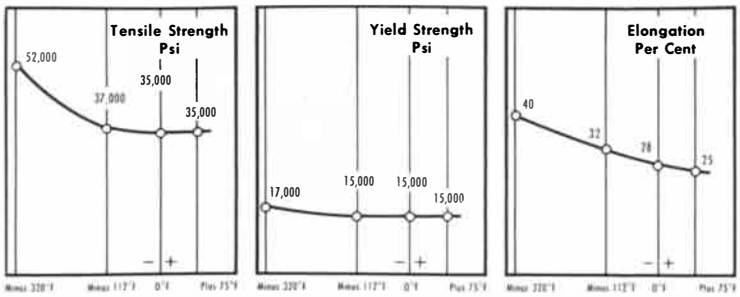
When *you* are looking for a low cost answer to the many problems of satisfactory equipment and piping performance in low temperature operations, *it will pay you to specify Alcoa Aluminum.* ALCOA engineers have worked with aluminum in the process industries for over 30 years. Use their accumulated knowledge to help you find satisfactory answers to *your* process equipment problems. Consult the nearby ALCOA sales office listed in the Yellow Pages of your telephone directory . . . or outline your equipment requirements in a letter to ALUMINUM COMPANY OF AMERICA, 891-G Alcoa Building, Pittsburgh 19, Pa.

THE ALCOA HOUR
TELEVISION'S FINEST LIVE DRAMA
ALTERNATE SUNDAY EVENINGS

ALCOA ALUMINUM

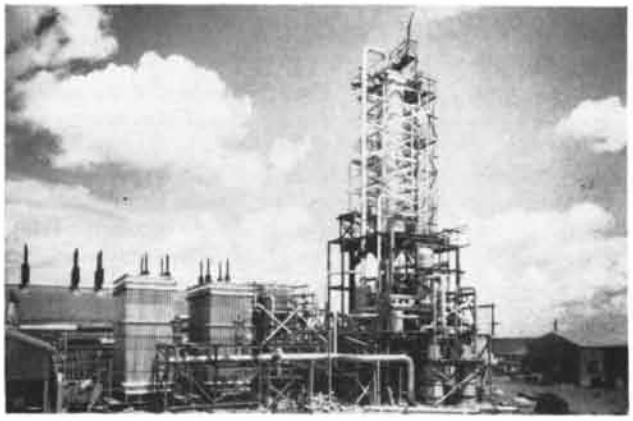
THIS FREE BOOK is filled with detailed data on the behavior of aluminum in the process industries . . . the result of more than 30 years of Alcoa engineering experience with aluminum in a variety of applications in nearly every temperature range. Use it as your guide to trouble-free, corrosion-free process equipment and piping. Write today for *Process Industries Applications of Alcoa Aluminum.*





LOW TEMPERATURE PROPERTIES OF ALCOA ALLOY 5154-0

Alcoa Aluminum actually increases in strength with no loss in ductility as temperatures drop to minus 320°F and below. Alloy 5154-0, for example, improves 50% in tensile strength, over 13% in yield strength and approximately 60% in elongation.



Photograph shows installation of Alcoa Aluminum equipment and piping in oxygen plant detailed in flow diagram. Harp-type heat exchangers (left) are dip-brazed assemblies with thousands of fins for best heat transfer.

Diagram of first successful low pressure tonnage oxygen plant . . . designed to produce 175 tons of 95% oxygen per day for the manufacture of oxygenated chemicals. All of the process piping and most of the equipment are Alcoa Aluminum.

LETTERS

Sirs:

As a bridge player who believes firmly in the principle that one peek is worth two finesses, I wish to split a hair with respect to Martin Gardner's article on mathematical games in your April issue. It is stated therein that given a specific ace in a hand of 13 cards, the probability of another ace is 11,686/20,825; whereas if the ace is unspecified, the probability of another ace is less than 1/3. Not quite so! The statement confuses the probabilities of having *one or more* aces with having *one and only one more* ace. So that bridge players will not be led astray, I offer the following correct values:

When the ace is specified, the probability of one or more aces is 11,686/20,825 = .56115. For the case where the ace is not specified, the probability of one or more aces is 5,359/14,498 = .36964 (*greater* than 1/3). Now if we are interested in the probabilities of having just one more ace, the values are 8,892/20,825 = .42699 for the ace specified and 2,223/7,249 = .30666 for the ace unspecified.

Also of interest are the pertinent probabilities if the color of the ace is known. For this condition the probability of one or more aces is .50264, while the probability of only one more ace is .40327. Rather oddly, these figures are closer to the specified than to the unspecified case. The moral is clear: if you are peeking at an opponent's hand during the bridge game, be sure to catch the color of his ace if you can't ascertain the suit!

R. A. EPSTEIN

The Ramo-Wooldridge Corporation
Los Angeles, Calif.

Sirs:

Meteorologists should feel grateful that their problems have enlisted the assistance of so able an astronomer as Walter Orr Roberts ["Sun Clouds and Rain Clouds"; SCIENTIFIC AMERICAN, April]. It is hoped that under his direction a set of reliable indices of solar activity will become available to help settle the problem of whether unusual weather phenomena are caused by external factors (*e.g.*, anomalous solar radiations) or by internal action (atmospheric hydrodynamics and thermodynamics). But despite numerous qualifications Dr. Roberts conveys the impression that unusual solar radiations have significantly influenced terrestrial weather processes such as drought, jet-stream and temperature changes and hurricanes to such an extent that successful predictions have already been made.

Last summer a group of astronomers and meteorologists met under Dr. Roberts's direction in a cross-field seminar on solar-weather relationships at the High Altitude Observatory. Their summary of the present position of empirical solar-weather relationships was described by Dr. Roberts in the November, 1956, issue of the *Bulletin of the American Meteorological Society* as follows:

"1. There are many suggestive empirical solar-weather relationships, which merit further critical statistical and physical evaluation.

"2. Effects of variable solar activity in producing anomalous secular and climatic weather changes are suggested; further research will be needed to establish the reality of these effects and whether the changes are practically important and the degree to which they can be predicted."

In this quotation one notes the absence of certain expressions appearing in Dr. Roberts's *Scientific American* article: ". . . established convincingly . . ." (speaking of Ralph Shapiro's results) and ". . . pretty strong case" (describing H. C. Willett's work). Of course it is Dr. Roberts's privilege to dissociate himself from a group judgment resulting from a seminar which he organized and to express his more optimistic beliefs in an

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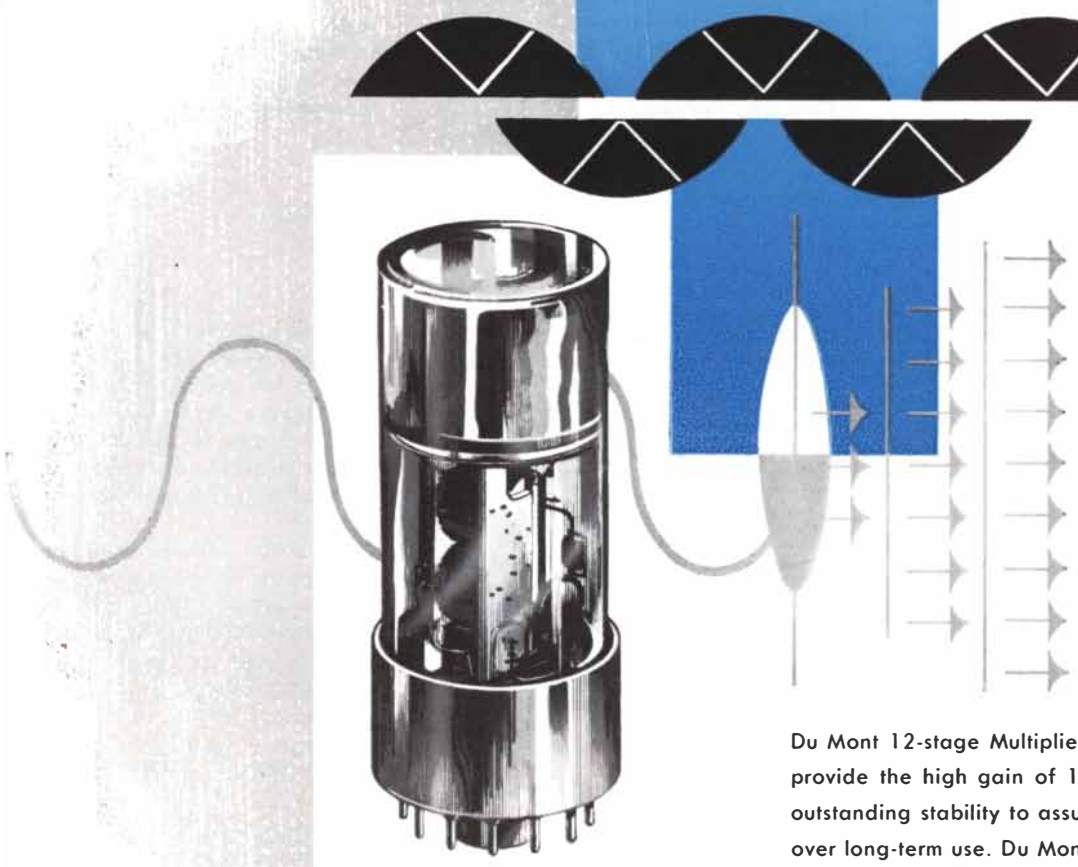
12 STAGES WITH STABILITY



Du Mont 12-stage Multiplier Phototubes provide the high gain of 12 stages *plus* outstanding stability to assure uniform results over long-term use. Du Mont 12-stage Multiplier Phototubes are available in 2", 3", 5", 12" and 16" sizes.

You can always count on Du Mont Precise Photoelectronics to do the job right—every time.

Precise **DU MONT®** **PHOTOELECTRONICS**

Industrial Tube Sales, **ALLEN B. DU MONT LABORATORIES, INC.** 2 Main Ave., Passaic, N. J.

Servicing Rocket Engines

Part II: Product Improvement

by Fred Barker

In this, the second of two articles describing the activities of service engineers and service representatives at Reaction Motors, Inc., Mr. Barker, Supervisor of the Product Service Department, illustrates how the technical "know-how" described in Part I is utilized by the department in the area of Product Improvement.

A good product can always be improved—particularly by those working closest to it. RMI's Product Service Department accepts this as a continuous challenge as it works with rocket engines and related components. The rewards of such a philosophy are three-fold: a superior, more easily serviced product, a pleased customer and the personal satisfaction of accomplishment.

At RMI we concentrate on four areas in the improvement of rocket engines: serviceability, reliability, safety and performance. For instance, in the area of reliability, initial ground runs on RMI's 6,000-lb. thrust engine in the Bell X-1A airplane frequently resulted in fuel pump cavitation upon starting the powerplant. Our service men traced the probable cause to the relocation, during installation, of the outlet port on the fuel diffuser case. It was found that air was being trapped in the case. This is a perfect example of how a seemingly minor change can radically affect engine reliability. To overcome this problem, the fuel pump was equipped with a bleed valve that automatically bled the entrapped air overboard during the liquid oxygen prime period prior to each engine start. Reliability was restored at the cost of adding another component, but installation demands could be satisfied only by this procedure.

Our service engineers and representatives often recommend design changes to improve products. A typical example of this is the way RMI worked with the National Advisory Committee for Aeronautics to improve the normal engine reliability of our 6,000-lb. thrust engine in the Douglas D-558-II airplane. The thrust chambers had failed to start on several random occasions. The trouble was traced to mechanical failures of the poppet retainer in the igniter oxygen poppet valve. This prevented the igniter from firing to start the thrust chamber. Service engineers in the home office then modified the poppet valve for greater mechanical strength. This improvement was proved successful by poppet valve tensile pull tests and igniter firing tests; replacement parts were obtained and installed in all engines in the field to prevent future failures from this cause.

Anxious to improve performance of the X-1E airplane, NACA considered the possibility of incorporating nozzle extensions on the thrust chambers of the X-1E's RMI rocket engine. After Service Department preliminary design work was accepted by NACA, installation problems were resolved with NACA by one of our service engineers. He then firmed nozzle extension design, assembly and installation details. This change proved so effective that now—for the same propellant consumption—thrust at altitude is appreciably greater. A good engine has been modified to perform even better.

Another function of the Service Department in its role to keep rocket engines going is the handling of engineering changes, all of which must be coordinated through and approved by the customer. Before any modification is made, RMI service engineers prepare "engineering change proposals" for approval by the customer. Upon this approval, the changes are incorporated into the affected drawings, and service bulletins are prepared to guide field personnel in effecting the change. Conversion kits are prepared, where needed, and service handbooks are revised.

Because the functions of RMI's Product Service Department are so varied, the men who make it up must be more than talented professionals. They must also have the traits of versatility and willingness to tackle new and different assignments. And—because our team is expanding—we would like to talk to *you* if you believe you have the professional qualifications and versatility that are so essential in good service men.

5274

If you desire reprints of this two-part article by Mr. Barker, or would like to receive additional information about RMI, write to our Information Services Coordinator, Reaction Motors, Inc., 90 Ford Road, Denville, New Jersey.

article for *Scientific American*. But the fact that his name is attached to a more guarded statement printed in another publication leaves one in doubt as to his true position.

Here are two specific examples of incomplete documentation in the Roberts article:

The two upper-air observation charts for April-May, 1955, offered to illustrate a direct solar effect really show a normal weather development which occurs many times in the western states and is particularly prevalent in April and May.

Dr. Roberts suggests that the inland penetration of hurricanes on the East coast of the United States in 1954 and 1955 is somehow related to low solar activity during that period but fails to mention that the severe hurricane of September, 1938, which moved into New England occurred during a period of maximum solar activity.

HARRY WEXLER

Falls Church, Va.

Sirs:

The distinguished meteorologist Harry Wexler makes the important point that it is too early to attempt practical applications of the hypothesis that solar changes induce changes of large-scale weather patterns. I fully agree, and do not think my article gave a contrary impression.

Dr. Wexler refers to my article summarizing the stimulating seminar held here last summer. In that article I was reporting the findings of a group, rather than expressing my own somewhat less conservative viewpoint. There are times and places, I believe, for a measure of well-tempered optimism!

The April-May weather sequence is, to be sure, a normal development. So are solar corpuscular clouds. We run into one or more such clouds a month, on the average. I am the first to admit that we do not yet have conclusive proof of the hypothesis that such weather developments are significantly related to corpuscular clouds—but there does seem to be enough positive evidence to justify vigorous research on the possibility. Alternative hypotheses surely deserve no less attention.

My point on hurricanes is based not on individual storms, but on average hurricane statistics. Severe hurricanes in New England can probably happen any year, but if some years show definitely fewer, this is significant.

In any event, the solar hypothesis is

trial by fire ...700 feet down!

A fire is burning deep under the earth's surface in Kern County, California, vital to the nation's usable oil reserves. In a cooperative effort involving eleven oil companies, General Petroleum Corporation is operating an experimental thermal recovery program which involves igniting residual oils in spent wells. Heat reduces the viscosity of oil in the reservoir, and a pressure front brings lighter oils to the production wells for recovery. Combustion and pressure are regulated and supported by the injection of compressed air. To control the rate of combustion, General Petroleum relies on a Consolidated Mass Spectrometer sampling system.

Recognized throughout the world as the leader in practical electronics for industry, Consolidated offers proven techniques for product improvement. See how CEC's instruments and systems aid industrial development and production. Write for Brochures 48 and 49, *General Catalog* and *Systems Engineering*.

General Petroleum Corporation depends on a special Consolidated Mass Spectrometer to analyze combustion gases and control underground firing for oil recovery.

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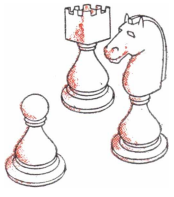
OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD



Your most profitable move to product improvement

subject to quite direct tests. My plea is that these tests be pursued with vigor. If the ideas behind them are wrong, they will bite the dust. I am betting, however, with the optimists.

WALTER ORR ROBERTS

High Altitude Observatory
University of Colorado
Boulder, Col.

Sirs:

E. S. Pondiczery of the Royal Institute of Poldavia has asked me to transmit the following communication. Dr. Pondiczery is traveling abroad and does not have your address.

"While I greatly appreciate Paul R. Halmos's flattering references to me in his article on Nicolas Bourbaki [SCIENTIFIC AMERICAN, May], I feel bound to admit that Poldavia was Bourbaki's homeland before it was mine; to him goes the credit (if credit it be) for the discovery of this fascinating land.

"May I take this opportunity to point out that on page 94 Halmos perpetrates the howler 'Chevallier' for 'Chevalley.' No real mathematician could do this. Is Halmos a pseudonym for a group of young people who write for *Scientific American*?" Signed: E. S. Pondiczery, Royal Institute of Poldavia (in Exile).

R. P. BOAS

Northwestern University
Evanston, Ill.

ERRATUM AND ADDENDUM

The name Claude Chevallier in the article on Nicolas Bourbaki [SCIENTIFIC AMERICAN, May] should indeed be Claude Chevalley. This error should be attributed not to Paul R. Halmos but to a group of editors on the staff of SCIENTIFIC AMERICAN.

In the article "Skin Transplants" [SCIENTIFIC AMERICAN, April] it was indicated that the photographs on page 62 were made during a study by A. Franceschetti, F. Bamatter and D. Klein. It should be added that this study was published in *Bulletin de l'Académie suisse des Sciences médicales*, Vol. 4, page 433; 1948.

Newly-designed stainless steel

OIL RING ASSEMBLY gives auto drivers 3-WAY ADVANTAGE

BETTER OIL ECONOMY

BETTER ENGINE PROTECTION

LONGER ENGINE LIFE

Oil rings do a very demanding job in an automobile engine. They control the amount of lubricant allowed to pass up to the compression rings and cylinder walls. In modern cars, with higher compression ratios, the tension of the oil ring expanders has had to be increased—and that's where Allegheny Type 201 stainless offers advantages.

Engine operating temperatures have virtually no effect on this new stainless alloy. It maintains constant tension whether the engine is hot or cold, permitting most efficient design for maximum flow of lubricant when friction is greatest, and less flow when the engine is warmed up and requires less. Formerly, carbon steel expander rings suffered a tension drop when heated to engine operating temperature. Then under heat they took a permanent set, which caused the loss of "cold tension." Allegheny 201 also has ended the problem of expander breakage due to the corrosive action of engine deposits.

This success story is just one of many being written with the new 200-series of low-nickel Allegheny Stainless Steels. Fabricating methods are virtually the same as with the higher-nickel 300-series, but you'll find some advantage in cost, and much greater availability in times of nickel shortage. • If these new steels seem to fit into your manufacturing or service picture, give us a call. *Allegheny Ludlum Steel Corporation, Oliver Bldg., Pittsburgh 22, Pa.*

WSW 6528

WRITE for a copy of our "Technical Horizons" bulletin on the Allegheny 200-Series stainless steels.

ADDRESS DEPT: SC-91

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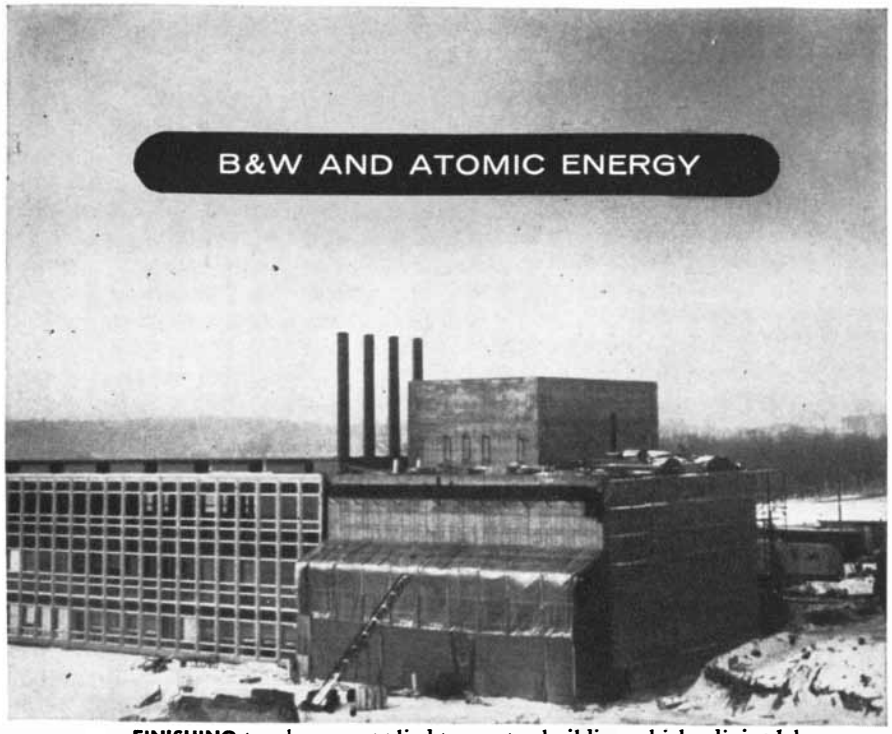
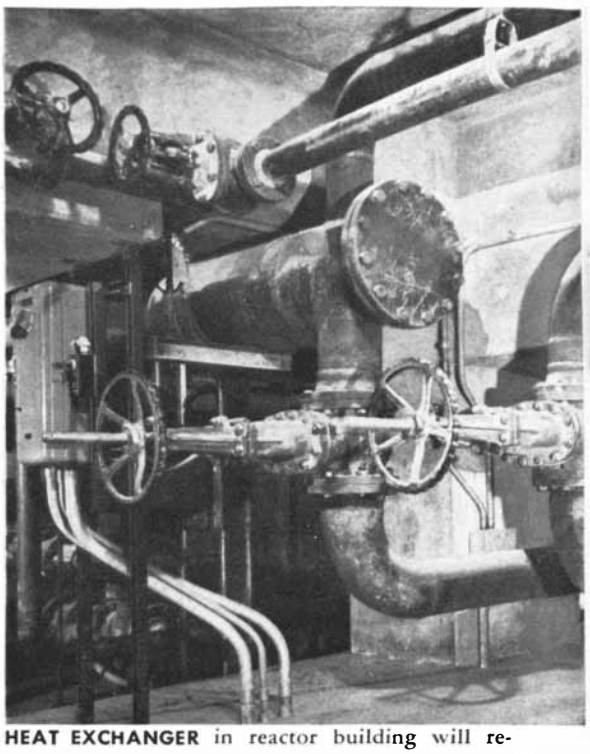


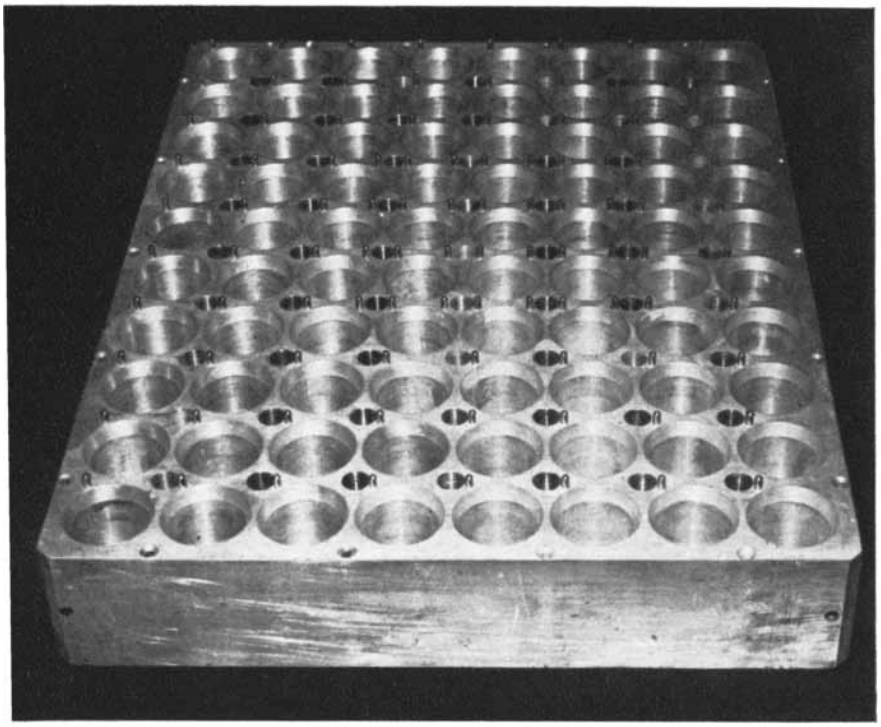
FINISHING touches are applied to reactor building which adjoins laboratory. Doors and building dampers are fitted with gaskets to provide a tight seal when closed.



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

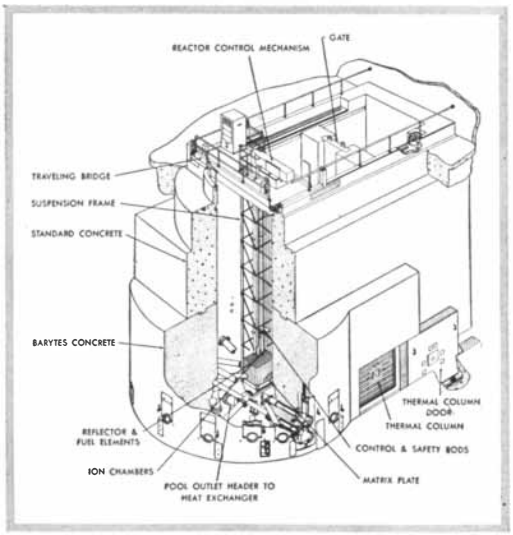
UNIVERSITY OF MICHIGAN LABORATORY ATTACKS

B&W Reactor Putting

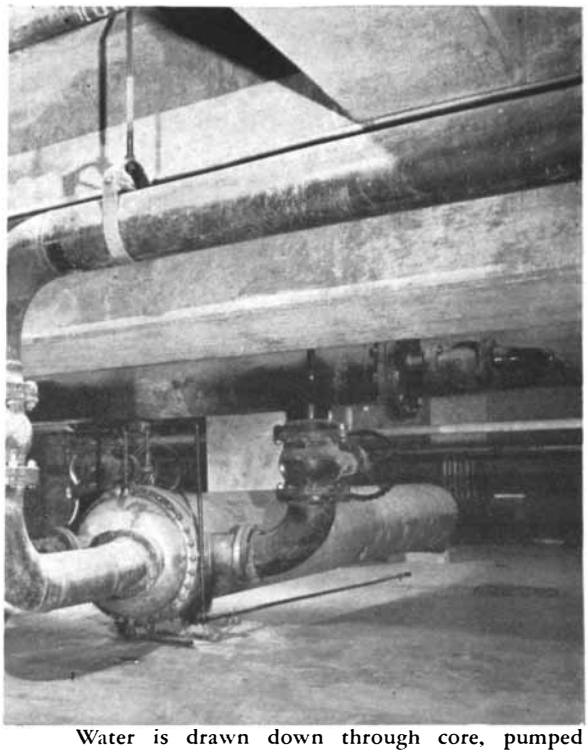


GRID PLATE has 80 different locations for fuel and graphite reflector elements, permitting many different core arrangements. Grid plugs for unused holes prevent the coolant from by-passing the fuel elements.

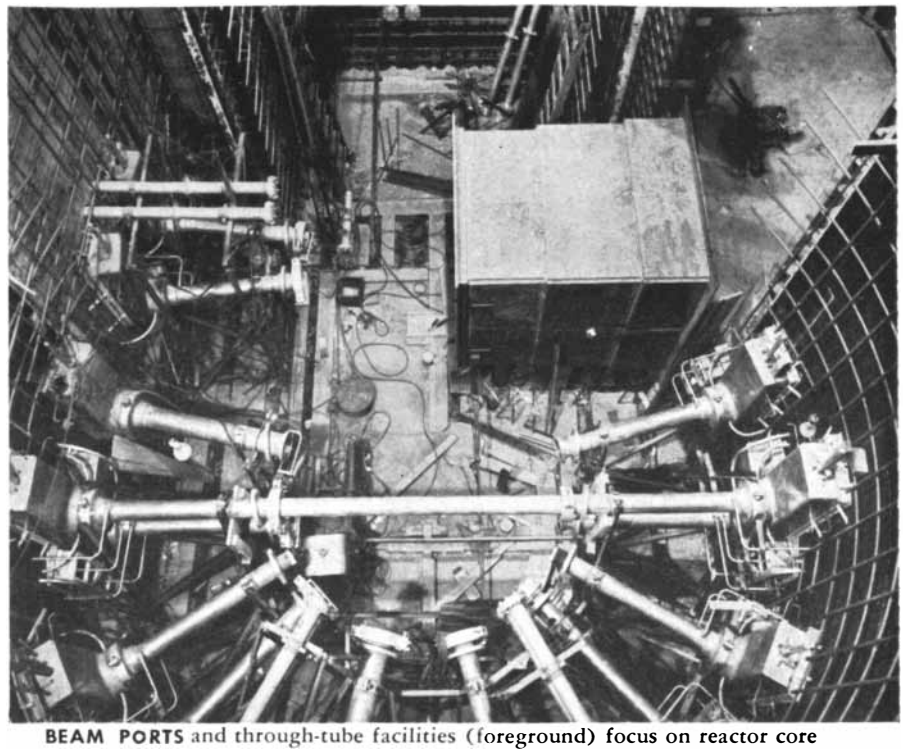
The Ford Nuclear Reactor provides an intense source of neutron and gamma radiation for basic medical, biological, chemical, physical, and engineering research and prac-



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



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

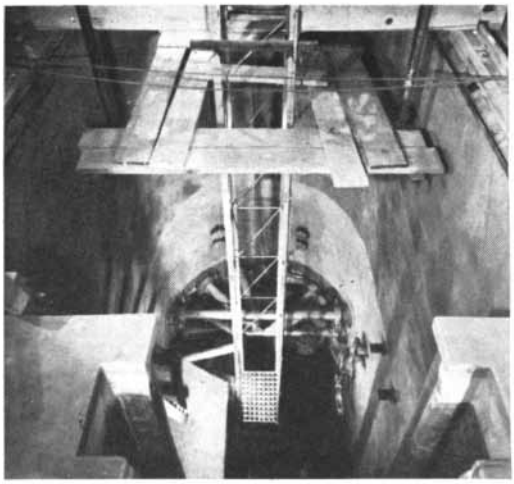


BEAM PORTS and through-tube facilities (foreground) focus on reactor core full-power operating position. Thermal column (upper right) is stacked with graphite blocks to slow down entering neutrons to thermal velocities.

BASIC RESEARCH PROBLEM WITH . . .

Neutrons to Work

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



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

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

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

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

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

AE-36-A

BABCOCK & WILCOX

ATOMIC ENERGY DIVISION

OX-250 / *a proved G.E. X-Ray product to make your products better*

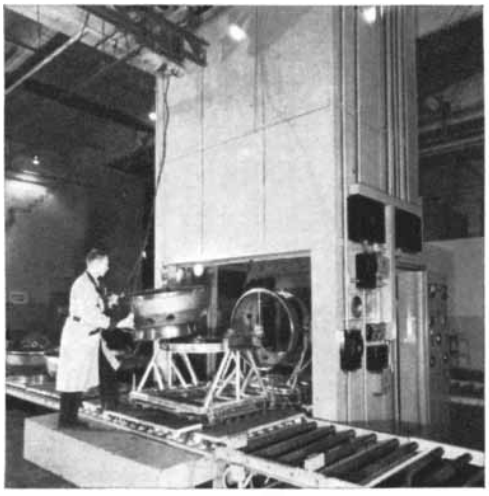
When missions can't fail...

G-E x-ray inspection detects trouble before it starts

This lean and lethal atomic bomber travels lighter, faster, safer thanks to engine weld inspection with the General Electric OX-250. No beefed-up design to compensate for weak welds on its J-57 turbo-jet components. No excess bulk to hamper speed. G-E x-ray spots troubles before they start.

In addition, the semi-automatic OX-250 at Ford's Aircraft Engine Division plant in Chicago does the work of four conventional units. Speeds inspection while it cuts down risks and costs.

Whatever your own production "mission" . . . from light alloy to armor plate . . . General Electric has x-ray apparatus to meet your needs. Call your local representative. Or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin for Pub. TT-74.

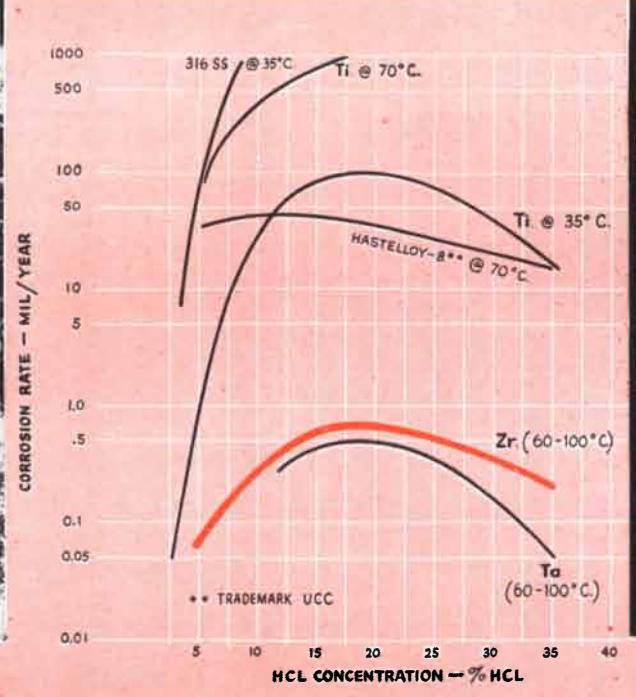


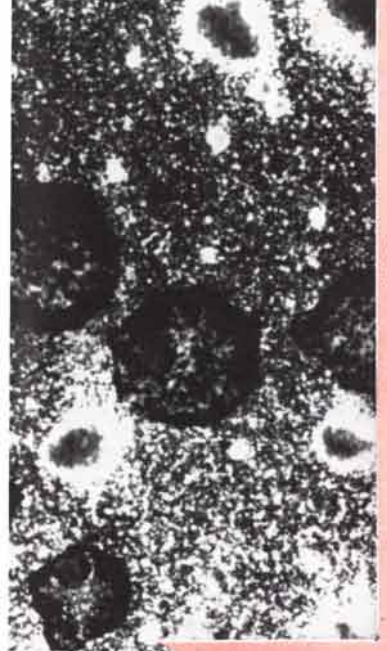
FORD AIRCRAFT ENGINEERS GIVE J-57 COMPONENTS A LIFE-SAVING "LOOK" to assure defect-free welds. Stainless steel .093-inch welds on diffuser cases above are about 10 feet long . . . must be 100% sound. Operator prepares second case for radiographing while first case moves into cabinet.

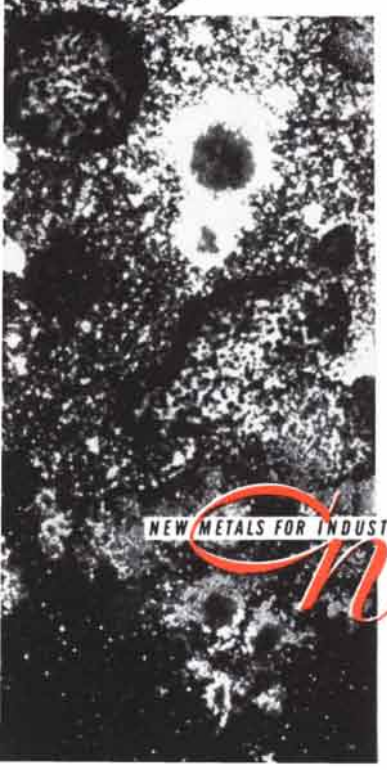
Progress Is Our Most Important Product

GENERAL ELECTRIC

C-N / Zr Tech Digest







want to keep a "hot fluid" in its place?

C-N ZIRCONIUM

Now, you can look at your product or process with zirconium in mind! For example, tests indicate that only tantalum is comparable to zirconium in resisting hydrochloric acid — and zirconium is less costly.

C-N Zirconium will be available in commercial quantities in the near future. Now is the time to investigate the remarkable corrosion resistance of zirconium—as demonstrated in the nuclear field and in certain industrial applications.

Columbia-National is undertaking a product research program to investigate the merits of zirconium in specific media. If you have severe corrosion problems, C-N offers laboratory and research facilities to establish how and where zirconium can solve your problem. Write us about your requirements. Send for technical data on properties and corrosion resistance of this new metal.

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CG-1

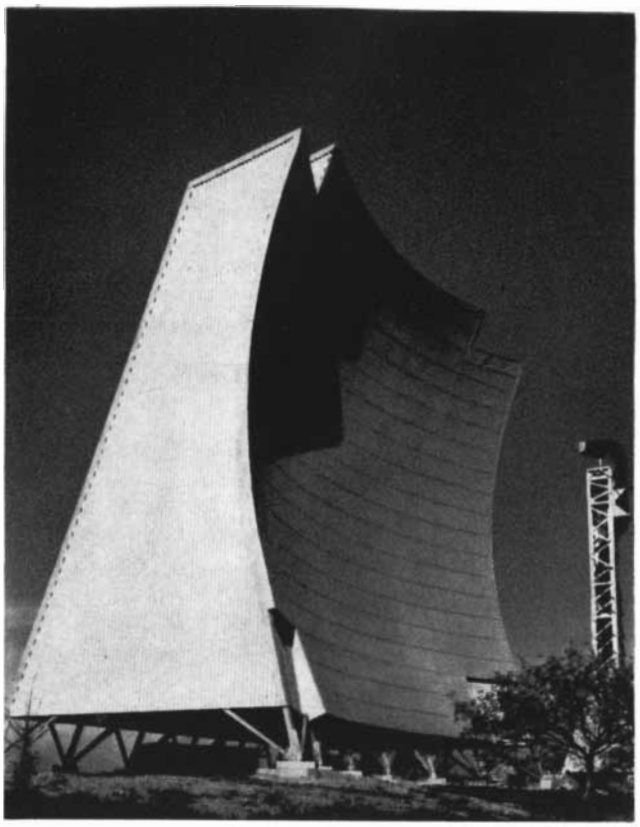
50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JULY, 1907: "One phase of wireless telegraphy to which we call attention is the necessity of making a thorough study of the causes that vary the transparency of space to long electric waves. This effect was first noticed by Marconi, and later by Fessenden. The transparency of the terrestrial atmosphere seems to vary from day to day and from hour to hour. It is better at night than in the daytime. There also seems to be another effect which is most noticeable near the transmitting antenna. This damping effect fluctuates from hour to hour and from month to month, according to laws not yet determined, and too little is known to enable any generalization to be made concerning it."

"One of the peculiarities of radium—perhaps the most important from a scientific standpoint—is its production or generation from some other element. It is generally considered that radium, and possibly actinium, are ultimately descended from uranium. This relationship has, however, never been definitely established. A more recent investigation by Dr. E. Rutherford seems to show that actinium is not the parent of radium; the true parent has not yet been identified, even though it is apparently possible to separate it from actinium and uranium. The new element, it is expected, will soon be described and properly christened. This particular phase of the study of radioactive elements is of absorbing interest, but unfortunately, or otherwise, we have as yet discovered no method of controlling the changes or transmutations."

"Sir William Perkin died last week at the age of 69 years. Few men of science have begun their careers so early and attained success so quickly. It was on an Easter vacation in 1856, when he was only 18 years old, that he discovered mauve. He was led to this when he tried to produce quinine artificially from allyl toluidine, which caused him to study the oxidation of aniline. While experimenting with the dyestuff thus obtained, he



Giant over-the-horizon antenna designed by Bell Telephone Laboratories for "White Alice," Air Force Alaskan defense communications network.

How UHF radio got seven-league boots

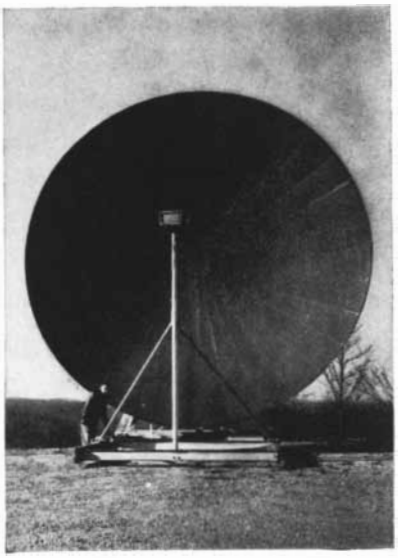
THE huge antenna systems which project ultra-high frequency radio communications beyond the horizon began when a Bell Telephone Laboratories engineer became intrigued with a strange phenomenon. Although these radio waves were supposed to be useful only over line-of-sight distances, the waves displayed a mysterious tendency to take off in a giant stride to antennas beyond the horizon.

This phenomenon had been studied both here and abroad, but no practical use was seen until the engineer became interested and thoroughly sifted the experimental data. He came up with the stimulating conclusion that over-the-horizon transmission is far stronger and much more dependable than was generally supposed. Further he predicted that it could be utilized to supply dependable broadband communications. He and his associates at Bell Laboratories confirmed the prediction experimentally, then drew up requirements for the first over-the-horizon UHF transmission system.

This pioneer work at Bell Telephone Laboratories has greatly increased the usefulness of UHF communications. For example, over-the-horizon transmission now provides critically important communications between remote military outposts in the Arctic and in the far north.

For the Bell System it can provide important new links for telephone conversations and television.

Kenneth Bullington, B.S.E.E., University of New Mexico; M.S., Massachusetts Institute of Technology; recipient of the 1956 Morris Liebmann Memorial Prize and the 1956 Stuart Ballantine Medal for his contributions in the field of over-the-horizon ultra-high frequency radio transmission.



Experimental antenna used in early over-the-horizon UHF radio transmission research. Research extended transmission from 30 miles line-of-sight to 200 miles.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

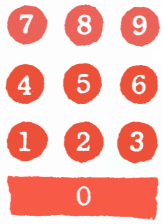
found that it produced on silk a beautiful violet, exceedingly resistant to light. Later that year, Perkin patented the process. Experimental attempts to use the new dye for other materials proved so successful that its manufacture was undertaken by Sir William Perkin, his father and his brother. His dye was a pioneer, and it cleared the way for all that came after it. It completely revolutionized the dyeing and textile-printing industry, and gave rise to an amount of chemical research in the coal-tar colors that is probably without an industrial parallel."

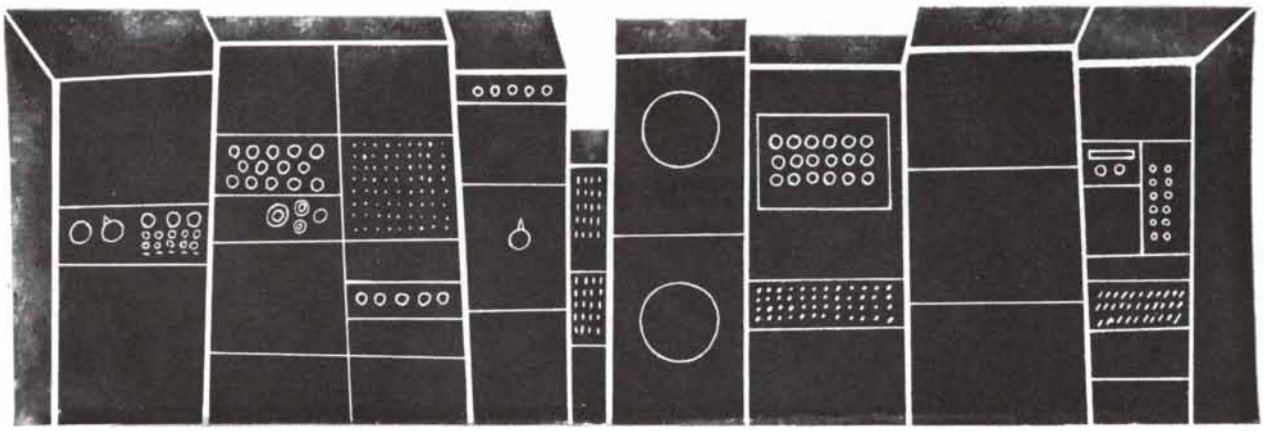
"The prophetic and lively imagination of Jules Verne made one of its most daring flights when he wrote *Around the World in Eighty Days;* it is probable that none of us who read its chapters supposed he would live to see the day when the Frenchman's estimate would be cut in half by an enterprising officer of the British army. In a recent letter Lieut.-Col. Burnley Campbell writes that he landed at Dover on June 13 at the completion of a trip around the world which occupied 40 days and 19½ hours. He left Liverpool on May 3 at 7:20 p.m., reached Quebec on May 10, and was at Vancouver on the Pacific Coast on May 16. Leaving there about noon of the same day, he reached Yokohama on May 26, Tsuruga on May 28, and Vladivostock on May 30. Here, after a wait of about four hours, he took a trans-Siberian train, reaching Harbin on May 31, Irkutsk on June 4, Moscow on June 10 and Berlin on June 12. On the following day he was at Ostend, and at 2:50 p.m. of the same day he landed in England at Dover. Throughout the whole trip Lieut.-Col. Campbell was remarkably fortunate in making connections; otherwise his time would have been several days longer."

SCIENTIFIC AMERICAN

JULY, 1857: "Some time ago an offer of $500 was made through the Boston *Courier* to any one who could exhibit in the presence and to the satisfaction of certain professors of the natural sciences at Harvard University any such marvelous phenomena as were commonly reported by spiritualists as having transpired through the agency of 'mediums.' This challenge was accepted, and several persons professing to have spiritual communications met in the Albion build-

simple as a desk calculator...





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combines advantages of both . . . and solves the problems "in-between," at low cost and with big savings in technical man-hours. Pinboard programming — an exclusive feature of the E101 digital computer — can be mastered in six hours; familiar notations, no coding. That's why more E101's are *at work* than all other comparable computers combined. Immediate delivery; instant serviceability. As a test: send us one of *your* problems. We'll program it, send your solution and proof of how we can serve. For demonstration, or descriptive booklet, write:

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ing, Boston, to show their powers. Among the number were the 'Fox girls,' celebrated for their achievements in this line. The committee appointed to judge the case consisted of Professors Peirce, Agassiz, Gould and Horsford. The spiritual experiments were conducted for several days, and the medium allowed ample and fine opportunities of making demonstrations; but like the priests of Baal, in the days of Elijah, they failed to call down their deities."

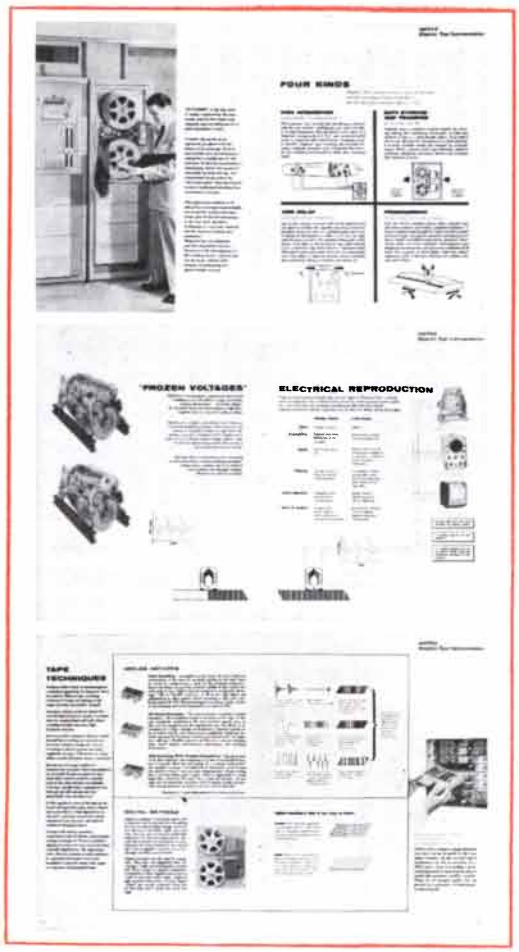
"The frigate *Niagara* was expected to be complete in her alterations on July 20, on which day she was to leave Portsmouth for Liverpool to take in her share of the submarine cable. It is to be stowed in five separate coils, each wound around a large wooden cone, to prevent fouling when running off. Two coils will be placed aft, the lower one on the 'orlop,' and the second one on the 'berth deck'; the three other coils placed forward will be arranged one above the other on separate decks, the lower one being on the hold floor. The cable will be run out at the stern through a hollow cone, and pass over friction rollers. It weighs nearly one tun to the mile, and will be 1,250 miles long. This cable is now finished, and lying at Birkenhead. It was completed by the contractors, Messrs. Newall of Liverpool, in 80 days, three weeks before their term for executing it had expired. The manufacture of the cable employed 100 machines for making spun yarn, with which the gutta percha insulation is covered. The cable consists of a main strand of seven copper wires covered with three coats of gutta percha. Over this is the spun yarn and 18 strands of twisted wires, seven wires in each strand, forming the exterior of the cable. There are in all 400,000 miles of wire—long enough to go eight times around the world. The Atlantic Telegraph and the steamship *Great Eastern* are the two most gigantic enterprises of the present age."

"It is said that the walls of the Capitol building at Washington have been recently found too weak to bear the magnificent iron dome which is in process of erection, and that this portion of the work will have to be suspended. The new dome was to have taken the place of the flatter and lighter one previously employed, and a strengthening of the walls would involve almost a reconstruction of the whole central portion of the building. The new houses of Congress, at the extremities of the wings of the building, are proceeding without interruption."

How to be a magnetic tape recording expert

Introducing a useful new brochure on tape in instrumentation

Tape is the stuff of which memories are made — the versatile data memories for a jet propelled age of electronic miracles. If you are one who keeps up with times and techniques, it is a field well worth knowing. This new brochure gives a wide-angle view of the whole subject.



Typical pages

What kinds of applications do you think of when magnetic tape recording is mentioned? Sound recording, of course, and telemetering, if you are in that business. But what about simulating a rough road to test truck axles, controlling a milling machine to cut an aircraft wing section out of a solid billet, monitoring for a sudden occurrence that may happen only once in a year or two, recording data that can be reduced to graphs and tabulations without ever being touched by human hands? These and many more are described.

How significant is the fact that magnetic tape recording reproduces data in the same electrical form in which it was recorded? Enormously important, when you realize all the things the reproduced data can do that couldn't be done with the original signals or with the common forms of visual recording. For example the data can be slowed down to look at fast transients. It can be speeded up for wave analysis. It can be read out in any form. A tabular comparison between original signals and taped signals gives the full story. And a step-by-step pictorial demonstration of magnetic tape recording and reproduction puts the electrical-data idea into tangible, easily visualized form.

What does the data on magnetic tape look like? You can't see it, but the brochure will give you an idea of what it would be like if you could. And incidentally this may help to clarify the differences between various magnetic-tape-recording techniques.

Do you talk in tape's language? When is a tape recorder not a recorder? What is the difference between a channel and a track? What is a servo speed control? A much needed glossary gives the consensus of our views on terms.

For whom did we write this booklet . . . the expert, or the man for whom the whole subject is new? Both. It is written and illustrated so that any engineer or technically trained person can readily grasp the concepts and gain a broad understanding of the subject. If you are one of those who has already worked extensively with tape, you will find some new twists in the way the subject is explained, and perhaps ideas on new areas you hadn't explored. And incidentally, a copy of this brochure in some handy file will give you a good start in indoctrinating that new man in the department.

For your copy, write us today on your company's letterhead. Address your request to Department S-5.

MAGNETIC TAPE APPLICATIONS BY AMPEX

ONE OF A SERIES 5

Series FR-100

Series 800 Mobile and Airborne

Model FR-200 Digital

Series FL-100 Loop Recorders

Series FR-1100

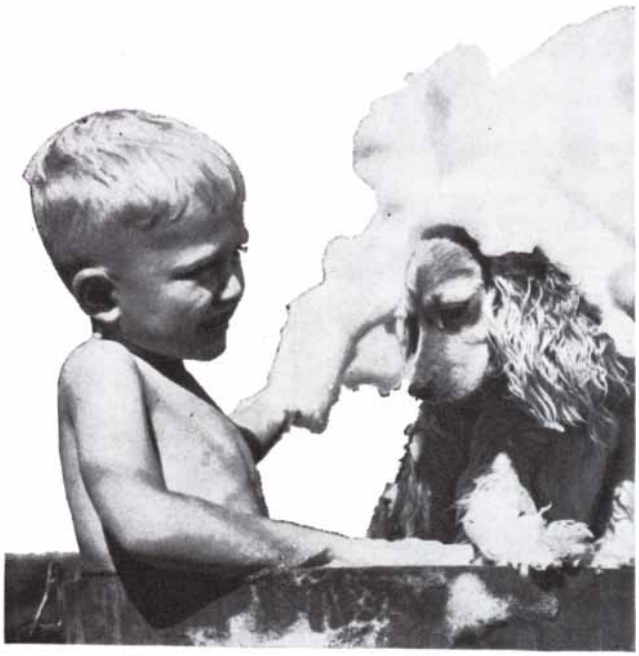
INSTRUMENTATION DIVISION AMPEX CORPORATION

FIRST IN MAGNETIC TAPE INSTRUMENTATION

934 CHARTER STREET · REDWOOD CITY, CALIFORNIA

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

Life on the Chemical Newsfront



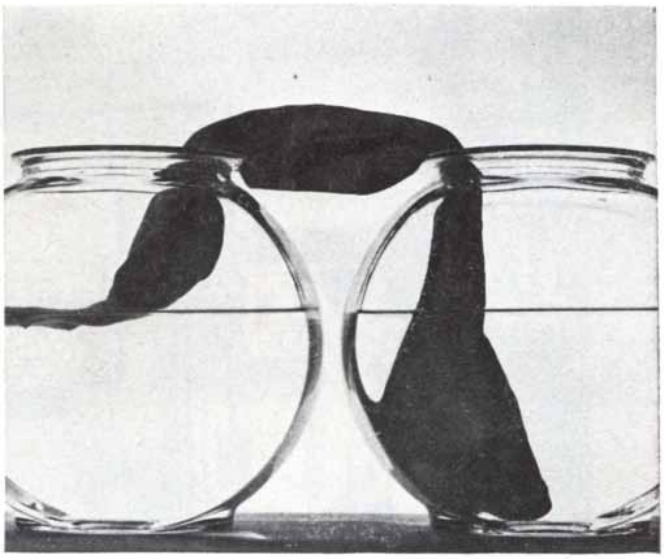
LASTING BEAUTY and liveliness that stays lively are qualities of rubber products made with Cyanamid's UNITANE® Titanium Dioxide. Thorough purification and careful controls imposed in manufacture give UNITANE Titanium Dioxide good whiteness, high brightening strength and excellent aging characteristics. White whites and bright pastels are assured by UNITANE Pigments. **(Pigments Division)**

RICHER LATHERING OF LIQUID SOAPS in hard water is made possible by Cyanamid's CYQUEST* 40 Sequestering Agent. By sequestering heavy metal ions CYQUEST 40 protects against the formation of undesirable insoluble soaps and insures sparkling clarity of soap formulations even after extended storage. CYQUEST 40 Sequestering Agent is a 40% solution of the tetrasodium salt of ethylene diamine tetraacetic acid, generally recognized as the sequestrant forming the most stable heavy metal ion complexes. **(Industrial Chemicals Division, Dept. A)**

*Trademark

A NEW BIFUNCTIONAL ACRYLONITRILE DERIVATIVE, potentially low in cost, has been announced by Cyanamid. Now available in research quantities, β-sulfopropionitrile could be produced on a commercial scale at a price in the bulk chemical range. Melting at 243-244° C, soluble in water, hot methanol and glacial acetic acid, this interesting chemical combines the functionality of the nitrile group and the sulfonic group. If you are curious to find what you can do with it, send for data sheet and sample. **(New Product Development Dept. A)**

FRESH FISH 3000 miles from its source is a reality in Canada. Now diners in Vancouver, B. C., can enjoy Atlantic Ocean varieties shipped across the continent. Making this possible is Cyanamid's ACRONIZE® Chlortetracycline. Added to the fillet dip tank, it greatly retards deterioration and maintains the delicate fish flavor through many days. ACRONIZE Chlortetracycline has been used in the United States for two years to extend the freshness of poultry, and the application to fish has just received approval in Canada. **(Farm and Home Division)**



THIS "FISHBOWL TEST" graphically demonstrates the powerful wetting action of DECERESOL® Wetting Agents. The tank on the left contains plain water, and the tank on the right contains water with 0.025% DECERESOL Wetting Agent. Plain water hardly wets the fabric, which continues to float, while the treated water wets rapidly, causing the fabric to sink quickly. The rapid wetting action of DECERESOL Wetting Agents, which are stable through a wide pH range, aids greatly in such textile treating operations as desizing, bleaching, dyeing and finishing. They do not affect the appearance or feel of the treated fabrics.
(Organic Chemicals Division)

TWO NEW IMPACT-RESISTANT COATING RESINS for metal finishes have been introduced to the paint industry. CYZAC* 1006 and 1007 Resins provide an unusual combination of properties in enamels for metal: maximum hardness with much greater impact and chemical resistance than conventional finishes. Among expected major uses are finishes for metal toys, appliances, automobiles and metal cabinets and furniture. Other properties imparted by these resins are flexibility, high gloss and gloss retention, unusually good enamel stability and better adhesion.
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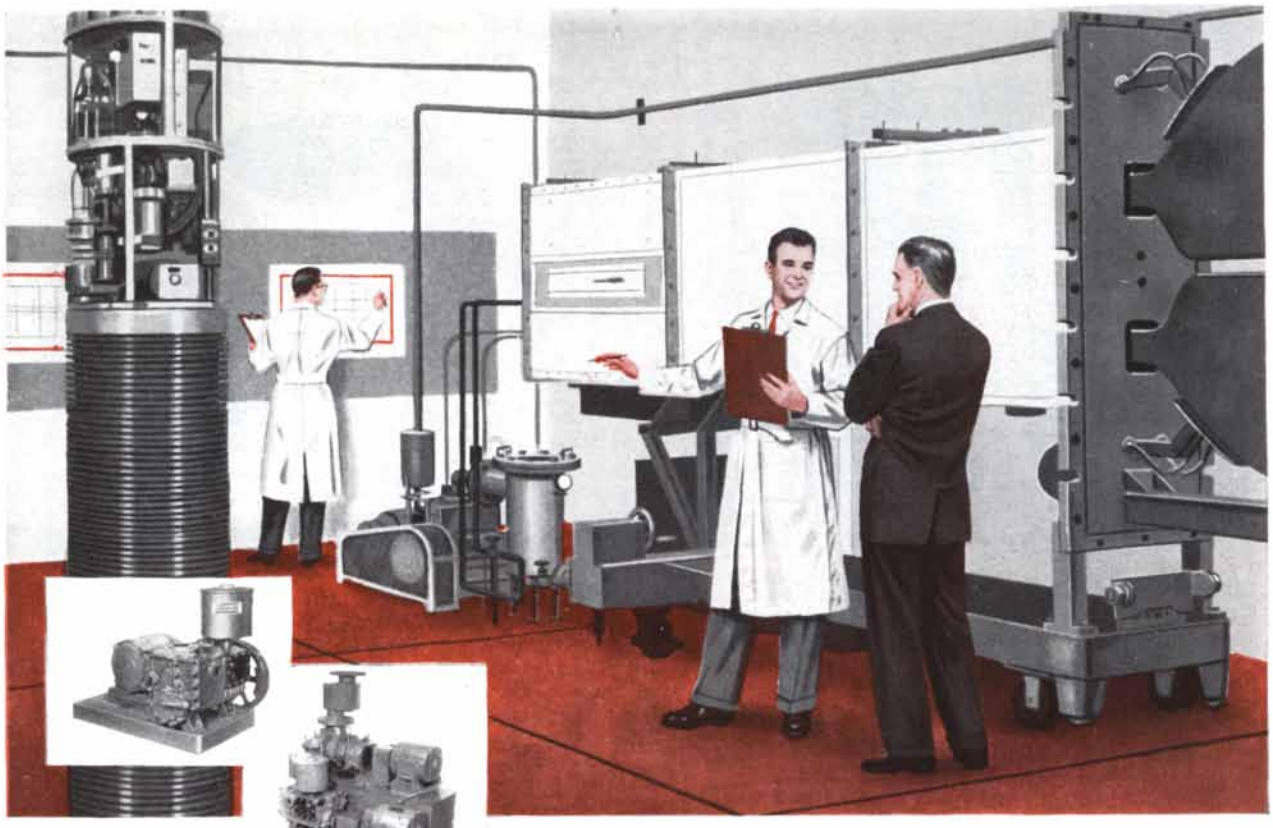

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KINNEY Mechanical Booster Vacuum Pump

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High Vacuum Mechanical Pumps, single stage, 13 to 780 cfm, pressures to .01 mm Hg; two stage, 2 to 46 cfm, pressures to .0002 mm Hg; Mechanical Booster Pumps, 30 to 5000 cfm, pressures to .0001 mm Hg. Rotary Liquid Handling Pumps to 3000 gpm.

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Camden, N. J.

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HYDRECO Hydraulic equipment for industrial and mobile applications. Gear and Dual-Vane Pumps and Motors to 2000 psi, to 120 gpm, to 120 hp. Control Valves to 2000 psi and 150 gpm. Cylinders: Telescopic, Single and Double-acting to 10" diameter, strokes to over 20 ft.

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Watertown, N. Y.

Railroad Air Brake equipment of all types; STRATOPOWER Hydraulic Pumps and Motors for Aircraft, to 5000 psi for operation to 400° F.

AURORA PUMP DIVISION
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AURORA Centrifugal Pumps to 8500 gpm and 600 ft. heads. APCO Turbine type Pumps, 5 to 150 gpm, heads to 700 ft. Condensate Return Units 800 to 100,000 sq. ft. radiation.

Modern High Vacuum technology is opening many doors which physicists and scientific researchers now know lead to exciting developments in the future. As dramatic as they are, today's accomplishments are but forerunners of many more to come. To name but a few which had their genesis in Vacuum Processing, there are: Atomic Accelerators, Radar, Transistors and other Electronic Components, TV Tubes, Neon and Incandescent Lighting, Refrigeration and Air Conditioning, "Wonder Metals" Titanium, Zirconium, etc. and the Mycin "Wonder Drugs."

Engineers of The New York Air Brake Company are bringing ever-improved Vacuum Equipment to the scientist in the laboratory and the production engineer in the plant. The KINNEY MFG. and VACUUM EQUIPMENT Divisions of The New York Air Brake Company are the natural sources for the answers to questions and problems involving High Vacuum. Remember the name KINNEY—it's important to those who use Vacuum . . . it may well be very important to you!

New developments are the norm throughout The New York Air Brake Company. In Hydraulics, HYDRECO Fluid Power components enable builders of Mobile Equipment and Machine Tools to attain higher and higher performance from their equipment. STRATOPOWER Pumps and Fluid Motors, of watch-like precision, help to advance frontiers in the sky in aircraft, guided missiles and rockets. Railroad Air Brakes of new design, bearing the NY mark, are on New York Central's famous Train X.

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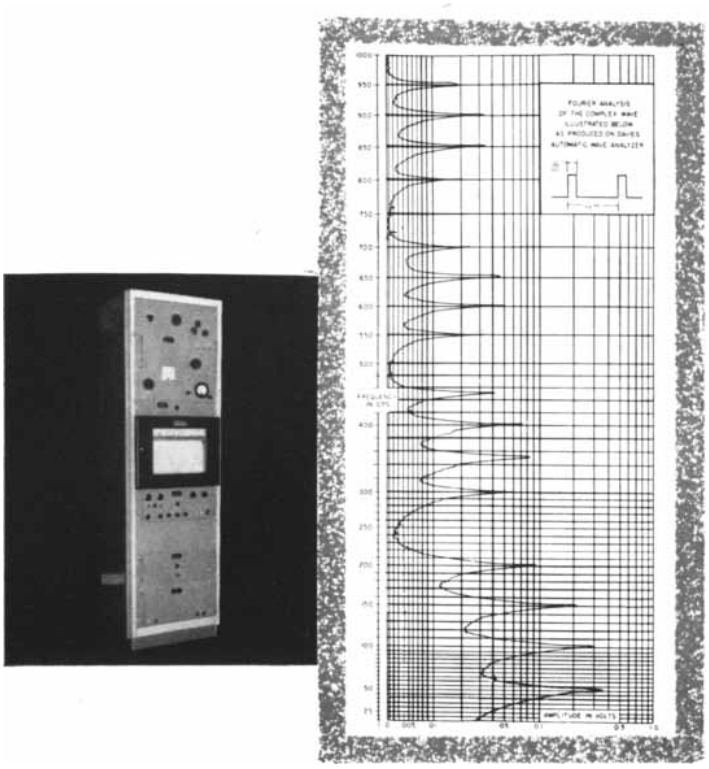


Once the data is on magnetic tape, there still remains the job of analyzing it. You can convert it to digital values, manually measure and sample it, and feed it to a digital computer on punched cards . . . but that takes considerable time and effort by skilled personnel. Rather than limit the number of analyses taken and the length of samples analyzed, labs are turning to direct analog analysis, which merits consideration by speeding reduction . . . permitting larger samples . . . increasing statistical reliability.

how automatic wave analyzers speed analog data reduction, improve statistical reliability

Automatic wave analysis is probably the least complicated technique for reducing analog data. Feed the taped data to an analyzer, flip the switch, and a complete Fouriér series is automatically plotted and printed in permanent record form. There are no intermediate steps, and what little the operator has to do can be trusted to relatively unskilled personnel.

Both of the two models available from Davies can accurately plot Fouriér series data as either *amplitude* versus *frequency* or *power* versus *frequency* at the flip of a selector switch. Both are also equipped with a "quick look" facility. Model 9020A provides a quick analysis across its frequency range of 3 cps. to 2 kc in 6 minutes; Model 9050A across its range of 3 cps. to 10 kc in just 15 minutes. Linear or square law output, as desired, is recorded by a Brown *ElectroniK* Potentiometer as a large, easily readable plot. You can visualize results immediately without any further curve tracing.

Multichannel inputs permit you to analyze as many as seven channels of data simultaneously. But the ultimate in automation is provided by the addition of a Davies Automatic Channel Selector, which you can program for serial analysis of up to 14 channels, changing tape speed, bandwidth, and output as you desire . . . all without any further attention.

It must be conceded that, while Davies Analyzers do provide high amplitude accuracy across wide frequency ranges, no analog analysis equipment could provide the *point* accuracy of manual and digital computer methods. But too often, that point accuracy is only achieved at the expense of reliable results. The speed with which Davies Automatic Wave Analyzers can run through data—in as little as 3% of the time required by digital methods—permits such large samples to be analyzed that the statistical reliability of the overall result remains unequalled.

That's why Davies Analyzers, first designed for aircraft studies, have since been successfully applied to vibration, noise, shock, and flutter analysis in vehicles, aircraft, missiles, and ships . . . seismic interpretation . . . power-line disturbance analysis . . . noise analysis . . . and any number of other phenomena characterized by randomly fluctuating data.

You'll find considerable additional information on Davies Automatic Wave Analyzers, how they operate, and what you can expect from them in the way of specific performance characteristics in Bulletin 9001. Write Minneapolis-Honeywell Regulator Co., Davies Laboratories Division, 10721 Hanna Street, Beltsville, Maryland, or call Webster 5-2700.

MINNEAPOLIS **Honeywell**

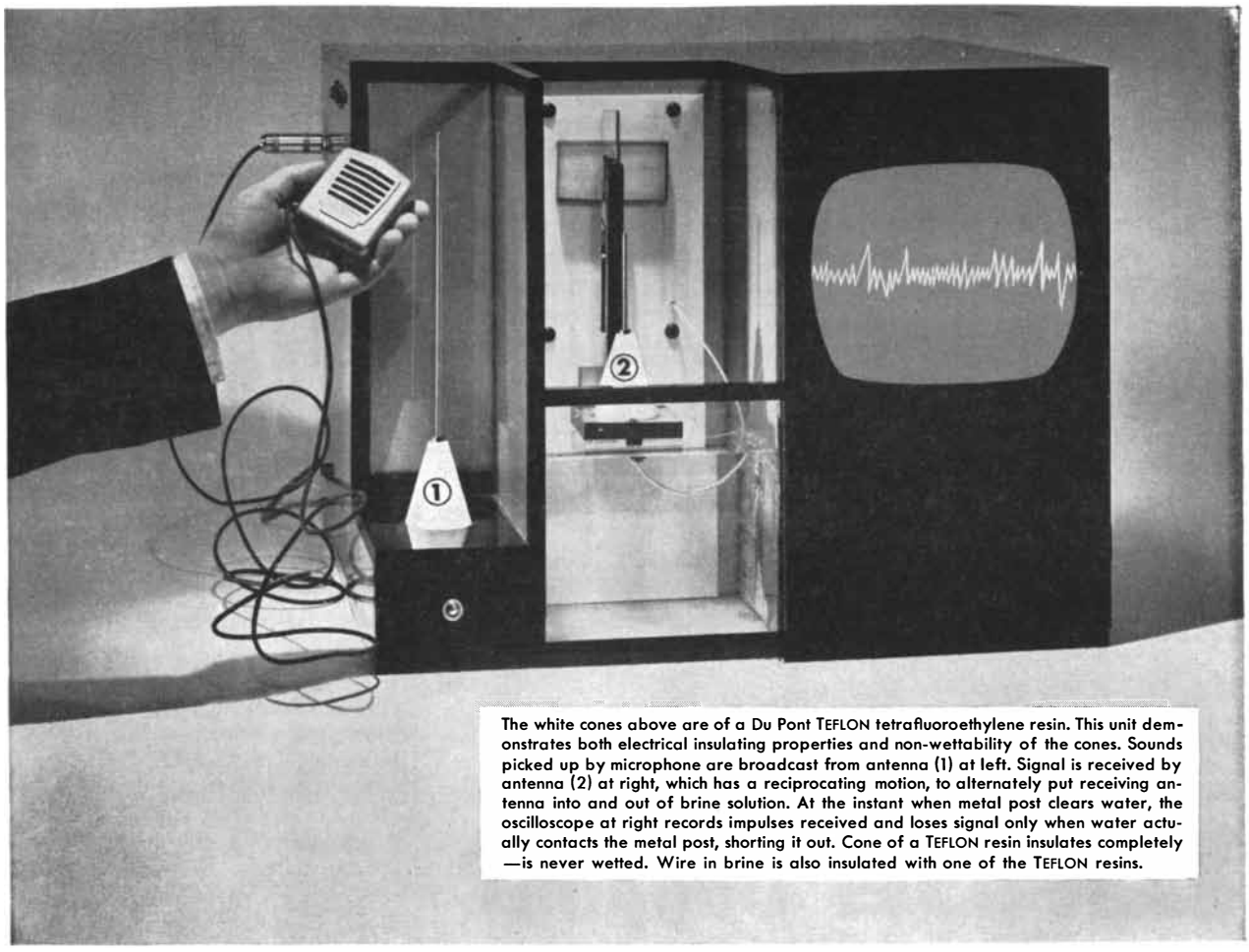
DAVIES LABORATORIES DIVISION

THE AUTHORS

HAROLD BLOOM and HAROLD F. WALTON ("Chemical Prospecting") are, respectively, special lecturer in geology at the Colorado School of Mines, and associate professor of chemistry at the University of Colorado. Though trained in chemistry, Bloom first worked for the U. S. Geological Survey as a topographic and photogrammetric engineer. In 1948 he transferred to the geochemistry and petrology branch of the Survey, where he acquired a background in the analysis of igneous rock for trace metals. In 1950 he accepted an invitation to take charge of the newly established Geochemical Prospecting Analytical Laboratory in Denver and there developed a portable kit for the field analysis of heavy metals. He writes that the new courses in geochemical prospecting at the Colorado School of Mines are particularly popular: "No wonder! Where else can a lucky student end the term with a grade and a mine?" Walton, who has written articles on ion exchange and chelation for SCIENTIFIC AMERICAN, was born in England and educated at the University of Oxford, where he received his doctorate in 1937.

A. E. LILLEY ("The Absorption of Radio Waves in Space") is a physicist at the Naval Research Laboratory in Washington, D. C. As an undergraduate and graduate student at the University of Alabama, Lilley majored in physics. In 1951, after meeting Donald H. Menzel of the Harvard College Observatory, he decided to go into astronomy. He received his Ph.D. in astronomy from Harvard in 1954. While there he participated with Bart J. Bok in the original Harvard radio-astronomy project. Lilley's arrival at the Naval Research Laboratory in 1954 coincided with the detection of the absorption of radio waves by hydrogen in space. Since then he has been chiefly responsible for the physical interpretation of the hydrogen-absorption studies conducted at that laboratory.

JAMES K. HOLLOWAY ("Weed Control by Insect") is an entomologist in the U. S. Department of Agriculture and the University of California. Fascinated by electricity in his childhood, Holloway went to Mississippi State Agricultural and Mechanical College to prepare for a career in electrical engineering. Because he had an aptitude for drawing, the college's department of en-



The white cones above are of a Du Pont TEFLON tetrafluoroethylene resin. This unit demonstrates both electrical insulating properties and non-wettability of the cones. Sounds picked up by microphone are broadcast from antenna (1) at left. Signal is received by antenna (2) at right, which has a reciprocating motion, to alternately put receiving antenna into and out of brine solution. At the instant when metal post clears water, the oscilloscope at right records impulses received and loses signal only when water actually contacts the metal post, shorting it out. Cone of a TEFLON resin insulates completely —is never wetted. Wire in brine is also insulated with one of the TEFLON resins.

We're speaking of TEFLON® tetrafluoroethylene resins —and opportunities in fabrication and design

Imaginative use of TEFLON resins has helped many manufacturers make a good product better, or a new one possible. TEFLON tetrafluoroethylene resins offer a unique combination of properties. Need amazing chemical resistance? Superior electrical resistance? Unmatched high-frequency properties? Are working temperatures –450°F. to 500°F. needed? Would you like to design moving parts that require no lubrication? Need something to be waterproof and weatherproof?

Jet aircraft use flexible hose of TEFLON resins to withstand corrosive fuels and lubricants. Electronic computers and control equipment of every description use insulation made from TEFLON resins because the dielectric properties are not affected by heat to 500°F., and miniaturization problems are more readily solved. With a coefficient of friction less than that of ice on ice, parts made from TEFLON resins need no lubrication.

Many dramatic new design developments have utilized one or more of the dependable properties of Du Pont TEFLON tetrafluoroethylene resins. Evaluate the valuable properties TEFLON resins have to offer. For more information, clip the coupon.

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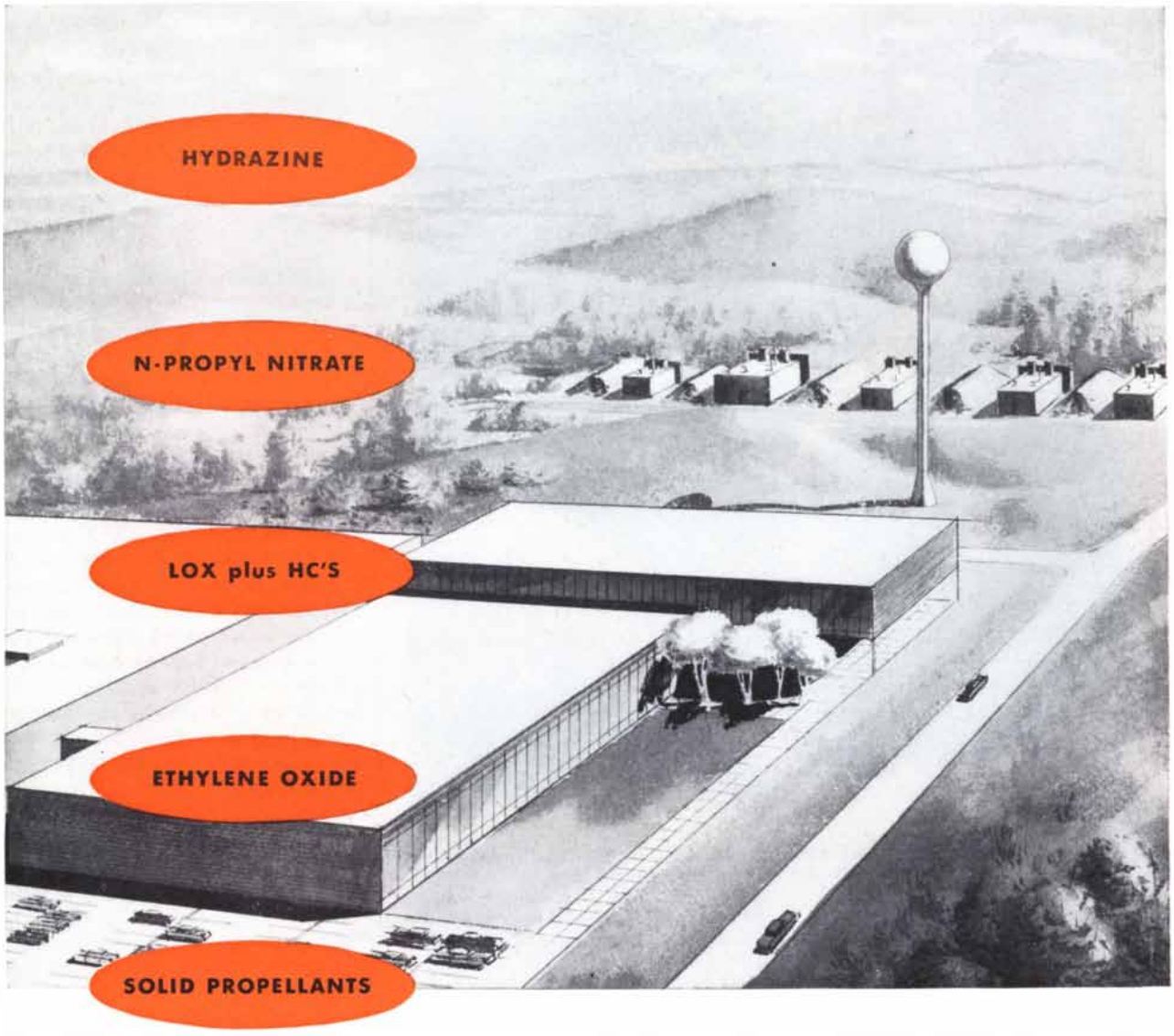
tomology asked him to illustrate some of its publications. The job proved so interesting that he switched to entomology. After receiving his B.S. in 1926, Holloway enrolled as a graduate student at Ohio State University. While there he decided to accept a job with the Department of Agriculture to work on the natural enemies of the Japanese beetle. He has continued in the biological control of U. S. insects and weeds ever since.

MURRAY GELL-MANN and E. P. ROSENBAUM ("Elementary Particles") are, respectively, a theoretical physicist and a member of the Board of Editors of SCIENTIFIC AMERICAN. Gell-Mann was born in New York City, did undergraduate work at Yale University and took his doctorate at the Massachusetts Institute of Technology in 1951. Later that year he attended the Institute for Advanced Study in Princeton, after which he went to the University of Chicago's Institute for Nuclear Studies. Gell-Mann's interest in mathematics and physics was first stimulated by his father, whose hobby is mathematics. At M.I.T. he studied with Victor F. Weisskopf; at Chicago he had an opportunity to observe Enrico Fermi at work. Of Fermi, Gell-Mann writes: "His great genius was not something he could share with others, but he could communicate something of his style." Gell-Mann likes to travel; he worked out many of his ideas on "strange" elementary particles during trips through the U. S. and Europe. He is now professor of physics at the California Institute of Technology.

DAVID GITLIN and CHARLES A. JANEWAY ("Agammaglobulinemia") both call themselves New Yorkers displaced to New England, where they work in Janeway's laboratory at Children's Hospital in Boston. In 1946, when Gitlin was in his last year at New York University College of Medicine, one of his professors went on a skiing trip and met Janeway. The professor, who had noticed the relationship between the experimental work of the two men, mentioned Gitlin to Janeway. A year later Janeway invited Gitlin to his laboratory at Children's Hospital. Janeway, whose father and grandfather were also physicians, obtained his M.D. at the Johns Hopkins University in 1934. It was in the two years following his internship that Janeway had his "first exposure to the contagion of research," appropriately enough in the Harvard department of bacteriology and immunology. While at Harvard he joined a research team organized by the late Edwin J. Cohn to de-



In this new lab, these new fuels will be harnessed

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Specialists in the design, development and manufacture of aircraft and missile fuel systems and pumps, small gas turbines, turbine-driven accessories, power packages, and nuclear-energy accessories and components.

velop methods for the fractionation of blood. Later Janeway's interest in immunology led him into pediatrics. Janeway is now physician-in-chief at Infants' and Children's Hospitals in Boston and Thomas Morgan Rotch Professor of Pediatrics at the Harvard Medical School. Gitlin is associate physician at Children's Hospital and assistant professor of pediatrics at the Harvard Medical School.

WALTER B. EMERY ("The Tombs of the First Pharaohs") is Edwards Professor of Egyptology at University College London. He says that his interest in Egyptology was possibly inspired in boyhood by "a surfeit of H. Rider Haggard novels." He attended St. Francis Xavier's College and the University of Liverpool's Institute of Archaeology. On separate occasions during World War II Emery escorted Generals Eisenhower and Patton through the Luxor temples of Egypt; he was able to show Patton wall paintings of the earliest known amphibious attack. After the war Emery was attaché and later First Secretary to the British Embassy in Cairo. He has been Norton Lecturer of the Archaeological Institute of America and in 1943 was made a Member of the Order of the British Empire.

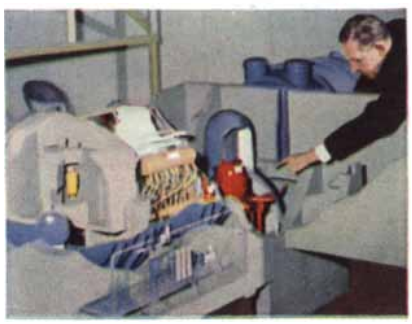
CARL WELTY ("The Geography of Birds") is professor of zoology and chairman of the biology department at Beloit College in Wisconsin. Welty took his Ph.D. in zoology at the University of Chicago in 1932. For the past 16 years he and his wife, a free-lance writer, have lived outside Beloit on 12 acres of rolling woodland which they are slowly converting into a bird refuge. His article "Birds as Flying Machines" appeared in this magazine for March, 1955.

PHILIP SIEKEVITZ ("Powerhouse of the Cell") is on the staff of the Rockefeller Institute for Medical Research. Philadelphia born, he graduated from that city's College of Pharmacy and Science in 1942, after which he entered the Army Air Force. In 1949 Siekevitz obtained his Ph.D. in biochemistry from the University of California. His next five years were spent in fellowships at the University of Wisconsin and Harvard University. Siekevitz's attention was focused on mitochondria when he found by chance that they provided the source of energy for certain reactions involved in the synthesis of proteins. He is presently on leave of absence from the Rockefeller Institute as visiting investigator in cytochemistry at the Wenner-Gren Institute in Stockholm.

10,276 Anaconda Tubes, ⅞" diameter and 30 feet long, were inserted in 1½"-thick, 6-ton Anaconda Muntz Metal plates of condenser at Shippingport.

First big atomic power plant uses 60 miles of Anaconda Tube

HOW TO "BURN" URANIUM. America's first big atomic power plant at Shippingport, Pa., will give vital information on how best to use uranium for fuel on a large scale. Operating experience will measure the performance of the nuclear power source and help guide the design of new and bigger plants.



Hand points to the heart of the atomic power plant shown in a cutaway scale model. In this Pressurized-Water Reactor, uranium elements heat water to more than 500 degrees F at a pressure of 2000 lb. per sq. in. Water heated by the reactor makes steam in heat exchangers to run the turbine-generator. Over-all plant design by Westinghouse. Duquesne Light Company, Pittsburgh, is building the electric generating plant, shares in the cost of the reactor plant with the Atomic Energy Commission and will operate the entire plant.

The turbine-generator in this plant requires nearly one million pounds of steam every hour to produce a maximum of 100,000 kilowatts of electric power. To re-use this tremendous amount of water and to get the greatest possible efficiency from the system, the huge steam condenser shown above is used.

In it, 60 miles of Anaconda Arsenical Admiralty Tubes provide 70,000 square feet of condensing surface. Cooling water from the nearby Ohio River is pumped through the tubes. The turbine's exhaust steam condenses on the surface of the tubes, and the resulting water is pumped to the nuclear boilers for re-use.

THE PROBLEM OF CORROSION. Arsenical Admiralty Alloy is one of the important developments of Anaconda's American Brass Company laboratories, where corrosion problems are constantly being studied.

The contributions of Anaconda specialists are helping to make condensers and heat exchangers give longer and more dependable service in electric power plants, ships, oil refineries, chemical plants, and almost every branch of industry.

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SEMICONDUCTORS are but one example of Hughes Products leadership in electronics research, development and manufacturing. These and other Hughes electronic advances promise undreamed-of wonders as spectacular as cargo-carryingmissiles.

Hughes backs its semiconductors, electron tubes and industrial systems and controls with a long record of technical accomplishment. These include not only the FALCON, but also the self-directing Hughes Automatic Armament Control, standard equipment on all Air Force interceptors.

Your own business can undoubtedly benefit by the application of Hughes electronic products to office and plant problems. A Hughes Products sales engineer will work with your staff on request. Please write: Hughes Products, Los Angeles 45, California.

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How far away is the pocket size TV camera?

Samples were used at the last political conventions.

Production models—built around subminiaturized circuits requiring semiconductors—can be expected any day. The proved reliability of Hughes DIODES, even under severe shock or weather conditions, makes these tiny, compact semiconductors a logical choice for such circuits.

The unique advantages of Hughes DIODES typify Hughes Products leadership in research and development of semiconductors and other electronic advances. Such advances will play an important part in the greater electronics era ahead—when we will have pocket-size TV cameras, television-telephones and other wonders.

As one of the country's largest electronics research and manufacturing firms, Hughes backs its semiconductors, electron tubes, and industrial systems and controls with a long record of technical accomplishments. These include the "thinking" FALCON air-to-air missile, and the self-directing Hughes Automatic Armament Control which is standard equipment on all Air Force interceptors.

Chances are that the application of Hughes electronic products to your own business can save you time and money. A Hughes Products sales engineer will welcome the opportunity to work with your staff. Please write: Hughes Products, Los Angeles 45, California.

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How soon can you enjoy on-the-wall television?

Chances are, it will be here in a relatively short time.

One of several important requirements will be the development of a special miniaturized circuit. And tiny, compact Hughes TRANSISTORS will be ideally engineered for use in such circuits to replace relatively large vacuum tubes.

The high performance characteristics of Hughes TRANSISTORS represent only one example of Hughes Products leadership in research and development of electronic advances. That is why you can expect Hughes semiconductors, electron tubes, and other electronic products to play a vital role in countless wonders of the electronics era.

As one of the country's largest electronics research and manufacturing firms, Hughes backs its semiconductors, electron tubes, and industrial systems and controls with a long record of technical accomplishments. These include the "thinking" FALCON air-to-air missile, and the self-directing Hughes Automatic Armament Control which is standard equipment on all Air Force interceptors.

There are probably many ways by which you can effect savings or product improvements in your own business through application of Hughes electronic products. A Hughes Products sales engineer will gladly work with your staff. Please write: Hughes Products, Los Angeles 45, California.

RELY ON HUGHES FOR ELECTRON TUBES, SEMICONDUCTORS, INDUSTRIAL SYSTEMS AND CONTROLS

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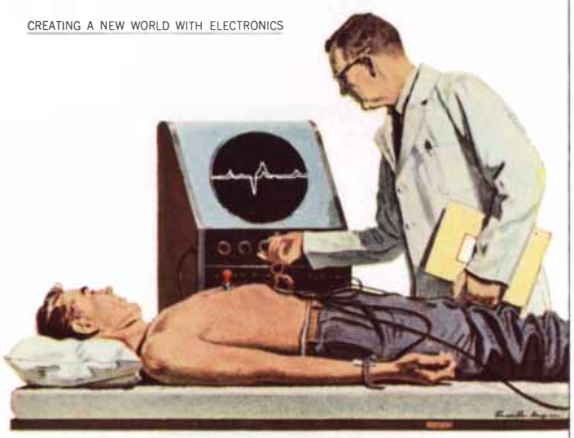

How soon can you have a better heart check?

It probably isn't too far away. The Hughes MEMOTRON direct-display storage tube will enable your doctor to study several waveforms of your heartbeats at the same time. This uncanny tube can hold and superimpose any number of patterns for immediate visual comparison.

The MEMOTRON is but one of many electronic achievements that attest to Hughes Products leadership in research and development of electron tubes, as well as transistors and diodes. Advances like these will accelerate the dynamic electronics era—when you will be able to see over the phone, to control factory production electronically, and to enjoy countless other marvels.

As one of the country's largest electronics research and manufacturing firms, Hughes Products backs its semiconductors, cathode ray tubes, and industrial systems and controls with a long record of technical accomplishments. These include the "thinking" FALCON air-to-air missile, and the self-directing Hughes Automatic Armament Control which is standard equipment on all Air Force interceptors.

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Established 1845 **SCIENTIFIC AMERICAN** July, 1957 Volume 197 Number 1

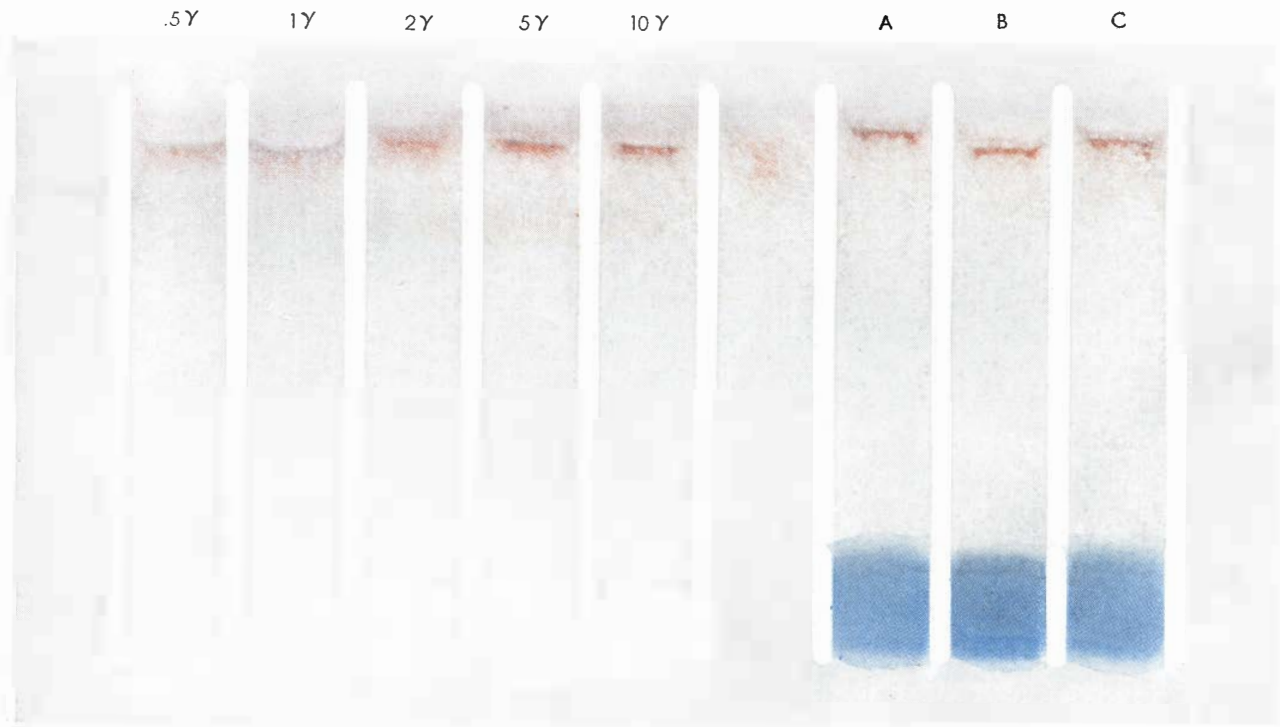
Chemical Prospecting

The modern prospector may carry not only a Geiger counter but also test tubes and plastic bottles filled with chemicals. With them he can detect the traces of metal which surround a hidden body of ore

by Harold Bloom and Harold F. Walton

The old-time prospector, with his pick and shovel and gold pan, his burro and his eternal optimism, is part of Rocky Mountain tradition. His spirit is still very much alive, though the burro has given way to the jeep and the gold pan to the Geiger counter. In addition to these modern appurtenances the truly up-to-date prospector is likely to carry something else: a few test tubes and some plastic bottles filled with chemicals. In the world-wide search for ore, chemistry has joined forces with geology and physics.

The basic idea of geochemical prospecting is simple. Bodies of ore are often surrounded by "halos" of rock or soil which are minutely enriched in the metal of the ore. If the enrichment can be detected by chemical tests, such tests can be used to help locate buried ore



TRACES OF URANIUM may be detected by paper chromatography. A sample is placed at the foot of each column, and the bottom edge of the paper put in a solvent. The solvent moves up the columns carrying only uranium salts with it. The paper is then dried and sprayed, revealing brown lines characteristic of uranium. Five columns are "standards" with uranium given in micrograms (γ). A, B and C are "unknowns" which also contain iron (*blue*). Uranium content is determined by comparing unknown and standard.

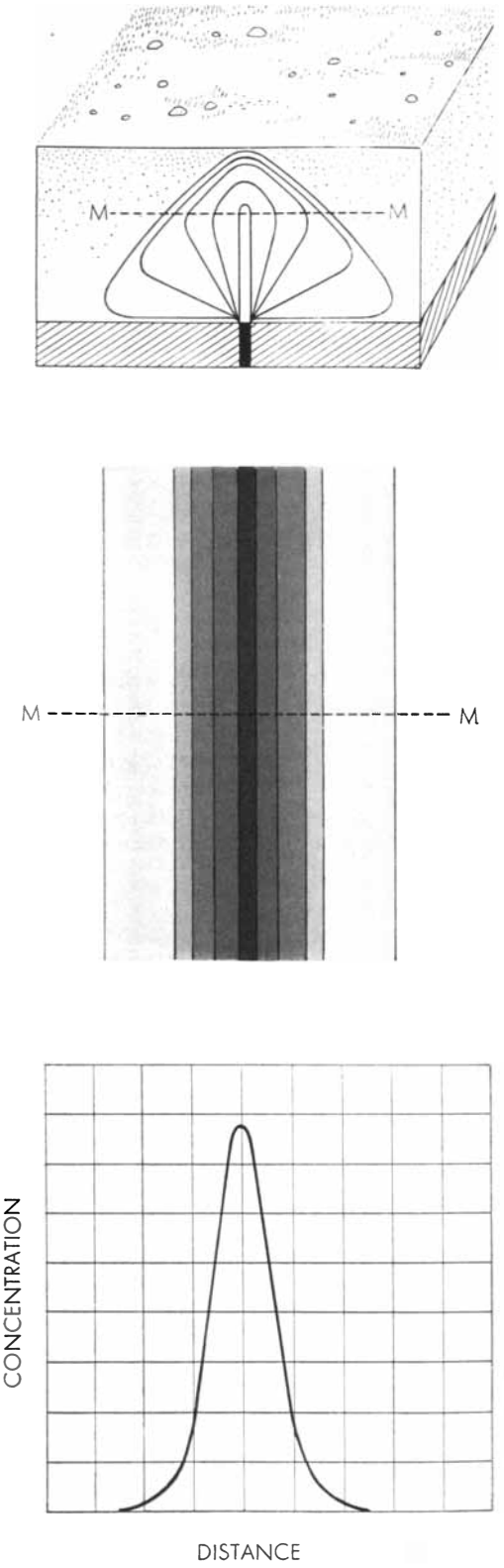
bodies. This was demonstrated by the pioneer studies of Scandinavian and Russian scientists, notably Thoralf Vogt and E. A. Sergeev, and has been abundantly verified by workers at the U. S. Geological Survey under such men as T. S. Lovering, H. E. Hawkes, Jr., and H. W. Lakin. The extremely sensitive chemical tests that have been developed will detect and measure minute traces of metal, yet they are so simple that many of them can be done in the field, and they are so fast that one man can handle hundreds of samples in a week. Thus it is possible to determine the pattern of distribution of trace elements over a wide area, and if the soil in a certain place contains, say, a few thousandths of 1 per cent of copper above what is normal for the area, it may conceal a useful deposit of copper ore. We use the word "may" advisedly; the surface enrichment does not tell us how much ore is present, any more than the smell of bacon and eggs indicates the size of a breakfast. But the indication is a valuable one, especially when it is combined with evidence obtained by other means.

How do the chemical halos arise? Metal from an ore body cannot simply diffuse into the surrounding rock. Atoms can diffuse through solids, but the process is so slow that it could not possibly account for the growth of halos. Ore material must be transported by an agency other than diffusion. Sometimes the movement occurred when the ore was laid down: metal-bearing solutions or molten rock spread through fissures beyond the bounds of the main ore body and left outlying veins of ore; the rock was then weathered into rubble or soil which now hides the ore vein, yet carries tell-tale traces of metal. Glacial ice or flowing water can tear particles of ore from the vein. Salts and acids in the water can dissolve the ore, transporting metal away from the ore body and depositing it elsewhere. Prospectors therefore look for traces of metal in rock or soil, in plants which grow in this soil, in deposits of glacial material, in stream beds and in stream or spring water.

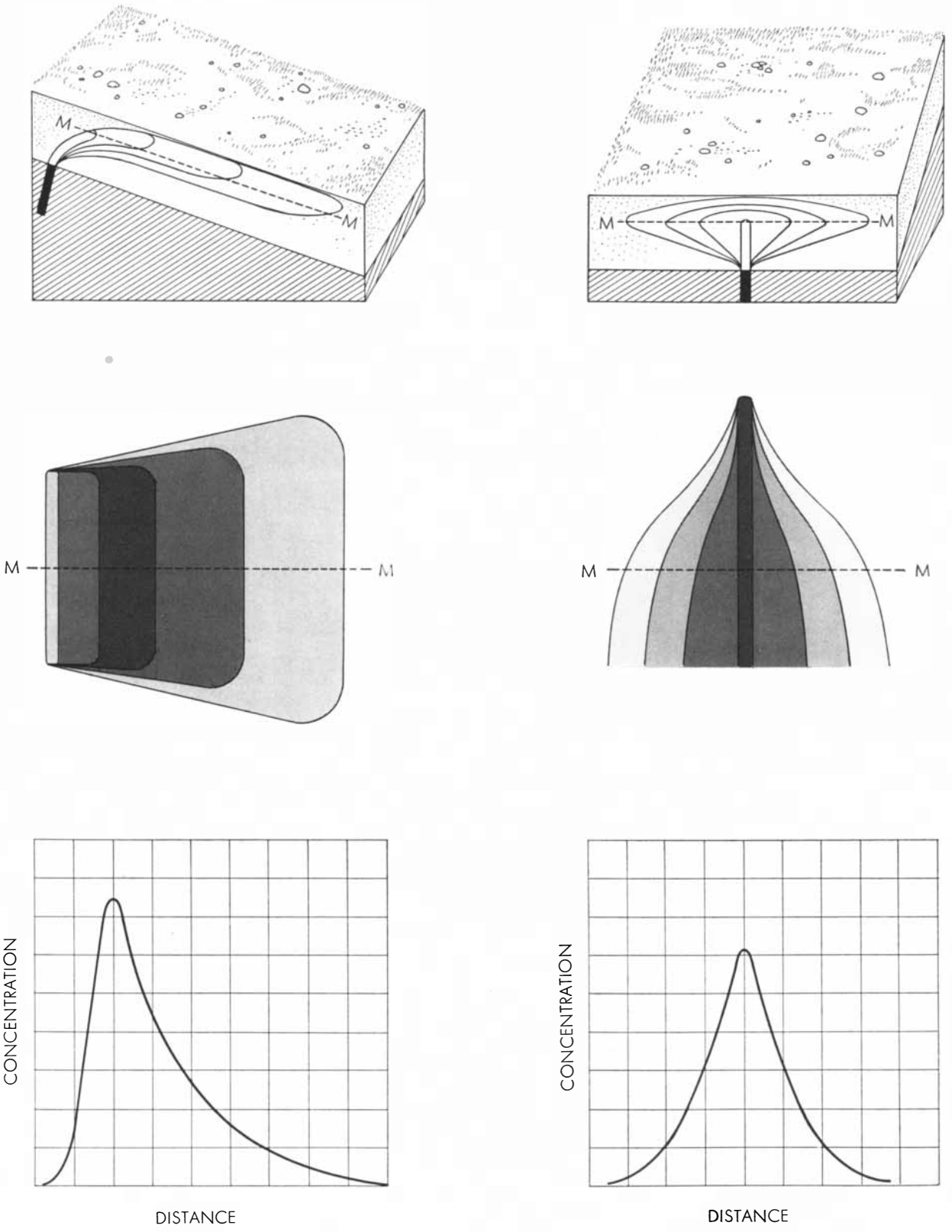
The first geochemical prospecting was done in the stream beds. We refer, of course, to gold panning. Perhaps "geochemical" is the wrong word, since gold panning involves no chemical test. Nonetheless the persistent prospector would pan farther and farther upstream in hope of finding the "mother lode." Today this very principle is used to look for common metals, except that sediment from the stream is tested by chemical means. The chemist-prospector proceeds upstream, making tests at each stream junction to know which tributary to follow. As the ore vein is approached the metal content rises; it falls back to normal after the vein is passed. A good ore body will throw a "train" as much as five miles downstream, and an open mine will project one considerably farther. In a small area, on the other hand, an insignificant pocket of ore, or even a discarded piece of galvanized pipe, can cause as high a concentration of metal as a really useful deposit. When analyses for the concentration of a metal in a particular drainage area are consistently negative, they warn the prospector not to waste time and money in further investigation there.

Geochemical prospecting is particularly useful as an adjunct to geophysical prospecting. For example, geophysical methods are used in the Bathurst district of the Canadian province of New Brunswick to detect ores of metallic sulfide; airplanes traverse the area carrying equipment which can detect small variations in the magnetic field of the ground below. The trouble with the method is that it shows too many variations, most of them caused by formations with no economic value. By combining this information with chemical surveys of stream sediments, however, the unpromising magnetic variations can be eliminated. Two such variations in the Bathurst area marked valuable ore bodies which would have been overlooked but for the encouraging stream-bed analyses.

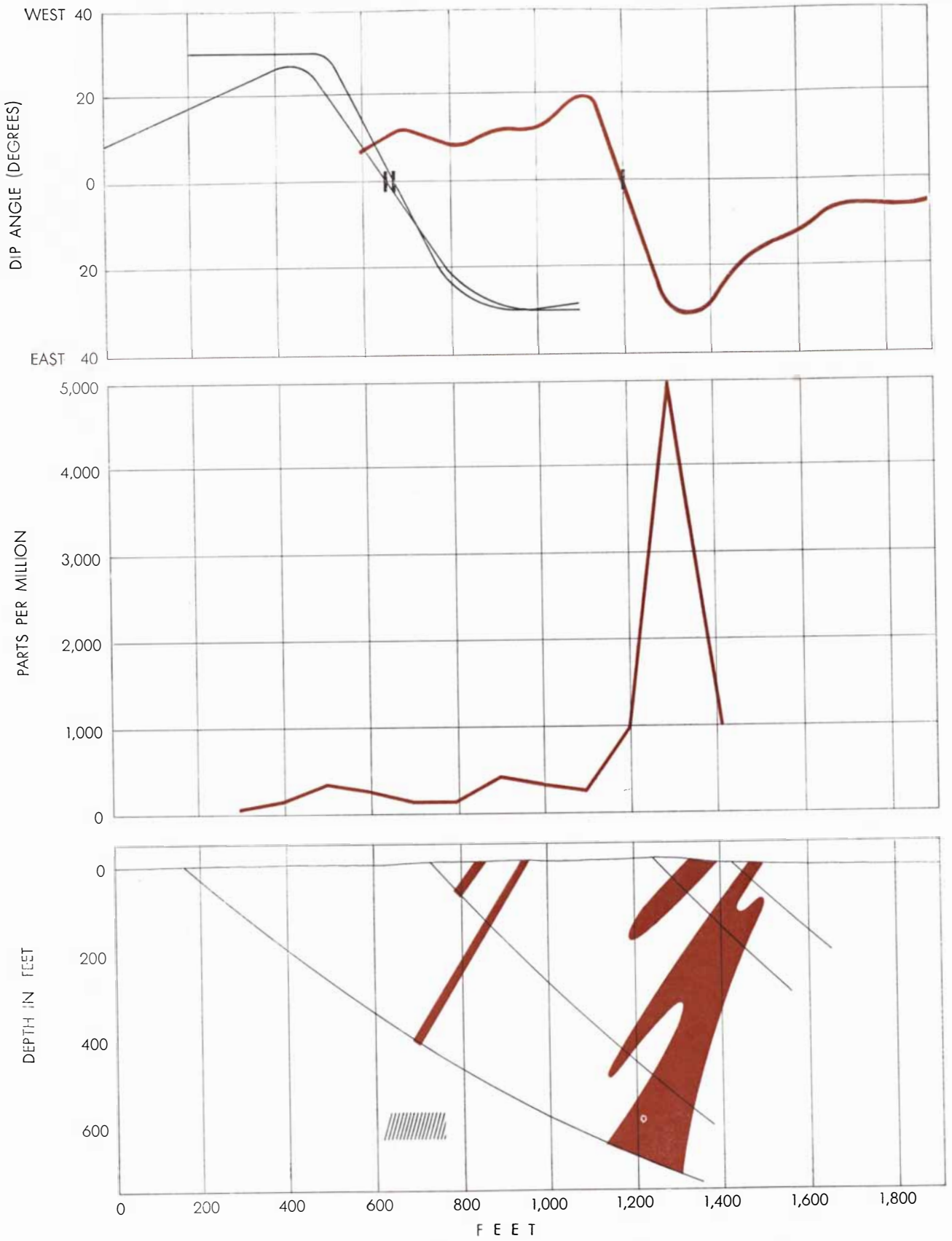
Closely allied to the geochemical analysis of stream sediments is the analysis of water itself. Waters from streams, springs or wells have been widely used for prospecting, but have certain disadvantages. The amount of metal dissolved in water is generally very small—well below one part in a million—and special care and special techniques are required to detect it. The concentration of metal depends very much on the amount of water flowing at the time; moreover, water is even more likely than stream sediments to be contaminated by stray buckets, old washtubs, artificial fertilizers (which often contain traces of metal) and other works of man. Finally, in the arid and semi-arid country where so much of our mineral wealth is found the stream beds are dry during most of the year. Yet water analysis does have two big advantages. One is that the water of a spring may have come from far beneath



ORE-BEARING "HALO" often surrounds a vein of ore that is near the surface of the ground. Chemical tests can detect this halo and locate the body of ore beneath. Here



three typical halos are shown schematically. At top left is a sectional view of the halo surrounding a vein of ore that is under level ground. Below this is a view of the area seen in a horizontal plane (M—M) showing the relative concentration (*gray*) of ore in the soil. The curve at the bottom shows the concentration revealed by chemical tests. The other sectional views show how the halos can be distorted by downhill movement of the soil. The drawings are adapted from a paper in Russian by E. A. Sergeev.



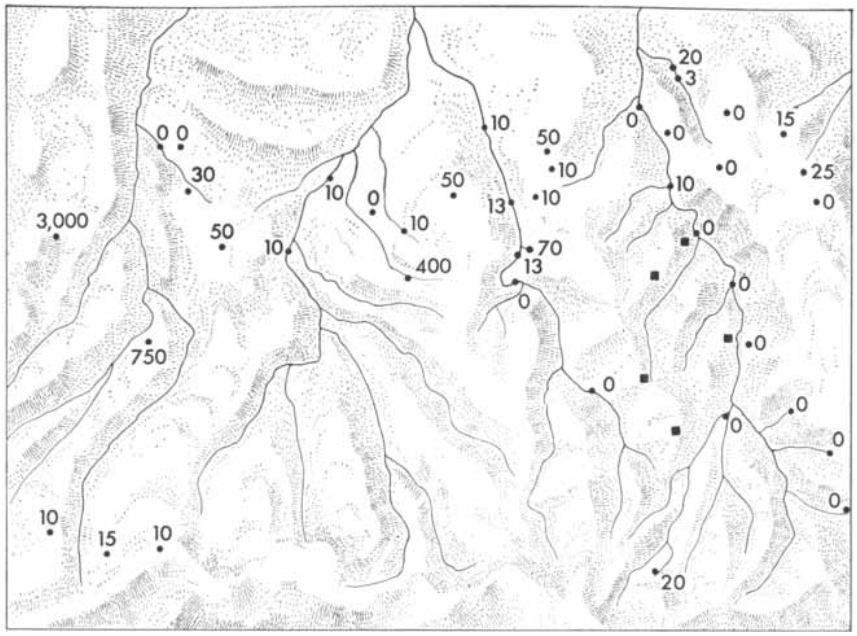
MAGNETOMETER flown over the Bathurst district of New Brunswick indicated two ore bodies. The curves at the top show that in three flights over the area the needle of the magnetometer dipped to the west and then to the east. When the dip was zero, it reflected an ore body below. The curve in the middle shows the result of a chemical survey of the same area. Drillings indicated that the chemical survey had distinguished between a deposit of graphite (*hatched area at bottom*) and one of metallic sulfide (*colored*).

the ground. The other is that flowing water provides the prospector with a uniform sample, which is hard to come by in assorted sediments.

The geochemical analysis of water has special promise in the search for uranium. There are chemical and physicochemical tests which will detect without much difficulty two parts of uranium per billion parts of other elements. (This concentration, incidentally, is too low to be indicated by the radioactivity of the metal.) Furthermore, uranium is easily dissolved by water, provided it is in the oxidized form found in yellow uranium minerals such as carnotite.

To test the effectiveness of water analysis for the detection of uranium, studies have been made in areas which bear known deposits of uranium minerals. One such area is the Gas Hills of central Wyoming, where there are several uranium mines. In the streams and springs of the region concentrations of uranium ranging from below two parts per billion (about normal for river or sea water) up to 3,000 parts per billion have been found, and the concentrations are well correlated with known uranium deposits. These studies show the value of negative prospecting information. One valley near the Gas Hills is pitted with scores of prospect holes dug on the strength of rather high readings with scintillation counters, which detect radioactivity. No ore has been found here, and much time and money might have been saved had the prospectors known that the streams of this valley, sampled at several points, contain practically no dissolved uranium. On the other hand, at Iron Springs Reservoir in the Gas Hills the counter readings are only four times as high as the background radioactivity, yet the water contains 400 parts of uranium per billion.

Obviously there is ore somewhere behind Iron Springs, but the water analysis does not say exactly where, or how much. We return to our bacon and eggs analogy: bacon and eggs do not smell until they are cooked (provided they are fresh!), and uranium is not taken up by water unless it is oxidized. Water from the middle of the biggest known uranium reserve in North America—the recently discovered Ambrosia Lake deposit in New Mexico—contains no uranium at all. The reason is that the ore is coffinite, a black, unoxidized uranium silicate which is quite insoluble in water. Thus the Iron Springs area may harbor ores which are not detected by water analysis.



WATER ANALYSES of uranium were made along streams in the Gas Hills of Wyoming. The figures (*uranium in parts per billion*) closely correlated with deposits bearing known amounts of uranium. Iron Springs Reservoir, noted in the text, is at 400. The squares are the prospect holes that "failed" because they were based only on readings of radioactivity.

Today most geochemical samples are taken not from water but from soil. In Brazil last year some 25,000 soil samples were collected; prospectors in Canada probably gathered twice that number. In the African colony of Rhodesia one company alone is reported to be analyzing soil samples at the rate of 100,000 a year. The Russians are said to have collected a colossal 11 million geochemical samples of all kinds during the years 1954 and 1955.

Under favorable conditions anomalies in the concentration of metals in the soil can reflect ore bodies as much as 100 feet below the surface. The halos are usually very wide and therefore easily detected; samples may be readily collected and analyzed. The place from which the sample is taken must be carefully noted. The "horizon," or layer of soil, which is sampled is particularly important. For example, the upper horizons tend to bear more zinc than the lower, or at least the zinc is easier to extract. The reason is that the upper horizons contain much decayed vegetable matter, which is rich in zinc. Why? Because trees concentrate zinc in their leaves. The upper horizons vary in thickness, and a sample taken of a given depth in one locality may contain more zinc than a sample taken at the same depth in another. Recently a survey party in Canada wasted much effort in drilling for ore in an area where soil analyses showed a high concentration of zinc. It turned out that the party had taken all its samples at the same depth, without reference to the varying thickness of the horizons. As a result most of its samples were from low horizons, but some were from the upper ones. Of course the latter samples were rich in zinc, and gave the party a false impression of how the metal was distributed in the area.

As a rule the soils next to the bedrock give the best indication of the rock's composition, but these soils are naturally the hardest to sample. Someone once had a brilliant idea. Instead of digging holes, why not sample a tree? The roots of a tree go deep—often to bedrock itself—in search of water. From an analysis of the leaves and shoots of the tree it is possible to get an indication of the trace elements around its roots. Thus geochemistry has a subdivision called biogeochemistry.

How a plant transports trace elements from its roots to its leaves is dependent on its characteristic physiology. Different plants have widely different appetites (and tolerances) for trace metals. Sometimes even the kind of plants which grow in an area indicate what minerals are in the ground. On the Colorado Plateau the "loco-weed" species *Astragalus pattersonii* marks the presence of selenium, and sometimes of accompanying uranium. Helen L.

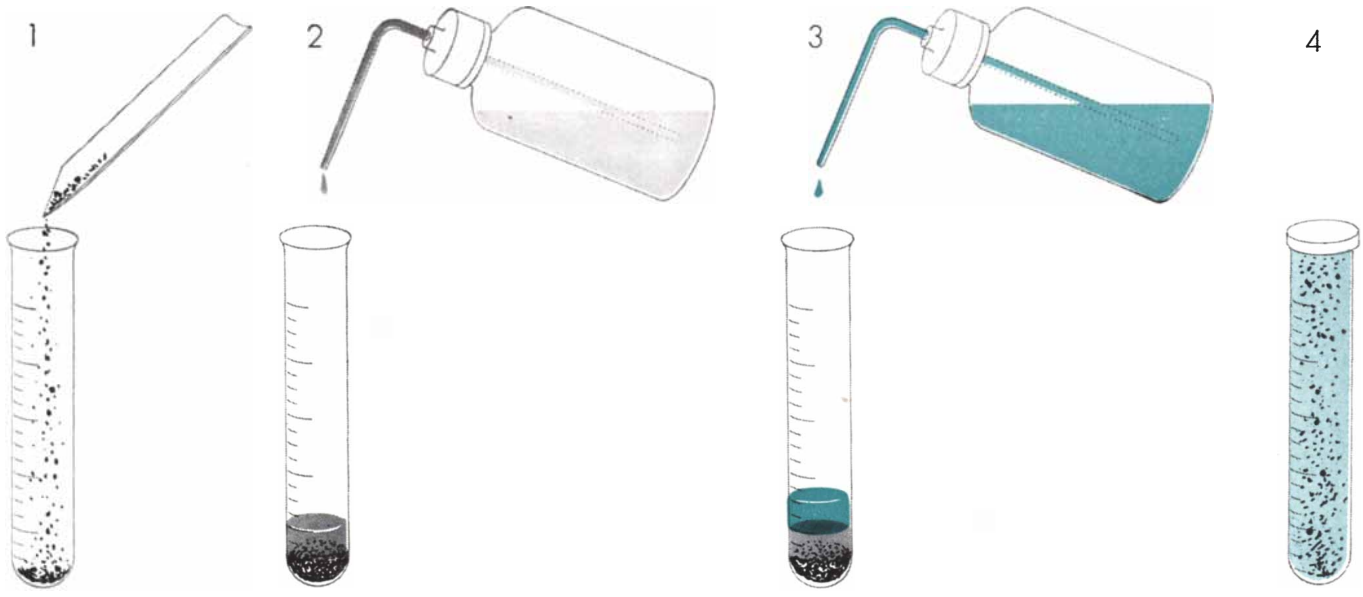
Cannon of the U. S. Geological Survey has listed a number of these "indicator plants," some of whose roots go down as deep as 60 feet.

In the moist Pacific Northwest H. V. Warren and R. E. Delavault of the University of British Columbia have done a vast amount of biogeochemical work. They have found, for example, that the twigs of a birch tree may contain up to 10 times as much zinc as the twigs of an alder growing beside it—and these two trees look much alike to the nonbotanist. The concentration of a trace element in one part of a tree differs from that in another part, as does the concentration in tree shoots of different ages. All this makes biogeochemical prospecting rather tricky, but it is still useful, especially in northern latitudes where the land is covered by deep snow, muskeg or glacial deposits.

Because the chemist-prospector looks for concentrations of metal which are greater than the normal, he must know what is "normal." This may involve a great deal of preliminary labor. "Normals" vary greatly from place to place, from one soil horizon to another, from one kind of plant to another. It is perplexing to find how common and how widespread many "trace" metals actually are. (This has its fortunate side, because these metals are needed by plant and animal life.) Certain limestones contain as much as .1 per cent, or a thousand parts per million, of zinc. Soils bearing 50 to 100 parts per million of zinc are quite common. Copper and lead are also abundant in soils. Under such conditions the prospector must detect increases in the concentration of a metal over and above a considerable normal concentration. He uses the rule of thumb that twice the normal concentration is geochemically significant. In some situations it is better to look not for the element actually sought, but for a less abundant element which accompanies it. Such companion elements are called "pathfinders." Most zinc ores contain a small proportion of cadmium; a few parts per million of cadmium in vegetation is a much better indication of an ore body than several hundred parts per million of zinc. Likewise arsenic is used as a pathfinder for cobalt, and molybdenum for copper. Molybdenum has two advantages as a pathfinder. First, the molybdenum content of soil, normally only one part per million, will jump to 100 times its normal concentration near a porphyry copper deposit, while the copper concentration will jump by a factor of only 10. Second, molybdenum forms soluble compounds more readily than copper, so that it spreads farther and is more easily detected.

Geochemical prospecting requires a great number of chemical analyses, and it is essential that these be not only sensitive but also rapid and cheap. The tests should be simple enough for people without training in chemistry to perform in the field, preferably on the spot where the sample is taken. The analysis need not, however, be very exact. It makes no difference to the prospector whether the amount of copper in a soil is 31 or 32 parts per million; he is often content to know that it lies between 20 and 40 parts per million.

One of the fastest and most sensitive tools of analysis is the spectrograph. This instrument produces a permanent photographic record which not only reveals the element sought by the prospector but also other elements. The instrument is expensive and bulky, and it requires a trained operator, but it is often used in a central location where samples can be sent for analysis. The U. S. Geological Survey has a spectrograph mounted on a truck. But even where a spectrograph is available there are certain elements to which it is not very sensitive, notably zinc and uranium. It is also inconvenient for the analysis of water. A modern alternative to the spectrograph is the X-ray fluorescence spectrograph, in which the sample is made to emit X-rays by bombarding it with X-rays of shorter wavelength, but this is even more expensive and cumbersome. An ordinary ultraviolet lamp is a very good tool for the detection of uranium. If ultraviolet is shined on sodium fluoride containing traces of uranium, the solid glows with an intense yellow fluorescence. But many elements quench the



DITHIZONE TEST for copper, zinc and lead is outlined. A given amount of stream sediment is placed in a graduated test tube. Ammonium citrate (*colorless*) is then added to strip the metals from the fine grains of rock and also to maintain the proper acidity. Next, a given amount of dithizone (*green*) is added; it floats on top of the mixture. The sample is shaken vigorously for five sec-

fluorescence, and the sample must be carefully freed of these elements before the method is fully sensitive. This requires a good laboratory and restricts the use of the method in the field.

Two other methods have found wide geochemical application: colorimetric analysis and paper chromatography. Of these colorimetric analysis is much the more important. There are many organic compounds which are intensely colored when traces of metal are added to them. The most useful for geochemical purposes is diphenylthiocarbazone, or "dithizone." This compound has a sulfur atom in its molecule and has an affinity for metals which are commonly found in sulfide ores, such as copper, lead and zinc. Dithizone itself has a forest-green color so intense that only a few parts per million of it dissolved in carbon tetrachloride or xylene (it is not soluble in water) give the solution a deep color. Its compounds with various metals are red, violet or yellow and are almost as intensely colored as dithizone itself. The characteristic color for a metal announces its presence.

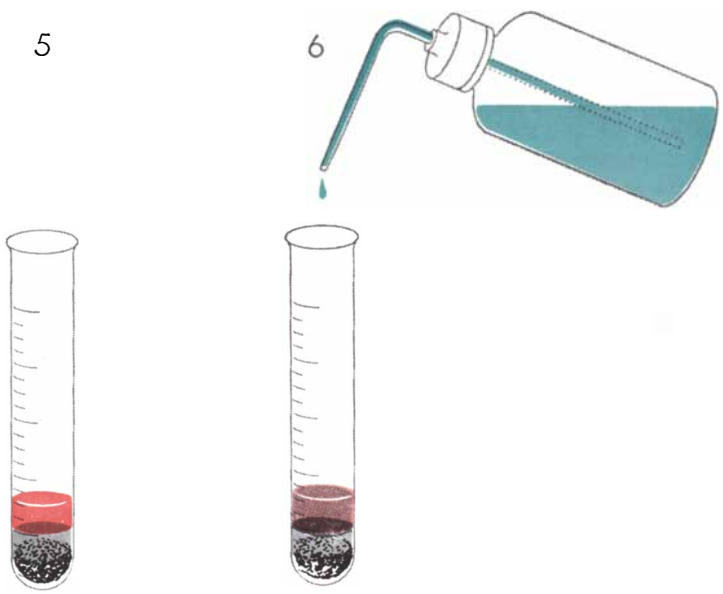
In the field dithizone tests are run something like this. Suppose the sediment in a stream is to be analyzed. First the trace metals in the sample must be brought into solution. To get all of them into solution may require a lengthy process involving intense heat or attack by strong acids. Fortunately it is not necessary to dissolve all the metals to determine the minerals present in the area. Informative analyses can be obtained by a mild attack which takes only a few seconds and does not require heating. The sample is first measured out with a plastic scoop and dumped into a graduated test tube with a plastic stopper. Ammonium citrate dissolved in water is squirted into the tube from a plastic squeeze-bottle which the prospector carries in his pocket. This does two things: it strips the metals from the outside of the tiny grains of rock in the sample, and it maintains the acidity at which dithizone will react with the sample. Now dithizone dissolved in xylene is added from another squeeze-bottle. The xylene floats on top of the water. The operator shakes the tube vigorously for five seconds. If heavy metals are present, the dithizone turns from green to blue-gray or red, depending on the amount of metal. If the color is red, dithizone solution is added one drop at a time until the red changes to a blue-gray or plum color. This shows that some green dithizone now remains, and that all the metal in the xylene solution has been taken up. From the graduations on the test tube the operator can tell how much dithizone he has added, and from this the metal content of the sample may be computed. In this way as little as two ten-millionths of a gram of zinc can be detected.

This simple test gives the "total available heavy metals," that is, the sum of copper, zinc and lead. Slight modifications of the procedure (for example, changing the acidity or adding a little potassium cyanide) indicate only the copper or only the lead. Other chemicals indicate the presence of other metals. The colorless reagent dimethylglyoxime, for example, turns yellow or red when nickel is added to it; the intensity of the color tells how much nickel is present.

The uranium prospector cannot use a colorimetric kit; there is no good color test for uranium. Instead he can use paper chromatography. This works as follows. A drop of a prepared solution of the sample is placed at one end of a strip of filter paper and allowed to dry. The same end of the strip is now dipped in a suitable liquid (ethyl acetate), which travels up the paper and carries the uranium, but no other metal, with it. Before the liquid reaches the other end of the strip the paper is removed, dried, and sprayed with a solution of potassium ferrocyanide. This leaves a brown line of uranium ferrocyanide at the highest level reached by the liquid. The more uranium, the deeper the brown line.

Another method of geochemical analysis, so new that it has barely been tested, has exciting possibilities. It depends on the proportion in limestone of the two isotopes of oxygen, oxygen 16 and oxygen 18. Eons ago a body of dolomitic limestone near Leadville, Col., was invaded by a hot solution of metals which dissolved some of the limestone and replaced it with ores of silver, lead and zinc. The intense heat of the solution baked the surrounding rock, causing visible changes in it which cover an area some 20 times wider than the ore body. Beyond this zone the limestone is apparently unchanged. When the ratio of the oxygen isotopes in the baked rock was measured, it was found to differ slightly from the normal ratio. The difference could be detected from 3 to 15 miles away from the ore body! When the isotopic ratio was mapped, its contour lines encircled the body of ore.

Geochemical prospecting, made possible by the joint efforts of the chemist, the geologist, the botanist and the physicist, has given a new sense to the baffled prospector. It helps him look below the thick muskeg of northern Canada and the tangled forest of the Amazon. Its successes have been encouraging, and its future is bright. It is no magic divining rod, but used with discrimination it is an invaluable addition to the older methods of geology and geophysics.



onds. The red color indicates the presence of heavy metals. Dithizone is then added a drop at a time until the red color of the top layer fades. The total amount of dithizone that must be added to the mixture indicates the amount of the heavy metals that are present.

THE ABSORPTION OF RADIO WAVES IN SPACE

In 1951 it was found that clouds of hydrogen between the stars radiate 21-centimeter radio waves. The clouds also absorb these waves, providing a sensitive new tool for the radio astronomer

by A. E. Lilley

It is an odd fact that astronomers have learned much about the universe from light that is absorbed before it reaches their telescopes. Each kind of atom in a star can emit light of a particular wavelength; the wavelengths emitted by various atoms may be spread out by the spectrograph in a spectrum of bright lines. The same kind of atom can also absorb light of the same wavelength. When light from the incandescent gas of a star passes through a cooler gas between the star and the spectrograph, the atoms of the cooler gas identify themselves by absorbing their characteristic wavelengths. These appear as dark lines against the bright background spectrum of the star.

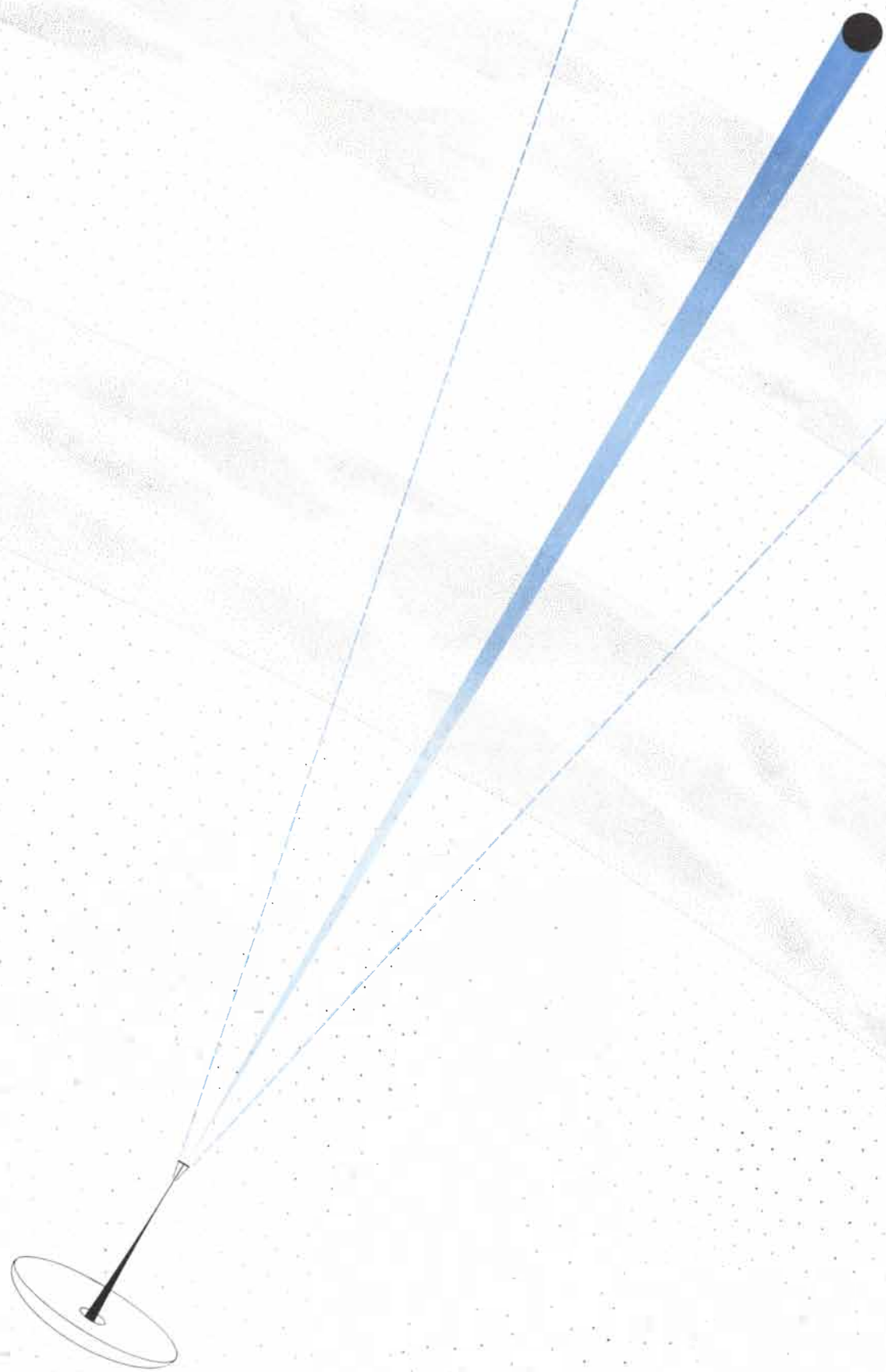
As readers of SCIENTIFIC AMERICAN are well aware, the earth receives radio waves from space as well as light waves. "Dark" lines can also be observed in the radio spectrum. Radio astronomers presently work with only one such line: the radio wavelength absorbed by the cold hydrogen in interstellar space. Since about 93 per cent of all the atoms in the universe are those of hydrogen, this dark line can tell us a great deal, particularly about the physics of the matter which lies between the stars.

The radio waves absorbed by hydrogen are 21 centimeters long. Waves of this length carry just the amount of energy needed to flip the single spinning electron of the hydrogen atom from a state in which its magnetic axis is opposed to that of the nucleus of the atom to a state in which the two axes are parallel. When the electron moves from the state of lower energy to the state of higher energy, 21-centimeter waves are absorbed; when the transition is in the reverse direction, waves of the same length are emitted. In 1951 Harold I. Ewen and Edward M. Purcell of Harvard University discovered that clouds of hydrogen in our galaxy steadily emit a rather faint signal of 21-centimeter radiation [see "Radio Waves from Interstellar Hydrogen," by Harold I. Ewen; SCIENTIFIC AMERICAN, December, 1953]. This signal, which may be compared to a bright line in the visible spectrum, has enabled astronomers to trace out the distribution of hydrogen in the galaxy. Most of the hydrogen is located in the central plane of the galaxy, and its strongest radio signal generally follows the path of the visible Milky Way. There are also two "bright" 21-centimeter areas in the constellations Taurus and Ophiuchus, where vast clouds of dust have trapped large concentrations of hydrogen [*see chart on pages 50 and 51*].

Like a dark line in the visible spectrum, an absorption line in the radio spectrum is seen against a small, bright source of radiation. These sources are sometimes called "radio stars," but they are not stars in the usual sense. They emit radio waves over a broad band of wavelengths, including those of 21 centimeters. The 21-centimeter radiation of such a source is much stronger than that emitted by the clouds of hydrogen in interstellar space. When the 21-centimeter signal of the source passes through a hydrogen cloud, a considerable fraction of its energy may be spent in flipping the electrons of the hydrogen atoms from the lower to the higher energy level; this energy is thus removed from the signal. Because the "brightness," or intensity of the signal, of the hydrogen cloud is so much lower than that of the source, the net result is a drop in the strength of the 21-centimeter signal from the source.

Detecting the drop is difficult, because the radio astronomer deals with very faint signals. He offsets this faintness by using receivers of very high sensitivity and large antennas to gather as much signal as possible. The effect he looks for may still be little larger than the unavoidable fluctuations in signal due to noise in the receiver. To pick out this minute effect he uses a comparison technique. The antenna is pointed at the small radio source and the signal is fed into a two-channeled receiver. One channel admits a narrow band of frequencies and can be tuned over the entire 21-centimeter region. The second

ABSORPTION of the 21-centimeter signal from a radio source (*black circle*) by hydrogen clouds in a pair of spiral arms of the Milky Way (*parallel bands*) is illustrated schematically. The broken colored lines extending outward from the antenna define its beam width: the angular region of space which the antenna effectively "sees." The much narrower absorption cone (*colored band*) thus enables the telescope to inspect a smaller sample of space; *i.e.*, it greatly increases the instrument's resolving power.



channel tunes up and down with the first, but covers a slightly different range of frequencies. The receiver compares the two signals, and its output (traced by a pen on a paper tape) indicates the difference between them. If there is no difference, as when both channels receive radio waves from a source undimmed by hydrogen, the pen wiggles slightly around a horizontal line. If the 21-centimeter signal is intensified, the pen moves up from the line; if the signal is weakened by absorption, the pen goes below the line [*see three illustrations on page 52*].

With this technique J. P. Hagen and E. F. McClain of the Naval Research Laboratory in Washington, D.C., first found the hydrogen absorption line in 1954. At about the same time W. Williams and R. D. Davies of the Jodrell Bank Experimental Station in England also detected the absorption line.

What can such measurements tell us? For one thing, they provide information on the motion of the hydrogen clouds. Like spectral lines in the visible region of the spectrum, the radio absorption lines are subject to the Doppler effect. When the clouds are moving toward the earth, the absorption line shifts toward shorter wavelengths; when they are moving away from the earth, the line shifts toward longer wavelengths.

Once we know whether a gas cloud is moving toward or away from the earth, we can also estimate its distance. This is possible because the hydrogen is concentrated in the outflung arms of our spiral galaxy. The galaxy turns around its center like a vast pinwheel. Up to a point the speed with which it rotates increases with the distance from its center; then the speed of rotation decreases. The result is that at every point in a spiral arm there is a characteristic component of motion toward or away from the earth. Hence when we measure the speed and direction of a gas cloud we can place it in a particular spiral arm and obtain its distance.

At the time the first absorption measurements were made, radio telescopes could be used to determine the direction of small radio sources with considerable accuracy. Nothing was known, however, about the distance of the sources. A number of workers quickly realized that the absorption measurements should be useful in roughly estimating these distances. If the radiation from a small source was known to pass through a hydrogen cloud, then the source must lie behind the cloud. Since the distance of the cloud could be estimated, it was now possible to put a lower limit on the distance of the source.

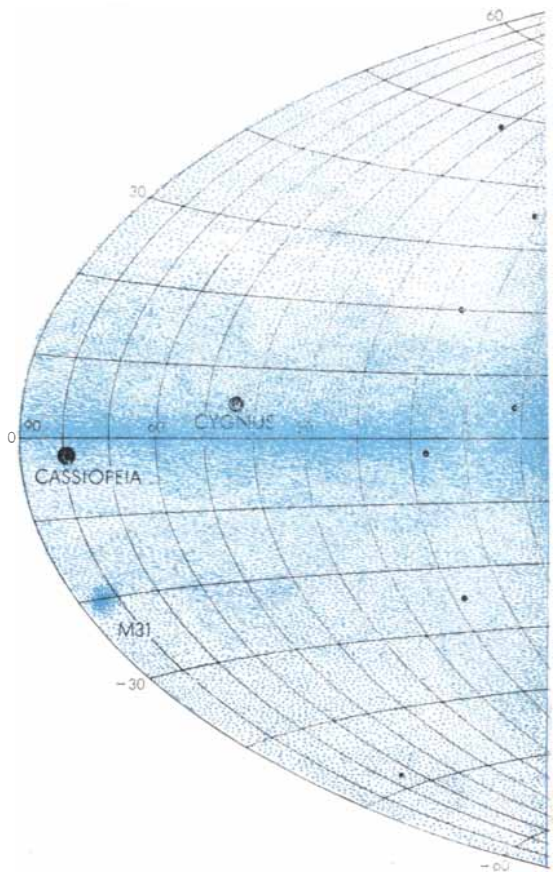
The method has been used to estimate the minimum distance of several small radio sources. Unfortunately in the only case in which we have an independent means of checking the estimate, there is a serious discrepancy between the two figures. The brightest of all objects at 21 centimeters is called Cassiopeia A. Its spectrum in the vicinity of 21 centimeters shows three distinct absorption lines, each corresponding to a gas cloud at a different distance. One of the clouds is in a spiral arm close to the earth; the other two, in a more distant spiral arm [*see illustration at bottom of page 52*]. According to the Dutch radio astronomers who have mapped the distribution of hydrogen in the Milky Way, the more distant arm is about 9,000 light-years from the earth. Since Cassiopeia A is behind this arm, its distance must be at least 9,000 light-years.

It happens that Cassiopeia A is one of the few radio sources that have been linked with a visible object in the sky. Walter Baade and Rudolph Minkowski of the Mount Wilson and Palomar Observatories have identified it with a new type of nebula characterized by filaments of gas [*see photograph at top of page 53*]. Using photographic methods, they have measured its distance as about 1,500 light-years.

There are uncertainties in both estimates, but this discrepancy is a bit too large to swallow. Something must be wrong with one of the measurements. On the radio side there are at least two possible sources of error. First, we may be dealing with two nearby interstellar clouds which just happen to have velocities precisely appropriate to the more distant spiral arm; this would be quite a coincidence. Second, the absorbing gas may be a part of the radio source, and its motion toward the earth may indicate that the gas is being pushed away from the source. Whether either of these explanations is correct, or whether the optical estimate is in error, is still not clear. Until the matter is cleared up both the optical and radio distance estimates will have to be regarded with some caution.

There are other and perhaps more important consequences of the absorption technique. For one thing, the technique endows the radio telescope with much greater resolution, or sharpness of view, for the study of interstellar matter. The antenna of a radio telescope may be considered to have a "beam" within which it can detect a radio signal. The greater the size of the antenna, the narrower the beam. When we study the interstellar gas by means of the 21-centimeter radiation it emits, the sharpness of view is determined entirely by the size of the antenna. Until radio astronomers obtain larger antennas, the clarity of view in the emission studies will remain rather poor.

In absorption studies, however, the sharpness of view is greatly increased. When we detect the absorption line of a radio source, we are looking only at the tiny cone of space extending from the antenna to the source. The area of sky over which interstellar gas ab-



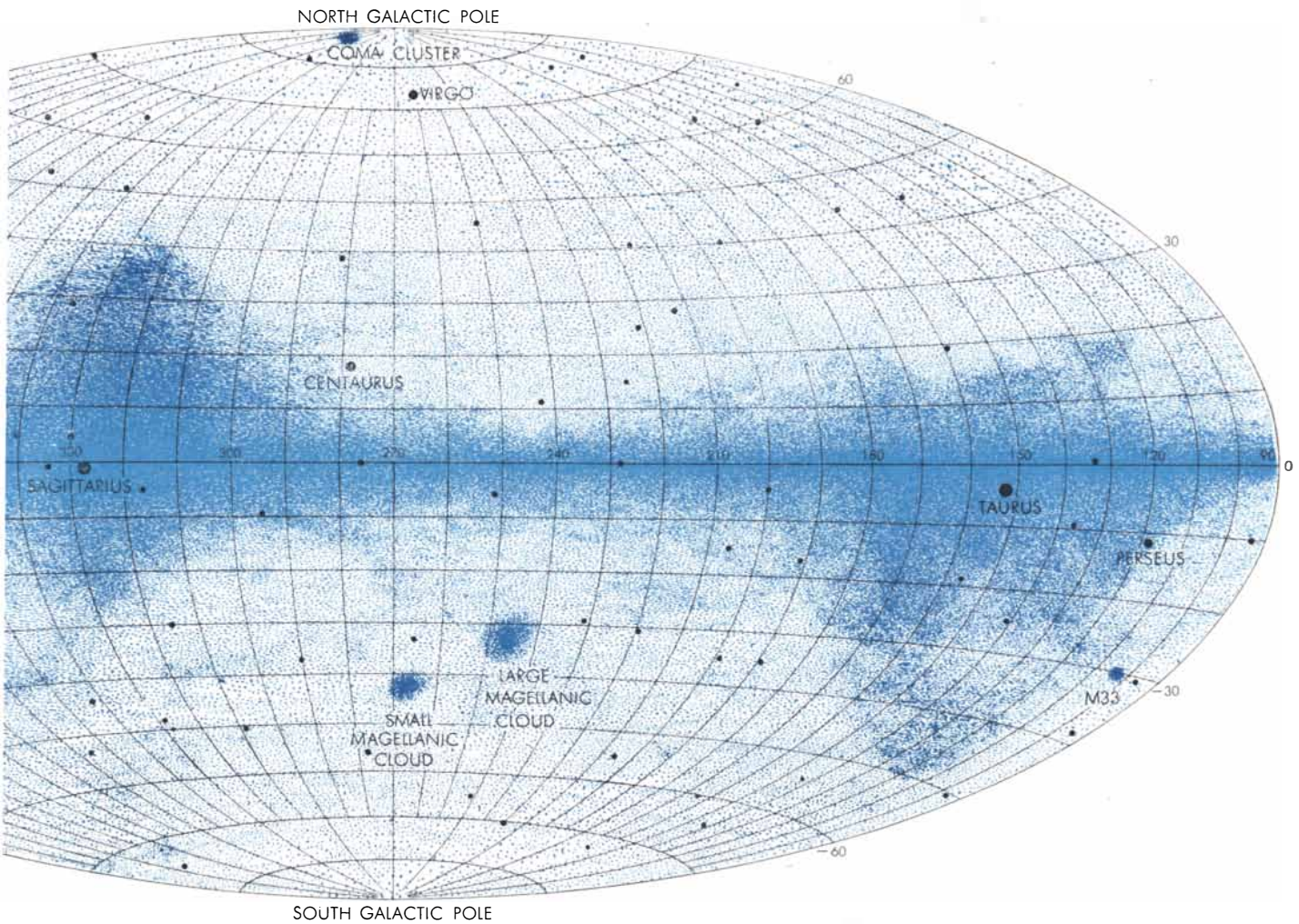
DISTRIBUTION OF HYDROGEN in space is shown in color on this map. The grid lines define galactic coordinates; *i.e.*, the equator of the projected sphere runs around

sorbs 21-centimeter radiation from Cassiopeia A has a diameter of five to six minutes of arc. To get a beam this narrow by other methods we should need an antenna 500 feet in diameter—something like a steerable football stadium. Some of the smaller radio sources provide a "beam" that would require an antenna a mile or more in diameter to duplicate.

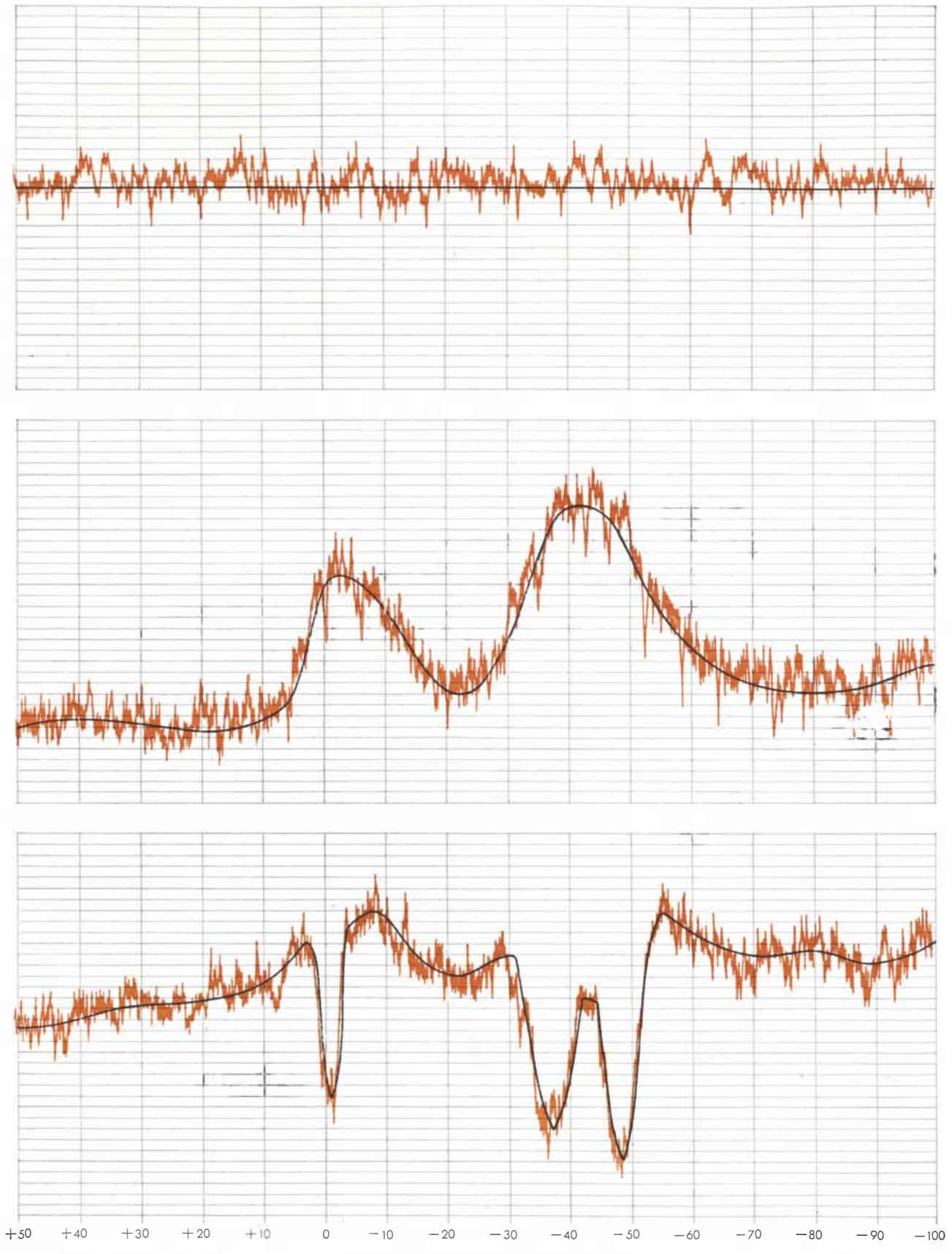
This increase of resolution gives a remarkably fine-grained view of interstellar space. As more radio sources are detected, through the use of larger antennas and better receivers, the picture will be more completely filled in. The amount of absorption is proportional to the energy-gathering power of the telescope, and a large antenna will reveal fine details that are now completely passed over by smaller instruments. The energy received by a parabolic antenna increases approximately as the square of its diameter, so that a comparatively modest increase in size results in a substantial improvement in the capacity of the instrument to reveal details in the structure of the interstellar gas. The new 60-foot dish at the Harvard College Observatory has already detected details in the absorption spectrum of Cassiopeia A which could not be observed in records that were made earlier with the 50-foot telescope at the Naval Research Laboratory.

With larger radio telescopes we shall be able to tell much more about the physical state of the interstellar clouds. Because the absorption studies reveal the structure of the gas in such detail, they will be of considerable interest to those who study the turbulence of interstellar matter. In some cases it may be possible to make direct measurements of the temperature of the gas clouds. Like lines in the visible spectrum, the hydrogen line will be split by magnetic fields. The Australian radio astronomers J. G. Bolton and J. P. Wild have pointed out that the splitting of radio-absorption lines offers the best hope of measuring the very weak magnetic fields in interstellar space.

Another interesting possibility is the study of substances in space other than ordinary hydrogen. Deuterium (heavy



the Milky Way. Most of the hydrogen in our galaxy is concentrated in the galactic plane. This edge-on view does not show the fact that the gas in the galactic plane is largely in the spiral arms. The large cloud above the equator centered at galactic longitude 350 degrees is near the constellation Ophiuchus; the cloud below the equator centered at 150 degrees is in Taurus. Bright sources of radio waves are shown as black dots. Extragalactic collections of hydrogen, such as those in the Magellanic Clouds, are also in color.



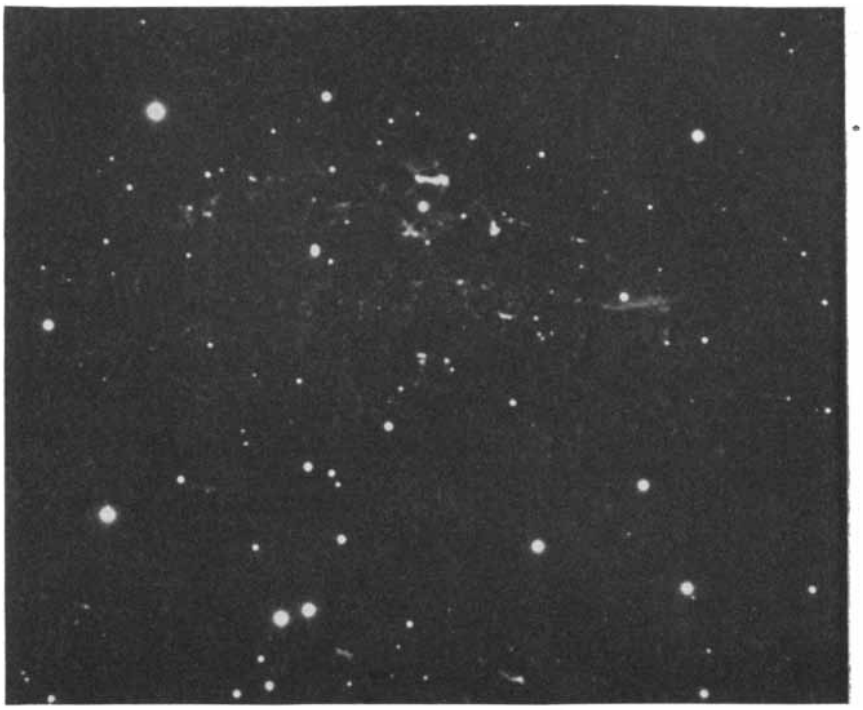
RADIO-TELESCOPE RECORDING compares signal in 21-centimeter region and neighboring frequencies. Zero trace (*top*) shows no hydrogen source. Peaks (*middle*) come from hydrogen clouds in two spiral arms. Dips (*bottom*) represent absorption of signal from Cassiopeia A by these clouds (second arm has two clouds). Frequency of absorption (*horizontal scale*) shows velocity of clouds.

hydrogen) has a spectral line with a wavelength of 96 centimeters. This line has been sought by many radio astronomers, so far without success. Bigger instruments should bring it out as an absorption line. Radio waves of some 18 centimeters are emitted and absorbed by the hydroxyl radical, in which one hydrogen atom is combined with one oxygen atom; we may be able to find them also. The detection of these and other substances will add valuable information about the relative abundance of the elements in the universe.

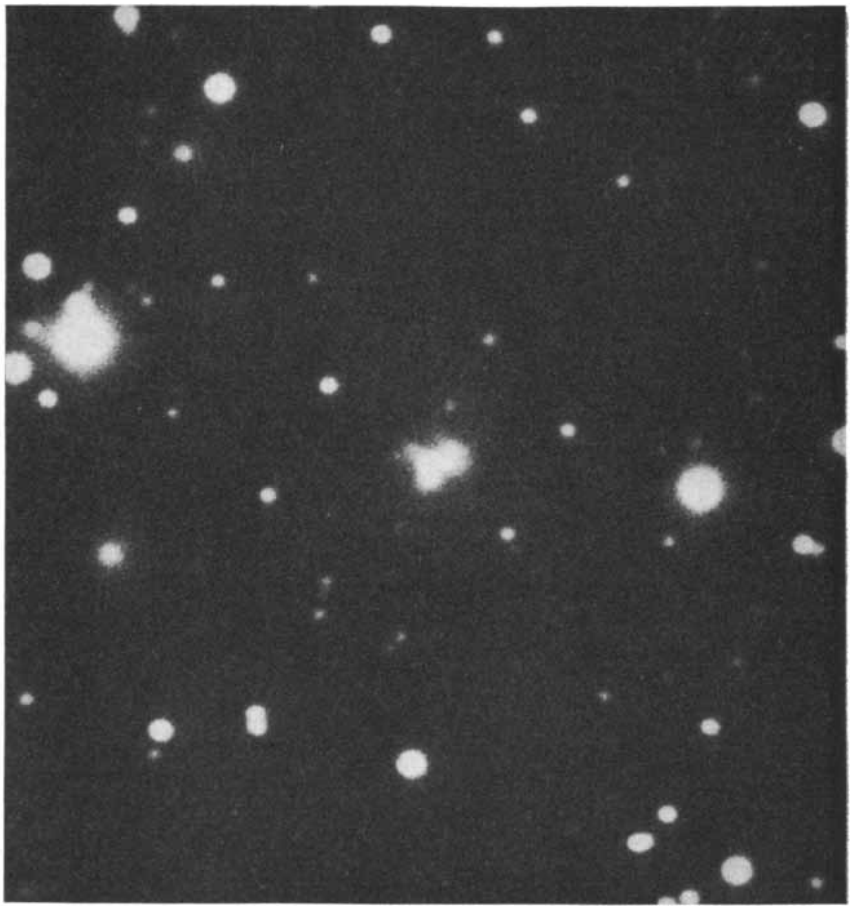
Finally, the hydrogen studies can be extended beyond our own galaxy. Indeed, such studies have already begun. As soon as the 21-centimeter line emitted by hydrogen was discovered, a number of workers began to try to pick it up from extragalactic objects. An Australian team did succeed in detecting 21-centimeter waves emitted by the Clouds of Magellan; the team has conducted extensive investigations of the distribution and motion of hydrogen in these two small galaxies near our own. But attempts to detect 21-centimeter waves emitted by more distant galaxies were at first unsuccessful.

Another frontier was opened when Baade and Minkowski announced that they had identified the second brightest radio source, known as Cygnus A, with a pair of colliding galaxies. The distance of this system is more than 400 million light-years. Would it be possible to detect the absorption of 21-centimeter waves by clouds of hydrogen in the two galaxies? If so, this presented an even more exciting possibility. Dark lines in the visible spectrum of galaxies are shifted toward the longer-wavelength, or red, end of the spectrum. This "red-shift" is generally interpreted in terms of the Doppler effect; that is, it is thought to indicate that the galaxies are receding from us, and that the universe is expanding. If the explanation is correct, it should hold true for radio waves as well as light. And if the radio waves absorbed by hydrogen clouds in Cygnus A were shifted toward the longer wavelengths, it would be new evidence of the fact that the galaxies are indeed receding.

At the Naval Research Laboratory E. F. McClain and the author began to think about ways to detect the absorption line in Cygnus A. The line would surely be weak. Moreover, the absorption would be caused by hydrogen clouds moving in various ways within the colliding galaxies; this would undoubtedly spread the line over a broad



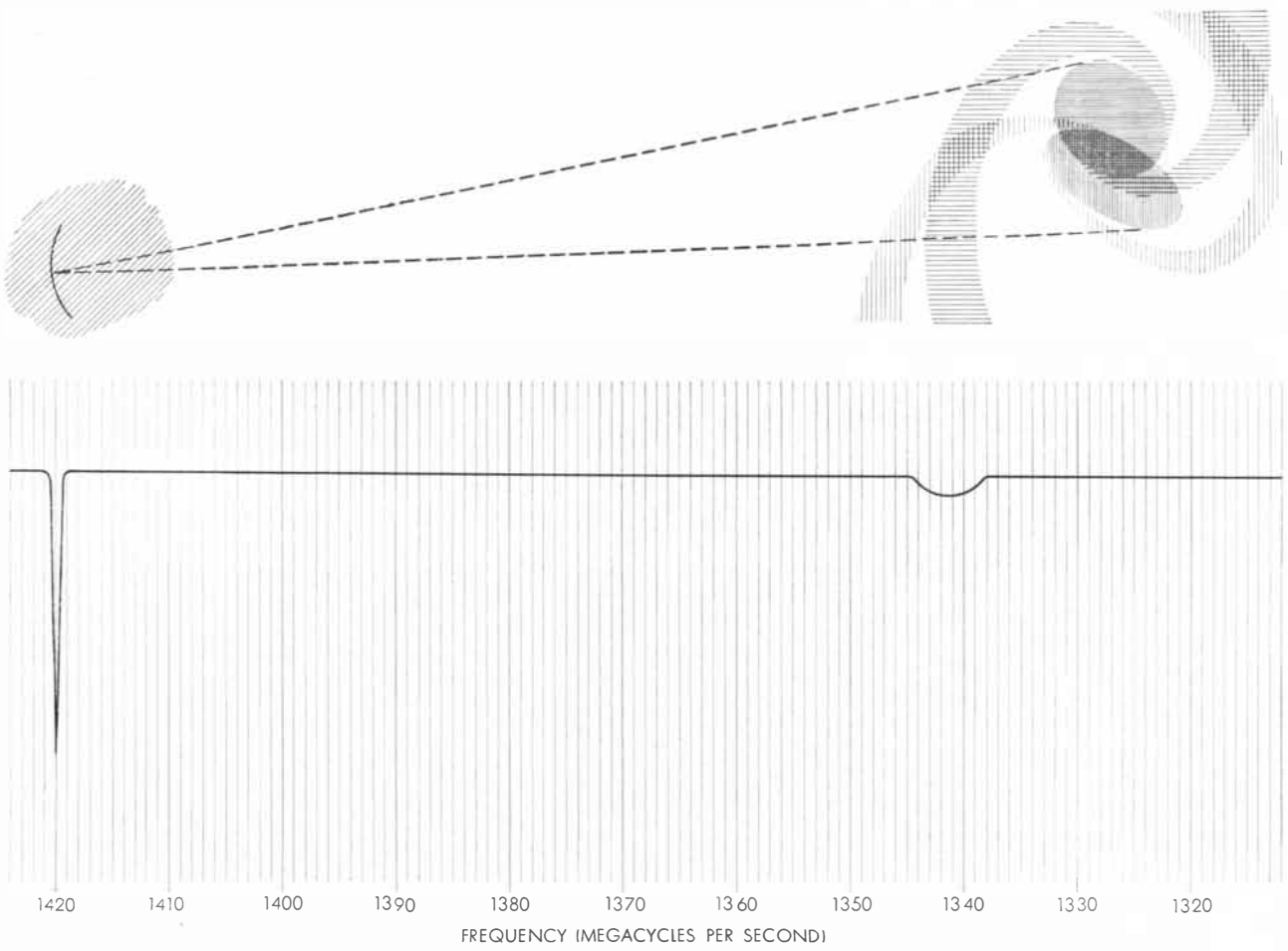
CASSIOPEIA A is the strongest radio source in the sky. It has been identified with the faint wisps of gas which appear in this photograph, made with the 200-inch telescope.



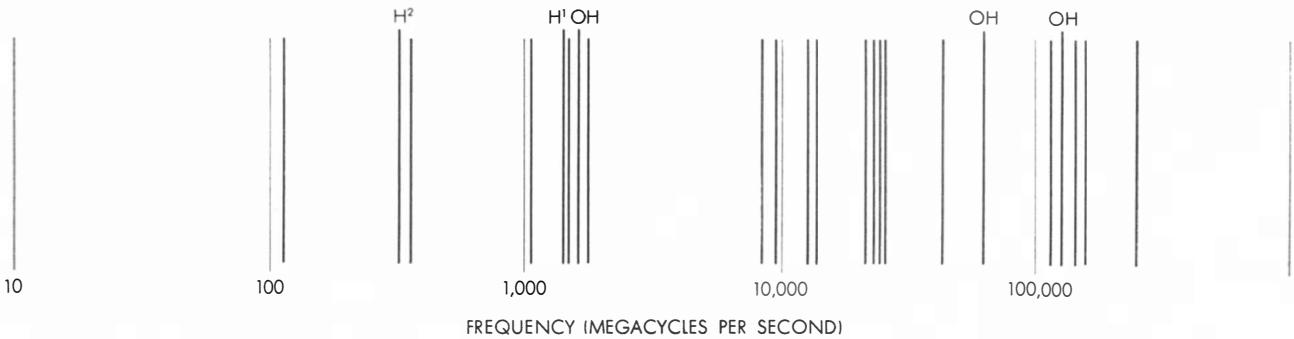
CYGNUS A, the second strongest radio source, is a pair of galaxies in collision. The pair appears in this 200-inch-telescope photograph as the double spot in the center of the field.

band of wavelengths. The net receding motion of the system would nonetheless far outweigh the various internal motions, and the center of the line should show an unmistakable displacement toward a longer wavelength. The visible red-shift indicated that the galaxies were receding at a velocity of 16,830 kilometers per second. Waves 21 centimeters long have a frequency of 1,420 megacycles per second; the velocity of the galaxies should lower this frequency about 80 megacycles.

Nothing could be done about the breadth of the line, but its apparent intensity could be increased by a huge antenna. Considerable thought was given to the possibility of making a 500-foot dish out of chicken wire suspended from an array of telephone poles. Such an antenna would be technically feasi-



EXTRAGALACTIC ABSORPTION LINE comes from hydrogen in colliding galaxies (*top right*). The line (*dip below galaxies*) is weak, broad and displaced about 80 megacycles per second from 1,420 megacycles, the frequency for stationary hydrogen. Radio receiver is shown schematically (*top left*), surrounded by Milky Way hydrogen. Below it is the corresponding absorption line.



RADIO-ABSORPTION LINES of some substances other than normal hydrogen may yet be detected. The lines most likely to be found are those of deuterium (H^2) and the OH radical. Lines of sodium and helium are among the others indicated in black.

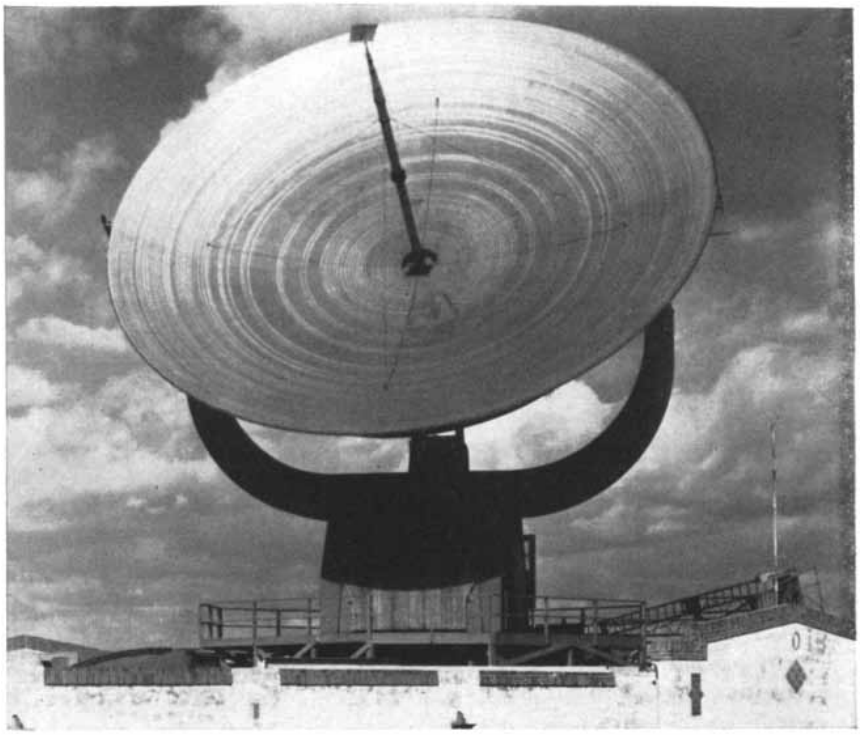
ble and relatively inexpensive, but it could not be rotated to follow the radio source as the earth turned. It happens, however, that at the latitude of Washington Cygnus A passes almost directly overhead. Thus a stationary horizontal dish would detect the radio source once a day.

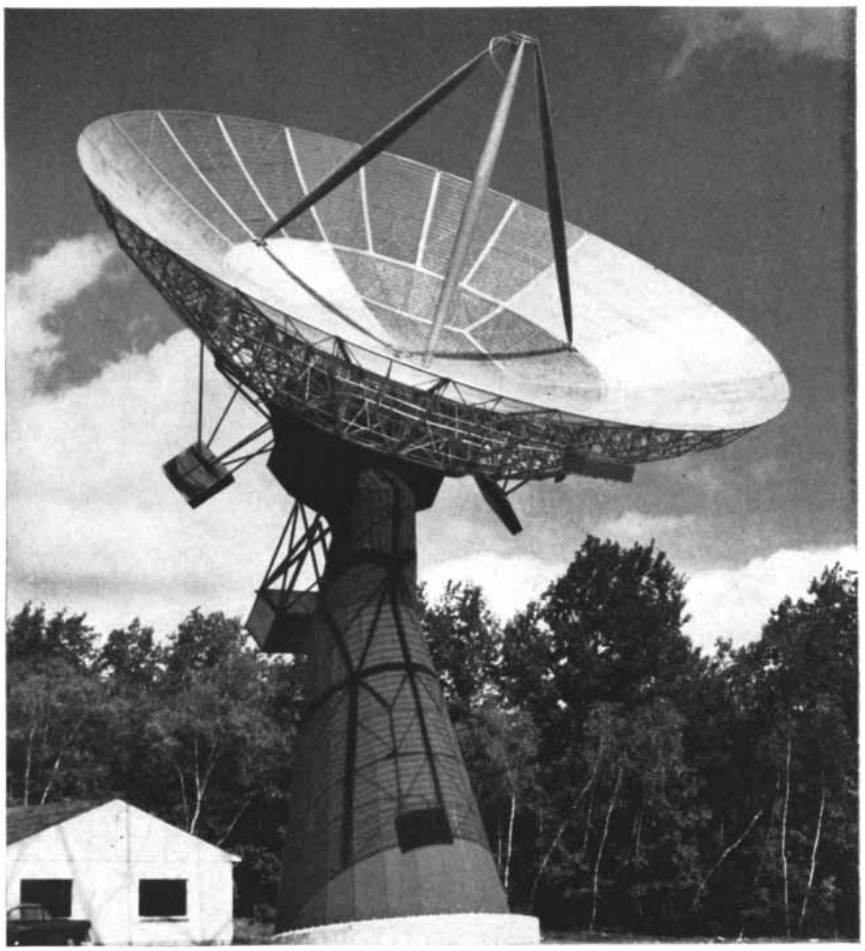
As the design of the chicken-wire dish evolved, it seemed worth while to try to pick up the absorption line with the 50-foot radio telescope at the Naval Research Laboratory. The two-channel, frequency-comparing technique described earlier could not be used because the line would be broader than the difference between the frequencies detected by the two channels. Another comparison technique was employed: the signals of Cygnus A and Cassiopeia A were compared at various frequencies. If, over a large number of observations, the waves absorbed by Cygnus A had a frequency 80 megacycles lower than 1,420 megacycles, the radio red-shift would have been demonstrated.

The observations were successful: a weak absorption line was found in the anticipated position. It was no longer necessary to put up the chicken-wire antenna. The validity of red-shift measurements is thus established over a range of frequencies some 100,000 times wider than that over which they had previously been observed. This result does not clinch the fact that the galaxies are receding, but it adds some highly persuasive evidence. The Doppler effect predicts the radio result; any other explanation of the red-shift must also meet this test.

The constancy of the red-shift in the radio region has since been confirmed with a different source and a larger antenna. Using the 60-foot Harvard radio telescope, David S. Heeschen has succeeded in detecting a faint 21-centimeter line emitted by the rich cluster of galaxies in Coma Berenices. The red-shift of this cluster is about one third that of Cygnus A, but again the radio and photographic measurements agree.

Cygnus A is not the only source which is due to the collision of two galaxies. There are probably many such sources, some of them well beyond the range of the 200-inch telescope on Palomar Mountain. This suggests that radio telescopes may be capable of detecting the red-shift of galaxies too distant to be perceived by light-gathering telescopes, and that they may provide some definitive information about the nature of the universe.





RADIO TELESCOPES which have been used in 21-centimeter absorption studies include the 50-foot instrument at the Naval Research Laboratory in Washington, D.C. (*top*), and the 60-foot instrument at the Harvard College Observatory's station in Harvard, Mass.

Weed Control by Insect

For 30 years Klamath weed, a noxious plant imported from Europe, had infested the range lands of northern California. How it was brought under control by introducing its European insect enemies

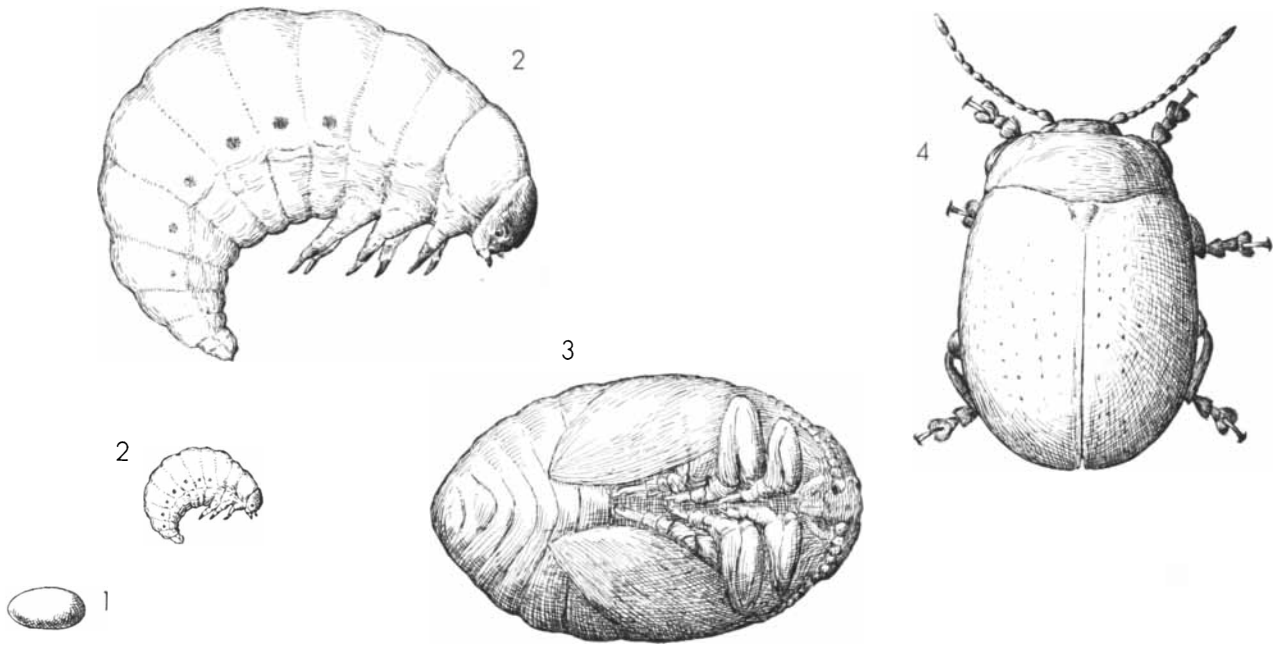
by James K. Holloway

For more than 400 years the mass migrations of man have been from east to west. In these migrations man has unintentionally brought with him many species of weeds, which may be defined as plants growing where they are not wanted. Such plants greatly increase the cost of crops and livestock by competing with useful plants, and their control has traditionally taxed human ingenuity. This is an account of how a troublesome alien plant was controlled by a novel device—the immigrant insect.

The plant *Hypericum perforatum* is a native of Europe, where it is commonly called St.-John's-wort because it blooms on or about June 24, the feast of Saint John the Baptist. St.-John's-wort is an erect, freely branching perennial herb with a stem one to five feet high. Its flowers are yellow and occur in clusters; its light green leaves are numerous and paired along the stem. Its root crown has many lateral runners which are capable of starting new plants; thus the spread of the plant is not entirely dependent on its seeds. These are produced in a pod which breaks into segments, releasing numerous small, cylindrical brown seeds which are spread by wind, water, man and animals.

St.-John's-wort was first reported in the U. S. in 1793 near Lancaster, Pa. By 1900 it had spread to California, where it was first reported in the northern part of the state around the Klamath River. Thus the plant's common name—Klamath weed. (In some parts of the West it is referred to as goatweed.) In 1929 a survey showed that the pest had spread to some 19 counties in northern California and had occupied some 100,000 acres of previously useful range land. It was predicted that it might become one of the worst range-land weeds in the entire state.

By 1940 the infestation of the weed had increased: 27 counties reported it in an estimated 250,000 acres of range land. Wherever it grew land values depreciated. Improvement loans were no longer granted for ranches heavily infested; bankers felt that Klamath weed held the first mortgage.



LEAF-EATING BEETLE ***Chrysolina gemellata*** **was one of four insects introduced to control the Klamath weed. This drawing shows the four stages of its life cycle: egg (1), larva (2), pupa (3) and adult (4). The beetle was originally a native of France.**

The weed not only competed with forage plants; it adversely affected the grazing animals which ate it. Cattle and sheep do not normally eat the plant, but in the late spring and early summer, when many of the food plants are dry or depleted, they will turn to Klamath weed. The plant has various effects on the animals, depending on the quantity they consume and the pigmentation of their skins. It contains an oil which, when it is ingested, sensitizes the white areas of the skin to light. The sensitized animal often suffers body sores, swollen ears and a sore muzzle. These afflictions do not kill the animal but reduce its weight and vigor, with obvious economic results for cattle- and sheepmen. The animals also become irritable, making them difficult to corral and transport.

How could the weed be controlled? Chemicals were out of the question: the range lands were too extensive and too inaccessible. For many years insects had been under consideration as a possible solution to the problem. As far back as 1920 the Commonwealth of Australia had begun to seek insect enemies of the weed. The search led to England and southern France, where it was found that St.-John's-wort was attacked by two leaf-feeding beetles, a root borer and a gallfly. If these insects were established in Australia, would they also be destructive to useful plants? Before the step could be taken, a wide variety of plants were exposed to the insects under controlled conditions in both Europe and Australia. Finally the desirable insects were released in Australia, and by 1944 encouraging results were reported.

When Harry S. Smith, then chairman of the Department of Biological Control at the University of California, heard of these results, he sought permission from the U. S. Department of Agriculture to introduce the beetles into California. The University was permitted to import two species of leaf-feeding beetles and a root borer, with the proviso that it test six additional plants which had not been exposed to the insects in Europe or Australia. The University and the Department of Agriculture then set up a cooperative project to import, test and breed the insect species.

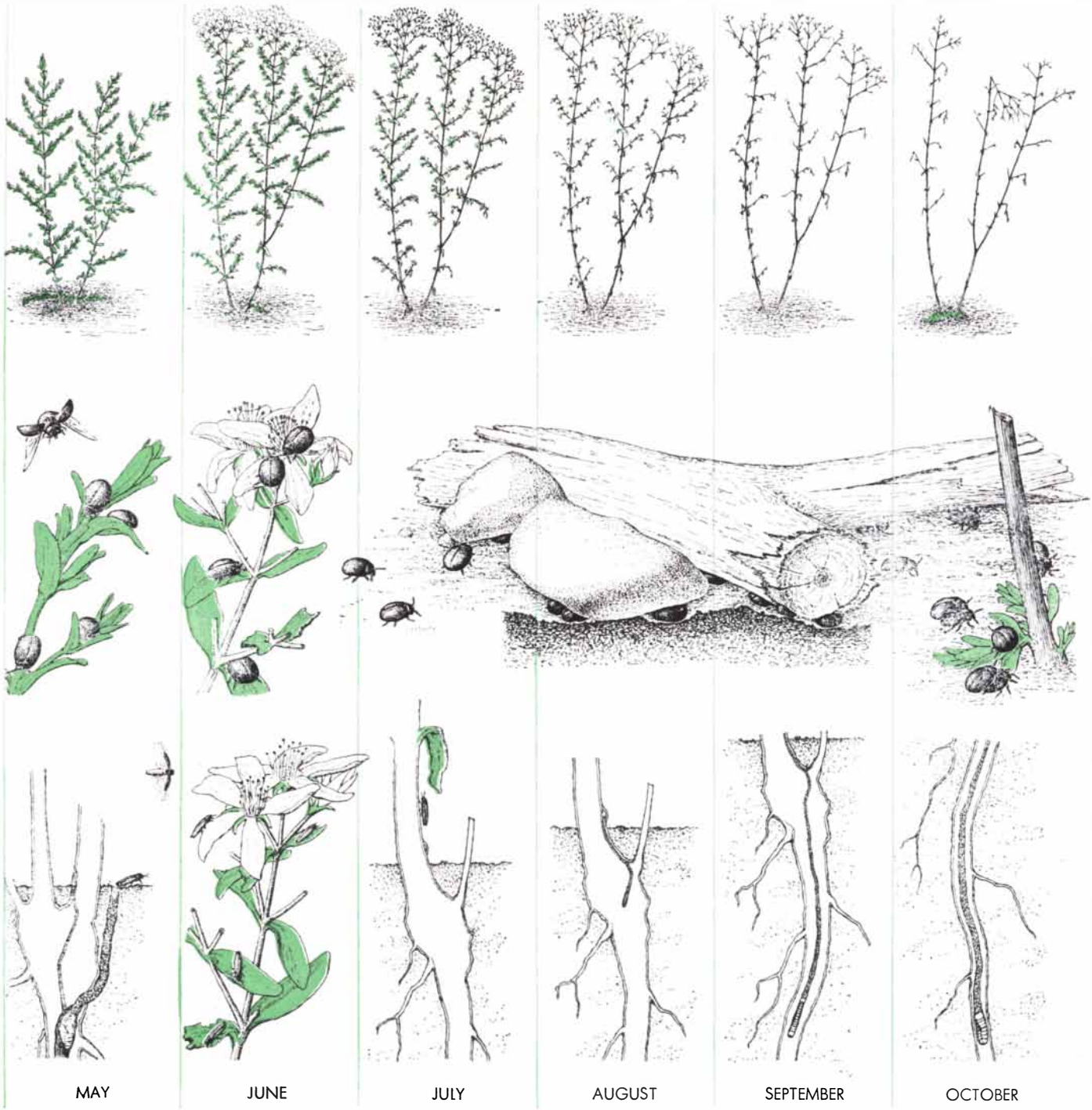
Because World War II was still in progress, the insects could not be obtained in Europe; they were thus imported from Australia. This created a curious problem: the life history of the insects was synchronized with the seasons of the Southern Hemisphere. The

KLAMATH WEED (*Hypericum perforatum*) is a perennial herb which grows one to five feet tall. Its flowers are yellow and edged with dots. In Europe it is known as St.-John's-wort.

two species of leaf-feeding beetles arrived in November; they were then in their summer resting stage. For them to be in step with conditions in California required that they be in their egg-laying stage, which follows the resting stage. It was supposed that in their original habitat of France the beetles came out of the resting stage after fall and winter rains; on this theory they were sprayed with droplets of water. In a few hours they began to move about, to show interest in food and to mate. After they had been subjected to artificial rain twice a day for two weeks, the beetles began to produce fertile eggs. Their life histories were now synchronized with the seasons of the Northern Hemisphere.

The root borers were a more difficult problem. They were received as larvae in the taproots of St.-John's-wort, and they could not be induced to emerge. It was decided to curtail their further importation until after the war, when they could be sought in Europe.

Within a year after the beetles had been imported it was determined that they would feed and reproduce only on Klamath weed. The Department of Agriculture granted permission to release

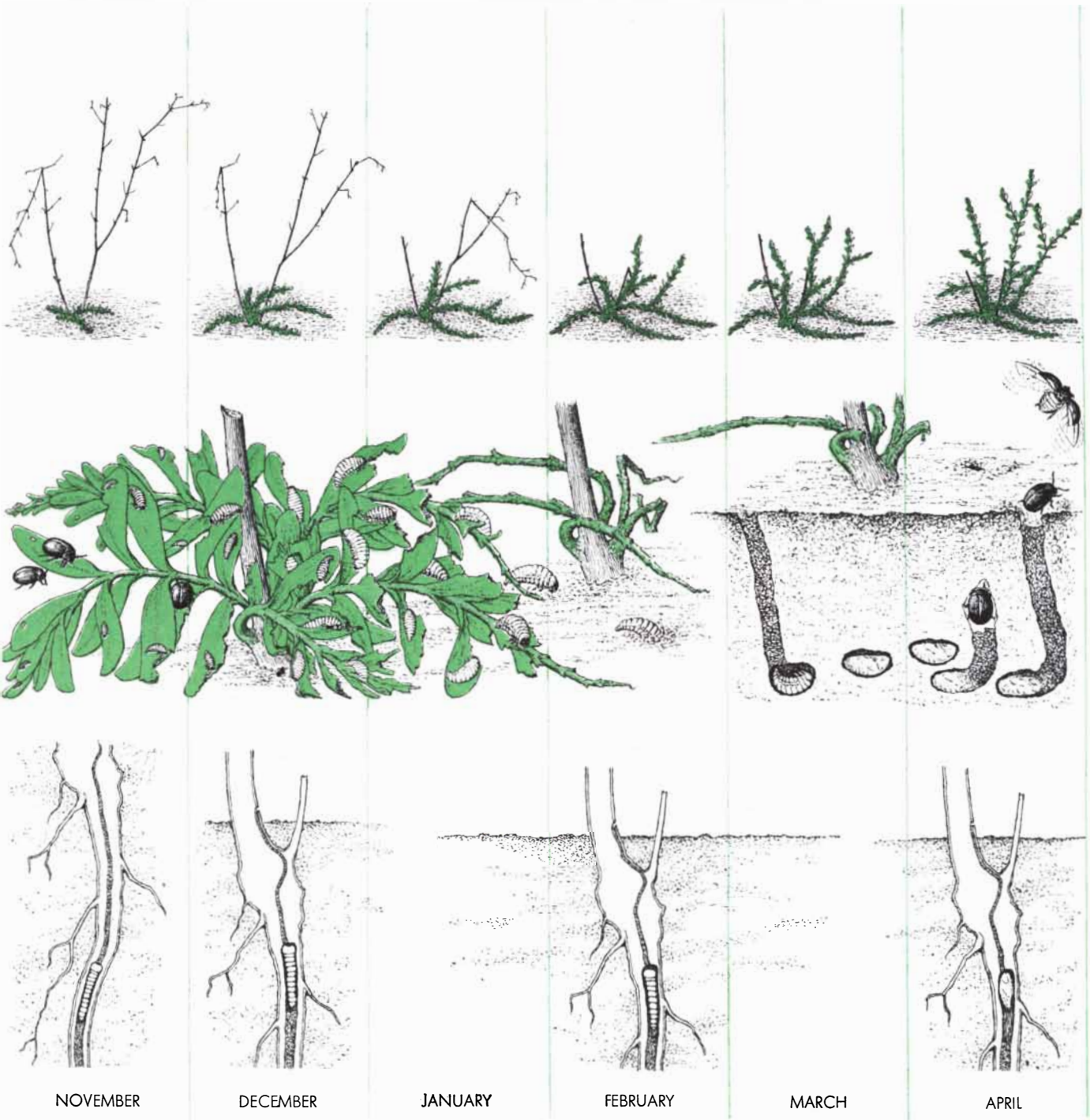


LIFE CYCLES of Klamath weed (*top*), the leaf-eating beetle *C. gemellata* (*middle*) and the root borer *Agrilus hyperici* (*bottom*) are shown in this chart. In May and June the beetles, having emerged from their pupal cases in the ground, feed on the leaves of the weed. In July they go into their resting stage. In the fall they emerge again, mate and lay their eggs. When the larvae hatch from

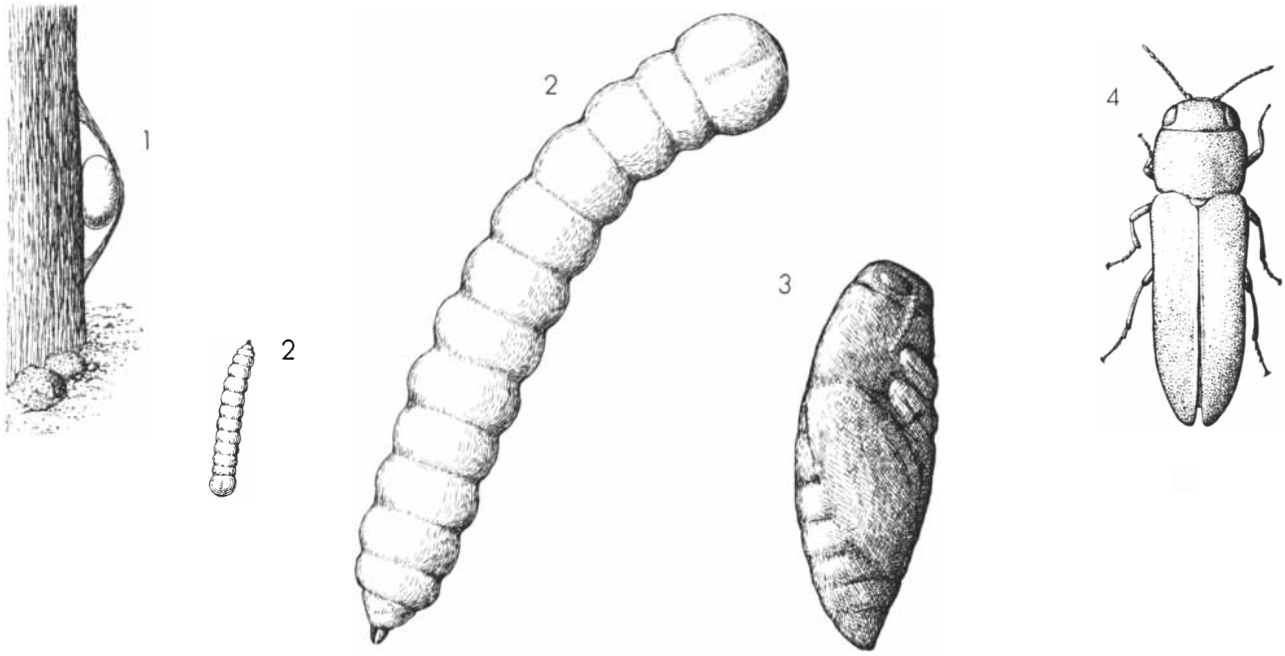
them in the field during 1945-46. This was the first attempt in North America to control a plant with plant-feeding insects. Both species established themselves readily, and by 1948 it was no longer necessary to import them. From two of the sites at which they had originally been released some 200,000 beetles were collected; these were transferred to locations in 16 counties.

The two beetle species are *Chrysolina hyperici* and *Chrysolina gemellata*. Both beetles are oval in shape and about a quarter of an inch in length; they have a metallic sheen and their color may be bronze, purple, blue or green. Within two years after they had been released it became apparent that, of the two, *C. gemellata* was multiplying much more rapidly. This species, a native of France, lays its eggs soon after the first fall rains. At that time the Klamath weed is at its most succulent; the larvae which hatch out of the eggs have time to complete their development while the plant is most suitable as food. Conditions are also favorable to prolonged egg-laying.

C. hyperici, a native of England, reacts more slowly to the fall rains. It does not start to lay eggs in abundance until



the eggs, both they and the beetles feed on the low winter growth of the weed. Late in the winter the larvae burrow into the ground and metamorphose into pupae. The adult root borer emerges from the taproot of the weed in May and feeds on its foliage. In July the adult lays its eggs. The larva which hatches out of the egg bores down through the root. Then it bores up and metamorphoses into a pupa.



ROOT BORER *A. hyperici* is particularly useful because it bores in the roots of Klamath weed during the summer, when the leaf-eating beetles are in their resting stage. This drawing shows the four stages of the borer's life cycle: egg (1), larva (2), pupa (3) and adult (4).

there is too little time for a large proportion of its larvae to complete their development. The arrival of the dry season and its hard soils is unfavorable for the metamorphosis of the larvae into pupae.

The whole life history of *C. gemellata* is nicely synchronized with the growth phases of Klamath weed and climatic conditions in the important range areas of California. In April and early May the adult beetles issue from their pupal cells just beneath the surface of the soil. They feed voraciously on the foliage of the weeds, which are producing flower buds or are actually in flower. By the latter part of June and early July the beetles seclude themselves beneath stones, in debris or in crevices of the soil. When they find a comfortable refuge, they cease activity and go into a resting stage for the remainder of the summer. The plant, too, enters a dormant phase, dropping its leaves and becoming dry and woody.

When the fall rains begin, both weeds and beetles become active. The plants produce a low, trailing, leafy growth upon which the insects feed sparingly. Around mid-October the adults mate and begin to lay eggs; the eggs hatch into larvae. Because adults, eggs and larvae can survive relatively low temperatures, all three forms live together through the winter. By spring most of the eggs have hatched and the larvae are approaching maturity. The larvae completely destroy the trailing growth of many plants. Early in the spring the plants which have escaped destruction develop upright shoots which are destined to become the flower-bearing stalks. At that time the larvae complete their feeding and enter the soil to a depth of about an inch, where they develop into pupae. This completes the one-year life cycle of the insect. The perennial plant has also gone through a complete growth cycle.

It was discovered that the adult beetles were very adept at finding new infestations of the weed. Their natural dispersion was greatly aided, however, by people who collected and distributed large quantities of them. The collecting program was organized with the cooperation of county agencies and the local press and radio. Ranchers and others interested in the destruction of Klamath weed met with the research staff on announced days in specified locations, and were given instructions on how to collect and pack the insects so that they could be moved to new localities.

The newly emerging beetles feed in voracious groups on the tops of the flowering stems. When they are disturbed, the beetles play dead and fall off the plant. The insects are easily collected by bending the heavily infested tops of the plants over a container. At first the collectors used containers of all kinds—automobile hubcaps, water buckets, paper cartons, hats. One woman was seen making her first catch in a tea strainer. Shortly after they are captured the beetles again become active and try to escape, but when the side of the container is given a sharp tap they again "drop dead." This makes it possible to collect large numbers of beetles before transferring them to a carton provided for transporting them to other locations. Fortunately the adult insects suffer no ill effects from being boxed in large masses; it is possible to transport them without much loss.

The containers most suitable for transferring the insects were round, half-gallon waterproofed paper cartons—the kind often used to pack ice cream. About one half to three quarters of a pint of beetles were placed in each carton; the remaining space was filled with Klamath weed. By providing this food supply every other day the beetles could be kept alive for two or three weeks. Beetles collected in the spring have not mated, and if they are distributed too thinly in their new location the probability that they will mate in the fall is decreased. The collectors were therefore advised to release 2,000 to 10,000 adult beetles in a circle not more than six feet in diameter. Where this recommendation was followed the beetles established themselves and produced flourishing populations. In the few instances where the advice was ignored and the beetles were spread thinly over a larger area, they became established, but their rate

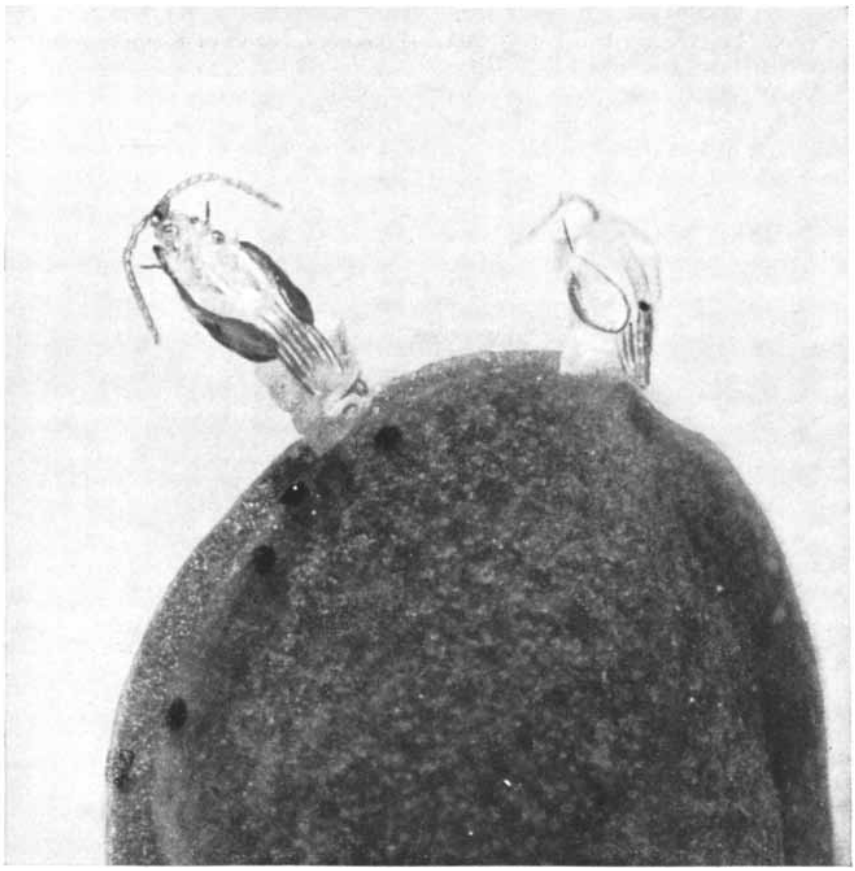
of increase was much slower; it took longer to control the weed.

Where the beetles wipe out the Klamath weed they must move on, because they will feed on nothing else. When they emerge in such an area in the spring, they take flight in search of food. They are capable of long, sustained flights. In the fall the beetles have not been seen to fly, but they disperse locally by crawling over the ground. They have remarkable ability to locate small and isolated patches of the weed. Individual beetles have been observed to travel more than a quarter of a mile in a month —visiting a plant, eating a little of it, depositing their eggs and moving on to the next plant. With man's help these natural modes of dispersion have spread the beetles to all areas in California where Klamath weed grows.

What about the root borer and the gallfly which the Australians had discovered would also attack the weed? They were not forgotten. At the end of World War II the root borer *Agrilus hyperici* and the gallfly *Zeuxidiplosis giardi* were imported to the U. S. from southern France.

The leaf-feeding beetle tends to avoid plants growing in the shade, but the root borer does not; thus the root borer may be used to supplement the work of the beetle. The root borer will efficiently attack Klamath weed found in feed lots, chicken yards and other locations where leaf-feeding larvae would be disturbed or eaten. It has proved to be effective in locating and destroying individual plants, as well as in completely reducing thick stands. The borer is a larva which gives rise to a beetle roughly the same size as the leaf feeders. This insect also has a metallic sheen but its color is mostly bronze.

Because the root borer attacks the roots and not the leaves of Klamath weed, it is not dependent on fall rains and the winter growth of the plant. Thus it is less important that the insect's life history be synchronized with the plant's growth phases. The root-borer beetles are active in June and July, when they feed on the leaves and flowers of Klamath weed. They place their eggs on the stem of the plant just above the surface of the ground. When the larvae hatch, they enter the plant immediately and burrow downward in either the main root or lateral roots. One or more larvae may be found in a root. In early fall they complete their downward feeding; then they move upward. By this time they are full grown. They remain all winter and



SPHERICAL GALLS may be seen on the Klamath weed at the top. The gall develops when the larva of the gallfly enters the leaf bud of the weed. The photograph at the bottom shows two adult gallflies emerging from their pupal cases, which are held by the lips of the gall.

spring in the taproot, from which they emerge as adults. The destruction of the root by the larvae kills the plant.

The natural spread of the root borer can be assisted by transplanting infested roots in the spring. This is best done after the spring rains have diminished, because the disturbed roots lose their capacity to repel water; when they are transplanted the unemerged insects may drown. Root-borer beetles may be collected by net, but this is difficult. The beetles are very active fliers; they are not found in bunches, and after they emerge they spread very rapidly.

The gallfly needs Klamath-weed foliage for most of the year, so it is less widely useful than the leaf feeder or root borer. Thus far gallflies have been most effective in localities which remain moist throughout the summer months. There the foliage of the weed remains luxuriant.

Depending upon the temperature and the availability of growing plants, the gallfly may give rise to several generations in a year. The adult fly deposits its eggs on the leaves and stems of the weed; the resulting larvae enter the leaf buds. There the larvae cause two opposite leaves to grow into a hollow spherical gall. The gall has two halves that meet in tightly compressed lips, which are exploited by the fly. When the pupa of the fly begins to emerge from its case within the gall, it wedges the case between the lips. The lips of the gall hold the case, permitting the adult to free itself completely. If the galls are injured in any way which keeps them from applying the proper pressure, the fly is not able to emerge successfully.

Because the adult gallfly is minute and fragile, it could not be successfully collected or transported in a container. The larvae, however, were successfully transported in the galls. The galls must not be allowed to dry out; the best way to prevent this is to transplant an infested plant. Another very successful way to distribute the insect is to place potted Klamath weeds among plants infested with galls; as soon as galls form on the potted plants, the pots are moved to new locations. Although it is difficult to spread the gallfly artificially, it has a very remarkable ability to migrate naturally. Gallflies released in one location have been found many miles away in a matter of two or three years.

The gallfly is most useful during the summer months, when the leaf-feeding beetles are inactive. It has a great capacity for rapidly increasing its numbers. The flies attack the weed by converting its leaf buds into galls; a heavy infestation of galls reduces the foliage, roots and vigor of the plant, impairing its ability to compete with other plants.

It is not necessary for insects to kill an entire stand of Klamath weed in order to control it. In most of the Western range lands the desirable forage plants are predominantly annuals. Klamath weed starts to grow in the fall, when the annual grasses germinate. It puts the annuals in the shade and competes with them for moisture and soil nutrients. Late in the spring, when the upper six to 10 inches of soil tend to dry out, the growing plants must go deeper for water; often their roots go as deep as 36 inches. Here Klamath weed has the advantage because its roots can go deeper than those of the annual forage plants.

The competitive edge of Klamath weed is dulled by the leaf-eating beetles. By eating the leaves of the weed, the adult insects and larvae cut down the shade. When the larvae feed on the low winter leaves of the plant, they reduce the extent of its root system. Ultimately the root system goes no deeper than a foot, and the weed no longer has this advantage over the annual plants. Usually the weed cannot survive more than three years of such feeding by the beetles.

Thus the destruction of Klamath weed by the beetles has been attended by the return of desirable forage plants. In California many thousands of acres now have a markedly greater capacity for the support of livestock; land values have risen; expenditures for the control of the weed are negligible. Because stands of Klamath weed are no longer extensive and the infested areas are now widely separated, all of the immigrant insects, totally dependent on the weed for survival, have decreased in numbers. Fortunately their ability to locate new infestations and their high rate of reproduction have prevented any important resurgence of the weed. All indications are that this noxious range plant will be held in check and that its insect controls will perpetuate themselves.

EFFECT OF LEAF-EATING BEETLES is shown by this photograph of a field in northern California covered with Klamath weed. In the light area in the foreground the weed is in bloom; in the darker area in the background the beetles have killed the weed.

Kodak reports to laboratories on:

four new sensitizings for an expanding universe . . . a clean deal for a liquid of refractive index 1.269 . . . easy entrée to a vast mass of knowledge about high speed photography

Finesse and sensitivity

Here we are, seemingly hoist in the dark with our own photographic petard, while in the act of coating photographic emulsion on glass to keep the astronomers in business.

Photographic emulsion, the heart of the matter, comes here in beakers —a little beaker to coat a couple of dozen 2 by 10's, a bigger beaker for a dozen dozens of 8 by 10's to go to a man who wants to make sure his whole autumn's observing program will be on the same coating. Up to now we have listed 104 combinations of emulsion types and spectral sensitizing classes in which we can make *Kodak "Spectroscopic" Plates.* Now we have added four sensitizing classes for *Emulsion Type IIa.*

The lower case "a" means that the sensitivity emphasis has been so applied as to require the fewest hours of exposure to make visible the incredibly faint rather than to freeze a split microsecond with the least burst of brilliance. *Emulsion Type 103a* is even more sensitive in this respect, but *IIa* beats it for fine image structure and signal-to-noise ratio in the microphotometer tracings of stellar and galactic spectra.

The new *IIa* sensitizings are *Class F,* a very uniform one for the whole visible spectrum, especially for the red to 680 mμ; *Class E,* with low green sensitivity but the highest total red sensitivity, peaking at about 645 mμ, and cutting off sharply beyond about 660 mμ; *Class D,* the most generally useful one for the green region to about 630 mμ; and *Class G,* which provides the highest green sensitivity obtainable without appreciable red sensitivity.

Astronomers and others who employ photographic sensitivity with this order of finesse conduct their negotiations for materials with Special Sensitized Products Division, Eastman Kodak Company, Rochester 4, N. Y., which arranges for delivery through Kodak dealers—the very same, in many cases, who supply portrait photographers with Kodak Opal Paper *on which to picture the local brides. This also requires finesse and sensitivity.*

A hydrogenless oddity

$$\begin{array}{c} CF_3CO \\ | \\ O \\ | \\ CF_3CO \end{array}$$

With the lowest refractive index among Eastman Organic liquids (1.269), *Trifluoroacetic Anhydride* boils some 30 degrees lower than does *Trifluoroacetic Acid* (Eastman 6287). In plain *Acetic Anhydride* (Eastman 4), where intermolecular hydrogen-to-oxygen attractions strive for a liquid condition as long as possible, the BP is 22 degrees higher after dehydration than before, but when the hydrogens are replaced with fluorines, volatility reigns.

Whether or not such oddity assures *Trifluoroacetic Anhydride* of a future, it already has a past and (for all we know) a present. It has been made to serve as an unconsumed intermediate for the synthesis under mild conditions of various esters (including some from solid reactants), long-chain polyesters, ketones, and sulfones. A British outfit has gone to the expense of patenting some of these findings. Along a different line, there is a U. S. patent that speaks of reacting *Trifluoroacetic Anhydride* with acetaldehyde to yield vinyl trifluoroacetate, which is less flammable and much more stable to heat and water than vinyl chloroacetates. Come to think of it, *we* own that one.

Anyone who places an order with Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company) for 25 grams of Trifluoroacetic Anhydride *is a valued customer of ours. Even if his outlook on life is wholly academic, as soon as our invoice for $3.35 plus transportation is paid he need feel in no wise indebted to us. Should his motive be suspected of being ultimately commercial, no salesman will call to assess the prospects for selling a tank car of it. This is not only a convenience to him but also to companies that sell chemicals by the tank car. About 3600 other such clean deals are set forth in List No. 40 of Eastman Organic Chemicals. Want a copy? (Incidentally, it tabulates 39 other available organic liquids in order of refractive index from 1.3289 to 1.7400.)*

Decency in the Temples of Science

Elsie Garvin keeps our researchers from wasting time with research. That is the properly bombastic way to describe the function exercised by Miss Garvin in our own Research Laboratories and by her equally competent sister and brother librarians in all the other great Temples of Science. They counteract the natural instinct of the scientist to rush to his test tubes and prove what had already been proved with crushing force 27 years previously.

But here *we sell the test tubes* or, less figuratively, the photographic materials that are just as representative a tool of research as test tubes used to be.

Yet we find Miss Garvin compiling a *Bibliography on High-Speed Photography* that runs to 35 pages of rather small type and provides easy entrée to a vast mass of knowledge accumulated over the decades about both equipment and techniques for every kind of high speed photography and about its findings in many, many branches of science and engineering—knowledge the duplication of which would consume incalculable miles of nice, fresh Kodak Film.

And what is to be done with Miss Garvin's bibliography? As long as the supply lasts, a free copy is to be sent *at our own expense* to any person wise enough to ask for it before plunging into a project in high speed photography.

Somehow it seems the decent thing to do. Requests should be addressed to Eastman Kodak Company, Professional Sensitized Goods Division, Rochester 4, N. Y.

Price quoted is subject to change without notice.

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

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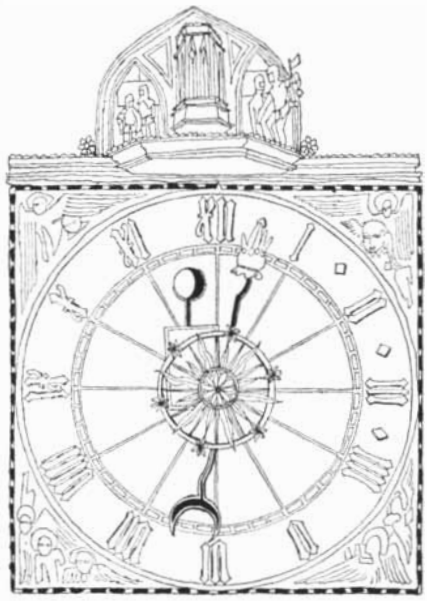


Isotope Economics

In three to five years U. S. industry and agriculture will be saving $5 billion annually through the use of isotopes produced in the atomic-energy program. This is the prediction of Willard F. Libby, chemist and member of the Atomic Energy Commission, who points out that atomic armaments and atomic-power development will then be "all free." Libby's estimate, which he announced in a speech at Houston, Tex., is a projection of figures on the present use of isotopes.

According to an AEC survey, U. S. industry saved about $390 million through the application of isotopes in 1956. Density and thickness gauges were worth some $110 million to manufacturers of cigarettes, sheet metal, paper, rubber and fabric for tires, and other products. The petroleum industry saved $150 million by using tracers to help improve the yield of oil wells and another $30 million or so by other applications. Radioactive tracers make possible the detection of minute amounts of wear, and saved $15 million in studies of wear in piston rings and similar devices. The value of radiographic testing with isotopes is put at $42 million; of industrial tracing, $18 million; of other industrial research with isotopes, $15 million.

In two or three years, Libby says, the applications of isotopes to petroleum extraction and refining should be worth more than $1 billion a year. Other applications will probably expand proportionately, and a number of additional uses are about to become commercially important. Among these are tracer work with radioactive carbon and hydrogen in the organic chemical industry; control of a great variety of processes, from the mixing of paints and dyes to the gluing of plywood, with the aid of tracers; routine medical diagnoses using radioactive drugs and other chemicals.

Assuming a large market for isotopes, many of them could be produced much more cheaply than they are today. Libby estimates, for example, that cobalt 60, now selling at $9 per curie, could be made for $.06; carbon 14, selling at $22,000 per curie, for $110; sulfur 35, selling at $2,000 per curie, for $.005; iodine 131, selling at $550 per curie, for $.0004.

The AEC is encouraging the use of isotopes by simplifying its regulations and increasing the quantities which may be possessed under general license. A large fission-products pilot plant is being built at Oak Ridge National Laboratory, where cesium 137 will be separated at the rate of 200,000 curies per year. The plant will also produce substantial quantities of strontium 90, cerium 144 and technetium 99.

Funds for Academic Research

As part of its continuing survey of U. S. research activity, the National Science Foundation recently reported that U. S. colleges and universities spent $285 million for research in 1953-54 (the most recent year for which figures are available). Of this, $211 million was for "separately budgeted" projects. The Federal Government supplied 70 per cent of these funds, the rest coming from industry, private foundations and the schools themselves. The remaining $74 million came out of the institutions' funds for departmental operating costs. While the schools' research expenditure is only 5 per cent of the total U. S. outlay, it represents most of the country's basic research. Since 1940 financial sponsorship for college and university research has increased by 1,000 per cent.

Rainmaking

The Council of the American Meteorological Society recently summed up the present evidence for the effectiveness of cloud-seeding. Its verdict: Not proven. Conditions favorable for artificial rainmaking, the statement points out, are very much the same as those which

usually lead to natural rain. Says the Council: "Cloud-seeding acts only to trigger the release of precipitation from existing clouds." There appears to be no convincing evidence that ground-based silver iodide generators can increase rainfall in flat country. They seem effective only in cold weather and in regions where a mountain range forces the air to rise. The seeding of inactive cloud formations may act to dissipate them rather than cause them to produce rain.

The Council emphasizes that the true effectiveness of cloud-seeding can be determined only by a large series of carefully randomized experiments and a thorough statistical analysis of the results. In any case, it does not believe that present rainmaking techniques can significantly alter weather patterns over a large region.

Deep Freeze

Scientists holed up at the South Pole for the International Geophysical Year have had a chilly fall and are looking forward to a hard winter. Edwin C. Flowers, a U. S. Weather Bureau man at the Amundsen-Scott South Pole Station, found a surface temperature of —71 degrees Fahrenheit when he began taking measurements on March 27. A week later the temperature had gone down to —89 degrees—only one degree warmer than the world's record of 90 below, reported from northeastern Siberia in 1933. Since the beginning of April at the South Pole corresponds to the beginning of September in the Northern Hemisphere, far lower temperatures may be expected as the Antarctic winter deepens. According to Paul A. Siple, the station's scientific leader, they may go down to 120 below.

A Larger Galaxy

The Milky Way is bigger, perhaps by 25 per cent, than had been previously supposed. So concluded astronomers at the recent meeting of the American Astronomical Society at Harvard University. According to the new estimate the earth is about 35,000 light-years away from the center of the galaxy instead of 28,000. The chief evidence for the revision comes from new distance measurements on bright "B" and cepheid variable stars by A. E. Whitford,

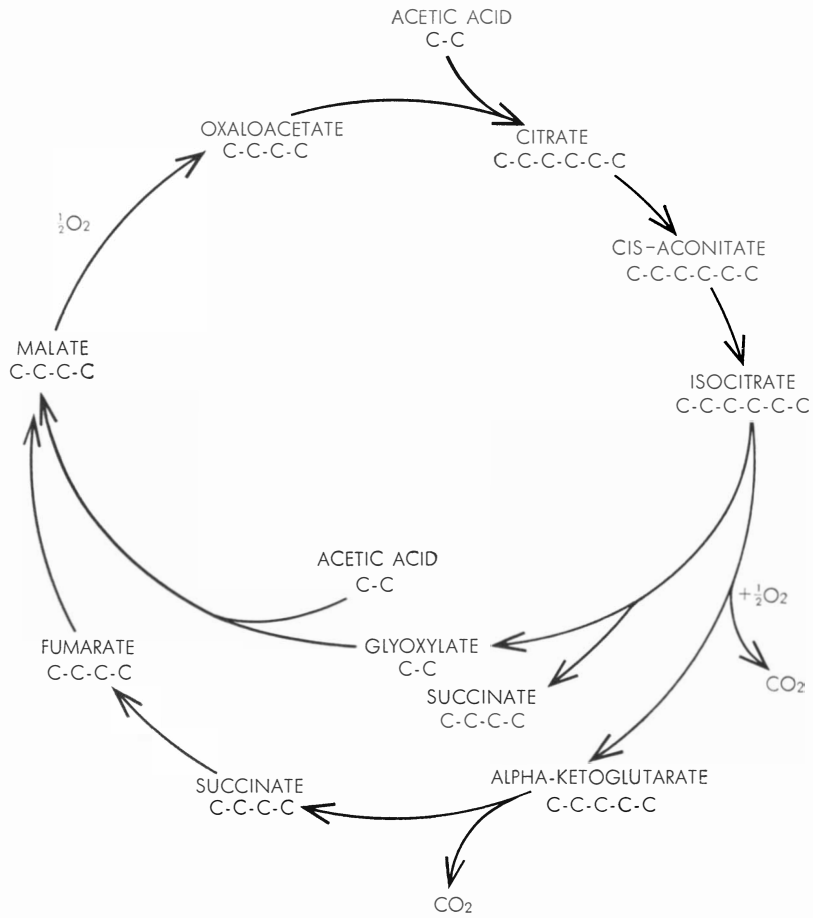
A. D. Code and J. D. Bahng of the University of Wisconsin. From the apparent motion of these stars toward or away from the earth, astronomers have determined the different rates of rotation of the galaxy at various distances from its center. If the distance to the stars is changed, the picture of differential rotation changes also. This in turn calls for a revision in the size of the galaxy. The astronomers emphasize that the estimate is still very rough and that many more observations must be made to obtain an accurate measure of the Milky Way.

Metabolic By-Pass

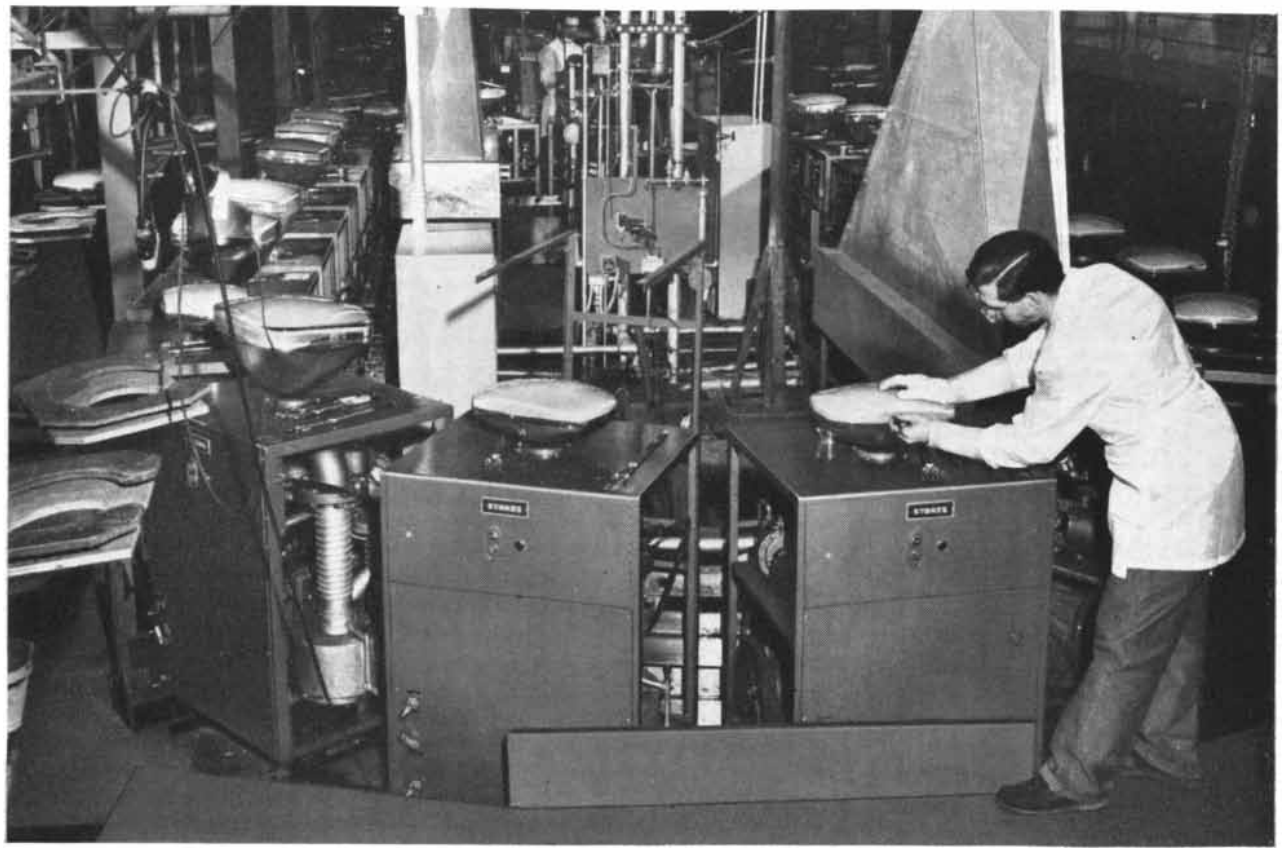
An important advance has been made in the understanding of "intermediary metabolism," the series of processes by which living things convert food to energy and tissue. H. L. Kornberg and H. A. Krebs of the University of Oxford have learned how certain bacteria can synthesize all their amino acids, sugars, proteins and other complex molecules from a simple diet of mineral salts and the two-carbon chain of acetic acid. (Higher organisms require raw materials whose molecules are about as complex as those of their own tissues.)

The secret of the bacteria turns out to be an alternative pathway in part of the famous citric-acid cycle, one of the chief biological energy sources. In this cycle, also discovered by Krebs, acetic acid is burned to carbon dioxide by means of a closed circle of reactions in which citrate is broken down and then regenerated [*see diagram below*].

The new "by-pass," as Krebs and Kornberg describe it in *Nature*, uses a



CYCLE OF SYNTHESIZING REACTIONS recently discovered in bacteria utilizes some of the same processes as the cycle which produces the cell's energy. In the Krebs cycle (*outer circle*) acetic acid coming from outside the cell combines with oxaloacetate in the cell to form a citrate. Enzymes and oxygen then aid in reconverting the citrate to oxaloacetate in a series of reactions yielding carbon dioxide and a net gain in energy. The newly discovered "glyoxylate by-pass" provides another cycle which differs only in the steps from isocitrate to malate: isocitrate is broken down into glyoxylate and succinate; the glyoxylate molecule then combines with another molecule of acetic acid to form malate. This cycle also requires only two-carbon acetic acid to keep it going but yields a net gain of succinate, a four-carbon compound which can be built up into more complex molecules. The rows of C's in the diagram show how many carbon atoms are present in the chain of each compound.



Sylvania "Silver Screen 85" TV picture tubes get Brighter Film . . . with Stokes In-Line Aluminizing System

A new Stokes In-Line Aluminizing System is making news in TV tube production by putting an aluminized reflector on Sylvania Electric Products' popular "Silver Screen 85" picture tube. This automatic equipment—now in operation at Sylvania's Seneca Falls, New York, plant—assures maximum control in the application of aluminum film to TV picture tubes.

The new system provides a bright and uniform film . . . operates at greater speeds than previous aluminizing equipment . . . provides the needed vacuum in the shortest possible time . . . requires a minimum of maintenance.

Here are other ways it can boost production and lower costs:

- versatile . . . adaptable to any size black and white tube, including the new 110° design . . . can meet changes in production rates.
- fully automatic . . . operator simply loads—and then unloads completely aluminized tube.
- saves time . . . makes possible the processing of maximum number of tubes in minimum amount of time.
- compact . . . single or twin tube units can be mounted singly, in banks, or adapted to in-line system—circular or straight line.

A Stokes engineer will be glad to talk about how this new system can be integrated into your production line . . . and about your specific tube production needs. He can help you apply Stokes 30 years of experience in high vacuum engineering and automatic production technology. For a consultation, or for informative literature, write to Stokes today.

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second molecule of acetic acid and produces the four-carbon compound succinate as a by-product instead of carbon dioxide. Thus the net effect is the synthesis of a four-carbon chain from two molecules of acetic acid. Many of the succeeding steps by which succinate is converted to citric acid, amino acids and other necessary substances had previously been worked out.

Of Time and the Unicorn

Biological clock-watching—the search for natural rhythms and cycles in plants and animals—is becoming an increasingly popular occupation among physiologists. Now Lamont C. Cole, professor of zoology at Cornell University, has demonstrated a biological clock in the unicorn. His "experiment," described in a recent issue of *Science*, is designed "to warn the uninitiated that there is a possibility of being misled in the analysis of complicated time series."

Cole measured the metabolism of his experimental animal by means of a sequence of numbers which were derived from a random-number table and which "seem eminently appropriate for representing the metabolic activity of unicorns." Starting with an arbitrary value of 20 for the initial metabolic rate, he took "hourly" readings of its variation from the number table. He followed the standard procedure of averaging the corresponding hourly data of several days and noted that "the data seemed to suggest underlying rhythms, but no pattern was clearly apparent." Cole continues: "While contemplating the data, it occurred to me that in summer at 40 degrees north latitude the hour of the rise of the moon may be retarded by approximately one hour each night. Consequently to eliminate any such lunar rhythm, we 'slipped' the data one hour per day, aligning 'hour 1' of the first day with 'hour 2' of the second day, with 'hour 3' of the third day, and so on. . . . Now, when the hourly figures for the five days were averaged, a daily rhythm came clearly into focus. This rhythm must have been obscured by the simultaneous presence of the lunar rhythm." After smoothing the curve further Cole concluded: "The unicorn obviously tends to be active in the early morning and quiescent in midday."

A Waste of Time

Isaac Newton has now entered the running controversy over the "twin paradox" of relativity—the question whether

the relativistic slowing of time means that a man who makes a round-trip space flight at high speed would actually return to the earth younger than a twin brother who remained behind [see "Science and the Citizen"; SCIENTIFIC AMERICAN, December, 1956, and March, 1957]. Newton has been brought in by W. H. McCrea, professor of mathematics at the University of London and a leading proponent of the fountain-of-youth point of view. McCrea undertakes to show that slow time is not immoral because it does not yield something for nothing. On the contrary, it represents a loss.

"Were a new Isaac Newton born today," McCrea writes in *Nature*, "we could send him space-traveling so as to return to us in 30 years' time at, say, the age of three . . . and all we should get for our efforts would be a retarded child." Similarly, a computing machine programmed for 30 years of computation and sent out on the trip with Newton would come back with only three years of its work done. "The loss," says McCrea, "is a real one. Also it is something about which all observers will agree. . . . The view of asymmetric aging as essentially involving a sacrifice of information may make the concept less repugnant to some minds."

Sociology of Alcoholism

Cultures, like individuals, seem to differ in their resistance to alcoholism: some are highly susceptible, others are almost immune. According to the Yale University sociologist Selden D. Bacon, the determining factor is not so much the amount of drinking in the culture but the attitude toward drinking.

In an article in *The Journal of the American Medical Association* Bacon contrasts the alcoholic tendencies of four cultural groups. Protestant, middle-class, urban Americans with Anglo-Saxon backgrounds have a nebulous and defensive attitude toward drinking. There is a great deal of feeling about the matter, but attitudes are often contradictory. Sanctions vary from one extreme to the other. Probably 3 to 7 out of every 100 drinkers in this group are alcoholic.

Among Mormons the use of alcohol is officially taboo. Members of the group equate drinking with atheism, disease and immorality. Very few Mormons drink, but among those who do the incidence of alcoholism is very high—more than 7 out of every 100 drinkers.

For orthodox Jews drinking has a sacred and symbolic character. It is used

to draw the family and group into a closer relationship with the deity. The custom is learned in childhood along with basic moral attitudes; the members of the group drink together hundreds of times a year. Emotional maladjustments in the group are at least as common as in any other segment of society, and yet alcoholism is virtually unknown.

Finally, a primitive Indian society in South America (not named by Bacon) uses alcohol almost like food. Drinking is a feature of almost every group activity and is an integral part of this people's way of life. They are frequently drunk, but almost none of them are alcoholic in the sense of being unable to function as effective members of their society.

Breakdown at the Pi Factory

The 385-million-electron-volt cyclotron at Columbia University, called the "pi factory" because of its intense beam of pi mesons, has been put out of action by a bizarre accident of the atomic age. A technician carrying a sharp piece of metal punctured a large plastic window in the cyclotron's vacuum chamber, and the shock wave of inrushing air hit the machine's interior with explosive force. Stripping a number of steel bolts, the wave tore loose the large semicircular copper plate forming the upper half of the "D" in which the particles are accelerated.

The window, which is six feet wide and almost a foot high, provides an exit for the meson beam and a view of the interior for the operators of the accelerator. It was covered with a sheet of Mylar only .0075 inch thick. Columbia physicists had often wondered whether, if the window broke, a man standing near it would be pushed into the vacuum chamber by air pressure. Now they have the answer: He was not.

Repairing the machine is a simple matter in principle. The copper plate must be bolted back into position and a few broken condensers and pieces of insulation replaced. However, the radioactivity of the parts, which is due to bombardment by fast particles, complicates the job. For three weeks after the accident the machine was left untouched, while the short-lived isotopes decayed. Repairs must be done in short intervals so that workers will not receive more than the permissible daily dose of radiation. Columbia officials hope to have the cyclotron running again early in July, two months after the accident occurred.

DOW CORNING

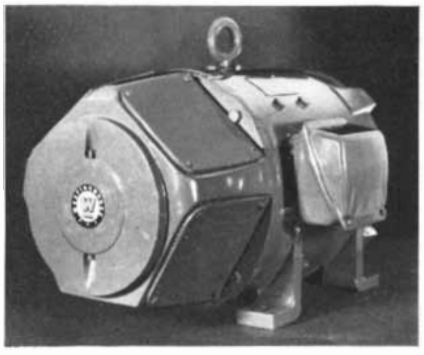
SILICONE NEWS

New Spice for Sales Recipes

- Silicones up life-expectancy of motor insulation
- More churn astern with Silicone-protected outboard
- Silicones get a "well done" from oven buyers

HOT COMPETITIVE CLIMATE — In today's increasingly competitive markets, many manufacturers are calling on Dow Corning Silicones to supply an extra product value. Here are several new examples of how alert marketers are using silicones to improve performance.

MOTOR MAKES BIG NEWS — A new line of standard dc motors, the Life-Line "H" series, has just been announced by Westinghouse Electric. The insulation in these motors has 10 times the life of insulation in other motors in their class. The new motors provide much faster acceleration and reversal, and promise big reductions in maintenance!



How does Westinghouse achieve these advantages? A silicone insulating system that provides the motors with greater reliability. Although rated at standard temperature rises, Silicones withstand high ambient temperatures and moisture . . . motor trouble due to insulation breakdown is practically eliminated.

Dow Corning silicone insulation plus a highly efficient design make the new Westinghouse motor ideal for automated processes. Here, where the failure of a single motor can shut down whole assembly lines, Life-Line "H" performance will keep production humming. It's calculated to keep Westinghouse sales humming, too.

LITTLE PLUG HELPS MAKE SALE Frequently, in large appliances, a single "plus" feature will sell brand "A" over brand "B". Just such a plus for kitchen ovens is a new plug-in meat thermometer made by King-Seeley Corporation of Ann Arbor, Michigan. A real help to the housewife, it translates meat heat into electrical impulses, so she reads on a dial how well her roast is done.

Silastic*, the Dow Corning Silicone rubber, plays an important part in making this handy unit possible. Silastic resists prolonged heat up to 500 F . . . a temperature that ruins regular rubber. That's why the flexible lead wire is covered with Silastic, and the sealing washers are fabricated from it.

First offered by Philco, this clever and durable thermometer is now a feature of Hotpoint, Magic Chef, Cribben & Saxton, and other ranges. Another example of how silicones help sell!

*T.M. REG. U.S. PAT. OFF.

SMOOTH PUTT — The outboard motors that used to be "putt-putts" have grown up into powerful engines. The newest and strongest production outboard carries a whopping 60 hp rating . . . enough to drive a small car! This motor, the "Mark 75", is produced by Kiekhaefer Corporation, makers of the Mercury line.

To help keep the Mark 75 and the eleven other Mercury models running smoothly —come cold, hot, or wet weather— Kiekhaefer employs Dow Corning Silicones. Several rubber, metal, and ceramic parts within the motors are coated with a water repellent silicone compound. The silicone coating preserves, protects, lubricates, and helps prevent short circuits. Here's a case where Dow Corning Silicones assure a steady purr from both motor and satisfied customer.

BABY BILLBOARDS — A slick trick for keeping your company name where it will be seen: give-away packets of Sight Savers imprinted with your sales message. Sight Savers—the Dow Corning silicone treated tissues for cleaning eyeglasses—are purchased and used regularly by millions of adults. Over 70% of your customers and prospects wear glasses, and glasses need cleaning often. What more logical place to put your message than where it will be repeatedly seen and appreciated? Imprinted Sight Savers are available in any quantity, at a surprisingly low price.

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ELEMENTARY PARTICLES

An account of the abstract theoretical ideas which physicists use to help them understand the material world. These ideas begin to show some order in the jumble of subatomic particles

by Murray Gell-Mann and E. P. Rosenbaum

There is no excellent beauty that hath not some strangeness in the proportion.
—Francis Bacon

This aphorism quoted from Bacon is doubtless true of science as well as art. But is too much strangeness not fatal to beauty? For years strangeness has afflicted one of the basic concerns of physics: the nature of matter. When physicists considered matter on the smallest scale, it appeared to be an arbitrary jumble of elementary particles. No simple and orderly relationship among the particles could be perceived. Now at last the picture seems to be clearing up a bit. The very word "strangeness" has passed into the vocabulary of physics, but its share "in the proportion" is being reduced to a point where the beauty of order can be seen.

The new regularity can best be appreciated against the chaotic background from which it is emerging. To begin we should go back some 30 years to one of the most triumphant periods in the history of science. The theory of the atom stood essentially complete: nearly all the properties of ordinary matter could be mathematically deduced in terms of the motions of negatively charged electrons around positively charged nuclei. Most of the problems with which physics and chemistry had grappled during the preceding centuries were in principle solved. But at that time physicists began seriously to probe the interior of the atomic nucleus.

Then their troubles began. They soon learned that the nucleus is made up of protons and neutrons, but they could not explain nuclear properties only in terms of these constituents. Indeed, we still do not know exactly what their motions are. Furthermore it turned out that when a nucleus is shattered, entirely new types of matter are created—a bewildering variety of short-lived particles which apparently do not exist within the atoms of ordinary material. Some of them were reasonably well accounted for when they turned up, but others fit nowhere in the physicist's scheme of nature. They were called "strange" particles.

The First Particles

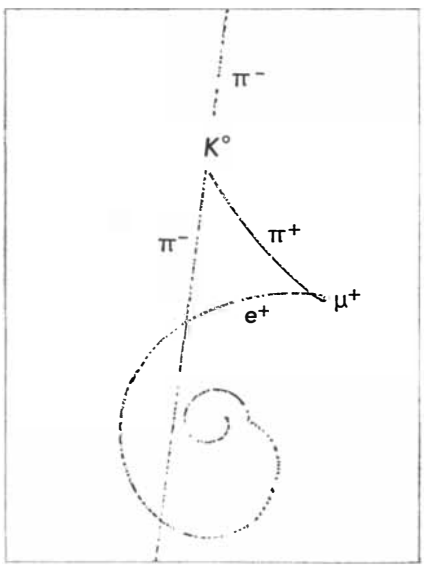
We are getting ahead of our story. We should begin in the early 1930s, when the atomic drama had only four characters: the electron, proton, neutron and photon. The first three are the building blocks of atoms—protons and neutrons in the nucleus and electrons in the space around it. The photon is the quantum unit of radiation; *i.e.*, it is the building block of the electromagnetic field.

The photon always travels with the velocity of light (denoted by the letter "c"); it can never be at rest. Because of its motion it possesses energy. It therefore also possesses mass, according to the famous relation $E = mc^2$. But the mass exists only by virtue of the motion. The electron, proton and neutron, on the contrary, can be at rest. Each has a mass when at rest and a corresponding rest energy. (When in motion, of course, they have additional energy and mass.)

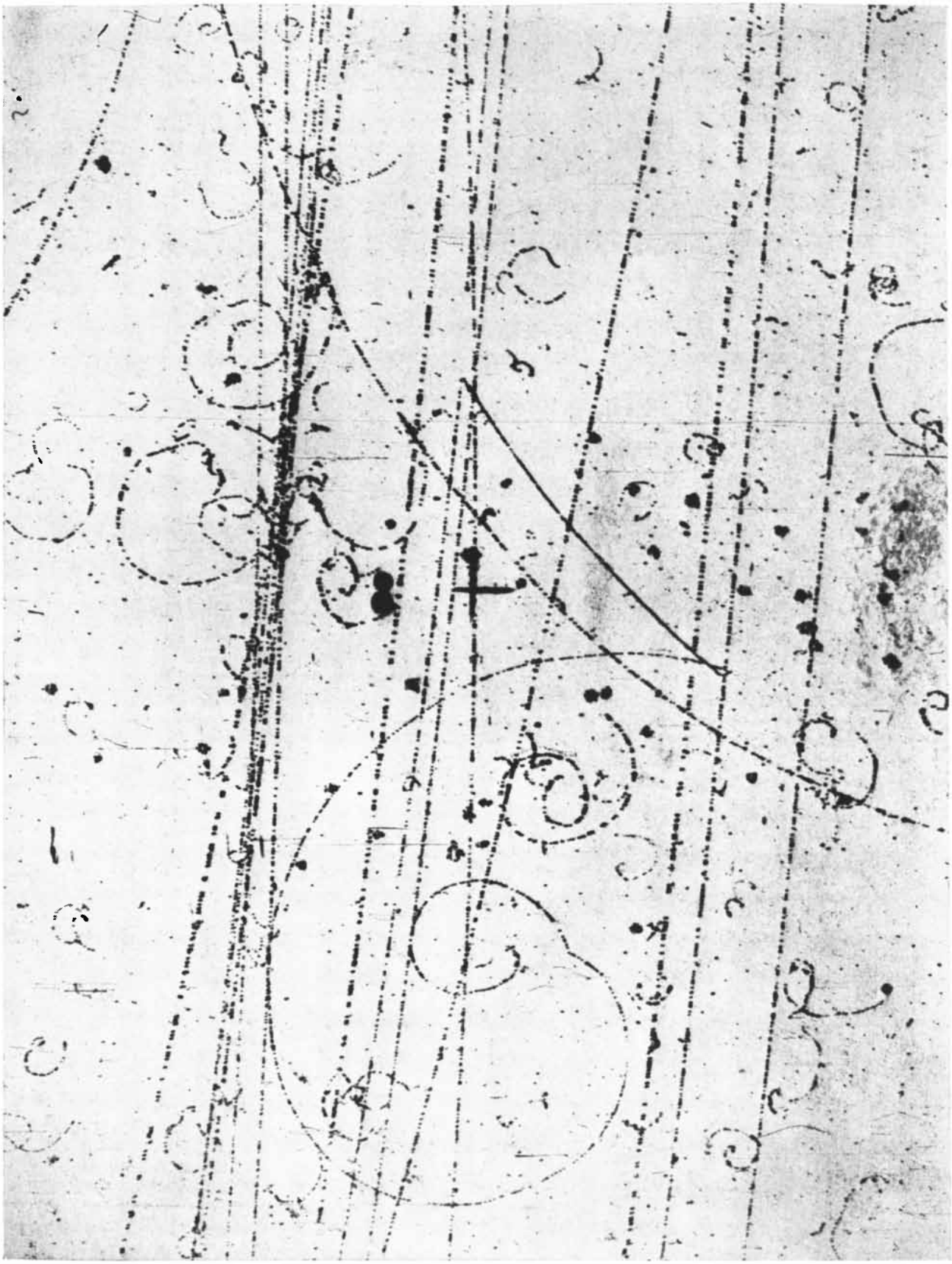
The electron is the lightest particle with any rest mass, and this mass is a basic unit in subatomic physics. The size of the electron's negative charge is likewise a basic unit of electricity. In these units the proton has a mass of about 1,836.1 and a charge of plus one; the neutron has a mass of about 1,838.6 and no charge. The photon, as we have said, has no rest mass; also it has no charge, although it is the carrier of electromagnetic energy.

All these particles spin on their axes and, if they are charged, the spin makes them tiny magnets. According to the rules of quantum theory the spin has a fixed rate characteristic of the particle. In the system of units used in quantum theory, the characteristic spin of the electron, proton and neutron is 1/2; the spin of the photon is 1.

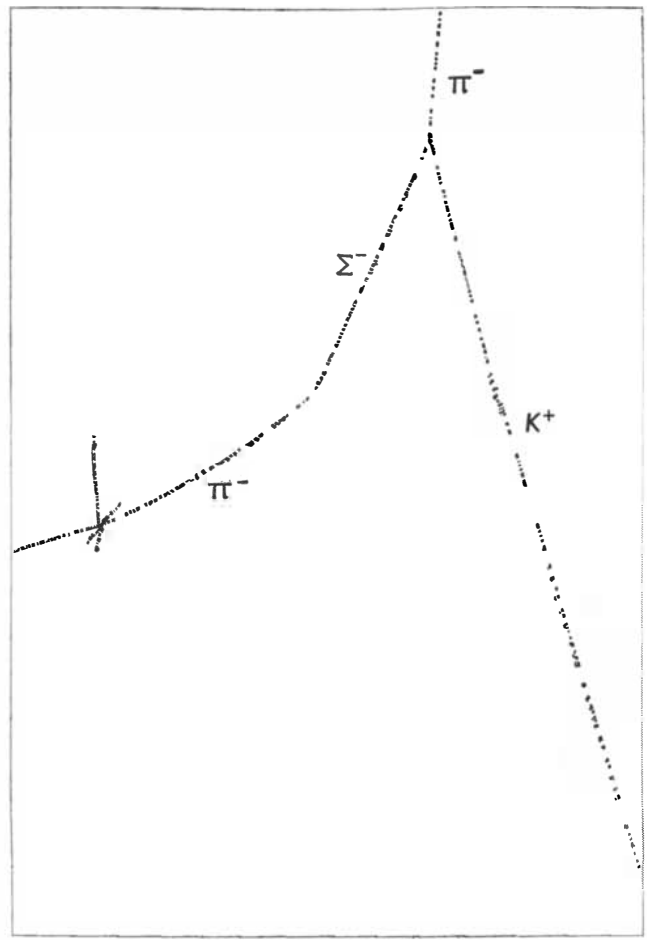
There is a further limitation on the spinning motion of these particles. If they are magnets, they are affected by external magnetic fields. In quantum mechanics the spin axis of each particle can assume only a few fixed directions with respect to an outside field. A particle with spin 1/2 can have two positions: its axis can point with or against the field. A particle with spin 1 can have



NEUTRAL K PARTICLE, formed in a collision of a negative pion with a proton, decays into a pair of oppositely charged pions, as outlined in the drawing. The



event is recorded in this photograph as a series of bubbles produced by charged particles in a chamber of liquid propane. The positive pion decays further to a muon and a neutrino, which leaves no bubble track. Finally the muon decays to a positron and two invisible neutrinos. A neutral lambda was presumably made together with the K, but if so it left the chamber without decaying to charged particles and made no track. The incoming pion was produced in the Cosmotron at Brookhaven National Laboratory.



SIGMA AND K PARTICLES are produced together when a pion hits a proton in the bubble chamber. The sigma decays to a pion and an invisible neutron. The pion then hits a carbon nucleus and makes a "star." The experiments shown here and on the preceding page were performed by J. H. Steinberger, N. P. Samios, R. J. Plano, F. R. Eisler and M. Schwartz, all of Columbia University.

three positions: its axis can go with the field, perpendicular to or against the field [*see diagram on page 79*].

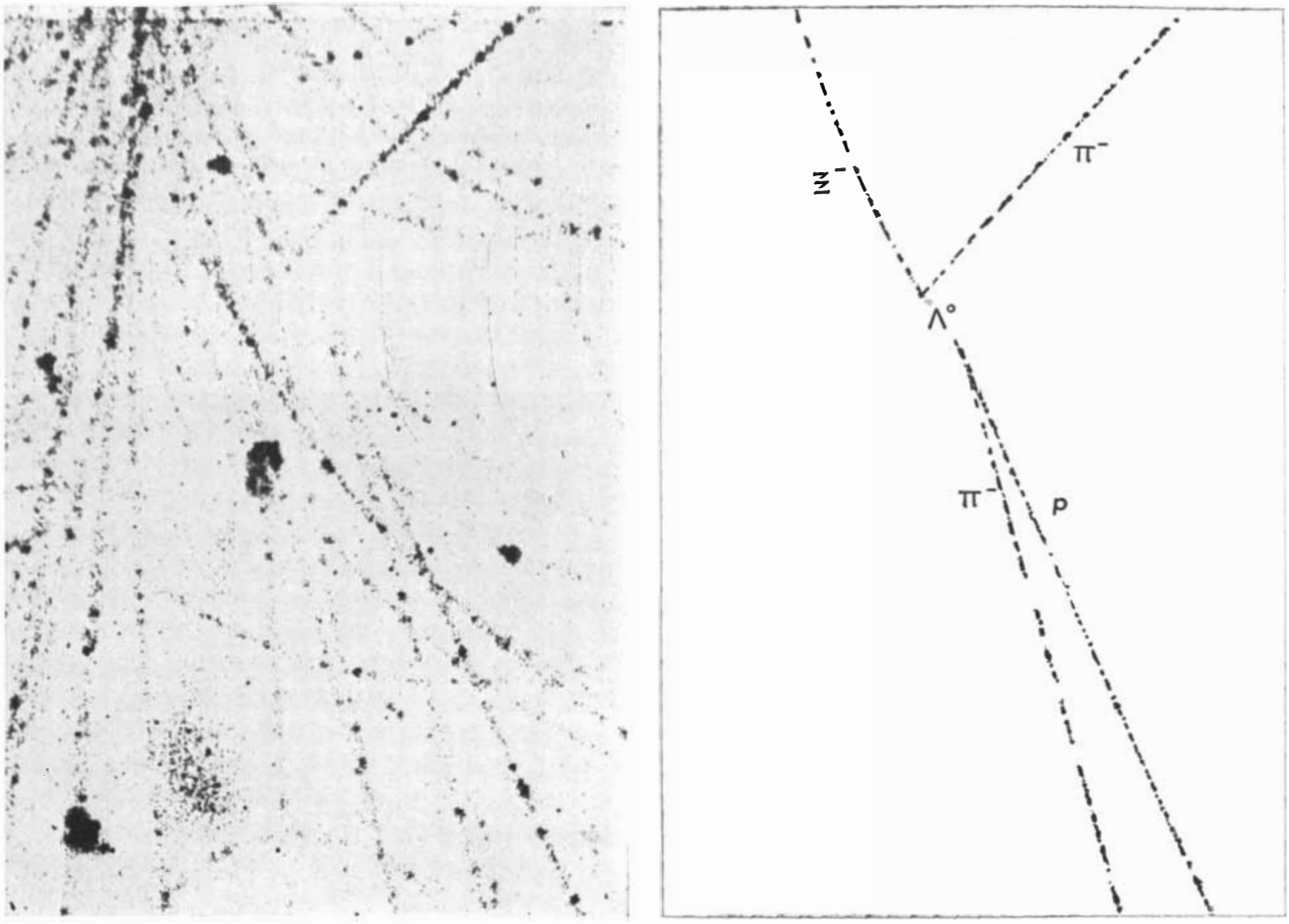
Another important property of particles, related to spin, is their "statistics." Electrons, protons and neutrons (and all other particles of spin 1/2) obey the famous exclusion principle. This says that only one particle of a kind can occupy a given quantum "state." Thus there can be only one electron at a time spinning in a particular direction and revolving in a given orbit around a nucleus. Particles which obey the exclusion principle are said to have Fermi-Dirac statistics: they are accordingly called fermions. Particles like the photon (and all other particles whose spins are whole numbers) do not obey the exclusion principle. They have Bose-Einstein statistics and are called bosons.

Interactions

So far we have been talking mainly about isolated particles. However, as will become increasingly evident, all particles are "coupled" to one another: when they are close together, they interact in various ways. The first such coupling to be recognized and studied was the one between the electron and the photon. It is this relationship which underlies quantum electrodynamics, the crowning achievement of atomic theory. Many physicists had a hand in the development of this theory, notably P. A. M. Dirac of England, Werner Heisenberg of Germany and Wolfgang Pauli, now in Switzerland. The theory explained the behavior of electrons in electromagnetic fields by saying that each electron continuously emits and absorbs photons. This pulsation is, so to speak, a "vital process" of the electron, and it is the means by which field and electron exert a force on each other.

We should point out that what has just been said does hardly more than name the theory. In quantum mechanics a theory is a set of mathematical relations which, given the interacting particles and the couplings between them, predicts their behavior in detail by yielding the probability of every possible reaction among the particles. Sometimes, particularly when the couplings are very strong, the mathematics turns out to be too difficult. Then the theory is not much help. In quantum electrodynamics, however, the mathematics is tractable, and this beautiful theory has successfully predicted the outcome of every fundamental atomic experiment at least as accurately as physical measurements can be made.

The basic "reaction" of quantum electrodynamics, in which electrons emit and absorb photons, is an example of what is called a virtual process. This concept, which concerns all the elementary particles, is peculiar to quantum theory. It involves an apparent violation of the law of the conservation of energy. The point is that a photon has energy; thus when a photon is spontaneously emitted by an electron, it would appear that the total energy of the system has suddenly increased. Quantum theory answers, in essence, that the photon is emitted and reabsorbed so fast that the gain in energy cannot be detected, even in principle. That is what is meant by a virtual pro-



NEGATIVE XI PARTICLE decays into a neutral lambda and a negative pion. The lambda then decays into a proton and a second negative pion. The xi was produced by the collision of a high-energy cosmic ray with a nucleus in a lead plate. This photograph, which shows tracks in a cloud chamber below the plate, was made by E. W. Cowan of the California Institute of Technology.

cess. If the photon is undetectable, the conservation of energy is effectively not violated because, according to quantum mechanics, laws deal only with observable quantities. By adding enough energy from the outside (for example, by accelerating the electron) the photons can be converted from virtual to real particles.

Virtual photons are involved in every interaction between charged bodies and electromagnetic fields. The positive proton is also considered to emit and absorb virtual photons. Here, however, the theory is not quite so successful; its predictions for protons are not as accurate as those for electrons.

In an important sense the scheme we have described so far was complete and satisfactory. Between them the electron and photon sufficed to explain all the external properties of atoms; the proton and neutron accounted for the observed charges of atomic nuclei and roughly for their masses. There was, to be sure, nothing in the theories to explain why nature had chosen just these particles as her elementary building blocks; but given that she had, they came close to being all that was needed.

Antiparticles

They did not come quite close enough. First of all, Dirac's theory of the electron predicted some additional particles [*see column II of chart on next two pages*]. It is well known that according to quantum theory a fundamental particle also has the properties of a wave. When Dirac's wave equation for the electron was solved, it yielded a negative frequency as well as a positive. Since frequency in quantum mechanics is proportional to energy, it was at first hard to see what the negative answer could mean. Dirac was able to prove that it does have a physical significance, and that it corresponds to an electron with positive charge. Furthermore, according to the theory, if a positive electron collided with a negative electron, they would annihilate each other and their mass would be converted into photons with an equivalent amount of energy. Conversely, if enough energy could be concentrated in a small volume, as in a high-speed collision between two particles, a positive and a negative electron could be created.

These remarkable predictions were not actually made (although they were implied by the theory) until Carl D. Anderson of the California Institute of Technology discovered the positron. It had the mass of an electron and a unit of positive charge; when it met with a negative electron, the two were annihilated; it could be created, together with a negative electron, in energetic collisions. The positron is called the antiparticle of the electron because it cancels out an ordinary electron.

There are similar equations for the proton and neutron, so they also have their antiparticles. These have only been detected during the past two years [see "The Antiproton," by Emilio Segrè and Clyde E. Wiegand; SCIENTIFIC AMERICAN, June, 1956]. Even the photon has an antiparticle in a mathematical sense. Here, however, the two solutions to the equation can be interpreted in the same way and the photon and antiphoton

are indistinguishable. To put it another way, the photon is its own antiparticle.

The Neutrino

The second necessary addition to the list of particles arose out of the behavior of the neutron. Inside the nucleus a neutron can live indefinitely. But when the particle is observed outside, it proves to be unstable. In an average time of about 18 minutes it spontaneously ejects a beta particle (the same thing as an electron) and turns into a proton. The proton and electron together are about 1.5 electron masses lighter than the neutron, so this amount of mass appears to be lost in the decay; it is equivalent to some 780,000 electron volts of energy. This should show up as the kinetic energy of the decay products, but in fact the proton and electron rarely have so much energy. To account for the discrepancy Pauli suggested that another particle, with zero rest mass and almost undetectable, also is formed in the decay, and that it carries off the missing energy. Enrico Fermi, who pursued the idea, named the invisible particle the neutrino. Reasoning

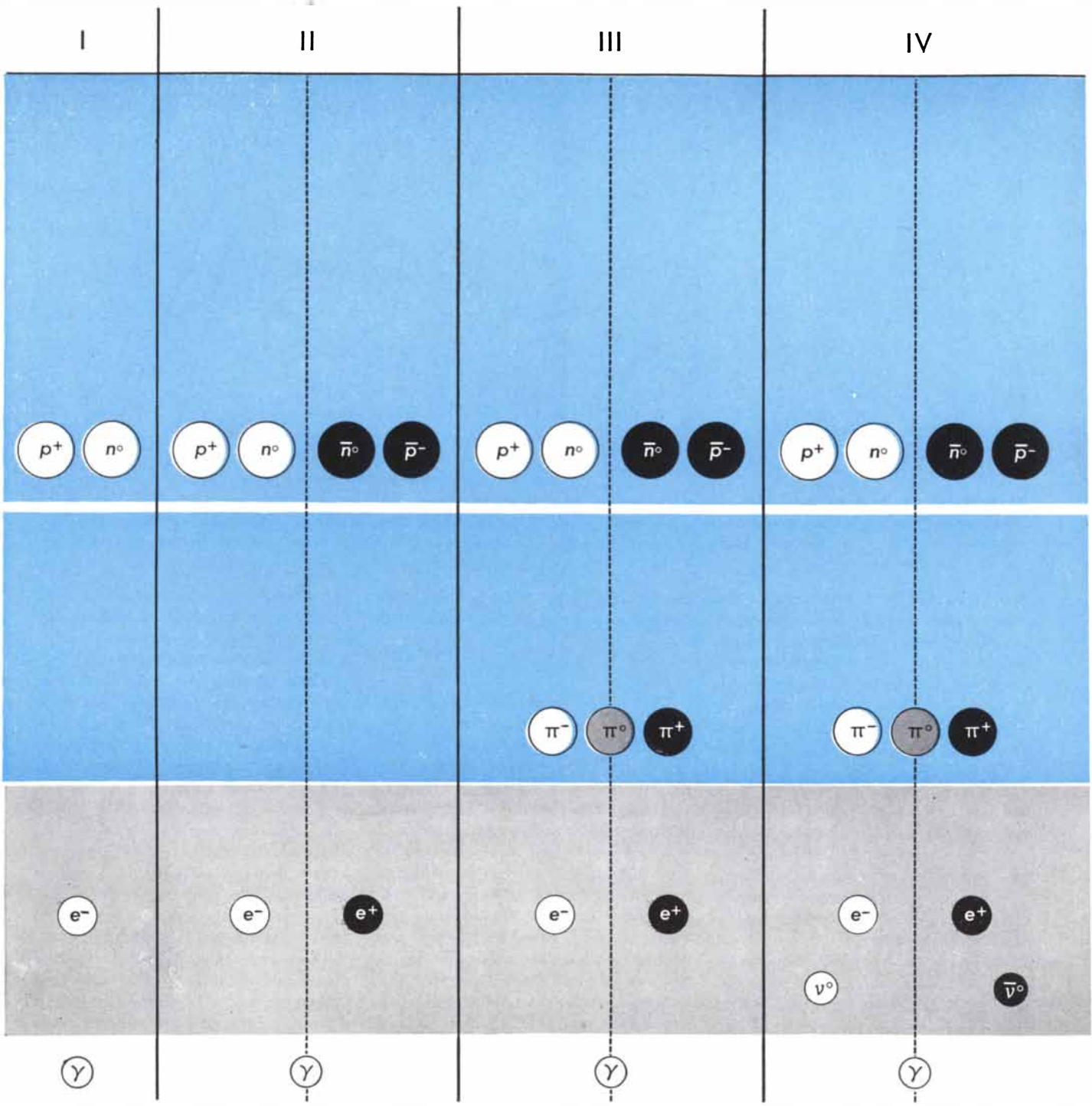
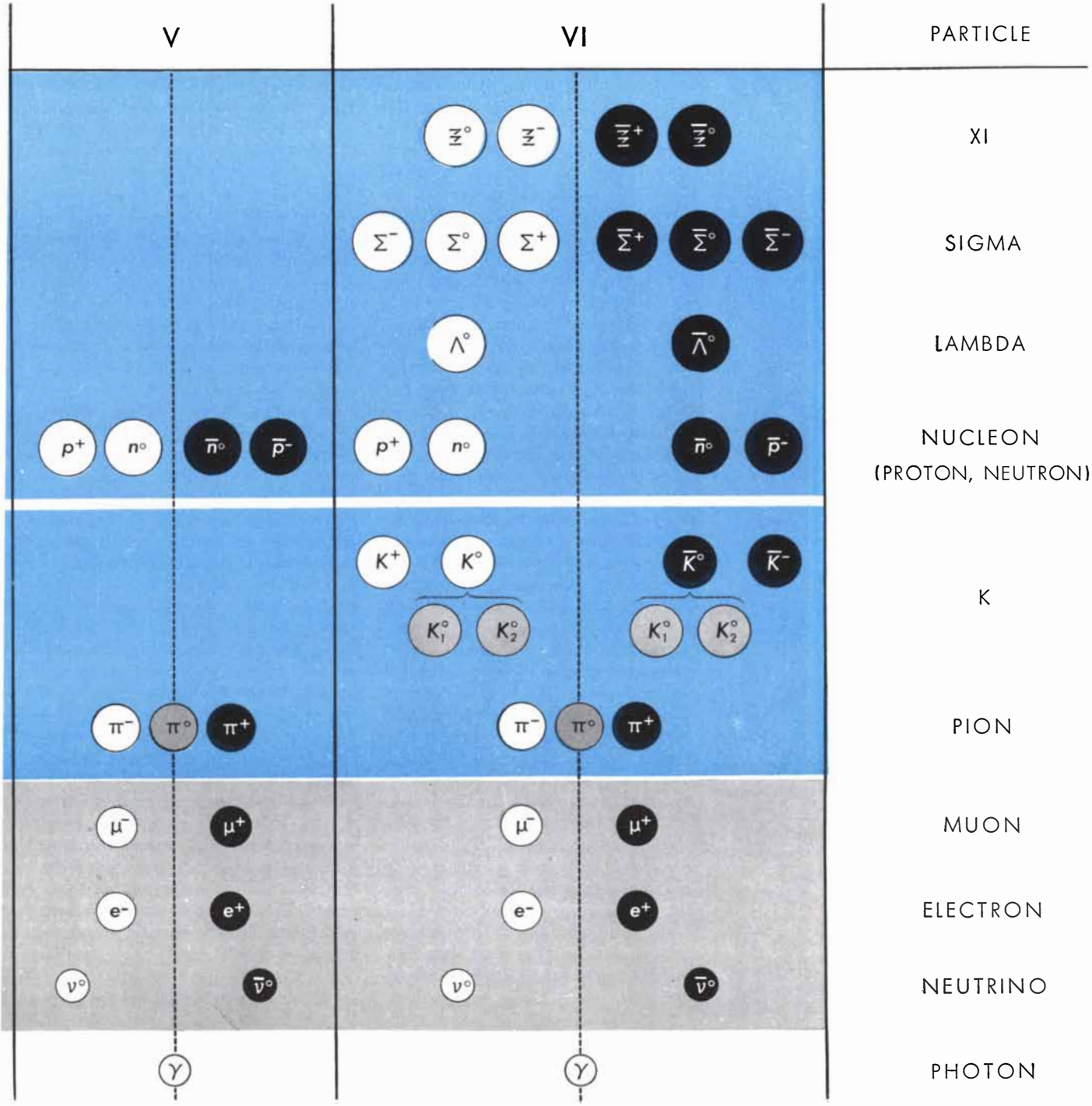


TABLE OF PARTICLES traces their increase over the past 25 years. Particles added in columns II·IV were first predicted theoretically. Those added in V and VI were discovered by experiment. "Ordinary" particles are shown as white balls, antiparticles as black balls. The neutral pion and the photon is each its own antiparticle. The top group comprises the heavy particles and the next

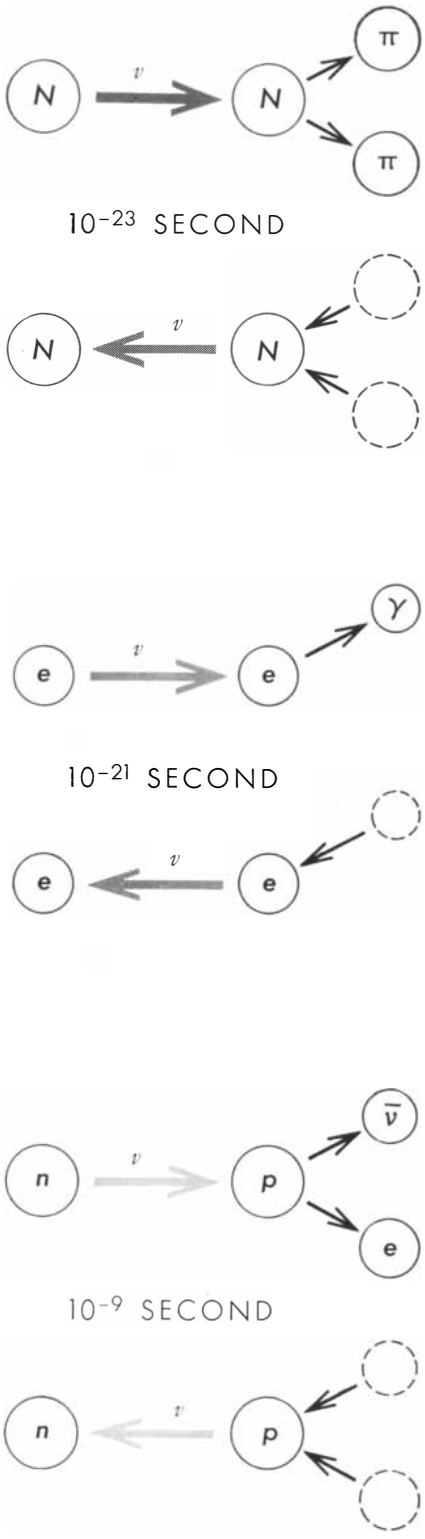
by direct analogy with Dirac's process for electrons and photons, Fermi constructed a complete theory of beta-decay. Its fundamental process is that a neutron continuously loses and regains an electron and a neutrino by virtual emission and absorption. (Strictly speaking the "neutrino" involved is actually the antineutrino.) Although Fermi's reaction was written as a virtual process, the emission or decay process can become real without the addition of outside energy because the mass lost in the decay provides the energy needed.

The Pion

The last particle to be added to the list was predicted by another analogy with the Dirac process. The problem was to describe the force that holds protons and neutrons (which may jointly be called nucleons) together in the nucleus. Since electromagnetic forces had been successfully explained in terms of the photon or field quantum, it was logical to try the same approach with nuclear forces. The Japanese physicist Hideki Yukawa took this step. He proposed that nucleons emit and absorb a



lower group the mesons. The color over both shows they are all strongly coupled. The wide band between the groups signifies that heavy particles are conserved. The third group, in gray, comprises the light particles. A bar over a symbol stands for an antiparticle, but the convention is not used for the pion, muon or electron. For explanation of K°_1 and K°_2 see page 88 of the text.



BASIC PROCESSES are shown schematically. In the strong Yukawa interaction (*top*) a nucleon "virtually" emits pions (*above*) and absorbs them (*below*). Time scale for the process is listed between the two reactions. In the electromagnetic interaction (*center*) an electron (or other charged particle) virtually emits and absorbs a photon. In the weak and very much slower Fermi interaction (*bottom*) a neutron virtually emits and absorbs an electron and antineutrino.

nuclear-field quantum called a meson, just as electrons emit and absorb photons. From the known properties of the nuclear force Yukawa was able to deduce some of the characteristics of the meson. The fact that the force extends only over a very short range could be shown to mean that the meson, unlike the massless photon, would have a finite rest mass. There were also various reasons to suppose that there would be both charged and neutral mesons.

Yukawa's conjecture was fully confirmed, but only after more than 10 years. The particle he predicted has been found and is now called the pi meson, or pion. It weighs about 270 electron masses, and comes in three forms: positive, negative and neutral [see "Pions," by Robert E. Marshak; SCIENTIFIC AMERICAN, January].

The emission of pions by a nucleon must of course be virtual, since the pions possess energy including energy in the form of rest mass. According to the theory the strength of the nuclear force field should depend on the number of quanta outside the emitting particle. The nuclear force is so strong that a nucleon must emit pions very frequently; there must usually be more than one outside the nucleon at the same time. In fact, the current conception of protons and neutrons is that they consist of some sort of core surrounded by a pulsating cloud of pions. As in the case of photons, if enough energy is supplied pions will materialize into real particles. Since the pion's mass is equivalent to 135 million electron volts (mev) of energy, it requires at least this amount to make one real pion.

Here we come to the end of the first part of the story. We have already accumulated a rather large number of "elementary" particles, but at least they all seem to make sense. In fact, most of them were predicted theoretically before they were actually discovered. As has already been pointed out, the neutrino has an antiparticle. The negative pion is the antiparticle of the positive pion, and *vice versa;* the neutral pion, like the photon, is its own antiparticle. Finally real pions, like the neutron, are unstable. After a very short time they decay into other particles [*see table on page 80*].

Twelve Particles

We might call the ideas we have sketched so far the dozen-particle theory of matter [*see column IV in the chart on the preceding two pages*]. As we have said, it is a fine theory for explaining the properties of atoms. It is rather crude in its attempt to account for the inner workings of the nucleus, but it does explain them in a general way. And in any event it makes a good case for each of the particles. They all have an explicit role to play and they emerge naturally from the theory.

What is more, the 12 fall into four well-defined groups: (1) heavy particles, consisting of the nucleons (proton and neutron) and their antiparticles; (2) mesons, or particles of intermediate weight; (3) light particles, consisting of the electron and neutrino and their antiparticles; and (4), in a class of its own, the photon. We may also note that the heavy and light particles, which are the "ordinary" constituents of matter, have spin 1/2 and are fermions [*see table on page 80*]. The mesons and the photon, which are field quanta, have spin zero and are bosons. The groups are interconnected by three basic reactions. The Yukawa process connects heavy particles with mesons, the Dirac process connects light particles with photons, and the Fermi process connects heavy particles with light particles [*see chart on this page*].

Of course the particles also behave according to the more general laws of physics. They obey the conservation of energy, and of linear and angular momentum. They also obey the conservation of charge. So far as we know the net amount of electric charge in the universe never changes. When charged particles are created out of energy, they can be created only in particle-antiparticle pairs, with each new positive charge offset by a negative. And in every particle reaction the net charge of the bodies entering the reaction must equal that of the products.

Another conservation principle arises out of the evident stability of nuclear matter. All the experimental evidence indicates that it is never created or destroyed; that is to say, that the number of nucleons must remain constant. Thus a proton can be created out of energy, but only together with an antiproton. The two cancel each other both mathematically and, when they come together, physically.

Particle Reactions

We should mention two other characteristics of particle reactions which appear to operate as general laws. First, the reactions are reversible. If one particle is observed to split into two others, we expect to find that the pair can also combine to form the original particle.

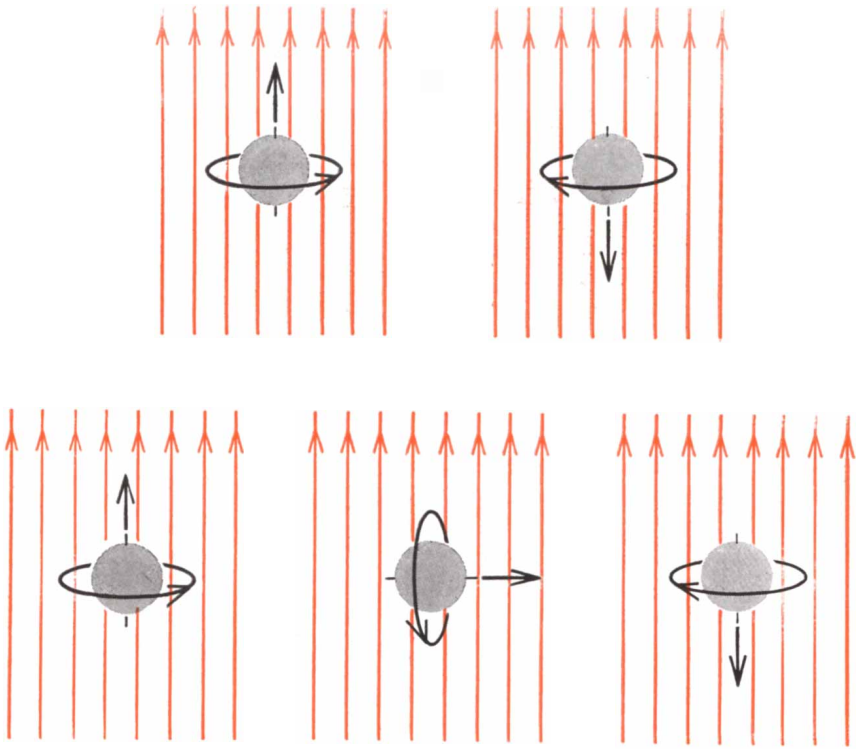
Second, the emission of a particle is related to the absorption of the corresponding antiparticle: if we know the "cross section" or probability for one, we can compute the probability for the other. For example, consider the beta-decay process [*see reactions 1-3 in the table on page 82*]. Since a neutron turns into a proton by emitting an electron and an antineutrino we expect to find the reverse reaction in which a proton absorbs an electron and an antineutrino, turning into a neutron [*reaction 2*]. Furthermore, since the absorption of an electron corresponds to the emission of an antielectron, or positron, we should also have the reaction in which a proton absorbs an antineutrino and emits a positron, again turning into a neutron [*reaction 3*]. This reaction is, in fact, the one by which the neutrino was finally detected experimentally.

Thus the rules provide a kind of algebra with which we can "solve" problems in particle physics. Let us see how they work for a sample problem—the decay of the pion. The neutral pion is found experimentally to decay into a pair of photons in a very short time: about 10^{-15} seconds. We want to show why it should do this [*reactions 4-8*]. We start out with the basic reaction involving pions, the Yukawa reaction in which a nucleon, let us say a proton, emits a virtual pion. We are interested in what the pion will do, so we should like to have an equation that starts out with a neutral pion followed by an arrow. By reversing the equation and transposing terms (changing particles into antiparticles) we arrive at the desired equation [*reaction 6*], which tells us that the pion turns (virtually) into a proton-antiproton pair. Such a pair annihilates, and can yield photons. Thus we have arrived at the desired result: a neutral pion decaying into two photons.

To someone seeing it for the first time, this chain of reasoning may seem just a trivial shuffling of symbols. But each shuffling summarizes a detailed (and often difficult) calculation of probabilities. Thus in the end we arrive at a reasonably exact prediction of what will happen, how long it should take, and so on. On the other hand, our knowledge of the situation is so incomplete that an apparently airtight chain of reasoning can also result in completely wrong answers.

The Muon

There is no better illustration of this than the decay of the charged pion.



SPINNING PARTICLE can take only certain fixed positions with respect to an outside magnetic field (*colored arrows*). Particles with spin 1/2 (*top*) can align their axes with or against the field. Particles with spin 1 (*bottom*) can go with, across or against the field.

Using our basic reactions and rules we can "prove" that the positive pion should decay to a positron and a neutrino [*reactions 9-14*]. But if the reaction ever happens, it is so rare that it has never been observed. How does the positive pion actually decay? It yields a neutrino and a totally new particle: the muon!

Here we have nature at her most perverse. She has given us a particle for which there is no theoretical justification and no use whatever. The muon was the unwelcome baby on the doorstep, signifying the end of days of innocence. The situation was further complicated by an unfortunate historical accident which for a long time made it impossible even to classify the muon. The muon was detected before the pion, and everyone took it to be the meson Yukawa had predicted. For this role, however, its properties are all wrong. It notably does not interact strongly with nucleons and thus could not be the particle responsible for the nuclear-force field. Thus until the pion was discovered the muon made even less sense than it does today.

Now that we know what the muon is not, we can at least accept it for what it is. It comes with both positive and negative charge (the negative pion decays into a negative muon and antineutrino). It weighs about 207 electron masses and has a spin of 1/2 (*i.e.*, it is a fermion). It lives for about a millionth of a second and then decays into an electron, a neutrino and an antineutrino. The positive muon must of course yield a positive electron, or positron, and the negative muon a negative electron. Each muon is the other's antiparticle.

Although the muon does not come out of the dozen-particle theory—indeed, it demonstrates that such a theory is incomplete if not wrong—it can be connected to the other particles. To see the connection we must re-examine our fundamental processes—the Dirac or electromagnetic interaction, the Yukawa or nuclear interaction and the Fermi or beta-decay process. It turns out that these processes differ enormously in "strength." The Yukawa process is known as a strong interaction; it accounts for the great force that holds nucleons together in the nucleus. Electromagnetic forces are some 137 times weaker than nuclear forces. Another indication of strength is the probability that a process will occur in a given time; *i.e.*, its average rate. The strong interactions are as fast as anything can possibly be. The emission or absorption of a pion takes place in some 10^{-23} seconds, which is just about the time it

would take a light ray to cover a distance equal to the diameter of a nucleon. The electromagnetic process is of course 137 times slower.

What about the Fermi interaction? It is incomparably weaker than the others. The factor is about 10^{-14}—it is a hundred thousand billion times weaker than the strong interactions! Furthermore, all the processes involving neutrinos—beta-decay and the decay of pions and muons—are about equally weak. Thus the muon participates in one of the three fundamental types of interaction. (As a charged particle, of course, it participates in the electromagnetic interaction as well.) Also, since it is a light fermion, it seems to group itself naturally with the electron and neutrino.

A glance at the table of lifetimes on this page will show that the decays which we have said are equally weak have widely different times. But speed is supposed to be an indication of strength. The answer is that speed is not determined solely by strength. It also depends on the energy available to make the reaction go. In the case of the neutron, which takes an average of 18 minutes to decay, there is very little available energy; the difference between the mass of the decaying particle and the mass of its decay products is only slightly more than the mass of one electron. For pion and muon decays there is much more energy; they are correspondingly faster. If corrections are made in each case for the available energy, it turns out that a kind of "intrinsic" speed for all the weak processes is very close to 10^{-9} seconds, which is 10^{14} times slower than the strong interaction.

It is surely remarkable that all the weak processes have the same strength, and it is probably significant. Nature is trying hard to tell us something, but so far we have been unable to decipher the message.

PARTICLE		SPIN	REST MASS (ELECTRON MASSES)	MEAN LIFE (SECONDS)	DECAY PRODUCTS
XI	Ξ^-	$\frac{1}{2}$	2585	10^{-10} TO 10^{-9}	$\Lambda^\circ + \pi^-$
	Ξ°	$\frac{1}{2}$	NOT YET FOUND		
SIGMA	Σ^+	$\frac{1}{2}$	2325	$.7 \times 10^{-10}$	$p + \pi^\circ$ $n + \pi^+$
	Σ^-	$\frac{1}{2}$	2341	1.5×10^{-10}	$n + \pi^-$
	Σ°	$\frac{1}{2}$	2324	NOT MEASURED	$\Lambda^\circ + \gamma$
LAMBDA	Λ°	$\frac{1}{2}$	2182	2.7×10^{-10}	$p + \pi^-$ $n + \pi^\circ$
PROTON	p	$\frac{1}{2}$	1836.1	STABLE	
NEUTRON	n	$\frac{1}{2}$	1838.6	ABOUT 1,000	$p + e^- + \bar{\nu}$
K MESON	K^+	0	966.5	1.2×10^{-8}	$\mu^+ + \nu$ $\pi^+ + \pi^\circ$ $\pi^+ + \pi^+ + \pi^-$ $\pi^+ + \pi^\circ + \pi^\circ$ $\mu^+ + \nu + \pi^\circ$ $e^+ + \nu + \pi^\circ$
	K^-	0	966.5	1.2×10^{-8}	$\mu^- + \bar{\nu}$ $\pi^- + \pi^\circ$ $\pi^- + \pi^- + \pi^+$ $\pi^- + \pi^\circ + \pi^\circ$ $\mu^- + \bar{\nu} + \pi^\circ$ $e^- + \bar{\nu} + \pi^\circ$
	K_1°	0	965	1×10^{-10}	$\pi^+ + \pi^-$ $\pi^\circ + \pi^\circ$
	K_2°	0	965	3×10^{-8} TO 10^{-6}	$\pi^+ + e^- + \bar{\nu}$ $\pi^- + e^+ + \nu$ $\pi^+ + \mu^- + \bar{\nu}$ $\pi^- + \mu^+ + \nu$ $\pi^+ + \pi^- + \pi^\circ$ $\pi^\circ + \pi^\circ + \pi^\circ$
PION	π^+	0	273.2	2.6×10^{-8}	$\mu^+ + \nu$
	π^-	0	273.2	2.6×10^{-8}	$\mu^- + \bar{\nu}$
	π°	0	264.2	10^{-16} TO 10^{-15}	$\gamma + \gamma$
MUON	μ^-	$\frac{1}{2}$	206.7	2.2×10^{-6}	$e^- + \nu + \bar{\nu}$
ELECTRON	e^-	$\frac{1}{2}$	1	STABLE	
NEUTRINO	ν	$\frac{1}{2}$	0	STABLE	
PHOTON	γ	1	0	STABLE	

PROPERTIES OF PARTICLES are being determined with increasing precision. This table presents the latest experimental values. Spins of the K mesons and the strange heavy particles are still doubtful. For the unstable particles which have more than one mode of decay the table lists all the sets of products now known. Others may still be discovered.

Strange Particles

With the muon nature gently warned physicists that they had not yet divined her innermost secrets. Then around 1950 she rudely introduced a whole procession of new particles. They were utterly unexpected and had properties which could not be explained on the basis of previous theory.

The new arrivals showed up first in the showers of particles which occur when high-energy cosmic rays strike a lead plate inside a cloud chamber. Among the tracks of the showers were found some curious two-pronged or V-shaped patterns that could not be explained by any known particle process. Physicists were forced to conclude that some unknown neutral particle (which would leave no track in the cloud chamber) had decayed into two charged particles. The neutral particle presumably had been made in the lead plate. Once people started looking for the so-called V-particles, they turned out to be very common.

As V-events were collected and studied, it became clear that there were at least two new neutral particles. One, which decays into a proton and a negative pion, was named the lambda; the other, which decays into a positive and a negative pion, was called the K.

When they had recovered from the shock, physicists began to try to fit the new particles somehow into the general scheme. From the pattern of its decay (into a fermion and a boson) the lambda

can be shown to be a fermion, presumably with spin 1/2. It is subject to the law of conservation of nucleons. Since one nucleon is produced in the decay, one must have been used in the formation process. For example, the lambda might be made in a collision between a proton and a negative pion—the reverse of the decay process. (Some other particle, such as a neutral pion, would also have to be made to carry off the excess energy.) The frequency with which lambdas appear shows that they are made by a strong process. The mass of the lambda turns out to be 2,181 electron masses.

The K particle has to be a boson because it decays into two pions, both bosons. Its spin must then be a whole number (most likely zero). It cannot be made out of a nucleon, because there are no nucleons in its decay products. It is, however, produced frequently, and thus by a strong process. It has a mass of 965.

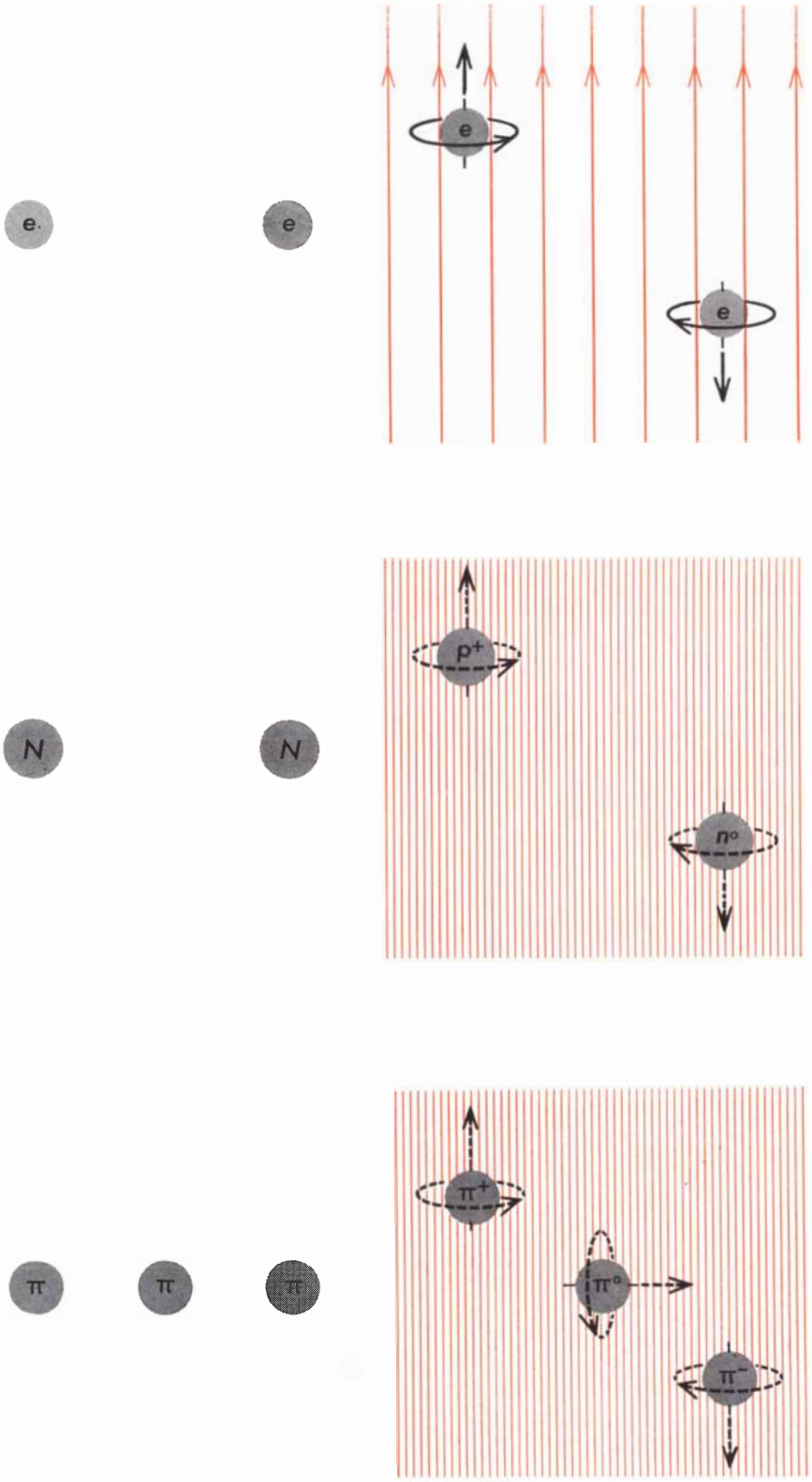
From these first considerations it is possible to classify the new particles to some extent. The lambda obviously belongs with the nucleons or heavy particles. It is made from a nucleon and, like them, it is a fermion. The K, on the other hand, is a boson; hence it is put in the meson group along with the pions.

The lambda and K particles were only the beginning. Soon other particles were identified. In the same category with the lambda are the sigma particles, charged and neutral, and the negative xi particle. Added to the neutral K were a pair of charged particles of about equal mass, called the positive K particle and the negative K particle.

Long Lifetimes

The very existence of all these distinct forms of matter is a difficult problem. But if we accept the fact that they exist, their behavior presents us with even deeper questions. The trouble arises with the decay of the new particles. Their lifetimes range from about 10^{-8} to 10^{-10} seconds, which is on the time scale of the weak interactions. But the particles are made, as we have seen, by strong interactions, the time scale of which is some 10^{-23} seconds. According to one of our most fundamental tenets—that of reversibility—a particle made in a strong interaction should also decay that way.

The new particles would seem to have ample opportunity to decay by strong processes. Consider, for example, the neutral lambda particle and let us play our equation-juggling game [*see reactions 15-19 on next page*]. By using two



DIFFERENT STATES of a particle can be recognized only through certain interactions. Two oppositely spinning electrons (*top*) would seem alike in the absence of an external magnetic field (*left*). When the field, indicated by colored arrows, is turned on, the electrons separate into different energy states (*right*). Similarly, in the absence of the electromagnetic interactions, all nucleons (*center*) are indistinguishable, as are all pions (*bottom*). When these interactions, indicated by closely spaced colored lines, are taken into account, isotopic "spin," which is represented by the broken arrows, separates the nucleons into protons and neutrons, and separates the pions into their three different charge types.

PARTICLE REACTIONS

1.	$n \longrightarrow p + e^- + \bar{\nu}$	*Fermi process.* Neutron splits into proton, electron and antineutrino.
2.	$p + e^- + \bar{\nu} \longrightarrow n$	*Reverse reaction.* Proton, electron and antineutrino combine into neutron.
3.	$p + \bar{\nu} \longrightarrow e^+ + n$	*Transpose electron as antiparticle.* Proton interacts with antineutrino to yield positron and neutron.
4.	$p \xrightarrow{v} p + \pi^\circ$	*Yukawa process.* Proton splits (virtually) into proton and neutral pion.
5.	$p + \pi^\circ \xrightarrow{v} p$	*Reverse reaction.* Proton and pion combine into proton.
6.	$\pi^\circ \xrightarrow{v} p + \bar{p}$	*Transpose proton as an antiproton.* Pion splits into proton and antiproton.
7.	$p + \bar{p} \longrightarrow \gamma + \gamma$	Proton and antiproton annihilate to yield photons.
8.	$\pi^\circ \longrightarrow \gamma + \gamma$	*Net result.* Neutral pion decays to photons.
9.	$p \xrightarrow{v} n + \pi^+$	*Yukawa process.* Proton splits (virtually) into neutron and positive pion.
10.	$n + \pi^+ \longrightarrow p$	*Reverse reaction.* Neutron and pion combine into proton.
11.	$\pi^+ \xrightarrow{v} p + \bar{n}$	*Transpose neutron as an antineutron.* Pion splits into proton and antineutron.
12.	$p + \bar{\nu} \longrightarrow e^+ + n$	*Fermi process.* Proton interacts with antineutrino to yield positron and neutron.
13.	$p + \bar{n} \longrightarrow e^+ + \nu$	*Transpose antineutrino and neutron as their antiparticles.* Proton interacts with antineutron to yield positron and neutrino.
14.	$\pi^+ \longrightarrow e^+ + \nu$	*Net result.* Positive pion decays to positron and neutrino.
15.	$\pi^- + p \longrightarrow \Lambda^\circ + \pi^\circ$	*Hypothetical process.* Negative pion and proton interact to yield lambda and neutral pion.
16.	$\Lambda^\circ + \pi^\circ \longrightarrow \pi^- + p$	*Reverse reaction.* Neutral pion interacts with lambda to yield negative pion and proton.
17.	$\Lambda^\circ \xrightarrow{v} \pi^\circ + \pi^- + p$	*Transpose neutral pion (it is its own antiparticle).* Lambda decays (virtually) into a neutral pion, a negative pion and a proton.
18.	$p + \pi^\circ \longrightarrow n$	*Yukawa process.* Proton absorbs neutral pion.
19.	$\Lambda^\circ \longrightarrow p + \pi^-$	*Net result.* Lambda decays quickly to proton and negative pion.
20.	$\pi^- + p \longrightarrow \Lambda^\circ + K^\circ$	*Hypothetical process.* Pion and proton interact to yield lambda and neutral *K*.
21.	$\Lambda^\circ + K^\circ \longrightarrow \pi^- + p$	*Reverse reaction.* Lambda and *K* interact to yield pion and proton.
22.	$\Lambda^\circ \xrightarrow{v} \pi^- + p + \bar{K}^\circ$	*Transpose K as antiparticle.* Lambda decays (virtually) into pion, proton and anti-*K*.
23.	$p + \pi^- \longrightarrow n$	*Yukawa process.* Proton absorbs pion, turning into neutron.
24.	$\Lambda^\circ \longrightarrow n + \bar{K}^\circ$	*Net result.* Lambda decays into neutron and anti-*K*.

strong processes, one known and one hypothetical but plausible, we arrive at the statement that the lambda is converted to a proton and a negative pion, which is its actual mode of decay. There is plenty of energy available for the process: the lambda's mass is 74 units greater than that of the proton and pion, which gives an energy difference of 37 mev. Thus we have "proved" that the lambda must decay as fast as it is made. The same thing can be demonstrated for all the other new particles. The only trouble is that they live 100,000 billion times longer than they should! It was this enormous discrepancy between their expected and observed lifetimes that was chiefly responsible for the designation "strange" or "queer" particles.

Associated Production

After contemplating the situation for a couple of years a number of theoreticians, in particular A. Pais of the Institute for Advanced Study, were able to suggest a possible resolution of the paradox. Their idea was that strange particles are made only in groups of two or more at a time. The concept is now known as associated production. It implies that the strong interaction which manufactures a strange particle somehow works only on more than one at a time. The trick here is that a strong process of this kind would not be reversible because of lack of energy.

For example, suppose that a lambda and a K were made in the collision of a negative pion with a proton. Now we apply our reaction rules to this process in order to predict the fate of the lambda [*reactions 20-24*]. We arrive at the conclusion that it "decays" into a proton and an anti-K. But of course this is impossible, because the two daughter particles have a combined mass greater than that of the parent. A thorough analysis shows that every possible case of associated production leads to a similar result for the separate decay of any one of the strange particles that are made. The possible avenues of decay always turn out to require too much energy. Thus, by moving away from each other immediately after they are created, the strange particles are saved

PARTICLE EQUATIONS summarize certain detailed chains of reasoning discussed in the text. Some of the chains of reasoning are found to be faulty, as indicated by the fact that the reactions they predict do *not* take place. These have been shown in gray.

from death by strong interaction, and they live until the much less probable weak processes catch up with them.

At first there was little or no experimental evidence for associated production. However, when the Cosmotron at the Brookhaven National Laboratory began to make strange particles on order, it appeared that the rule was indeed obeyed. In fact, the very first reaction to be discovered was the pion-proton collision suggested above, leading to the associated production of the lambda and the neutral K particles.

Now the question arose: What does associated production mean? Can it be related to any other principles? It tells us that strong reactions involving single strange particles are forbidden. When nature rules out an event, her legislation often takes the form of a conservation law. Such-and-such cannot happen because something must be conserved. To take a simple example, we never see a particle decay into products whose total mass is greater than its own. The conservation of energy forbids it.

Once the rule of associated production had been found, it was natural to ask whether there might not be a conservation law behind it. If the law could be discovered, we might find out much more about strange particles. Associated production says they must be made more than one at a time. But are all combinations possible or are some ruled out? The conservation law should tell.

Isotopic Spin

It appears that the law has been discovered, and we do know some of the rules by which strange particles are made. In order to see what the principle and the rules are, we must go back to the older particles and to a concept which we have not mentioned until now. This is the notion of "isotopic spin."

First let us have another look at ordinary spin. Imagine that we have a pair of isolated electrons which we can actually see as small specks. So far as we can tell, they are identical. We believe they are spinning, but they are so small that we cannot detect their motion. Now we put them in a magnetic field. Obeying the laws of quantum mechanics, their spins line up with or against the field. Suppose one goes with and the other against. Then the two particles have different energies, and we can distinguish one from the other. This imaginary experiment underlines the fact that the electron is a "doublet" so far as its magnetism is concerned. It may be in one of two possible energy states. But without an external magnetic field there is no way to tell the states apart; they "degenerate" into indistinguishability.

Now in the early days of modern nuclear physics—soon after the discovery of the neutron—a situation arose that was reminiscent of this magnetic "degeneracy." Experiments on the deflection of moving protons and neutrons by other protons and neutrons disclosed the surprising fact that the nuclear force, or strong interaction, between nucleons is the same regardless of the type of particle involved. The forces between two protons, two neutrons, or a proton and a neutron are all equal. This phenomenon, called charge independence, means that so far as strong interactions are concerned the neutron and proton look like the same particle. They can be distinguished only by their electromagnetic interaction. Suppose electromagnetism could be "turned off" like a magnetic field in the laboratory. Then the proton and neutron would also degenerate into indistinguishability. Hence the nucleon can be thought of as a "charge doublet," with one state representing the proton and the other the neutron.

This idea occurred to Heisenberg, who proceeded to express it mathematically. He constructed a mathematical description of the nucleon which included a variable that could take on just two values. One value thus represents the proton and the other the neutron. The mathematics is very much like that used by Pauli to describe the spin of an electron. Thus Heisenberg called his quantity isotopic spin. "Isotopic" refers to the fact that in a sense the proton and neutron are isotopes: they have nearly the same mass but different charge. "Spin" is purely an analogy, and a somewhat misleading one at that. It simply reflects a similarity to the mathematical term for real spin.

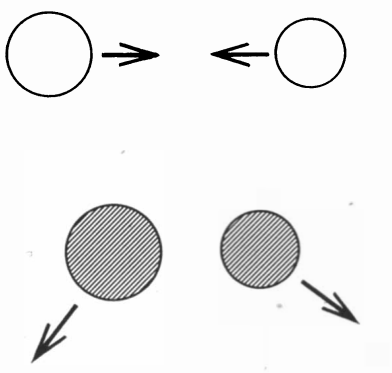
Isotopic spin, then, is a mathematical device which distinguishes the proton and neutron; physically they are distinguished by their different couplings to the electromagnetic field. The analogy to real electron spin is very close: the isotopic spin of the nucleon is also 1/2. Like real spin, it has components $+1/2$ and $-1/2$ with respect to a given, or reference, direction. In quantum electrodynamics it is customary to place a particle in a system of coordinates, the "Z" axis of which is parallel to the surrounding magnetic field. Hence the reference direction for isotopic spin is also considered to go along the Z axis, and the components are denoted by I_z. The convention has been adopted that I_z of $+1/2$ represents the proton and I_z of $-1/2$ the neutron. In Heisenberg's mathematical theory charge independence becomes a conservation law. When nucleons interact, the total isotopic spin is conserved. This statement can be shown to mean the force is equal between a proton and a proton, a neutron and a neutron, and a proton and a neutron. So far, it should be emphasized, the idea of isotopic spin is a mere formality. It adds nothing to the notion of charge independence, and is simply another convenient way of expressing it mathematically.

Charge Multiplets

When Yukawa explained nuclear forces in terms of pion emission and absorption, isotopic spin took on a somewhat broader significance. The British physicist Nicholas Kemmer, now at Edinburgh University, realized that the concept must also apply to pions. His reasoning was as follows: Nuclear forces, involving the virtual exchange of pions, are charge-independent. Therefore pions must be charge-independent, and the isotopic spin concept should apply.

Now we recall that the pion has three possible charges: plus, minus and neutral. Thus it constitutes a charge "triplet" which, if charge could be turned off, would also degenerate into indistinguishability. In the case of real spin, a triplet means that the particle has a spin of 1, since it may then assume three different directions with respect to the field. Its Z components are $+1$, 0 and -1. So we assign an isotopic spin of 1 to the pion, and we say that its components with respect to the reference direction (its I_z's) are $+1$, 0 and -1.

The grouping of particles into charge doublets or triplets (collectively called multiplets) provides a convenient short-



ASSOCIATED PRODUCTION is suggested in this diagram. Two normal particles collide (*top*), making a pair of strange particles (*bottom*) which immediately separate.

hand way of identifying them. If we say that the pion is a triplet with its center of charge at zero [*see chart on opposite page*], this tells us at once that the charges are +1, 0 and –1, the isotopic spin is 1, and the I_z's are +1, 0 and –1. Similarly, to say that the nucleon is a doublet with center of charge at +1/2 means that the charges are 0 and +1, the isotopic spin 1/2 and the I_z's +1/2 and –1/2. As can be seen in the chart, the antinucleon is another doublet centered at –1/2. Its isotopic spin is 1/2 and its I_z is –1/2 and +1/2.

Note that the isotopic spin and charge multiplet concepts give us another difference between nucleons and pions. Nucleons are a doublet centered at +1/2, while the pions are a triplet centered at 0.

Now let us turn to the strange particles. An obvious question is whether their interactions are also charge-independent and conserve isotopic spin. Are positive sigma particles, for example, just like negative and neutral ones except for their electric properties? There is no direct experimental evidence on the point, but it seemed reasonable to suppose that charge independence would apply to the strong interactions of the new particles as it had been found to apply to the strong Yukawa coupling. This would mean that the strange particles are charge multiplets. If so, it was generally supposed that they would follow the same classification as the nucleon and pion. That is, the heavy strange particles seem to be related to nucleons; they are made out of nucleons and decay back to nucleons. Therefore the heavy particles were generally thought to be doublets, having an isotopic spin of 1/2 and a charge center at plus or minus 1/2. The K particles, on the other hand, apparently belong with the pion, so it was supposed they would fall into a triplet, with an isotopic spin of 1 and charge center at 0.

About five years ago one of the authors of this article (Gell-Mann) and the Japanese physicist Kazuhiko Nishijima independently conceived the idea that the strange particles might not follow this arrangement. Furthermore, the departure from the expected arrangement might account for their strange behavior. In the case of the present author it was a matter of discovery by slip of the tongue. Discussing the heavy strange particles one day, he spoke of them as having an isotopic spin of 1, but then quickly corrected himself, saying "I mean a half, of course."

The more he thought about the "mistake" later on, the more he began to wonder whether it really was one. How do we know that heavy particles are doublets with isotopic spin 1/2? To be sure, the particles seemed to be related to the nucleon—and for the sake of order and simplicity one certainly hoped that they were related. But if they were members of that family, they were strange members. Perhaps it was precisely in their isotopic spin that their strangeness lay. Suppose the heavy particles, instead of being doublets of isotopic spin 1/2, like the nucleon, were triplets of isotopic spin +1 or even singlets of isotopic spin 0. (A particle with zero isotopic spin has only one possible state and is thus a singlet.) Suppose the K particles, instead of being triplets like the pion, were doublets? (At the time the table of strange particles was just being filled in by experiment. It was not even known, for example, whether there were charged K or lambda particles.)

After toying with the idea for a while, the author began to see that it might contain in it just the conservation law that was needed to explain associated production and the strangely long lifetimes of strange particles. In a moment we shall try to show roughly how this comes about. First let us pursue the idea a little further.

Displaced Multiplets

Recall that a simple way of describing a group of particles is to indicate its center of charge and whether it is a doublet or triplet. The nucleon is a doublet with center at +1/2; the pion is a triplet with center at 0, and so on. Now suppose that among the heavy particles there is a singlet at charge 0 [*see chart on opposite page*]. Could this, by any chance, be the neutral lambda? If it is, note that the center of this "multiplet" (a singlet is a multiplet with one member) is at 0—one-half charge unit less than the center of the nucleon doublet. The original expectation was that all heavy particles would have their multiplet centers at +1/2. Therefore the lambda is "displaced" by –1/2 charge unit. Perhaps this displacement is the essential physical characteristic of the particle which accounts for its "strangeness." Let us assume that it is; in fact, let us invent a new physical quantity and call it strangeness. For reasons of mathematical convenience we make the strangeness equal to twice the displacement. Thus the strangeness of our putative lambda particle is twice the displacement of –1/2, or –1. (The strangeness of the nucleon is of course 0. Its charge center sets the reference point from which the displacements of other heavy particles are measured.)

Next we observe that, in our system of classification by multiplets, the antinucleons form a doublet which is an image of the nucleon doublet, mirrored on the zero-charge line [*see chart*]. Thus the other heavy particles should also have antiparticles in corresponding multiplets. We accordingly place in our table an antilambda, which is also at 0. Its displacement is +1/2 (from the "normal" charge center of the antinucleon). Hence its strangeness is +1.

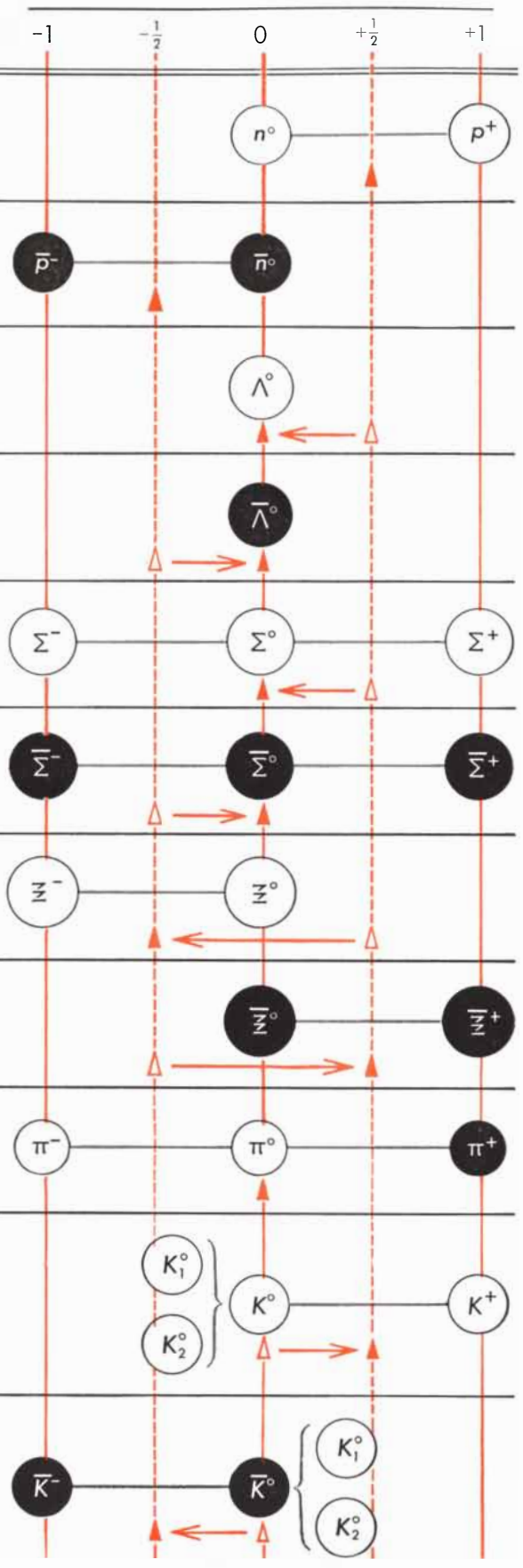
Now we can try something else—say a triplet centered at 0. Its strangeness would be –1. If there is such a triplet, there should be three strange particles, positive, negative and neutral, all with approximately the same mass. At the time the strangeness theory was conceived, no such triplet was known. Now it has apparently been found in the sigma particle (Σ^+, Σ°, Σ^-). Again we expect a corresponding multiplet of antiparticles.

Still another possibility is a heavy-particle doublet displaced a full charge unit, from +1/2 to –1/2, *i.e.*, with strangeness –2. This would mean a pair of particles with charge –1 and 0. We now believe that the negative member of the pair is the xi particle (Ξ^-). The neutral member (Ξ°) has not yet been detected, but the general success of the strangeness theory gives us considerable confidence that it will turn up.

The K particles may fall into doublets like the nucleon and antinucleon. This would mean that the K^+ and K° constitute one doublet with its charge center at +1/2. Since these particles are grouped with the pion, whose "natural" charge center is at zero, their displacement is +1/2 and their strangeness +1. The K^- then is part of a doublet together with a second neutral K, the anti-K°, which is the antiparticle of the first. The

STRANGENESS is illustrated in tabular form. Particles (*white circles*) and antiparticles (*black circles*) are grouped in multiplets with their charges indicated by the colored vertical lines. The solid colored carets mark the charge center of each multiplet; open carets mark the "expected" location of charge centers (1/2 for heavy particles, –1/2 for heavy antiparticles and 0 for mesons). Horizontal colored arrows show the displacement of each center from the expected position. The strangeness equals twice the value of this displacement.

PARTICLE	ISOTOPIC SPIN	STRANGENESS	CHARGE
NUCLEON	$\frac{1}{2}$	0	
ANTI-NUCLEON	$\frac{1}{2}$	0	
LAMBDA	0	−1	
ANTI-LAMBDA	0	+1	
SIGMA	1	−1	
ANTI-SIGMA	1	+1	
XI	$\frac{1}{2}$	−2	
ANTI-XI	$\frac{1}{2}$	+2	
PION	1	0	
K	$\frac{1}{2}$	+1	
ANTI-K	$\frac{1}{2}$	−1	



center of this doublet is $-1/2$, its displacement is $-1/2$ and its strangeness is -1. The pion plays the same role in the meson group as the nucleon does in the group of the heavy particles. That is, its charge center provides the reference point for measuring strangeness, so its own strangeness is 0.

Conservation of Strangeness

Now we have assigned a strangeness to all the strongly coupled particles. What is the point of this exercise? Simply this. It is possible to prove from the principle of charge independence that strangeness must be conserved in the strong and electromagnetic interactions. That is to say, in any reaction of these two types the total strangeness of the particles entering the reaction must equal the total strangeness of the products. We will show that this conservation law accounts for the observed behavior of strange particles.

To begin with, it obviously "explains" associated production. Strange particles are made in collisions between ordinary particles. The strangeness of the latter is 0. Therefore the total strangeness of the products must be 0. This means that at least two must be made at a time so that their individual strangenesses offset each other. Consider the case we have already mentioned: the production of a lambda and a neutral K from the collision of a pion and a proton. The lambda has a strangeness -1 and the K° has strangeness $+1$: total strangeness, 0.

As we have already seen, associated production explains why strange particles do not decay by strong interaction. But they must also be immune to the electromagnetic process, since their lifetimes are on the time scale of the weak interactions. The law of conservation of strangeness shows us how the particles avoid decay by electromagnetism as well as by strong interactions.

We can indicate only crudely how the law does so. It can be shown that the conservation of strangeness is mathematically equivalent to the conservation of the Z component of isotopic spin: I_z. The latter quantity is essentially a measure of charge: in any multiplet, the greater the I_z, the greater the charge. (For example, in the nucleon doublet I_z's of $-1/2$ and $+1/2$ correspond to charges of 0 and $+1$; in the pion triplet I_z's of -1, 0 and $+1$ correspond to charges of -1, 0 and $+1$, etc.) Electromagnetic interactions are thought to depend only on charge. By a general rule of quantum mechanics this means that they should conserve I_z (which measures charge). But to say they conserve I_z is the same as saying they conserve strangeness. Hence an isolated particle whose strangeness is not 0 cannot decay into particles with zero strangeness by an electromagnetic process.

Eventually, of course, the strange particles do decay into ordinary ones, and on a time scale about the same as that for the weak interactions. So it seems that the strange-particle disintegrations are members of this great class of processes. Weak interactions, therefore, do not conserve strangeness. It has recently been discovered that they also violate another conservation law, the conservation of parity, which has to do with symmetry in nature between right and left [see "The Overthrow of Parity," by Philip Morrison; SCIENTIFIC AMERICAN, April]. Whether there is any deep connection between the two laws and their violation is not yet known. In any case, it is clear that nature has been concealing some of her most important secrets in the weak processes, and that one of the major jobs facing physics today is to discover the laws which govern these processes.

Selecting Particles

When we began the search for a conservation law to account for associated production, it was with the hope that it would tell us still more about the birth and death of strange particles. And so it does. For instance, the rule of associated production would permit a reaction in which two neutrons collide to form a pair of lambdas.

In fact, this was considered one of the more likely reactions. But the reaction has never been observed, and the conservation of strangeness tells us that, practically speaking, it never will be observed. The neutron's strangeness is 0 and the lambda's is -1. Thus the neutron collision, if it yields a lambda, must also yield another particle with a strangeness of $+1$, such as a neutral K: for example ($n+n \rightarrow \Lambda^\circ + n + K^\circ$).

Once again let us consider the case of the sigma and K particles. The sigma is a triplet with strangeness -1. The K particles are a pair of doublets; the pair including the K^+ has a strangeness of $+1$, while the pair including the K^- has strangeness -1. Hence it is possible to make a Σ^- (strangeness -1) and a K^+ (strangeness $+1$) together, but not a Σ^+ and a K^-, both of which have strangeness -1. The first reaction has been discovered in pion collisions with protons ($\pi^- + p \rightarrow \Sigma^- + K^+$). Aside from the conservation of strangeness, there seems no

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reason why the reaction should not also go the other way ($\pi^- + p \rightarrow \Sigma^+ + K^-$). But this has not been found to happen, and the strangeness principle tells us why it has not.

As a still further example of the power of the strangeness rule, we may examine the decay of the neutral sigma. The sigma triplet has the same strangeness (−1) as the lambda. The sigma is also some 150 electron masses heavier. Therefore it should be possible, both from the standpoint of available energy and of conservation of strangeness, for the sigma to decay to the lambda. That is to say, the sigma should not have to wait for the weak processes to end its life. However, in the case of a charged sigma, there would have to be some other charged particle in the decay products to conserve charge. It might be a pion ($\Sigma^+ \rightarrow \Lambda^\circ + \pi^+$). The pion's strangeness is 0, so the strangeness accounts are in balance. But the pion's mass is 270, or about 120 more than is available energetically. The neutral sigma, on the other hand, does not need to produce any other charged particles. Its excess energy can be carried away by photons ($\Sigma^\circ \rightarrow \Lambda^\circ + \gamma$). This reaction has in fact been observed. It is an electromagnetic process (since it involves photons) and is therefore only a little slower than the strong interactions themselves.

Thus strangeness gives us rules for selecting the possible strange particles and their possible decays. As a matter of fact, a few particles were predicted by the strangeness table before they were actually found. The only one still missing is the neutral xi.

The Neutral K

Before leaving this "periodic table" of strange particles, one final comment is in order. It will be noticed that the K° and its antiparticle are also listed as a different pair of particles called the K°_1 and K°_2. One of the most striking successes of the strangeness theory was the prediction of this situation. The reasoning which led to the prediction is too complicated to set forth here, but it indicates a remarkable shuffling process on the part of nature. The K° and anti-K° are made in different processes. Once made, each of them can decay in two different ways, one of which takes a little longer than the other. Quantum theory shows that only half of each type of particle can follow either mode of decay. Thus we have two different manufacturing processes and two different decay processes, with a reshuffling in between. Nature segregates the neutral K particles on one basis in their manufacture and on another in their decay. She makes K°'s and anti-K°'s. After they are made, half of each of these particles "become" K°_1's and half become K°_2's. This is demonstrated by the way they decay.

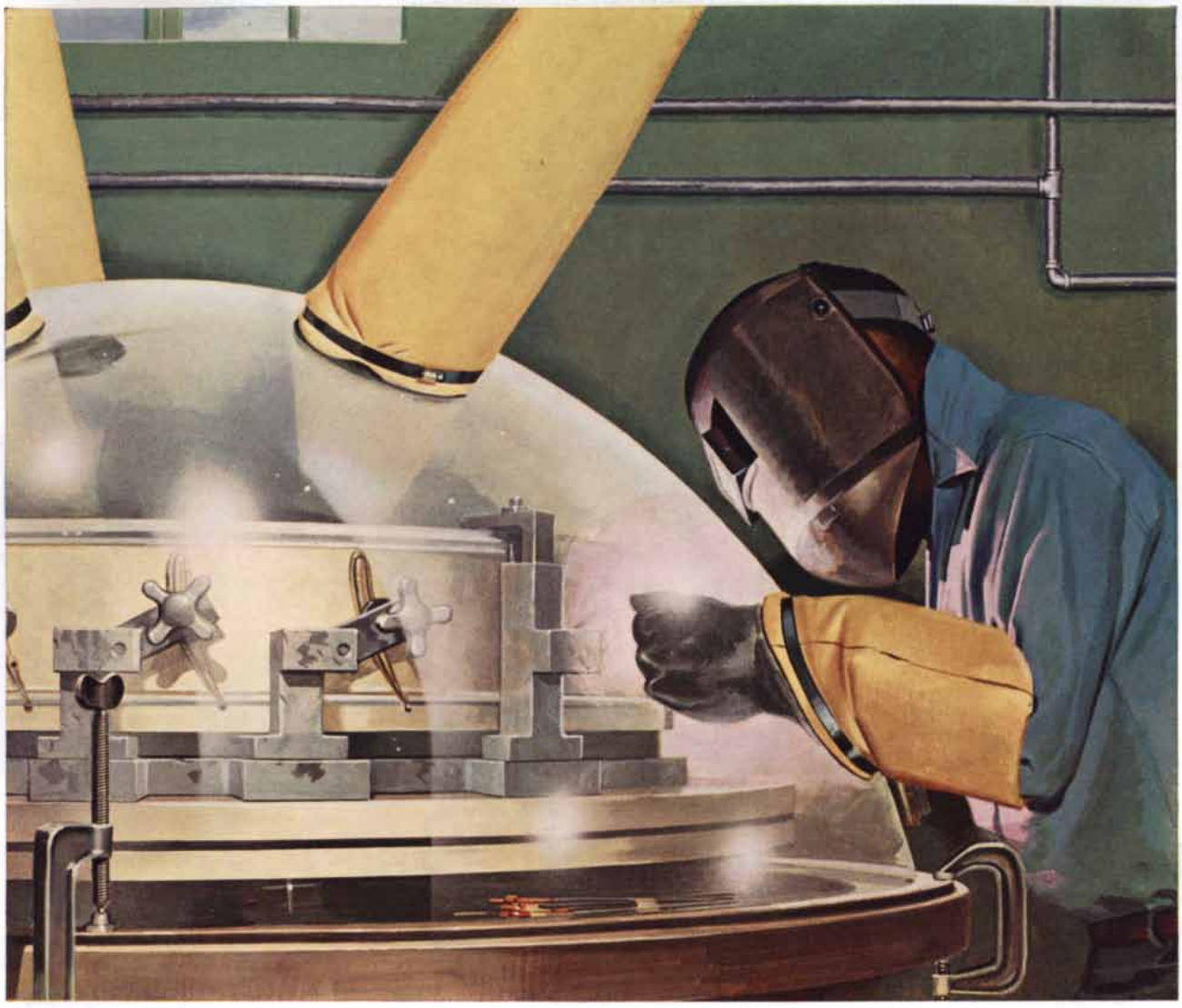
In the strangeness theory, then, we have a means of classifying strange particles. The theory is consistent with the fundamental idea of four groups of particles and three types of reaction. Thus we still have only the heavy particles (some of them strange), the mesons (some of them strange), light particles and the photon. And the couplings between them are strong, electromagnetic or weak.

At present our level of understanding is about that of Mendeleyev, who discovered only that certain regularities in the properties of the elements existed. What we aim for is the kind of understanding achieved by Pauli, whose exclusion principle showed *why* these regularities were there, and by the inventors of quantum mechanics, who made possible exact and detailed predictions about atomic systems.

We should like to know the laws of motion of the particles; to predict, among other things, how they will interact when they collide and how these interactions will deflect one particle when it collides with another. As this article is written a number of physicists are hard at work on theories which they hope may supply the laws. Time will be the judge.

On a still more fundamental level there are questions to which the answers seem as yet much more remote. Are all the particles we have mentioned really elementary, or are some of them just compounds of other particles? If so, which are elementary and which are not? Why has nature chosen to use this particular set of particles to build the material world? Why are the charges of elementary particles limited to the values +1, −1 and 0? These and many other such puzzles seem to lie entirely beyond the power of our present theories. Shall we ever know the answers? Every physicist has an abiding faith that we shall. But it will probably require some wholly new ideas. For one thing, many theoreticians believe that the present concepts may be entirely inapplicable at extremely short distances —of the order of the dimensions of the particles. In fact, it is suspected that here these concepts become self-contradictory.

It is likely to be quite a while before the particle physicist finds himself out of a job.



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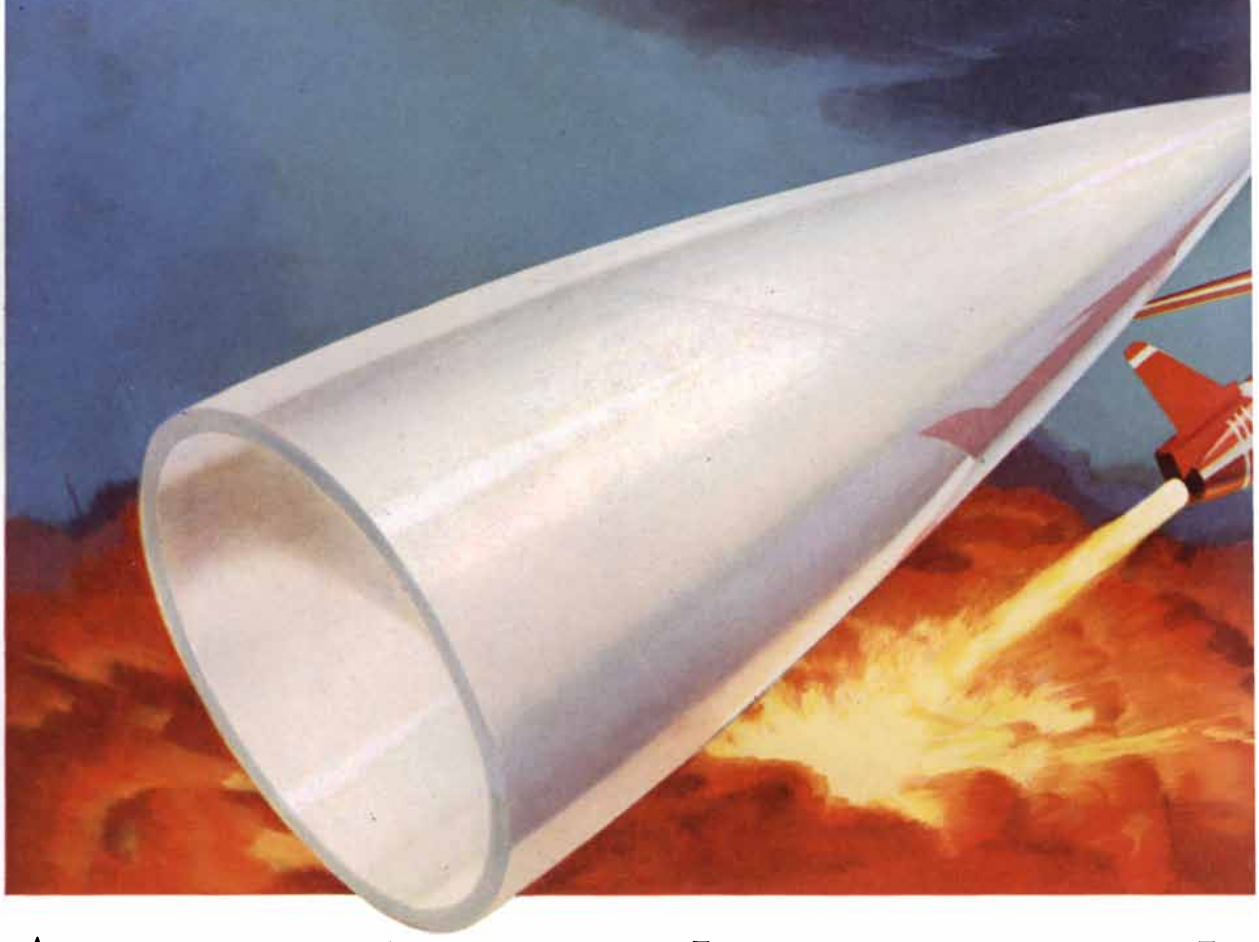

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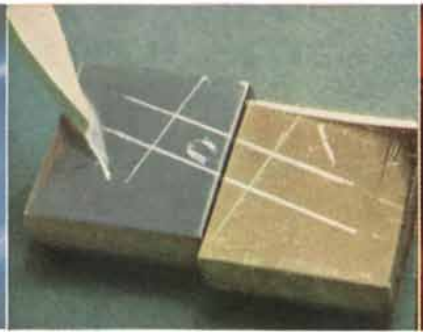

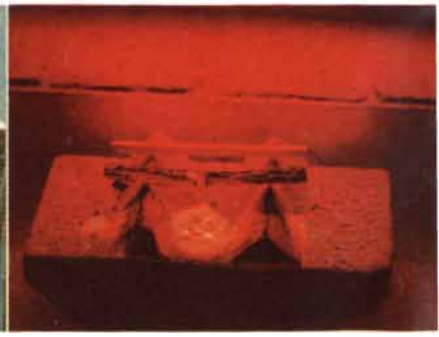

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AGAMMAGLOBULINEMIA

This nonstop word refers to a disease in which the blood lacks gamma globulin. Because antibodies are found in gamma globulin, those who suffer from the disease are prey to grave infections

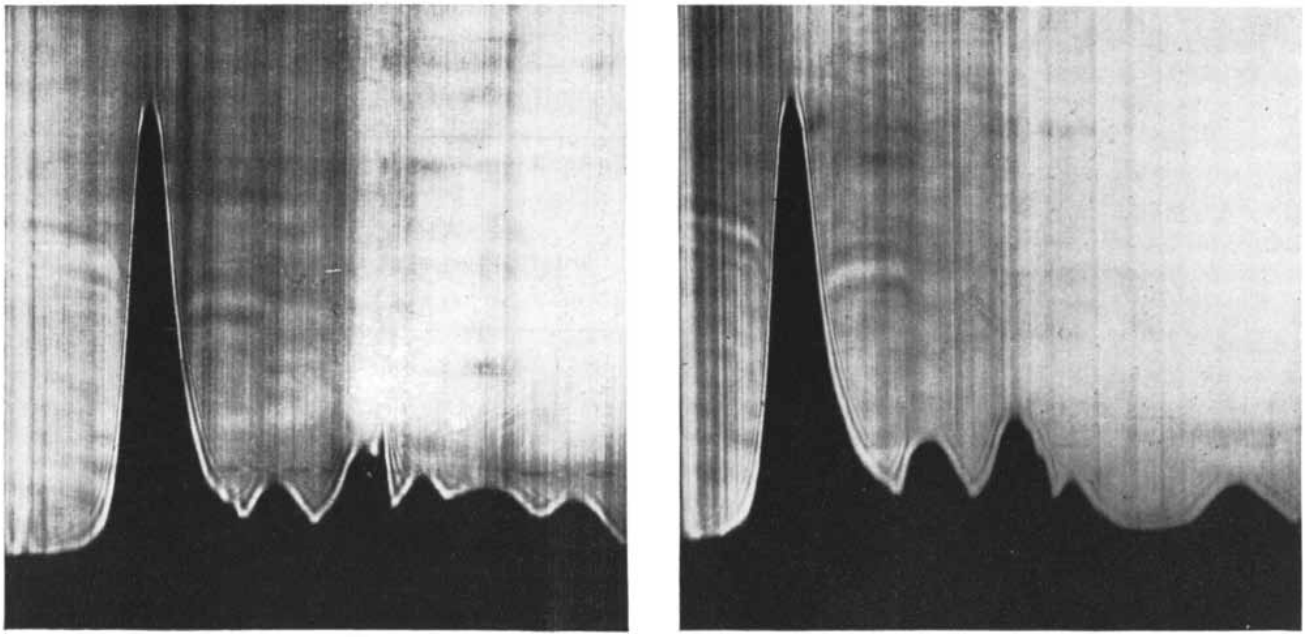
by David Gitlin and Charles A. Janeway

One day in 1951 a very sick eight-year-old boy was admitted to Walter Reed Hospital in Washington, D.C. His illness was not particularly unusual: bacteria had invaded his bloodstream to cause septicemia, or "blood poisoning." But the boy's medical history was distinctly unusual. Within the preceding four years he had suffered more than 20 grave infections, and in 10 of them bacteria had been found in his blood. On each occasion the bacteria had been identified as pneumococci.

Several attempts had been made to immunize the boy against the recurring infections. He had been injected with vaccines containing dead pneumococci and with substances manufactured by these bacteria. Ordinarily the injections would have stimulated his production of specific proteins, or antibodies, which would have increased his resistance to the pneumococci. The injections had been of no avail. Even when he had been injected with the vaccines of other bacteria, he had produced no antibodies against them. It seemed obvious that the boy suffered from a defect in his ability to make antibodies. But what sort of defect was it, and what could be done about it?

Antibodies are found in blood serum, the mixture of proteins that remains after the rest of the blood has clotted. Some 20 years ago Arne Tiselius of Sweden showed that the serum proteins could be fractionated by electrophoresis, in which an electric current is passed through a solution to separate one protein from another by the characteristic electric charge of its molecule. Tiselius separated the serum proteins into four main fractions: albumin, alpha globulin, beta globulin and gamma globulin. He noted that the antibody proteins were mostly in the gamma globulin fraction.

Colonel Ogden Bruton, the physician in charge of the boy's case, arranged to



PROTEIN FRACTIONS of blood serum are separated by electrophoresis, in which one protein is separated from another by the electric charge at its molecule. The result is a pattern of dark peaks, one for each fraction. At left is the pattern of normal serum. The tall peak corresponds to albumin. Merging with the right side of this peak is a peak corresponding to alpha-one globulin. The second visible peak to the right corresponds to alpha-two globulin; the third, to beta globulin; the fourth, to fibrinogen; the fifth to gamma globulin. At right is the pattern of serum from a child with agammaglobulinemia; the gamma globulin peak is missing.

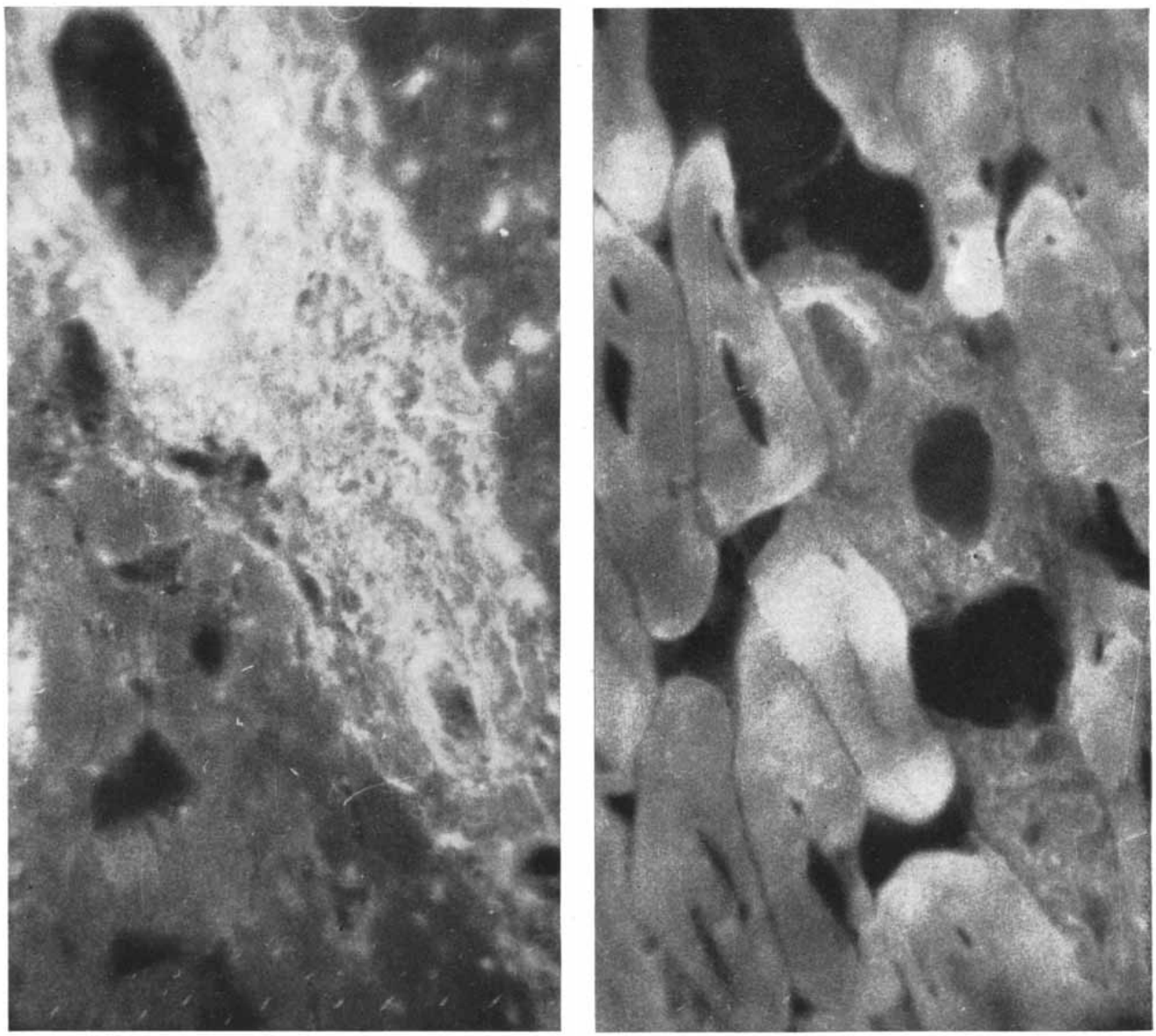
have the blood serum of his patient analyzed by electrophoresis. The analysis showed that the serum contained no gamma globulin! This was an astonishing result. It meant that the boy probably lacked antibodies of any kind.

At about the same time two other boys were under observation at Children's Hospital in Boston. They too had suffered from many severe bacterial infections, most of which would have undoubtedly been fatal if they had not been liberally treated with antibiotics. When the attending physicians heard of Bruton's case, they had the boys' blood serum analyzed by electrophoresis. Gamma globulin was absent in both patients.

Bruton named this newly recognized defect "agammaglobulinemia," which simply means "absence of gamma globulin in the blood." The story of the three boys was told by Leonard Apt of Children's Hospital at a pediatrics meeting in 1952, where the ensuing discussion indicated that the disorder had also been observed in other hospitals. Since then more than 40 cases of agammaglobulinemia in children have been reported.

This was not the end of the story; it was only the beginning. Agammaglobulinemia is a significant experiment of nature. Before the advent of antibiotics the disorder could not have been detected, because without them most of its victims cannot survive the severe infections they contract early in life. Now it provided a unique means of studying the production of antibodies and their role in infections and other disease processes.

There were at least two possible explanations for the absence of gamma globulin from the blood of these children. One was that they were able to manufacture gamma globulin but destroyed it so rapidly that little or none remained in the blood. The other was that they could not make gamma globulin at all. To decide this question gamma globulin from normal individuals was injected into children with agamma-



GAMMA GLOBULIN IN TISSUE shows up as a bright area when it is stained with a fluorescent antibody and photomicrographed under ultraviolet. At left is such a picture of connective tissue in the muscle of a normal person; the bright area runs from upper left to lower right. At right is similar tissue from a child with agammaglobulinemia; the tissue glows slightly but has no bright areas.

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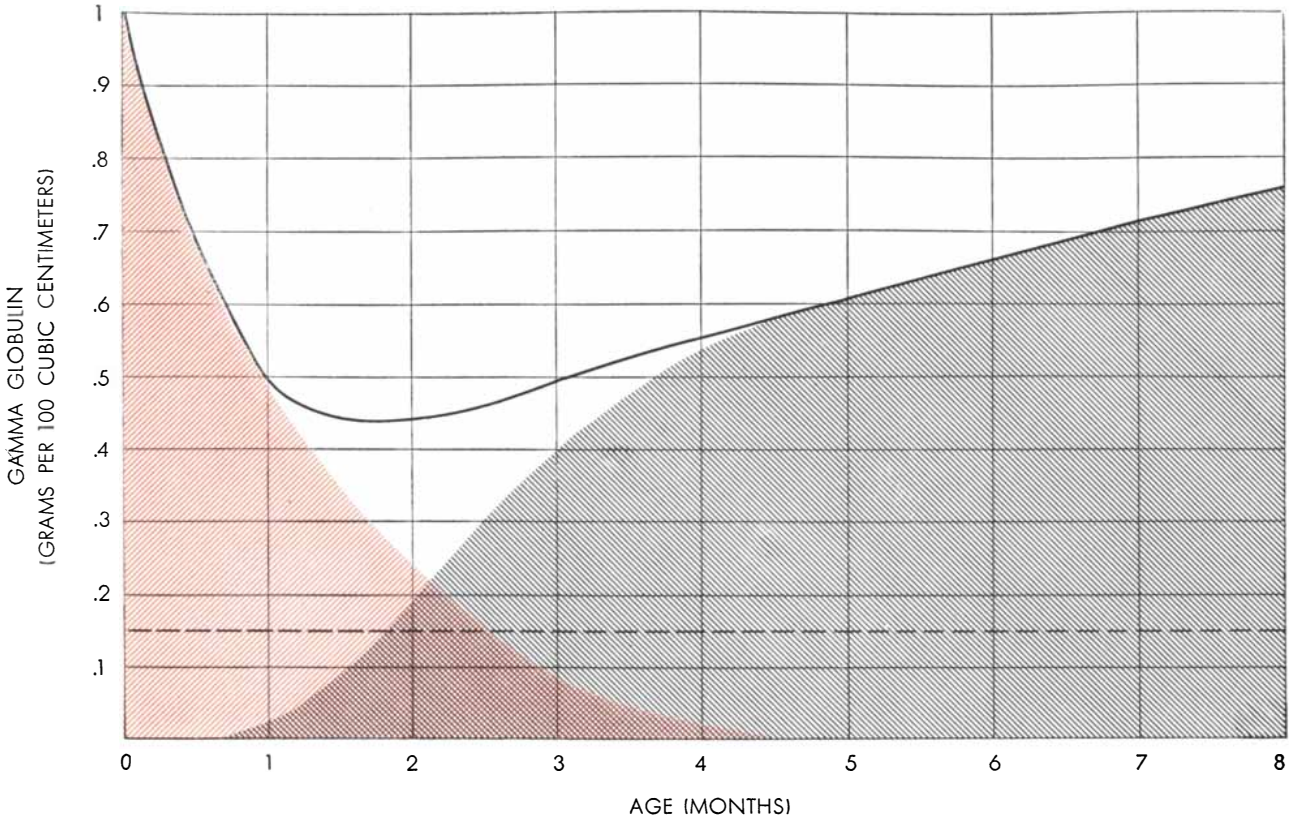

INFANT'S GAMMA GLOBULIN SUPPLY first comes from the mother's blood. This gift is gradually depleted (*colored area*) in the first four months of life. The normal infant starts to manufacture its own gamma globulin before it is one month old and gradually builds up its store (*gray area*). The black line shows the actual concentration of gamma globulin usually found in an infant's serum during its first eight months. In agammaglobulinemia the concentration drops below the level marked by the dashed line.

globulinemia. It was found that, if anything, gamma globulin was destroyed more slowly in these children than in a normal child. Thus it appeared that the absence of gamma globulin was due to a defect in its manufacture.

This finding was now corroborated by another line of investigation. It had long been suspected that antibodies are made not by all cells but by certain kinds of cells found notably in the lymph nodes, the spleen and the walls of the large and small intestines. Recently Albert H. Coons and his colleagues at the Harvard Medical School, using an ingenious technique in which antibodies labeled with a fluorescent dye are used to locate substances in tissue sections, have shown that the ultimate source of antibodies is not certain kinds of cells but a single kind of cell: the so-called plasma cell.

Further studies showed that when a normal child had suffered from an infection, or had been injected with a vaccine or toxoid, large numbers of plasma cells appeared in its lymph nodes, spleen and intestinal wall. When a child with agammaglobulinemia had been similarly injected, practically no plasma cells were found in any tissue. Indeed, no plasma cells appeared after prolonged infection. This evidence supported the hypothesis that the plasma cell is essential to the formation of antibodies. It also indicated that the lack of antibodies in a child with agammaglobulinemia is due to the absence of the plasma cells by which they are normally formed. Finally, since antibodies constitute most, if not all, of the gamma globulin fraction, these findings substantiated the other evidence that the disorder is caused not by the destruction of gamma globulin but by a defect in its production.

It was now possible to investigate another question. It had been suggested that since antibodies were gamma globulins, specific antibodies might arise from the direct modification of gamma globulin already present in the body. To test this hypothesis several agammaglobulinemic children were injected with both gamma globulin and a vaccine. If the hypothesis were true, some of the gamma globulin should have been converted into an antibody against the vaccine. Subsequent tests of the children's blood gave no indication that any of the gam-

Authors' Note

In preparing this article the authors have drawn upon their own work and upon information obtained by others. They would like to acknowledge their indebtedness to Colonel Ogden C. Bruton of the U. S. Army Medical Corps; their colleagues Drs. John Craig, Leonard Apt, Hans Habich, Walter H. Hitzig and Theodore C. Jewett, Jr.; and others in the U. S. and abroad, particularly Drs. Lee F. Hill of Des Moines, Conrad M. Riley of New York, Norman Kendall of Philadelphia, Robert A. Good of Minneapolis, Philip L. Calcagno of Buffalo, Nicholas Martin of London, Andrew Sass-Kortsak of Toronto and A. Hässig, S. Barandun and H. Isliker of Berne, Switzerland.

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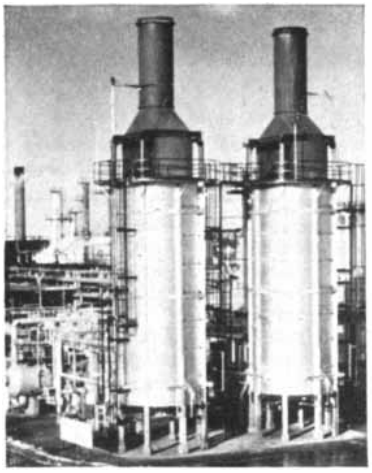

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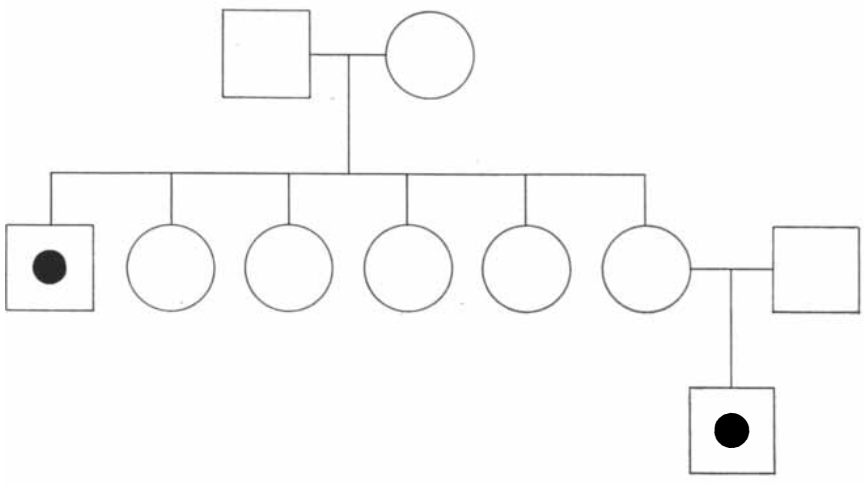
ma globulin had been converted into the antibody; thus it appeared that preformed gamma globulin is not readily made into specific antibodies, at least in the absence of plasma cells.

As physicians continued to study agammaglobulinemia they made new clinical observations. One was that although children suffering from the disorder were dangerously susceptible to infection by bacteria, their resistance to infection by viruses appeared to be relatively normal! For example, their medical histories frequently indicated that although they had been exposed to measles and chicken pox on numerous occasions, they had contracted these virus diseases only once. Moreover, the infections seemed to have been no more severe than usual. This observation demanded further study. If it could be substantiated, it would mean that factors other than antibodies are important to normal immunity to viral infection.

The cowpox virus, which confers immunity to smallpox, was admirably suited to test the observation. As almost everyone knows, when a person who is not immune to smallpox is vaccinated with cowpox virus, a blister surrounded by a red area forms on the skin; later the blister is replaced by a scab. When an immune person is vaccinated, no blister forms and there may be only a slight and transient area of redness. Children with agammaglobulinemia were vaccinated, resulting in the usual nonimmune response. When they were vaccinated again, their response was identical with that of normal immune individuals. Even when they were vaccinated a third time on a patch of skin far removed from the site of the original vaccination, their response was normal. Despite their immunity, no antibodies against cowpox virus could be detected in their blood. The conclusion could only be that, although antibodies are necessary for immunity to at least some bacteria, they are not required for immunity to certain viruses.

How much antibody is necessary to prevent infection by bacteria? Here again children with agammaglobulinemia provided an answer. When the disorder was first discovered, a method had already been developed to isolate large quantities of gamma globulin from pooled blood plasma, thus concentrating the antibodies of all the individuals from whom the blood had been obtained. The children were immediately given large injections of the missing protein fraction, providing them with antibodies made by others. Because the disorder appeared to be permanent, it was necessary to administer the gamma globulin at regular intervals. It became apparent that to treat most cases of the disorder successfully it was necessary to maintain the concentration of gamma globulin at between 100 and 200 milligrams per 100 cubic centimeters of plasma. When the concentration fell below that level, infections occurred. The concentration of gamma globulin in a normal person is between 600 and 1,200 milligrams per 100 c.c. Since the gamma globulin given to the children came from the pooled plasma of hundreds of adults, this would seem to indicate that the average adult



HEREDITARY TRANSMISSION of agammaglobulinemia is illustrated in this family tree based on an actual case. The disease (*black dot*) appears only in males (*squares*) but is transmitted by females (*circles*). The defective gene is carried as a sex-linked recessive trait by the mother. Daughters who receive the gene will also be carriers although they appear normal. Sons who receive the gene will show symptoms of agammaglobulinemia.

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SKIN TRANSPLANTED from a 45-year-old woman to a boy with agammaglobulinemia has remained in place for three years. The graft was made by Robert A. Good of the University of Minnesota Medical School. This photograph is from the journal *Pediatrics*.

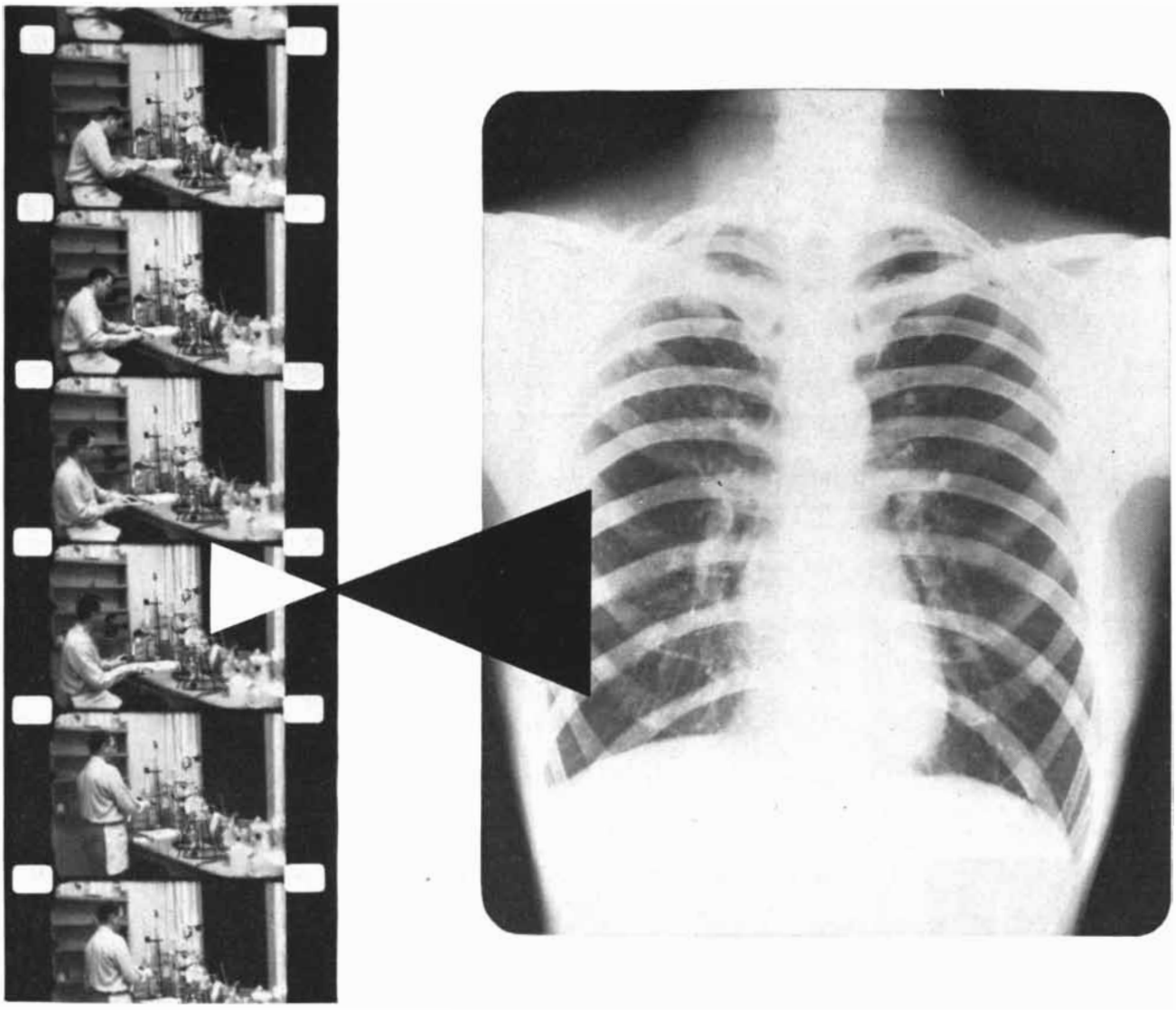
has a safety factor of about six in his supply of antibodies to prevent infection by bacteria.

Antibodies are not always a blessing, as people with allergies can testify. For example, when some individuals inhale ragweed pollen, they manufacture a special kind of antibody which sensitizes them to the pollen instead of protecting them against it. In such a person a subsequent encounter with ragweed pollen causes a local reaction between the pollen and the antibody—an attack of hay fever. Other diseases which are not usually described as allergic may be due to a similar reaction. Rheumatoid arthritis, for example, may be caused by a chronic reaction between an antibody and a substance in the body tissues. The nature of the substance is not known: some investigators think it is derived from substances which enter the body; others, that it is a constituent of the body.

How does agammaglobulinemia fit into this problem? It was observed that at least a third of the children with the disorder developed chronic arthritis. Some years after the onset of the infections, their ankles, knees, wrists and the joints of their fingers began to swell. Although acute infection caused arthritis in some of the children, the chronic disease was not due to local infection. Surprisingly the chronic arthritis was accompanied by little pain; the generalized symptoms were few and less severe than would be expected were similar swellings to develop in a normal person. Under the microscope the tissues of the affected joints had some features characteristic of rheumatoid arthritis and others that were not.

Was this rheumatoid arthritis? The answer is still not clear. If it is rheumatoid arthritis, the implications are startling. For example, it may be that in a normal individual the generalized symptoms of rheumatoid arthritis are caused by a reaction between a specific antibody and the tissue of the joints, but that the arthritis itself is due to another process entirely. It is even possible, if these observations are correct, that antibodies made by the normal person protect him against rheumatoid arthritis. This cannot be construed to mean, however, that the administration of gamma globulin will prevent or ameliorate rheumatoid arthritis. A third of the children with agammaglobulinemia suffered from arthritis even though they had received large amounts of gamma globulin.

Periodic injections of gamma globulin have been very successful in preventing infections in children with agammaglobulinemia; regular doses of antibiotics have also been helpful. Obviously these measures are expensive and inconvenient. Would it not be better to supply the missing plasma cells, so that the child could produce his own antibodies? Lymph nodes containing plasma cells have indeed been transplanted from a normal child to a child with agammaglobulinemia. Unfortunately the nodes failed to produce antibodies when vac-



Two ways to look at a technician

Here are two photographs made on Du Pont film.

The enlarged 16mm film strip to the left was made on Du Pont Type 931 Rapid Reversal motion picture film. Photographed at the rate of one frame per second and projected at the normal rate of 16 frames per second, the film compresses an hour's work into a few minutes' viewing, makes it easy to analyze procedures.

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cines were injected into the abnormal child. When the nodes had been stimulated with vaccines before they were transplanted, they manufactured small quantities of antibodies for a short time. When the nodes were transplanted from a normal adult and then stimulated, they manufactured antibodies, but again only temporarily.

Although these transplants were unsuccessful, much has been learned from other grafts between normal individuals and children with agammaglobulinemia. Skin cannot be successfully transplanted from one individual to another (unless the individuals are identical twins). When such a graft is made, the transplanted skin ordinarily degenerates in two or three weeks [see "Skin Transplants," by P. B. Medawar; SCIENTIFIC AMERICAN, April]. It has long been thought that the reason why the transplants do not "take" is that the individual who receives the graft makes antibodies against it. If this were the case, it should be possible to make successful skin transplants between a normal person and a child with agammaglobulinemia.

Robert A. Good and Richard L. Varco of the University of Minnesota Medical School have succeeded in making such grafts. In some cases, however, the transplants did not survive. The reasons for this are not clear. At this point it should be said that agammaglobulinemia is not a total absence of gamma globulin; it would be more accurate to describe the disorder as a severe deficiency of the protein fraction. Sensitive tests on children with agammaglobulinemia have indicated that some of them can make traces of gamma globulin. It may be that this small amount is sufficient to account for the failure of some of the skin transplants. It may also explain the immunity of the children to certain viruses. At the moment, however, these are pure speculations.

As more children with agammaglobulinemia were discovered, the fact that all of them were boys became more striking. It strongly suggested that heredity played a role in the disorder, and the families of the patients were accordingly studied. It was found that in many of the families brothers or maternal uncles of the patients had died of what appeared to be agammaglobulinemia. In several cases the disorder was diagnosed in a younger brother of the patient. In another it was found that a maternal nephew of the patient was affected. It is now clear that agammaglobulinemia is a hereditary disorder. Like hemophilia, it is a sex-linked recessive characteristic

A Man Nobody Wants

Now the old horse, which never gets this man anywhere, has unobstructed vision. Our mounted subject's current project is necessarily long term: he is out to prove that Univac made a mistake in contradicting one of his pet hypotheses. (It took Univac four hours to come up with its answer.)

This equestrian is so pedestrian that he would never be interested in the fancy-stepping Rogers stable.

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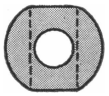
that is transmitted from mother to son. The mothers show no symptoms of the disorder, but half the sons will suffer from it. Because of this, and because the disorder begins in infancy or early childhood, it has been renamed "congenital agammaglobulinemia."

Agammaglobulinemia occurs not only in children. At present all those with congenital agammaglobulinemia are children; some day they will obviously be adults. But another form of the disorder has been recognized in both men and women. These patients appeared to be perfectly normal until they were adolescents or adults; then they began to suffer from repeated bacterial infections. In one case it was definitely shown that the blood of the patient had previously contained gamma globulin. It is not known whether this form of the disorder, like diabetes, is inherited as a tendency which is manifest only later in life. In any case it has been named "acquired agammaglobulinemia." There are certain differences between the effects of agammaglobulinemia in adults and those in children. For example, the adults are less likely than the children to accept skin grafts. At least some of these differences may be attributed to the fact that the blood of the adults contains more gamma globulin than that of the children. The concentration of gamma globulin in the plasma of agammaglobulinemic adults may be as high as 100 milligrams per 100 c.c.

Agammaglobulinemia occurs in still another form which may be much more common than the congenital or the acquired. The gamma globulin in the blood of a newborn child was manufactured not by the child but by its mother. Normally the child begins to make its own gamma globulin at the age of four to 12 weeks; meantime the maternal protein gradually disappears. Sometimes, however, the development of the ability to manufacture gamma globulin is delayed. The result is the same as that of congenital agammaglobulinemia: the child may suffer from severe bacterial infections. Fortunately this type of agammaglobulinemia is temporary, and it can now be treated with injections of gamma globulin.

The study of agammaglobulinemia continues. Thus far it has made possible the successful treatment of the disease, and has clarified how normal individuals resist infection. It may yet provide significant evidence as to the nature of diseases such as rheumatoid arthritis, and shed further light on basic problems of immunity and allergy.



GRID FRAME
(actual size)

Electron Tube Grid so precise, it can act like Diffraction Grating

A tiny electron tube grid, made by Western Electric, offers an example of remarkable precision in a volume-produced unit. This grid is manufactured to such exacting standards of precision that it is capable of acting as a "transmission" type diffraction grating – putting it in the class of the most precise scientific instruments that man has been able to make.

The conventional diffraction grating as used in spectroscopes consists of a silvered optical plate which has been ruled with some thousands of tiny parallel lines. When light is reflected from such a grating, it is broken up into its primary colors, the effect resembling that produced by a glass prism. The grating is superior to the prism because the colors are more cleanly separated.

The highly precise grid under discussion is used in the revolutionary 416 type electron tube that makes possible the transcontinental radio relay network of the Bell Telephone System and was designed for this purpose by the Bell Telephone Laboratories. The 416 is a planar type triode used as an amplifier or frequency multiplier at frequencies in the order of 4,000 megacycles.

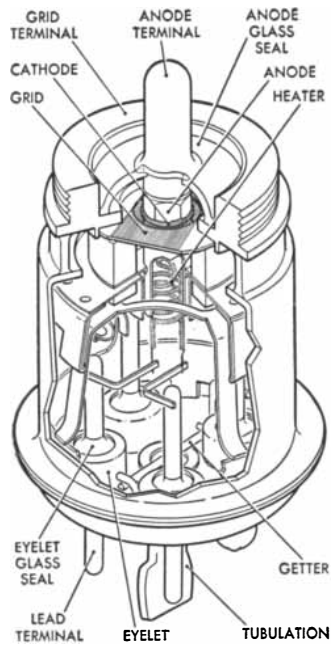
The grid consists of wires of microscopic diameter, wound on a grid frame (shown above in actual size) in parallel lines on centers .001 of an inch apart. Western Electric engineers developed a machine to etch wire chemically so as to reduce it to a diameter equivalent to fifteen wave lengths of light. Sixty such strands would be required to form a cable of the thickness of a normal human hair.

Next, a way had to be found to wind this virtually invisible thread on the grid frames in accurately parallel lines spaced a thousand to the inch. Western Electric engineers designed a machine that feeds out the wire under constant tension to avoid sagging and insure accurate spacing. This tension is rigidly controlled, as a gentle pull of only three-quarters of an ounce would snap the delicate wire thread.

Anchoring the wires securely to the frame posed another problem. In the finished tube, the spacing between the grid and the cathode must not exceed .0005 of an inch. The positioning is shown in the cross-section of the assembled tube at right.

The fastening agent had to be such as not to increase unduly the thickness of the grid. Gold was chosen because it is a good conductor, is inert in a vacuum, reduces grid emission and is suitable for the working temperature of the tube. Conventional plating could not give the thin, even coating required. So Western Electric engineers designed a machine in which 24-karat gold is disintegrated into a vapor which settles evenly on the frames, brazes the wires firmly to them and adds only .00002 of an inch to the overall thickness of the unit.

Despite the formidable specifications of precision, these grids – and the tubes of which they are a component – are being turned out by the thousands. Solving mechanical, metallurgical, chemical, electrical and other problems of such degree is a continuing story at Western Electric, making a practical reality of boldly-imagined new ways in telephony. Western Electric's ability in these manufacturing engineering areas is an important reason why the operating telephone companies of the Bell System are able to provide the finest telephone service – and to do so at modest cost.



416-TYPE TUBE

Western Electric

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM

THE TOMBS OF THE FIRST PHARAOHS

Before the kings of Egypt made pyramids, they were buried in great brick-lined pits topped by rectangular buildings. These structures provide clues as to how civilization came to the Valley of the Nile

by Walter B. Emery

When the famous British archaeologist Flinders Petrie published his *History of Egypt* in 1894, he devoted only 10 pages of it to the period before 2680 B.C. Yet by that time there had already been three dynasties of Egyptian kings. Egyptologists had learned much about the succeeding 27 dynasties by archaeological excavation, but their knowledge of the first pharaohs was based only on the lists of kings compiled by later Egyptians and on the writings of Greek and Roman historians. Indeed, some authorities believed that these kings were figures of myth and legend rather than men who really lived. But at the turn of the century the pick of the excavator revealed many monuments of the First Dynasty, and the shadowy figures of the first pharaohs stepped forth onto the stage of history to tell their story of the rise of civilization in the valley of the Nile.

The most important of these discoveries was made in 1895 at Abydos, a site on the Nile 300 miles south of Cairo. Here the French Egyptologist Emile-Clément Amélineau discovered a group of graves consisting of great pits lined with brick. In 1899 Petrie began to work at Abydos, and in two years of brilliant research he established its tombs as monuments of the kings of the First and Second Dynasties. He was also able to identify the royal owner of each tomb and to establish the order of his succession. Originally each brick-lined pit was roofed with timber and surmounted with a superstructure. In all cases this part of the building has disappeared, and no indication of its precise form exists. We do know, however, that because the tombs are so close to one another the superstructures cannot have covered an area much larger than the pits themselves. Each tomb was surrounded by numerous graves which contained the bodies of slaves sacrificed to continue their service to the king in the afterworld.

Petrie believed that the kings of the First Dynasty were actually buried at Abydos, and until recently there was no reason to doubt this conclusion. Later excavations strongly suggest, however, that the kings were buried not at Abydos but at Sakkara, far down the Nile [*see map on page 108*]. Sakkara, the vast cemetery of ancient Memphis, is best known as the site of a great stepped pyramid of the Third Dynasty. At its north end are the remains of tombs which had long been recognized as perhaps even older than this pyramid. But it was not until 1912 that any really serious research was undertaken at North Sakkara. The late J. E. Quibell, then Chief Inspector of the Egyptian Department of Antiquities, excavated for two seasons and proved the existence of First Dynasty tombs far better preserved than those at Abydos.

The site was still not considered especially promising because it had been systematically ravaged by tomb-robbers for more than 5,000 years, and so after the interruption of Quibell's work by World War I the site lay untouched until 1930. Then his successor, the late C. M. Firth, resumed the excavations. Firth cleared several more First Dynasty tombs, the most notable of which was known as 3035. The paneled exterior and burial pit of this great structure were excavated, but its interior was left untouched. This was because it was believed that the interior of the superstructures of such monuments was a solid network of brick walls filled with rubble. The excavation of Tomb 3035 was not very productive, for the burial chamber had been plundered and replundered in ancient times. Nonetheless Firth was able to establish that the tomb had been built during the reign of Udimu, fifth king of the First Dynasty. Firth

EXCAVATED TOMBS of the pharaohs of the First Dynasty are on the right side of

died suddenly in 1932, and once again the exploration of North Sakkara was interrupted.

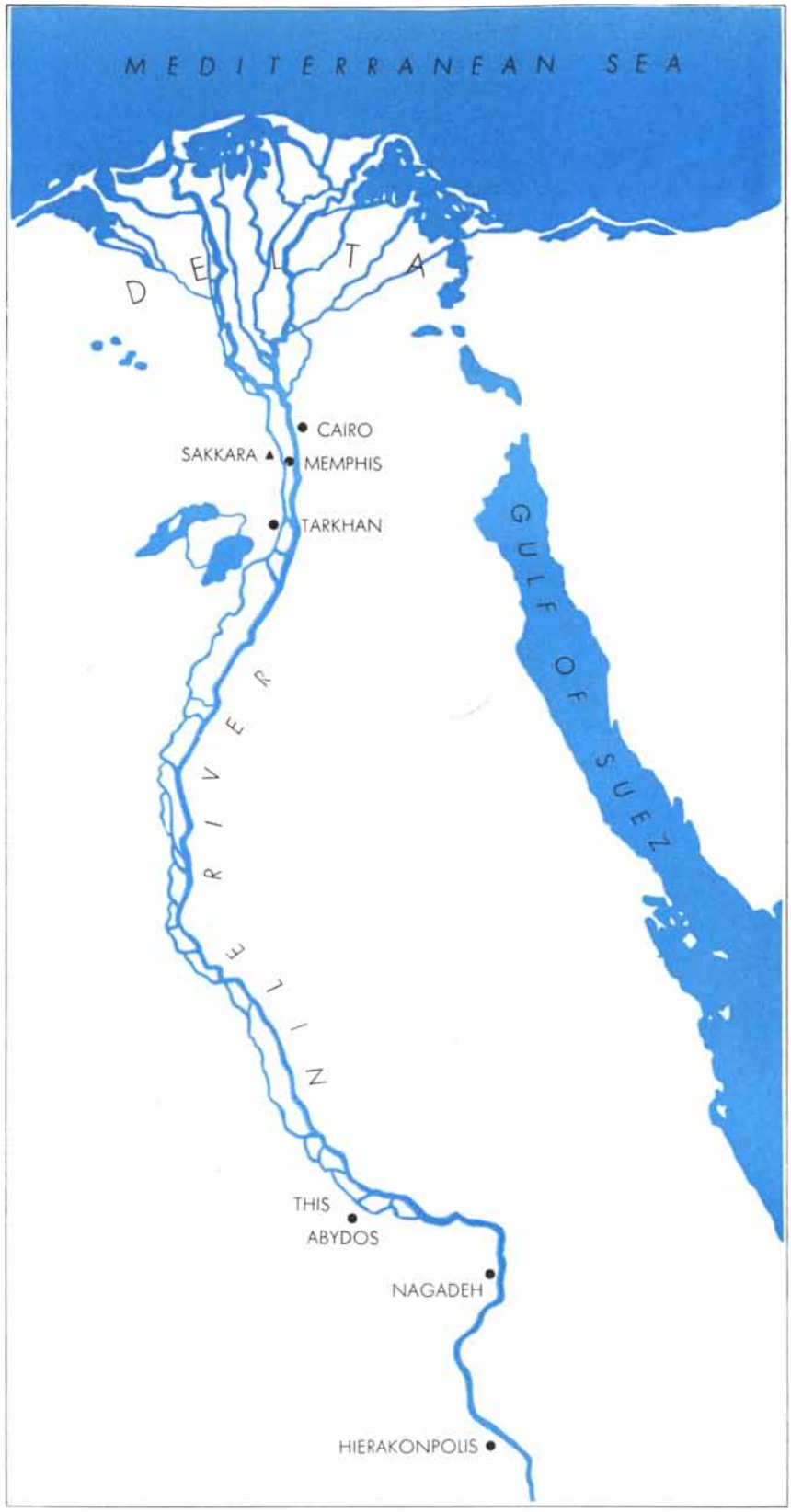
In 1935, when the Director General of the Department of Antiquities instructed me to reclear the tombs, I also turned my attention to Tomb 3035. In order to determine certain details of its construction I cut rather ruthlessly into the big brick superstructure and found that it was not just a solid mass of brickwork and rubble but was divided up into a series of 45 storerooms, many of which had escaped the attention of the ancient tomb-robbers. In these storerooms we found a great collection of funerary equipment—food, tools, weapons, games and drinking vessels—lying where they had been placed 5,000 years before. Inscriptions on the clay seals of jars led us to believe that the tomb belonged to a great noble named Hemaka, vizier of the pharaoh Udimu. This was the greatest single discovery of First Dynasty material that had been made up to that time. Its importance was at once appreciated by the Egyptian Government and I was given permission to explore the whole area systematically.

Digging continued from 1935 until the beginning of World War II; one great tomb after another was cleared, each showing that civilization during the period of the First Dynasty was far more advanced than we had supposed. Tombs contemporaneous with the kings Hor-Aha, Zer, Udimu, Enezib and Ka-a were discovered—all much larger and more elaborate in design than their counterparts at Abydos. We knew that these kings originated at This near Abydos, but that they conquered the lower Nile Valley and established their capital at Memphis. Thus it seemed possible and even probable that the tombs at Sakkara were their actual burial places, and that the structures at Abydos were empty monuments. Only further excavation could confirm this theory, but at the outbreak of the war the work was shut down. With the exception of a short season in 1946, nothing further was done at North Sakkara until 1952. In that year an arrangement was made whereby the Egypt Exploration Society reopened the excavations on behalf of the Department of Antiquities. The clearance is still in progress.

In 1952 we discovered a tomb which probably belonged to Uadji, the third pharaoh of the First Dynasty; in the following year we excavated another which we ascribed to Ka-a, the last king of the dynasty. A third large tomb was cleared in 1955, and although its ownership could not be established it supplies conclusive evidence that all the burials almost certainly belonged to the kings, queens and princes of the First Dynasty.

These big tombs of the First Dynasty have the same fundamental design: a large pit cut in the ground, within which were built the burial chamber and subsidiary rooms [*see drawing on pages 110 and 111*]. Here were stored the owner's most precious possessions. This

this photograph of the area around North Sakkara, 15 miles from Cairo. In the distance at the far left are three pyramids of the Fifth Dynasty. Beyond them are the three famous pyramids built by the Fourth Dynasty kings Khufu (Cheops), Khafra and Menkaura.



SITES mentioned in this article are located on a map of the Nile Valley. The pharaohs of the First Dynasty originated at This but later established their capital at Memphis. It was once thought that they were buried at Abydos, but it now appears that their graves are at Sakkara. Tarkhan, Nagadeh and Hierakonpolis are other sites of the First Dynasty.

substructure was covered by a large rectangular superstructure of brick, enclosing chambers in which were stored reserve supplies for the use of the deceased in afterlife. This was only the general scheme of the funerary edifice; refinements and developments occurred in rapid succession throughout the 250-odd years of the dynasty. The developments were confined principally to the substructure; the superstructure increased in size but remained largely unchanged. These great buildings, made only of unbaked brick, were undoubtedly dummy copies of the actual palaces of the kings. Although they now stand only five feet above their foundations, there is evidence that they originally rose to a height of not less than 30 feet. The elaborate recess-paneling of their exteriors was gaily painted with geometrical designs simulating the colored matting which adorned the interior walls of buildings at that time.

Although the burial chambers were ravaged and, in many cases, set afire by plunderers, we can reconstruct them with considerable certainty. The deceased lay slightly bent on his right side within a great wooden sarcophagus measuring about 10 by six feet. Outside the sarcophagus were furniture, games for the amusement of the deceased, and his last meal, served in vessels of alabaster, diorite, schist and pottery. These meals were of an elaborate character, consisting of soup, ribs of beef, pigeon, quail, fish, fruit, bread and cake. We found such a meal remarkably preserved in a tomb of the early Second Dynasty, and from fragments found with burials of the First Dynasty we have every reason to suppose that the same rich repast was left during the earlier period. Other rooms in the substructure were devoted to the storage of wine and food, furniture, clothing, games, tools and weapons of flint and copper. Similar objects were stored in the chambers of the superstructure: hundreds of great wine jars, furniture inlaid with ivory, toilet implements, agricultural equipment—all the appurtenances of a well-organized and highly developed civilization.

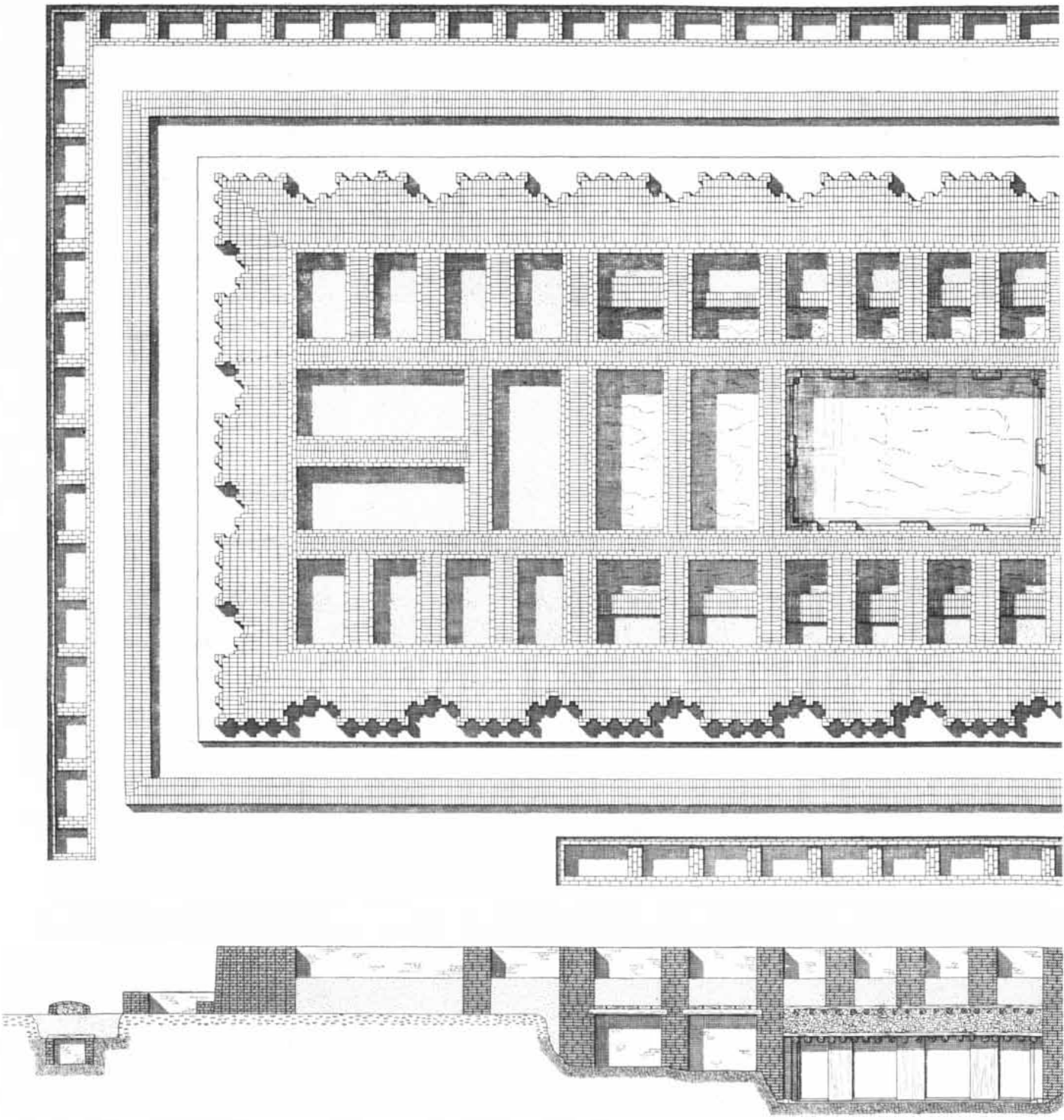
The principal evolution in the design of the substructure was the introduction of a stairway entrance which enabled the architect to build the whole funerary edifice before the burial. Before this innovation had been introduced the superstructure was built after the burial—obviously an unsatisfactory arrangement. At the end of the First Dynasty a small funerary temple was built at the north side of the tomb; both tomb and temple

SUPERSTRUCTURE of a First Dynasty tomb is exposed by excavation. The recessed walls of the superstructure originally stood at least 30 feet high and were painted with geometrical designs. This is probably the tomb of Queen Meryt-Nit of the First Dynasty.

CLAY MODEL of an ancient Egyptian estate is excavated beside the tomb of Hor-Aha, the first king of the First Dynasty. Such models may have been small-scale copies of the royal estates, presumably to be re-created for the use of their owners in the afterlife.

were enclosed by walls with an entrance to the east. In this final evolution of the First Dynasty tomb we have the prototype of the pyramid complex of later dynasties.

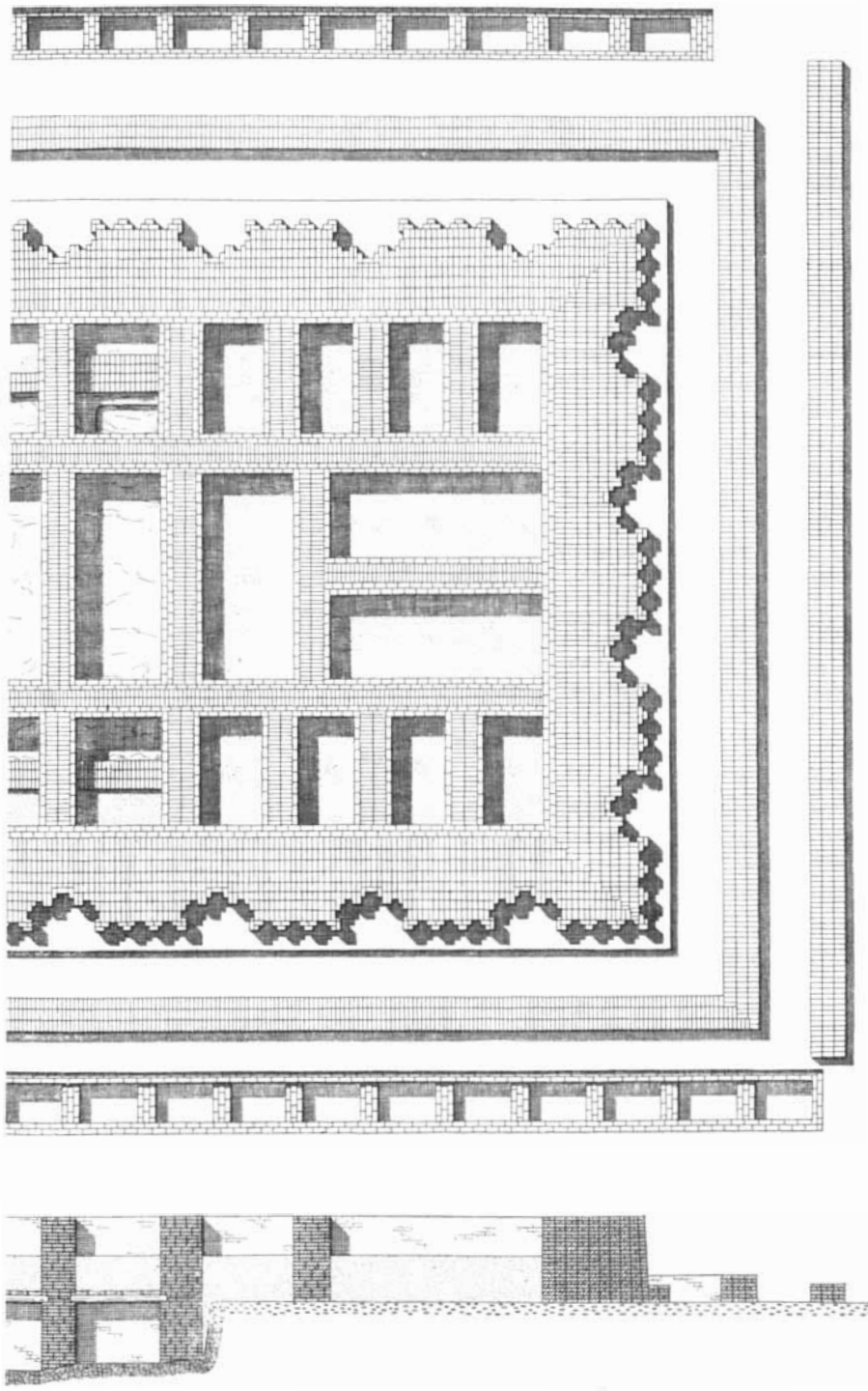
We still have much to learn about the earliest First Dynasty tombs, which are perhaps the oldest examples of monumental architecture in the world. They are not entirely what they seem. In the course of our excavations we have often been puzzled to discover stairways and passages which lead nowhere. For a time we were inclined to dismiss these mysterious features as the result of alterations in the architect's plans. Now we know that the tombs were built in two distinct stages. First they were raised to serve some unknown purpose; then, after this purpose was fulfilled, they were altered so that they could serve



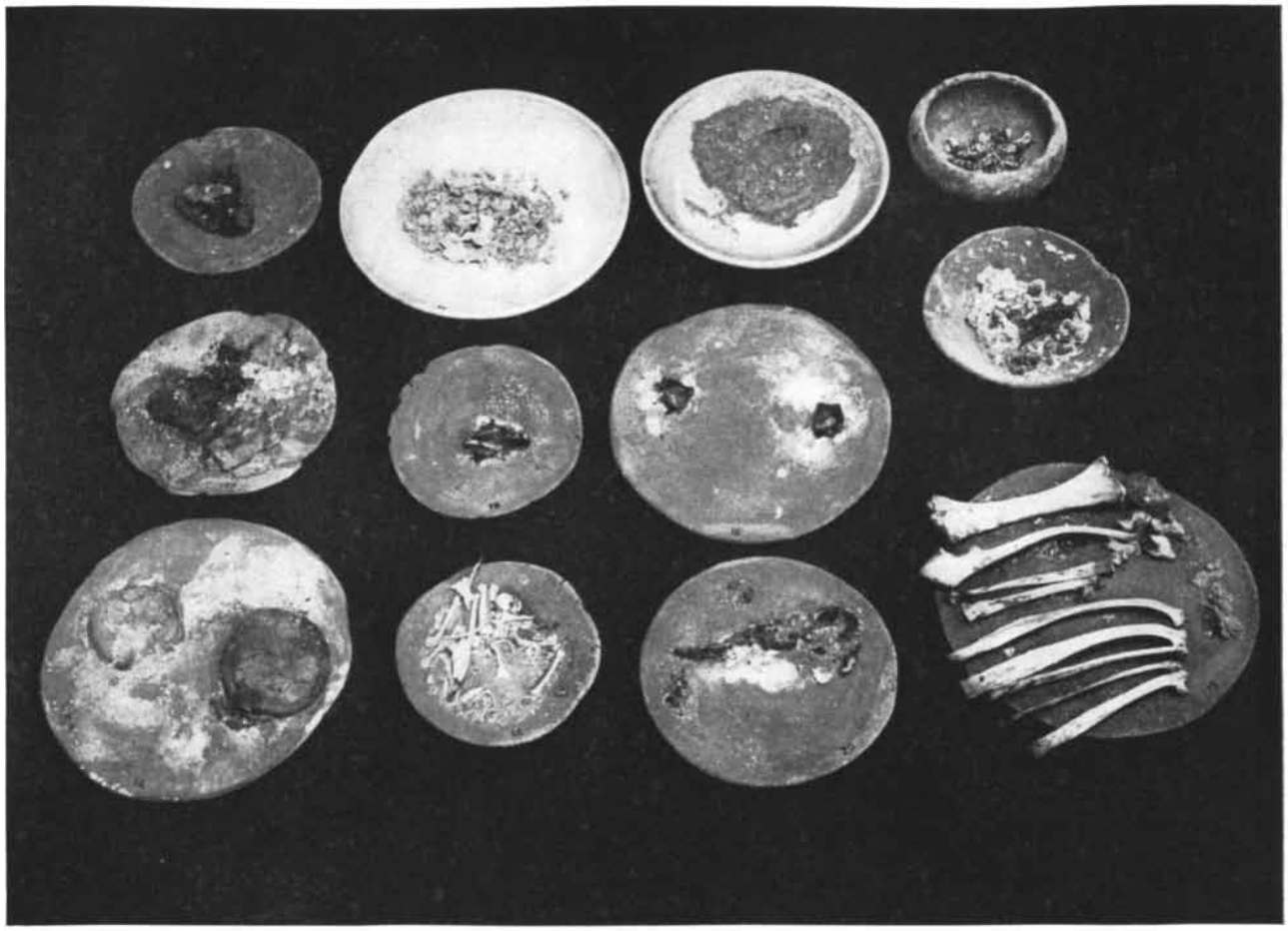
TOMB IS RECONSTRUCTED in plan and elevation by these drawings. This is Tomb 3504 at Sakkara. It is dated to the reign of Uadji, third king of the First Dynasty. The tomb is roughly 200 feet long and 100 feet wide. In the center is the burial chamber. Around

their final function as a house of the dead. We are still entirely ignorant as to the purpose of the original structure, and we can only hope that further excavation will give us the answer to this fascinating question.

The complete funerary installation consisted not only of the tomb, but also of surrounding graves of retainers sacrificed to accompany the king in death as in life. These small graves are of great interest, for we often find objects buried with the dead retainer which indicate his occupation: paint pots with the art-



it are many rooms for the storage of food and other goods. The long rows of small chambers on three sides of the tomb are the graves of retainers sacrificed to accompany the king.



FUNERARY MEAL found in a tomb of the early Second Dynasty is in a remarkable state of preservation, considering that it was set out some 5,000 years ago. Fragments found in tombs of the First Dynasty indicate that similar meals were buried with its pharaohs.

ist, model ships with the shipmaster, varieties of pottery with the potter, and so on. Around the tombs we frequently find the remains of gardens with rows of trees and plants. Near one tomb is a clay model of an estate with houses, granaries and fields. It is tempting to see in this model an exact copy of the royal estate, to be re-created in the next world for the service of its dead owner. Beside the tomb of Udimu are the remains of a wooden ship to carry the pharaoh with the celestial gods in their voyage across the heavens. This vessel, which was 50 feet long, was built 400 years before the recently discovered ship of Cheops.

There are still other sites of the First Dynasty awaiting excavation. It is thus a little early to come to any conclusion regarding the origin of civilization in the Nile Valley. Enough has been disclosed, however, to show that a highly developed culture existed in Egypt by 3000 B.C. In assessing this culture we must remember that we do so on evidence which has survived 5,000 years of destruction by nature and man. But even in their ruined state the magnificent monuments of Sakkara, Abydos and other sites show that they were built by a people with an advanced knowledge of architecture and a mastery of construction in both brick and stone. The scattered contents of their tombs show that they had a well-developed written language, a knowledge of the preparation of papyrus and a great talent for the manufacture of stone vessels, to which they brought a beauty of design that is not excelled today. They also made an almost unlimited range of stone and copper tools, from saws to the finest needles. Their decorative objects of wood, ivory and gold are masterly, and their manufacture of leather, textiles and rope was of a high standard. Above all they had great artistic ability: the motifs of painting and sculpture that were characteristic of Egypt for 3,000 years had already appeared.

This advanced civilization appears suddenly in the early years of the third millennium B.C.; it seems to have little or no background in the Nile Valley. Yet the Valley had been inhabited for a long period before the First Dynasty. Excavation has indicated that during this period burial customs developed little; the passage of time is marked only by changes in the design of pottery and other objects. The people of the period had an advanced neolithic culture which certainly made a contribution to the later Egyptian civilization. In my opinion, however, their culture does not provide a complete foundation for the Egypt of the pharaohs. It is of course possible that the architecture of the First Dynasty was the product of a superior people inhabiting the delta of the Nile, where constant flooding and agriculture has destroyed all remains of the period before the pharaohs. Since there is no evidence for or against this theory, it must remain speculative. In any case I feel it is unlikely that such a civilization could develop independently in the marshlands of the delta and suddenly impose itself on the upper Nile Valley. It is significant that during

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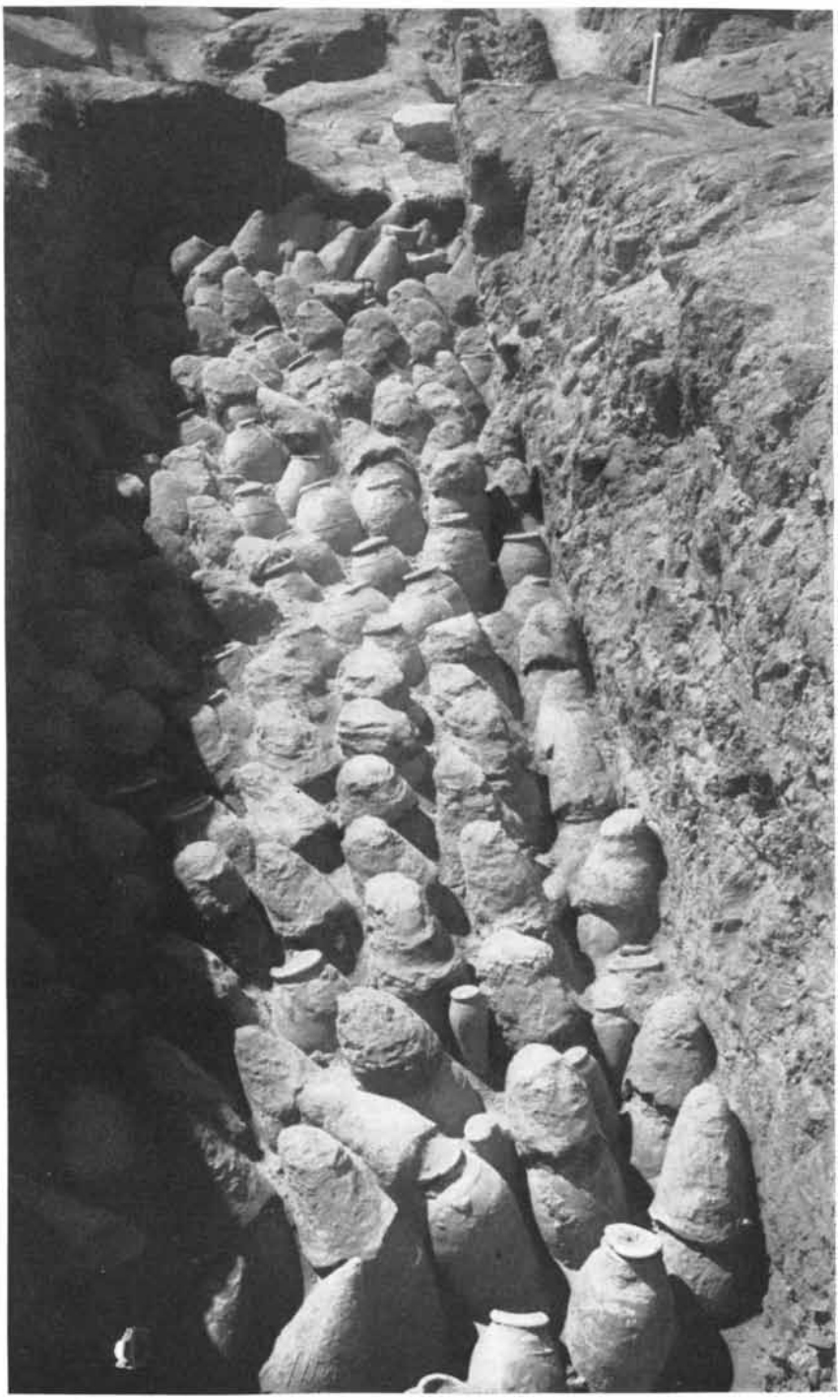
the First Dynasty only the nobles and officials were buried in monumental tombs. The mass of the people were buried in graves consisting of shallow pits with no superstructure beyond a circular mound of earth. The body lay in a huddled position on its left side; except for the objects in it such a grave had little to distinguish it from those of the period before the First Dynasty. By the end of the Second Dynasty we find the mass of the people had adopted the burial customs of their betters: the design of their tombs was the same in almost every detail except size. All this plainly suggests the existence of a superior culture which gradually imposed its burial customs on the conquered indigenes.

If we accept the theory that the



JARS CONTAINING WINE for the afterlife were stored in the superstructure of this First Dynasty tomb. The stoppers of the jars are stamped with the name of their owner.

SKELETON OF A SERVANT lies in one of the graves that surround the First Dynasty tombs. The small graves often contain objects which identify the occupation of the servant.

civilization of the pharaohs was brought to the Nile Valley by a new people, we must ask: Who were they and where did they come from? The British historian Reginald Engelbach suggested a horde invasion, and there is evidence to suggest something of the sort. We must not overlook, however, the possibility of gradual infiltration over a long period. The monumental architecture of the First Dynasty has been compared to that of the Jemdet Nasr period in Mesopotamia, and I think the similarity is beyond dispute. But there are also great differences, so a direct connection between the Euphrates and the Nile at that time is still a matter of doubt. Thus the problem of how the civilization of the pharaohs originated remains unsolved. It is to be hoped that the further work of the Egypt Exploration Society will contribute to its solution.

New trends and developments in designing electrical products...

- First radially heat-treated magnets ever mass-produced
- G-E thermistor makes new temperature controls more sensitive

G-E Magnet Engineers turn idea into reality

The physicist at Roanwell Corp., Brooklyn, New York, had the idea – but it took a revolutionary development in magnet manufacture to make it come true.

Roanwell was working on a new receiver for military headsets sensitive enough to distinguish sounds clearly, even under combat conditions.

A new, dynamic receiver design solved the sensitivity problem. But then the weight and height of the unit had to be reduced to make it less bulky in the aviator's helmet.

Original specifications called for an assembly of several magnets which was smaller than the plug-type magnet normally used. But the Roanwell physicist's idea was to use a *single* radially heat-treated Alnico 5 magnet to reduce the size still further, and eliminate extra fabrication steps.

No one had ever mass-produced a radially heat-treated magnet like this before (Fig. 1). And no one knew if it could be done. So Magnet Engineers from General Electric were called in to try.

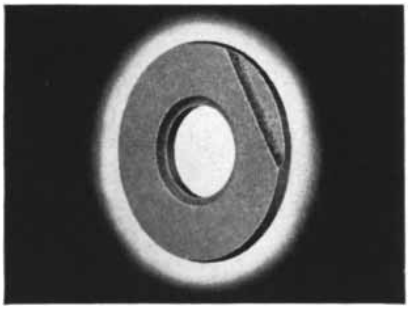


Figure 1

They solved the problem all right. But here's what they had to go through to do it:

First, they came up with special directionalizing equipment to orient the magnetic domains so the magnet could be magnetized radially.

Next, with engineers in G.E.'s unique Quality Standards Laboratory, they worked out the processing technology for mass production.

This meant starting from scratch to determine the initial heating temperature, rate of coiling, best field shape. It meant calculating axes of the directionalizing coil, computing proper aging time and temperature. And finally, it meant thorough testing and careful control of production.

The result: Roanwell is now using the first commercially produced radially heat-treated magnets (Fig. 2). The magnet produces the same flux density, but it requires less height (in fact, about half the height of a plug magnet).

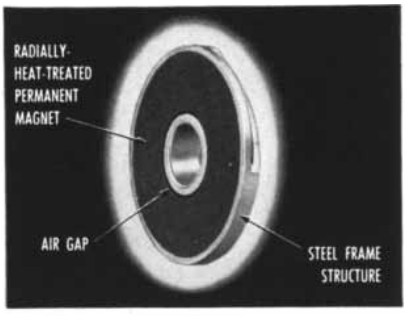


Figure 2

Because a single magnet is used, the unit is stronger, more reliable . . . and has the needed sensitivity. Equally important, the magnet can be machined accurately. This is critical because the circular air gap for the vibrating coil (see Fig. 2) is only a few thousandths wide, and magnet tolerances must be held as tightly as possible.

For Roanwell, G-E Magnet Engineers came up with this new method for mass-producing radially heat-treated magnets. For other manufacturers, they have handled jobs ranging from the design of complete magnetic circuits to development of new magnetizing and testing procedures.

Whatever the problem, G-E Magnet Engineers have the experience, skills, and the facilities behind them to solve it.

To get their expert design assistance, or your copy of the new G-E Magnet Design Manual, all you have to do is write: *Magnetic Materials Section, General Electric Company, 7810 N. Neff Road, Edmore, Mich.*

G-E thermistor gives new temperature control sensitivity to 0.075° F.

Furnace heat maintained at given levels, and alarms sounded when temperatures exceed specified limits – both can be controlled by a new device called the "Simplytrol."

The Simplytrol is made by Assembly Products, Inc., Chesterland, Ohio. It responds to changes as small as 0.075° F. because it uses a G-E thermistor as the sensing device.

The thermistor is one leg of a bridge in circuit with a D'Arsonval meter relay. (Fig. 3).

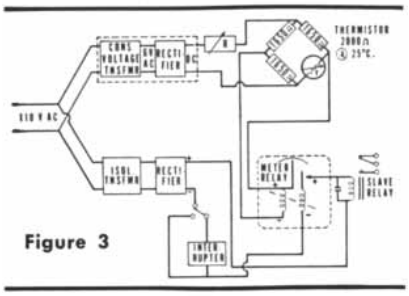


Figure 3

Because the thermistor has a large *negative* temperature coefficient of resistance, even minute changes unbalance the bridge to let the current actuate the relay.

The thermistor is more sensitive than other types of sensing elements. And in the Simplytrol, it can be wired up to 200 feet from the control without affecting accuracy.

In these and similar devices, the thermistor senses changes in ambient temperature. However, when it is heated by the current of the circuit, a whole new range of applications is opened: voltage regulators, time delays, sequence switching devices.

If you have problems in these application areas, experiment in your plant with G-E Thermistor Kits – they're only $12.50 each. To find out which is best suited to your needs, write: *Magnetic Materials Section, General Electric Company, 7810 N. Neff Road, Edmore, Michigan.*

Progress Is Our Most Important Product

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The Geography of Birds

Although they are free to fly wherever they please, few birds are cosmopolitan. After 150 million years of evolution in a constantly changing environment, most species are confined to provincial abodes

by Carl Welty

When birds took to the air, some 150 million years before the Wright brothers, they had a highway to every possible habitat on the earth's surface. Today they are at home in the polar regions and the tropics, in forest and desert, on mountain and prairie and on the ocean and its islands. Yet when one considers the superb mobility of birds and the eons of time they have had to populate the globe, it is surprising how few cosmopolitan species there are. Some shore and sea birds—sandpipers and plovers, petrels and gulls—are fairly world-wide in distribution. The barn owls, kingfishers, hawks and acrobatic swallows are at home on every continent. Ravens have inherited the earth except, for some obscure reason, South America. But what we mostly see, especially in land

BROWN PELICAN is restricted in range by its feeding habits. It must be able to see the swimming fish it seizes in plunging dives. The turbidity of the Atlantic at the mouth of the Amazon [*see map on page 122*] bars it from that region and the waters farther to the south. This and all the other photographs that accompany this article were provided by the National Audubon Society.

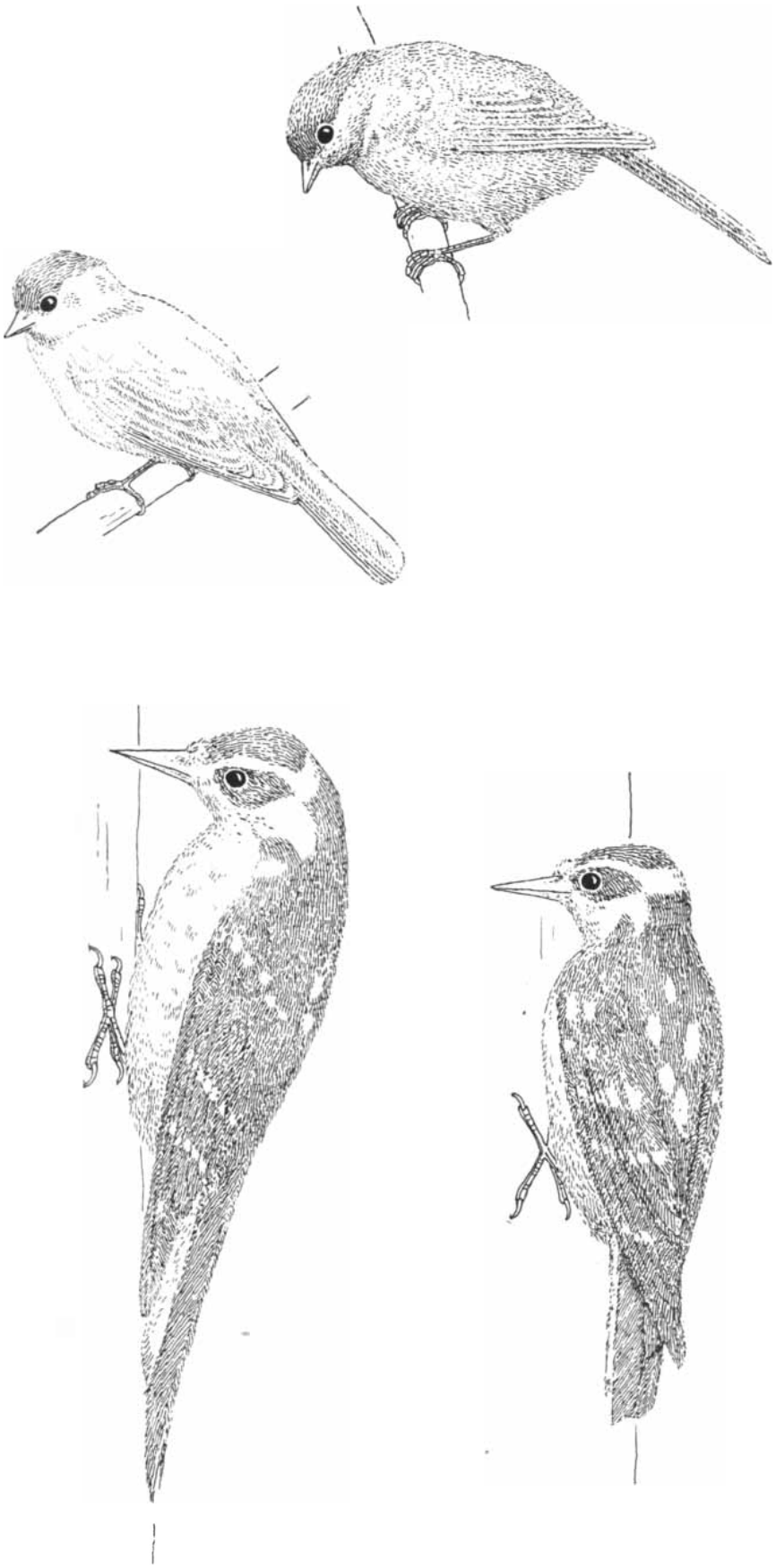
birds, is a picture of curiously limited and seemingly haphazard distribution.

Why are the birds of England and Japan more alike, though 7,000 miles apart, than the birds of Africa and Madagascar, separated by a mere 250 miles? Why does South America have more than 400 species of hummingbird and Africa, with quite similar habitats, not a single one? Why have the finches, found on even the most isolated oceanic islands, not found their way to Australia? Why does the North American turkey, Benjamin Franklin's nominee for our national bird, occur nowhere else in the world? How explain the even more circumscribed range of the wirebird plover, unique to the little island of Saint Helena; or the confinement of a species of Ecuadorian hummingbird to the slopes of the volcano Chimborazo at an elevation of 16,000 feet; or the perilous distinction of the 161 remaining Laysan teal that inhabit the tiniest range of all, the shores of a marshy lagoon, one square mile in area, on the tiny Hawaiian island of Laysan?

The main scheme of the world distribution of birds was laid out by Alfred Russel Wallace in his monumental *Geographic Distribution of Animals,* published in 1876. His six great zoogeographic regions today provide a useful way to sort out the distribution of species, as shown in the map on the next two pages. But this still does not explain how the birds came to be distributed as they are. As a Darwinian intensely aware of the dynamic nature of evolution, Wallace could have told us that we must seek our answer in the interplay of two great dynamic agents: the perpetually changing environment and the unending evolution of the birds.

A restless world of heaving earthquakes, wandering shorelines, shifting climate and changing coats of vegetation can scarcely be expected to have sedentary tenants. A species' range is not likely to stand firm before the chilling, grinding advance of a glacier. We dig up the bones of large ostrich-like birds in the U.S.S.R. and the U. S. The fossils around Paris tell us this was once the home of now pan-tropical trogons and parrots. Ancient guano deposits in Peru show how the native pelican shifted from place to place during prehistoric times.

But birds are not mere passive creatures of these forces. The very geological and climatic changes that move and isolate existing species provide the mechanism of natural selection through which new species evolve. The families



PIGMENTATION AND SIZE of bird species are correlated with climate. British chickadee (*upper right*) is more heavily pigmented than Siberian chickadee (*upper left*). Hairy woodpecker of Canada (*lower left*) is larger than the same species in Costa Rica (*lower right*).

of modern birds, though established as late as the Miocene, have still had enough time to undergo many profound genetic changes. These in interaction with the changing environment have played their part, too, in distributing species around the globe. The migratory birds that summer in the temperate latitudes and winter in the tropics must have evolved during the comparatively recent millennia in which the world developed its present climatic system. But evolution does not always provide for maintenance and extension of range. The Ascension man-of-war bird, for instance, is a splendid sea-flyer, yet cannot venture far from land. Its oil-producing preen gland has become so small that it cannot alight on the ocean without becoming waterlogged, and it is endangered if caught too far from shore by a heavy rain.

Wallace's map, then, is a single frame from a motion picture, a moment arrested in a long history. To understand how it came about requires the accounting of many factors. Principal among these are the arrangement of the earth's land and sea masses, the circulation systems of the oceans and of the atmosphere, climate, the availability of plant life and the competition of animal life. By considering what each element contributes to the picture alone and in concert with others we can begin to reconstruct the history that lies behind the present geography of birds.

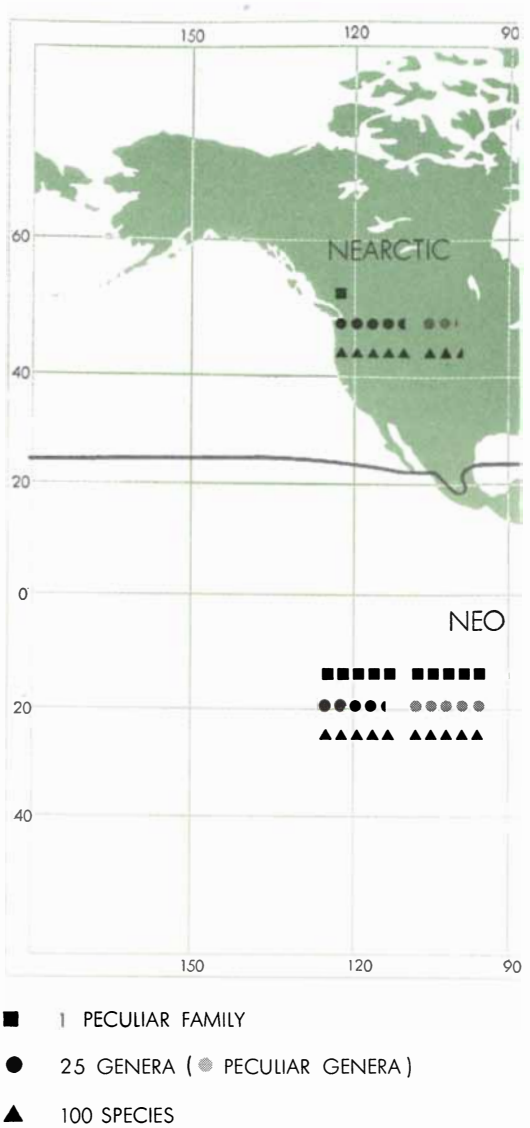
Let us consider first the accidents of geography. It is obvious that land masses are barriers to the spread of sea birds and that the seas are barriers to land birds. This leads straight to the explanation of why South American birds are so different from those of North America: It is because the two continents were so long separated by a sea before the Isthmus of Panama was thrust up. Conversely the fact that many North American birds are closely related to Asiatic species clearly means that their ancestors must have come over "from the old country" when the Bering Strait was a land bridge.

We can see the same processes going on today. As Ernst Mayr of Harvard University has observed, the geologically active regions are also regions of active species-making. The tributaries of the Amazon have cut the forest bordering the river into great "islands," each of which has isolated its distinct but related species of birds. The geologically recent building of the Andes split apart numerous populations of tropical birds in Colombia and Ecuador. They have evolved into new species, with those on the Pacific side of the range having their nearest relatives across the peaks in the Amazon basin. Just as mountains may isolate species, so mountain passes can provide bridges to join them. The ornithologist Frank Chapman described one pass where the tropical zone reaches nearly up to the saddle. Here we can actually see a large reservoir of species ready to spill over into a new and enlarged range the moment a saddle sinks, or the life zones rise, a few hundred feet.

Once a species surmounts a barrier, it may invade and colonize an enormously larger range with explosive speed, as did the starlings here or the skylarks in New Zealand. About 20 years ago the Old World cattle egret somehow made its way to South America, where it prospered mightily. Now it has reached the United States and is already consolidating its invasion by breeding.

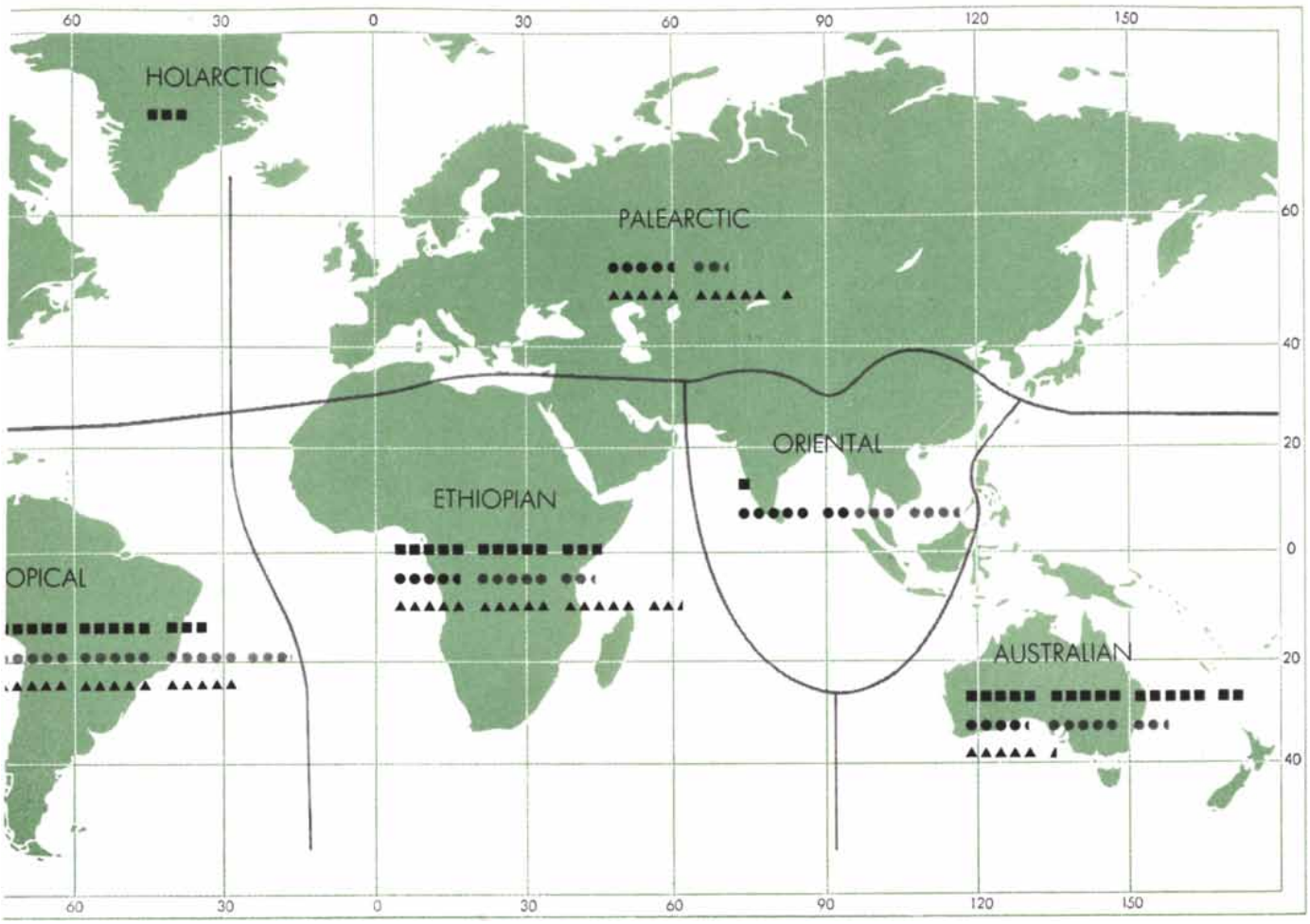
The winds set up by the circulation system of the atmosphere have played the decisive part in distributing some species. For birds as for planes the flight west across the Atlantic in the teeth of the prevailing westerlies is more difficult than the reverse trip. Only five species of wild European land birds have been taken alive in North America; in Great Britain, with but one tenth the coastline, there have been recorded 14 American land species, not to mention 25 aquatic. On the island of South Georgia in the Antarctic are two endemic species, a pipit and a teal, whose nearest relatives live 1,000 miles due west to windward, on the tip of Tierra del Fuego. The islands of the Caribbean are to the leeward of the late summer cyclones of the north equatorial Atlantic; hence they have received as guests from the eastern Atlantic one species each of the tropic bird, frigate bird and booby.

The circulation system of the oceans is important in the distribution of birds not only because it helps or hinders their locomotion but for its effects on climate and food resources. The royal tern, a warm-water species, is bottled up in the Pacific within 30 degrees of latitude, between the cool south-flowing California Current and the chilly north-flowing Peru Current. But in the Atlantic, thanks to the warm Gulf Stream and Brazil Current, its range covers 70 degrees of latitude, from Florida to Argentina. The shoemaker petrel, on the other hand, is tied to cold surface waters and is sandwiched in between the Antarctic pack ice and the Equatorial and Brazil currents. The 12-degree surface-water isotherm marks the northern limit of both the snow petrel and its chief food, the opossum shrimp.



Sea birds in general, unlike land birds, are more abundant in the cooler latitudes because the circumpolar waters are more fertile than the equatorial. Where cool upwelling currents bring nitrates, phosphates and other essential minerals upward into the sunlight, marine plants and consequently fish life abound. Hence the flying multitudes that follow the cold Peru Current, while the warm Sargasso Sea remains a silent watery desert.

The dependence of certain birds on the prevailing ocean currents is dramatically demonstrated on those occasions when nature experiments with the circulation of the oceans. Once about every

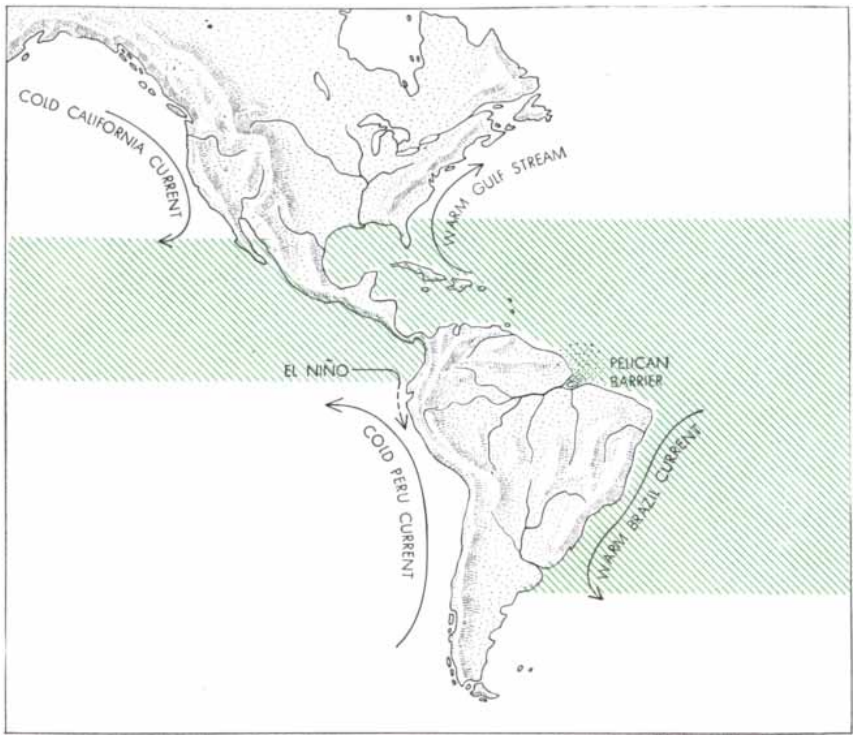


DISTRIBUTION OF BIRDS is mapped in the six zoogeographic regions proposed by Alfred Russel Wallace in 1876. The black squares tally the families "peculiar" to each region, but not all of the families in it. The black and gray circles together tally all the genera in each region; the black triangles, all the species. The Holarctic, comprising the two northern regions, has only three families peculiar to it. The contrast with tropical regions indicates that the latter have been the principal recent evolutionary center for birds.

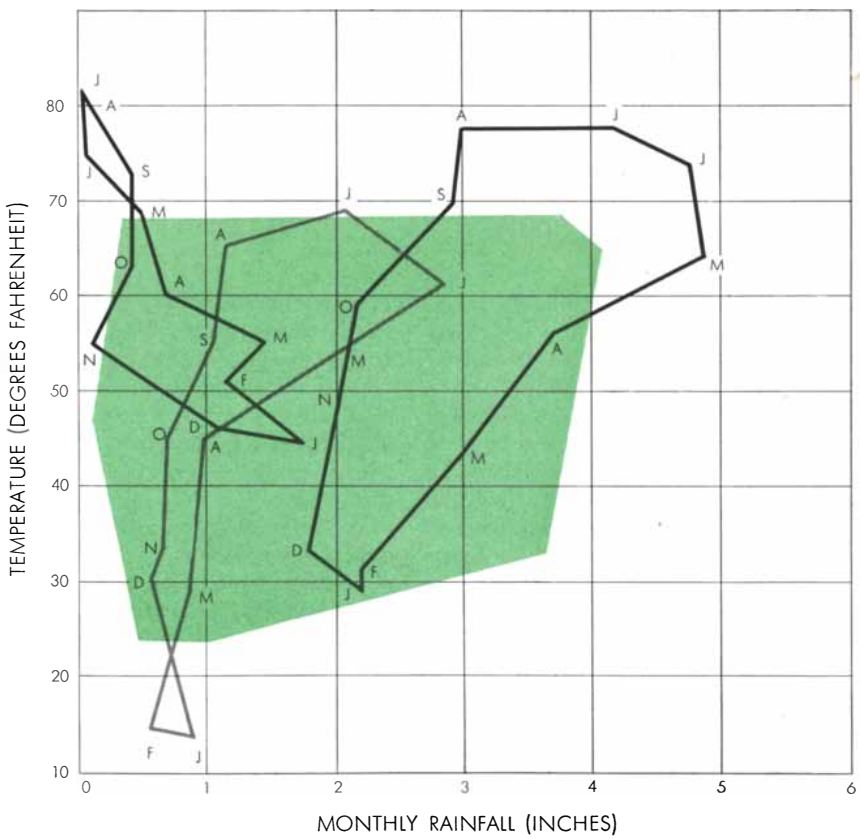
seven years *"El Niño,"* the warm equatorial countercurrent off Colombia and Ecuador, swings south, head-on into the Peru Current. In 1925 *El Niño* shifted its course so strongly that it warmed the littoral waters as far south as Arica, Chile, with these catastrophic effects: the Peru Current plankton died; the normal fish population died or fled and was replaced by warm-water species; hundreds of thousands of cormorants, boobies and pelicans perished or succumbed to disease; tropical sea birds moved down the coast, supplanting the sick and dying guano birds.

The distribution of sea birds, as has been indicated, runs counter to the major pattern of land-bird distribution. Some 85 per cent of all living species occur in the tropics, becoming progressively less abundant toward the poles. The major factor in these statistics is undoubtedly climate. Birds have special physiological problems of high body-temperature, rapid breathing and water conservation; all of these, to say nothing of food needs, are more readily solved in a warm, moist climate. This reflects the fact that more of the earth was tropical, humid and perpetually verdant in the Miocene and early Pliocene, when the birds were evolving. So today we find 1,780 species of birds breeding in Ecuador, 195 in New York State, 56 in Greenland and 3 in Antarctica.

The intimate and long-standing relationship between climate and bird distribution is reflected in the contrasting anatomy and physiology of warm- and cold-climate birds. The response of bird evolution to change of environment is so direct and systematic that it can be expressed in a series of biological rules. For example, species of birds living in colder climates will be larger than related species in warmer climates. This rule, which also holds for mammals, clearly results from natural selection in favor of the physiological advantage involved. Birds with larger bodies have relatively less surface through which to lose heat, a large bird being in essence the same as two or three small birds huddled together to keep warm. Birds in colder regions also have relatively shorter beaks, legs and wings from which to radiate body heat. According to another rule, the birds in the cooler part of a species' range will lay more eggs per clutch than those in the warmer. Egg counts by David Lack, the British ornithologist, show the European robin laying an average of 6.2 eggs per clutch in Scandinavia, 4.9 in Spain and 3.5 in the Canary Islands. Despite the short Scandinavian summer, birds can raise large broods of young because of the abundance of insect food and the long daylight hours. For less obviously adap-



OCEAN TEMPERATURE is important in the distribution of oceanic birds. The warm-water zone (*colored area*) of the Atlantic is wider than that of the Pacific; the currents in the two oceans account for the contrast. Caption on page 118 explains "pelican barrier."



CLIMOGRAPH charts monthly rainfall and temperature. The colored area is the optimum climograph for the European partridge. The black lines give the data for California (*left*) and Missouri, where this bird fails; the gray line describes Montana, where it succeeds.

tive reasons, birds and mammals in the tropics have more of the dark pigment melanin than their relatives in cooler climates. Where tropical birds have brighter and more metallic hues, those in the polar regions tend toward white.

The high correlation of range and climate in some species is clearly demonstrated when the climate changes. As is well known, the mean annual temperature of the Northern Hemisphere has been gradually rising during recent decades. It is equally common knowledge that many southern birds, like the cardinal, egret and mockingbird, have been slowly coming northward. In Sweden 50 years ago the hooded crow was a harbinger of spring; today it is a common winter resident. In Finland 262 bird species were known before 1885; now there are 298, the new ones coming mostly from southern Europe and the Mediterranean.

The principle of climatic distribution has been put to practical use in game management. Before a game species is transplanted to a new habitat a climograph, a chart combining temperature and humidity factors [*see illustration at bottom of this page*], is drawn up for its natural range and compared with that of its proposed home. Where the two match fairly closely, there is at least a chance that the transplant will take hold.

The concentration of bird species in the tropics is correlated with food supply as well as with climate. Since green plants supply the first step in the animal food chain, it follows that the verdure of the tropics offers more of all kinds of sustenance than other regions. Conversely it is clear that insect-eating birds must migrate southward from freezing temperatures when winter comes.

The connection between food supply and range is clearly indicated in cases of adaptation to special diets. Woodpeckers will scarcely seek wood-boring insects on steppes or prairies. Nectar-feeding hummingbirds must have long-season flower resources; some species are bound by the shape of their bills to particular flowering plants. The beaks of crossbills are peculiarly adapted to secure a diet of conifer seeds. The white booby specializes in the catching of flying fish; its breeding islands must accordingly lie in waters where they abound. Such narrow dependency is, of course, an invitation to extinction. When a natural catastrophe all but wiped out the eelgrass along the Atlantic coast of the U. S. in 1931-33, one of the many casualties was the sea brant that fed upon it; the numbers of this

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

AI develops reactors for largest power plants and smallest research labs

A wide selection of nuclear reactors, ranging in size from a 75-megawatt nuclear power plant to generate electricity, to a 5-watt laboratory instrument, have already been completed, or are at present under construction by ATOMICS INTERNATIONAL.

The Sodium Reactor Experiment, part of the Atomic Energy Commission's program to develop economical nuclear power, now undergoing tests in the Santa Susana Mountains near Los Angeles, will have an output of 20 thermal mw and will generate about 6.5 mw of electric power. It is the prototype of a full-scale sodium graphite reactor design, which will have a power output of 75 to 125 mw. ATOMICS INTERNATIONAL regards it as a promising reactor type for economical power generation.

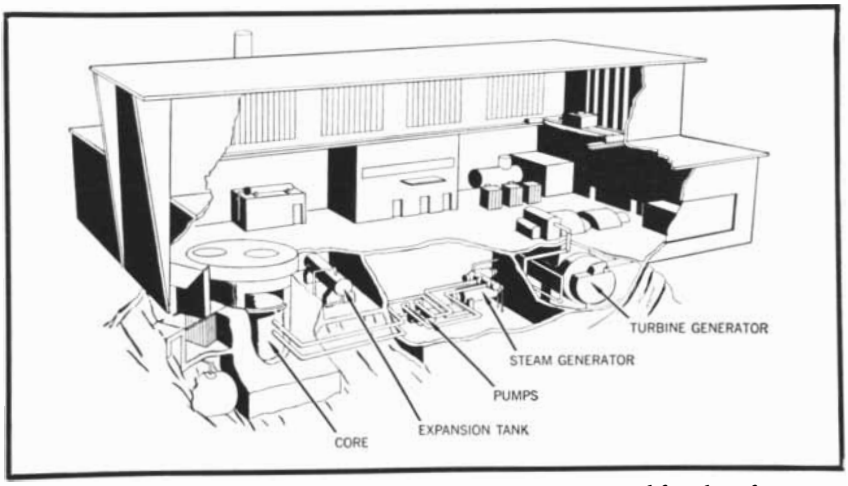
The Organic Moderated Reactor, a relatively new approach to economical nuclear power, is particularly appropriate for smaller plants. ATOMICS INTERNATIONAL is completing construction of the Organic Moderated Reactor Experiment for the Atomic Energy Commission at the National Reactor Testing Station in Idaho, part of a development program for the OMR. Basic advantages of the OMR include compact core with good neutron economy, low pressure coolant system, and freedom from corrosion problems. The OMR is also considered promising for ship propulsion, and ATOMICS INTERNATIONAL is making a design study of this reactor type for maritime use.

Research Reactors are now being built by ATOMICS INTERNATIONAL for Japan, Denmark, West Germany, and West Berlin. They are similar to the ATOMICS INTERNATIONAL reactor now in service at Armour Research Foundation, Chicago—the first to be designed specifically for private industrial research.

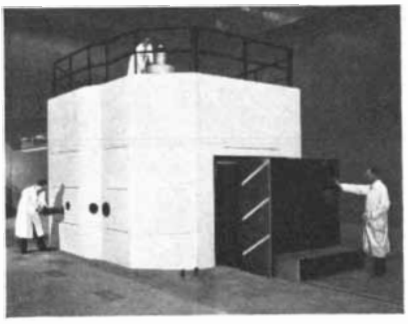
The Laboratory Reactor is a new, low-cost instrument designed specifically to meet the needs of universities and industrial laboratories for nuclear training and research.

ATOMICS INTERNATIONAL, one of America's major builders of nuclear reactors, is staffed and equipped to help you with any phase of reactor development. Please write: Director of Technical Sales, Dept. SA-73, ATOMICS INTERNATIONAL, P. O. Box 309, Canoga Park, Calif. Cable address: ATOMICS.

Reactor "heart". An AI technician installs zirconium "cans" containing the graphite moderator in the core of the Sodium Reactor Experiment. The use of a sodium coolant allows a high-temperature, low-pressure heat extraction system with high thermal efficiency of power conversion.



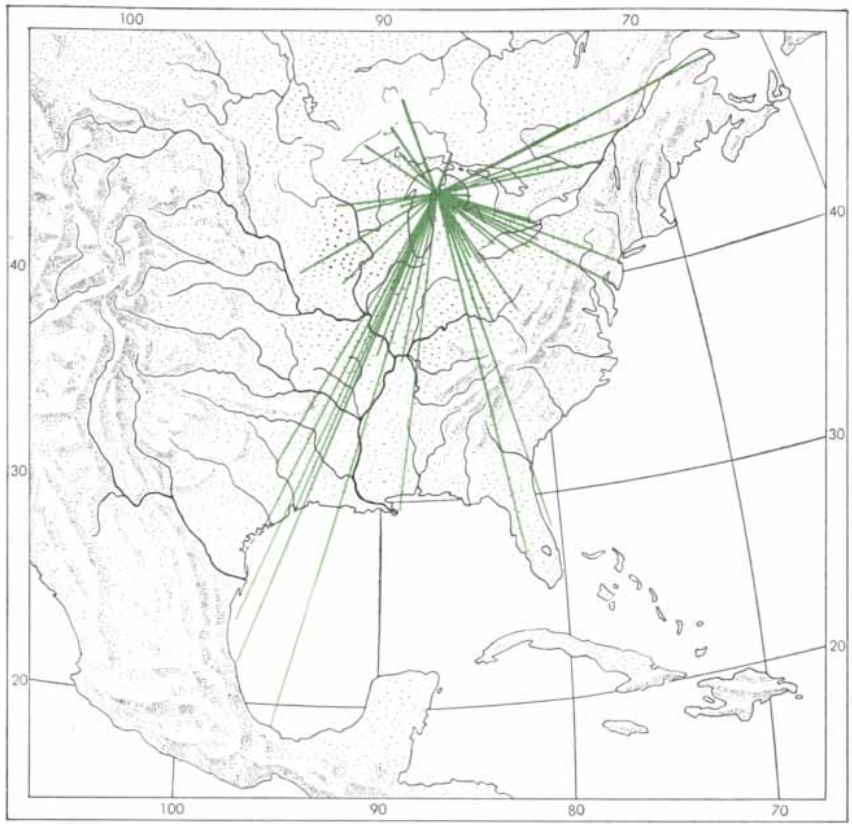
Typical OMR Central Station Power Plant. Basic advantages of OMR include small size, compact core, low-pressure system, and freedom from corrosion problems. This also makes it a promising reactor for ship propulsion.



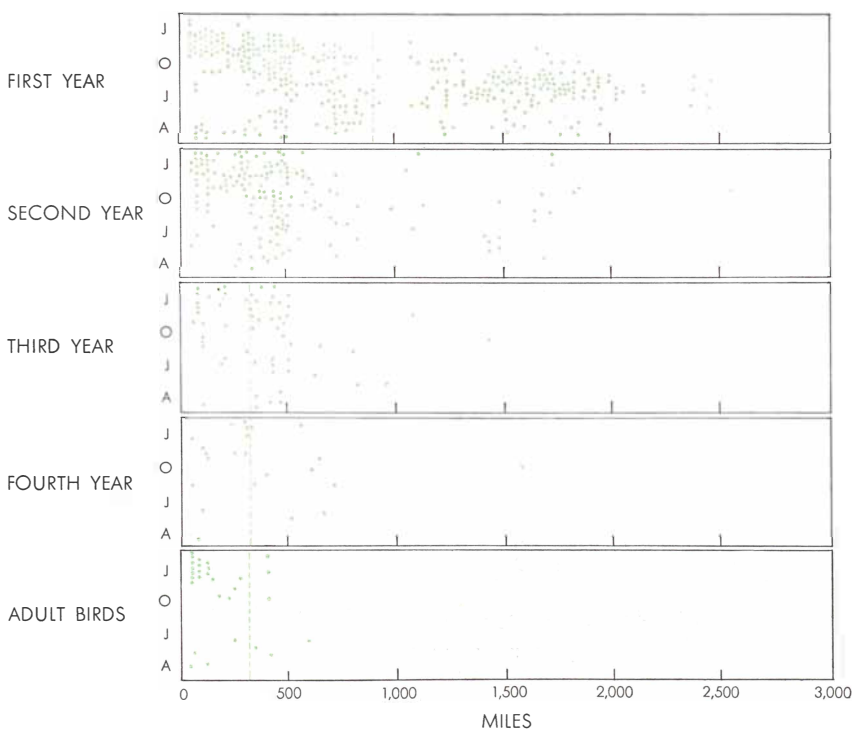
Armour Reactor is a 50 kw water-boiler unit for industrial research. It has nine beam tubes for experimental purposes.

Nuclear Nutshell. Laboratory Reactor operates at 5 watts of power and produces more than 100 isotopes. It can be operated by one trained man.

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.
PIONEERS IN THE CREATIVE USE OF THE ATOM



DISTANCES FLOWN by herring gulls, banded and released in the Great Lakes region, are charted here. Most of the birds recaptured at the most distant points were found to be yearlings. Dispersal tendency in young birds relieves population pressure on natal areas.



DISPERSAL TENDENCY of yearling herring gulls is indicated by this chart based upon recapture of 773 out of 23,434 nestlings banded in New Brunswick. The chart shows the age, the season of the year and the distance from home to the place of recapture of each bird. The mean distance traveled by the birds in each age group is indicated by the broken line.

goose were reduced by 80 per cent. Such a fate is not likely to overtake the wide-ranging South American kelp gull. Its diet includes fish, marine invertebrates and shellfish, the eggs and young of other birds, carrion, offal—in fact, almost anything.

The ranges of some species are fixed by adaptations to other aspects of their environment that may seem less compelling than food. For nesting sites Scott's oriole in the American Southwest is apparently dependent on the drooping dead leaves of the yucca; the European reed warbler, on beds of freshwater reeds; the palm swift, on the hanging fronds of the fan palm. The Tristan Island penguins depend upon the indigenous tussock grass to protect them from the elements and predatory gulls, and they reciprocally fertilize it with their droppings. The Bigua cormorant of Tierra del Fuego and the red-footed booby of Little Cayman in the Caribbean present a contrasting picture. They are tree-top nesters; sometimes they nest in such dense colonies that their guano kills the trees, compelling them to move on to new ones.

A force that seems always to promote the expansion of range and the wider dispersal of a species is the competition of other birds of the same species. Overpopulation—or the shortage of food, which is the other side of the same coin—gives a dramatic demonstration of its power in the occasional mass movements of a species, known as "invasions" or "irruptions." The snowy owl's repeated southward irruptions into the U. S. are known to coincide with the ebb years in the population cycle of the Canadian lemming. Siberian nutcrackers have invaded Germany 15 times between 1896 and 1933, each time when the pine-seed crop failed at home. Pallas's sand grouse has many times in years of drought burst out of its native steppes northeast of the Caspian Sea and swept in enormous numbers across Europe as far as Britain and Ireland. In the great invasion of 1888 the British Parliament, hoping to naturalize the bird, passed a special act for its protection, but four years later there was not a single grouse to be seen in all England. In these irruptions we see a momentary surmounting of normal barriers through the build-up of dispersal pressure from behind. They provide a mechanism for sampling new ranges, though they rarely succeed in establishing permanent new homes for the species.

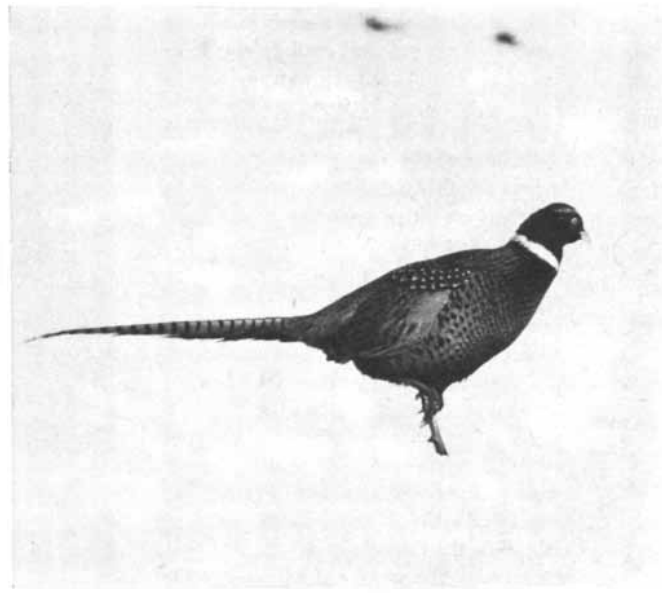
Competition within a species promotes the extension of range more com-

monly through what seems to be an inborn tendency in the young of all species to strike out and explore the world in all directions. Every new generation puts some added strain on the traditional habitat for food, territory and nesting sites, and the younger birds find themselves in unequal competition with the entrenched older ones. The wanderlust of first-year birds is the adaptive device by which natural selection has met this contingency. In Switzerland the banding of young barn owls showed that in years of high nestling productivity 57 to 68 per cent of them dispersed 50 kilometers or more from their natal nests; in years of normal productivity the percentage was only 37. Similar results were found by Alfred Gross in the banding of 23,434 herring gulls on Kent Island in the Canadian province of New Brunswick between 1934 and 1938. Of the 3 per cent recovered at points distant from Kent Island more than half were less than a year old and the great majority of these were captured hundreds of miles from their birthplace.

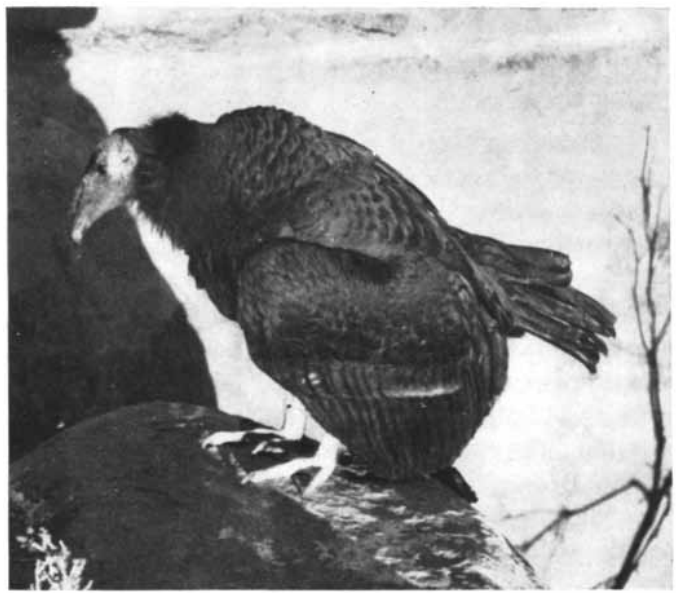
Seasonal migration is quite a different thing, but it also undoubtedly encourages the extension of range. Long-distance migrants are in a better position to discover new habitats, and they are naturally more tolerant of diversity in the environment. In the mountains of Colombia such winter visitors from North America as the yellow-billed cuckoo, the rose-breasted grosbeak and the yellow, blackburnian and mourning

HERRING GULL, shown here in adult plumage, is a wide-ranging bird, familiar in inland regions as well as on coasts of U. S.

SKYLARK, the common, field-nesting bird celebrated in Shelley's ode, was transplanted from Europe to New Zealand and has prospered there.



RING-NECKED PHEASANT, familiar to U. S. sportsmen, is an import, a hybrid of British and Chinese species.



CALIFORNIA CONDOR is nearly extinct. A carrion eater, it requires a wide range of undisturbed wilderness to sustain its life.

TURKEY is a genus peculiar to North America. Domesticated varieties now abound, but the wild bird is very nearly extinct.

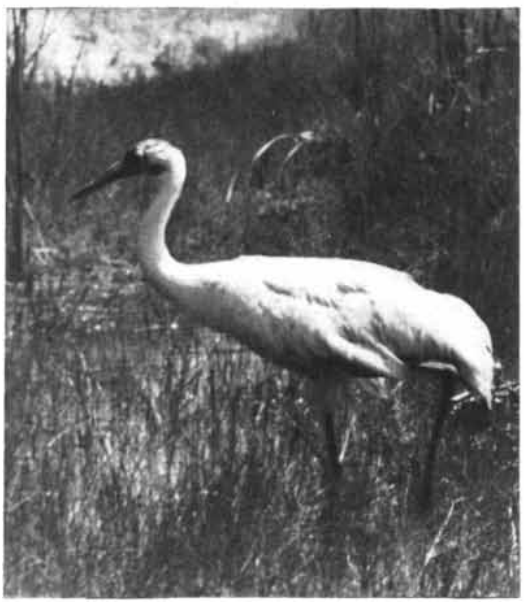
warbler have been observed ranging freely throughout the temperate, subtropical and tropical life-zones, whereas the permanent residents are more rigidly confined within zonal boundaries.

Competition between species, in contrast to the dispersal force of intraspecific competition, tends to confine species to narrower ranges. Lack observes that if two species of the same genus have the same diet, they rarely live in the same habitat. Competition between related species thus promotes the concentration of each in a slightly different locality. In this country the black-capped chickadee is without close relatives and ranges widely over forests and marshes. But in Europe this same bird must compete with eight other titmouse species and so breeds only in swampy thickets, leaving all its other possible habitats for relatives to enjoy.

The same sort of mutual accommodation is found even among unrelated species. The amateur naturalist T. E. Musselman tells of a late-spring freeze that killed several thousand bluebird eggs in the nesting boxes he had set up around Quincy, Ill. The birds laid substitute clutches, but this caused their incubation to coincide with the arrival of the house wrens from the south. In the ensuing competition for nesting sites the wrens destroyed many bluebird eggs. It may have been precisely to avoid such disastrous competition that natural selection had advanced the first nesting of the bluebird, thus permitting both species to occupy the same range.

Sometimes interspecific relations are even more accommodating. In Germany

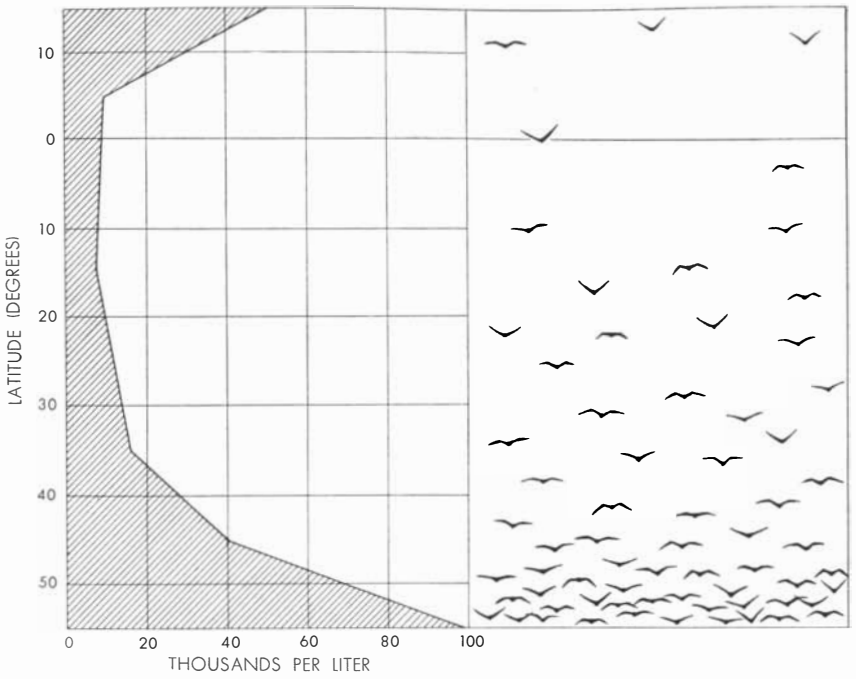
CATTLE EGRET, from Africa, is established in South America and is invading U.S.



WHOOPING CRANE is another nearly extinct American genus; some 30 survive.

the stock dove depends upon the black woodpecker to furnish it with nest holes. Small, defenseless birds have been known to build their nests in the margins of hawk and eagle nests, thereby securing the protection of their landlords against other predators.

On the other hand, it must be conceded that birds are not always so cooperative with one another. On Muskeget Island, off the coast of Maine, there used to be great colonies of terns. These were supplanted around 1940 by colonies of laughing gulls. Now the laughing gulls



DISTRIBUTION OF SEA BIRDS in Southern Hemisphere, roughly indicated at right, shows significant correlation with the concentration of plankton in ocean waters, indicated by the crosshatched area at left. Plankton provides food for fish on which the birds depend.

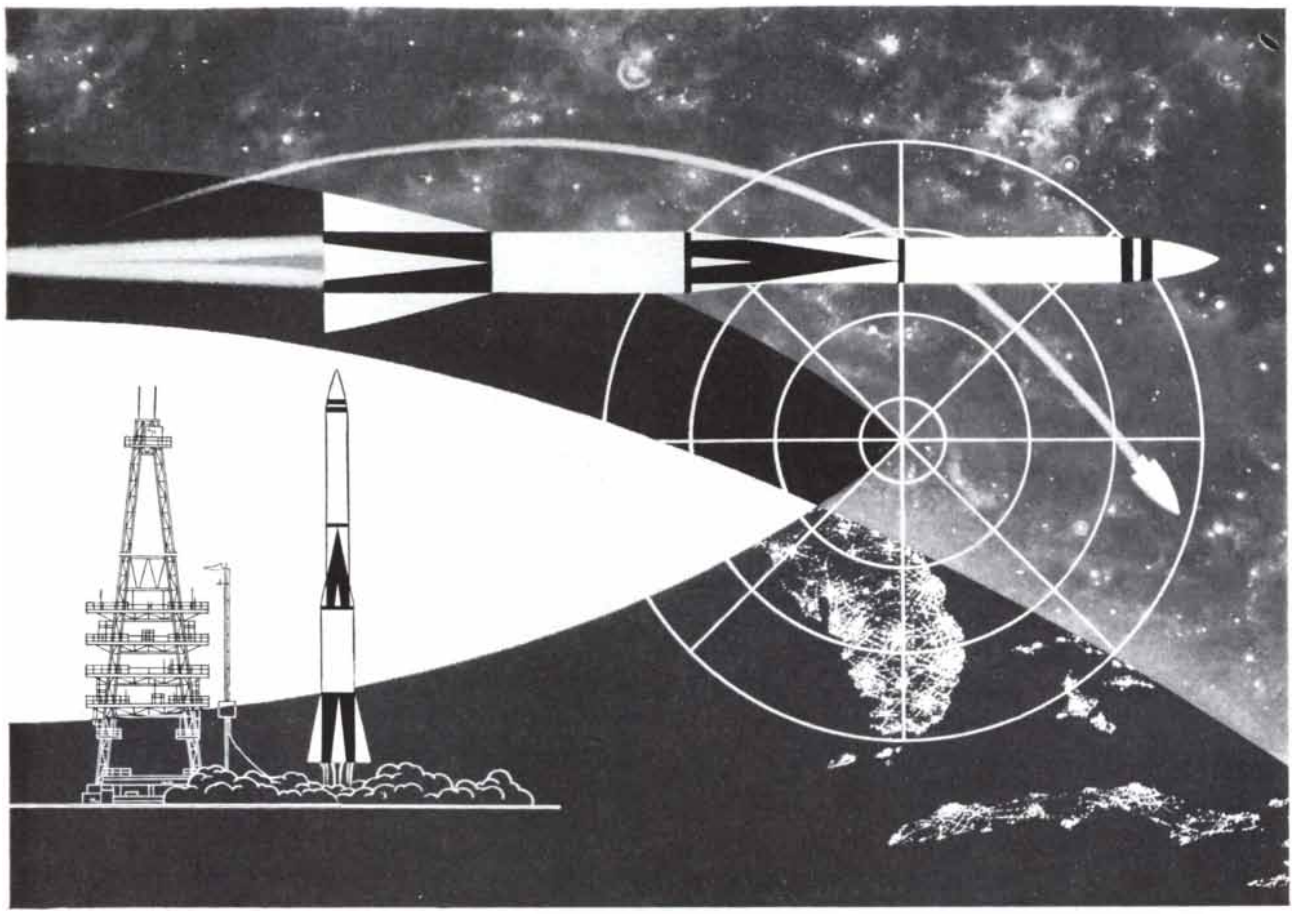
are being displaced by the more aggressive herring gulls. In rural areas of the U. S. the aggressive English sparrow has driven the cliff swallow from its former haunts under the eaves of barns and farmhouses.

Predators may close a habitat to a species, especially if they prevent it from breeding. In tropical forests many open-nesting species, like the pigeons, have been virtually eliminated by nest-robbing monkeys. Nesting ducks suffer heavy losses of eggs and young wherever there is an abundance of crows. Such predation may not be an unmixed curse; if the marauding crows did not force the ducks to stagger their egg-laying, their usually synchronized nesting would expose them to wholesale calamity in late-spring freezes.

The biological force that has had the harshest impact and most far-reaching effect on the geography of birds is man. In a few cases his cultural interference with the natural environment has encouraged the spread of a species, like the robin, barn swallow or chimney swift. The spread of the barn owl through the state of New York has been attributed to mechanical refrigeration and the resulting abandonment of old icehouses. But in the main man has been a force for restriction and extermination. The classic instruments of his predation have been the ax, the plow, the cow, fire and the gun. To which the modern era has added water pollution, insecticides and herbicides. Cats and rats have been known to depopulate oceanic islands of their birds, completely extinguishing a half-dozen species at a time. That byword for an extinct species, the flightless, ground-nesting dodo, was sent on its way by the pigs introduced onto the island of Mauritius.

Occasionally civilized man has tried to atone for his ecological misdeeds by importing foreign species. Alas, as with the English sparrow and the starling, only the less desirable species seem to take hold. The worst failures have been his experiments with the bird life of oceanic islands. There used to be about 40 passerine (perching) species on the Hawaiian Islands; more than half have been driven out by the hundred or more foreign species that have been imported there. Mayr says that more kinds of birds have become extinct on the islands of the Pacific than in all the rest of the world put together.

Even without man, of course, the bright tapestry of bird geography will continue to be alternately torn and mended by the wearing and restorative forces of nature. But since man has willy-nilly taken a hand in the process, we must hope he will acquire the wisdom to provide refuge for the most threatened species before they too go the way of the dodo.



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Powerhouse of the Cell

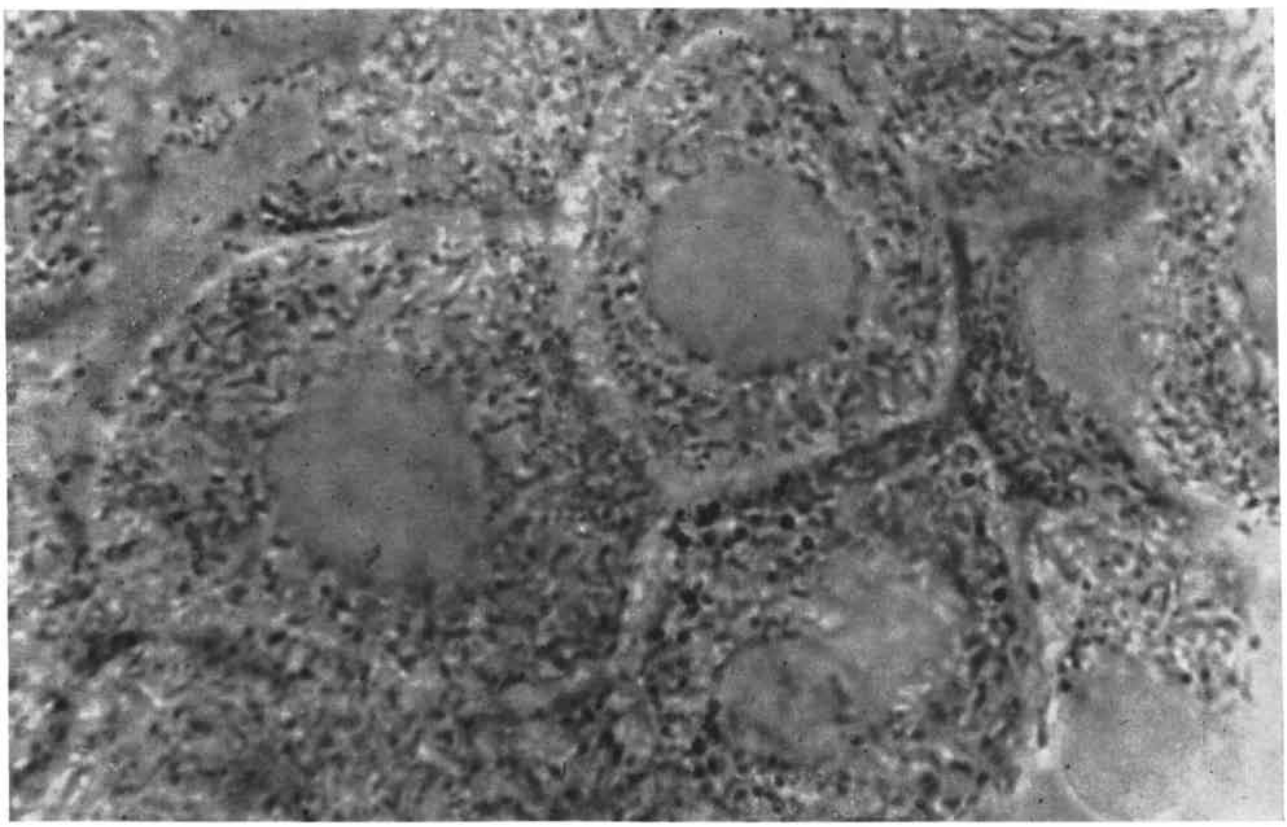
It is the mitochondrion, a small body which appears to play a central role in the oxidation of foodstuff. Its structure, as revealed by the electron microscope, mirrors its function

by Philip Siekevitz

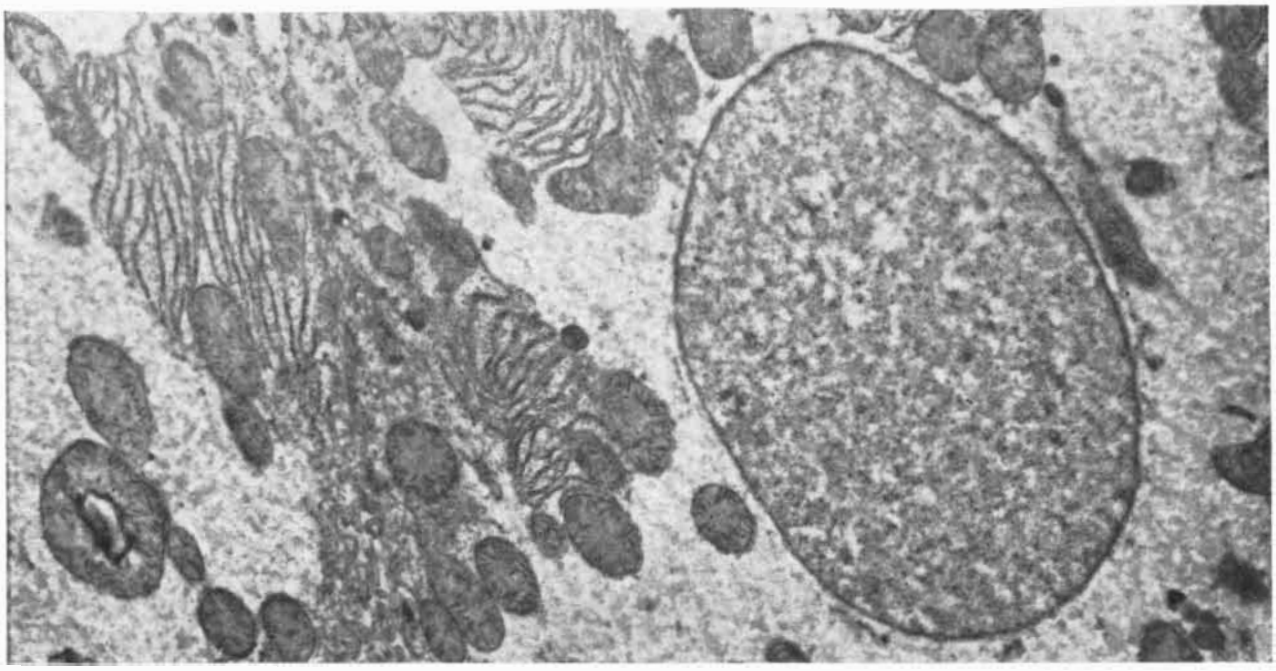
Nearly all living cells contain mitochondria, small bodies which are barely visible under a high-powered light microscope. Mitochondria are either spherical or rod-shaped, and they may change from one shape to another. When they are observed in living cells, they are in constant motion. The number of mitochondria in a cell varies with the kind of cell; the rat liver cell, which has been widely used in the study of mitochondria, contains about 1,000 of these bodies.

Mitochondria have been studied since the turn of the century, but it is only recently that progress has been made toward an understanding of their function. Today it appears that mitochondria supply the cell with most of its usable energy; they have been called the powerhouses of the cell. A cell without mitochondria is regarded as a biological curiosity, a ship without an engine. The red blood cell lacks mitochondria; it must rely on a less efficient source of energy which may be compared to the wind that drives a sailing ship.

Although the mitochondrion is barely visible under the light microscope, new methods of preparing cells for the electron microscope have revealed it in detail to the cell biologist, or cytologist. Over the years the chemistry of mito-



RAT LIVER CELLS each contain about 1,000 mitochondria, seen in this light-microscope photograph as numerous dark spots in the outer part of the cells. The clear area in the center of each cell is its nucleus. These cells were photographed in a droplet of rat liver tissue by George E. Palade of the Rockefeller Institute for Medical Research. They are enlarged some 2,200 diameters.



MITOCHONDRIA appear as small gray bodies in this electron micrograph of a section of a rat liver cell. The smaller particles and strings are microsomes; the large oval is the nucleus. This micrograph, enlarging the section 9,000 diameters, was made by Palade

SECTION OF MITOCHONDRIA enlarged 57,000 diameters shows that they have a double wall with finger-like projections. One of the mitochondria (*top*) has been cut lengthwise. This electron micrograph was made by Michael Watson at the Rockefeller Institute

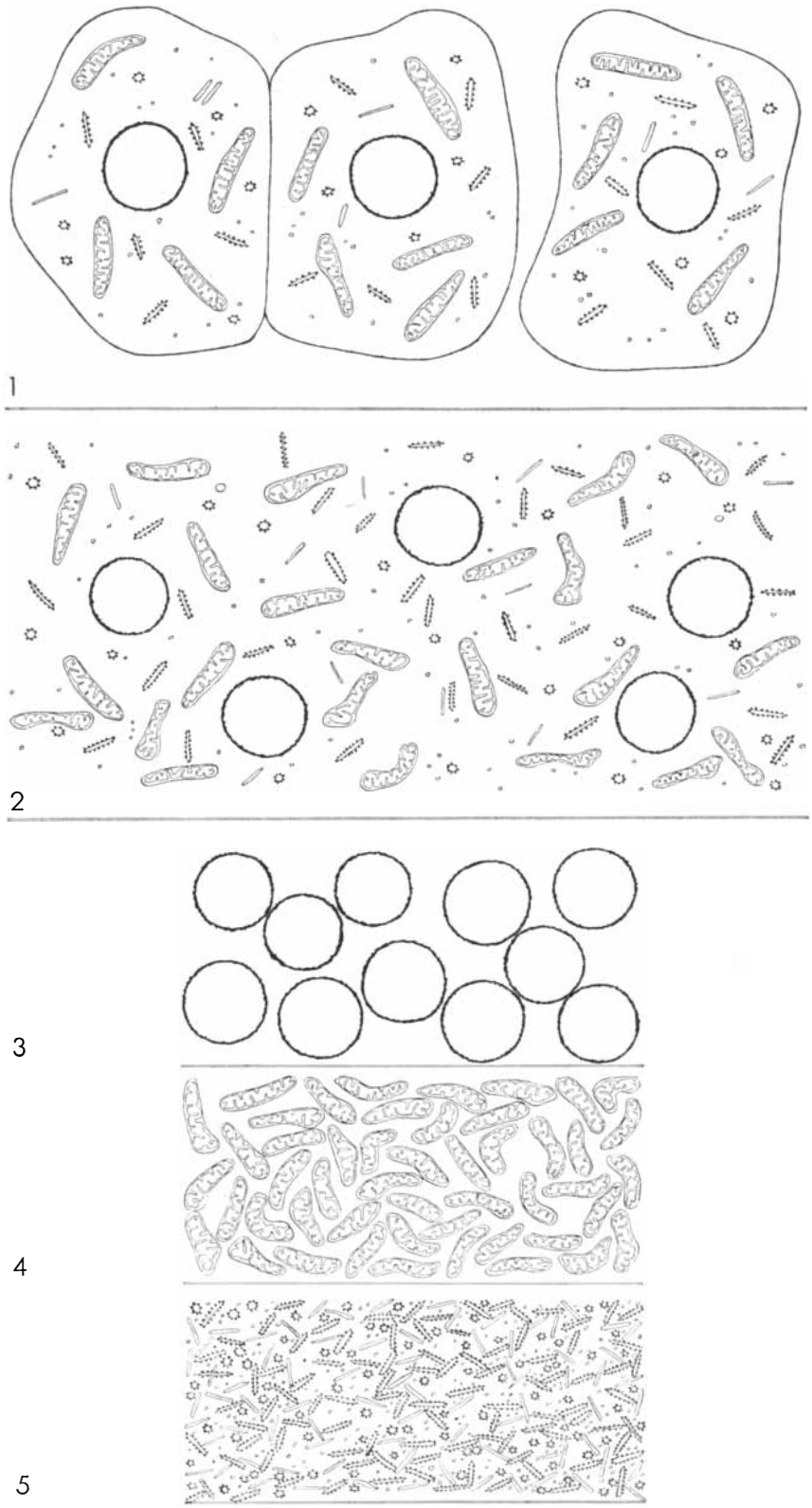
chondria has been separately studied by biochemists. The two approaches have now come so close together that they have given rise to an exciting new field of cell research: cytochemistry. We may describe this work as functional topography, for it is concerned with the relationship of biological structure to function on the submicroscopic scale.

The biochemist analyzes the activity of cells by breaking them up and isolating their chemical reactions. Similarly cytologists could learn little about the function of mitochondria until they could isolate them from the cell. This was first done some 20 years ago by Sylvia H. Bensley and Normand L. Hoerr of the University of Chicago and Albert Claude of the Rockefeller Institute for Medical Research. In the method now commonly used, animal cells are broken up by rapidly rotating a small pestle in a test tube containing a minced tissue. The test tube now contains a homogenized mixture of, among other things, cell nuclei, mitochondria and red blood cells (which are found in all animal tissues and are too small to be broken up in this way).

The mixture is placed in the tube of a centrifuge and spun at high speed; this separates its fractions according to their size and density. When the mixture is first spun, the heavy red cells and nuclei settle to the bottom of the tube in a tightly packed pellet. The remaining fluid is then transferred to another tube and spun again at a higher speed; the mitochondria form a second pellet. The fluid still remaining may be fractionated in the same way.

Now the isolated mitochondria can be suspended in a medium. The suspension can be examined in the light or electron microscope. Changes in the nature of the medium can be correlated with changes in the appearance of the mitochondria. The metabolism of the mitochondria can be studied with little or no interference by reactions taking place in other parts of the cell.

How does the cytologist know that the mitochondria are not contaminated with other constituents of the cell, and that they have not been fundamentally altered by this rough treatment? The fact is that he cannot be sure. He uses various means of protecting the mitochondria against contamination and damage, but his best criterion was introduced by two pioneers in the recent study of mitochondria: George H. Hogeboom and Walter C. Schneider of the National Institutes of Health. They assumed that if the concentration of a sub-



ISOLATION OF MITOCHONDRIA requires several steps. Intact cells (1) are broken up by means of a rod-shaped pestle rotating rapidly in a test tube. The broken fragments of the cells (2) are then suspended in sucrose solution and spun in a centrifuge at a speed which will throw down the heavier particles such as nuclei (3). This step also removes the red blood cells, which are found in all tissues but are not shown in the diagram. The remaining fluid is removed and spun at a higher speed. This step brings down the mitochondria (4) but allows most of the smaller particles to remain in suspension. The remaining fluid must now be centrifuged at a still higher speed in order to bring down the microsomes (5).

stance is higher in the mitochondrial fraction of the cell than in other fractions, the substance could be considered a constituent of mitochondria.

Mitochondria are commonly obtained from rat liver cells because rats are small, uniform and readily available, and their livers are large, homogeneous and easily accessible. The pellet of mitochondria isolated from rat liver has a tan color, though pellets from the lungs of rats raised in big-city laboratories have a grayish cast. About a fourth of the protein and fat in the liver cell is located in its mitochondria. They contain an even higher proportion of many enzymes, the substances which catalyze the chemical reactions of life. Some of the enzymes are firmly attached to the structure of the mitochondrion; others appear to be inside it, because they are released when it is broken.

The oxidation of foodstuffs occurs largely in mitochondria, at least those of liver, kidney, heart and brain cells. Although we do not know where all the enzymes involved in the oxidation are located in the cell, we can present the following hypothetical outline of the process: Carbohydrates are first broken down to pyruvic acid outside the mitochondria. The pyruvic acid then enters the mitochondria, as do the breakdown products of proteins and fats: amino acids and fatty acids. Inside the mitochondria these compounds undergo a complex series of reactions to form intermediate products, all of which are interrelated by a chain of enzymes called the citric acid cycle. The oxidations remove carbon atoms one at a time from the intermediate products of carbohydrate and protein breakdown, and two at a time from the products of the breakdown of fats. The carbon dioxide produced by the oxidations is ultimately exhaled. Many, but not all, of the enzymes which preside at these steps have been localized in the mitochondria.

Biological oxidation is not necessarily the direct action of oxygen on a substance. It may mean the removal of some electrons and hydrogen ions from the substance. The electrons and hydrogen ions are then passed along an assembly line of carrier substances; when they reach oxygen, they combine with it to form water. All of the enzymes involved in these transfers and all of the carrier substances are found in the mitochondria, some of them exclusively. Many of the reactions require a coenzyme which acts in concert with the enzyme. The mitochondria are also rich in coenzymes.

Concurrently with all these transfers and oxidations another process is going

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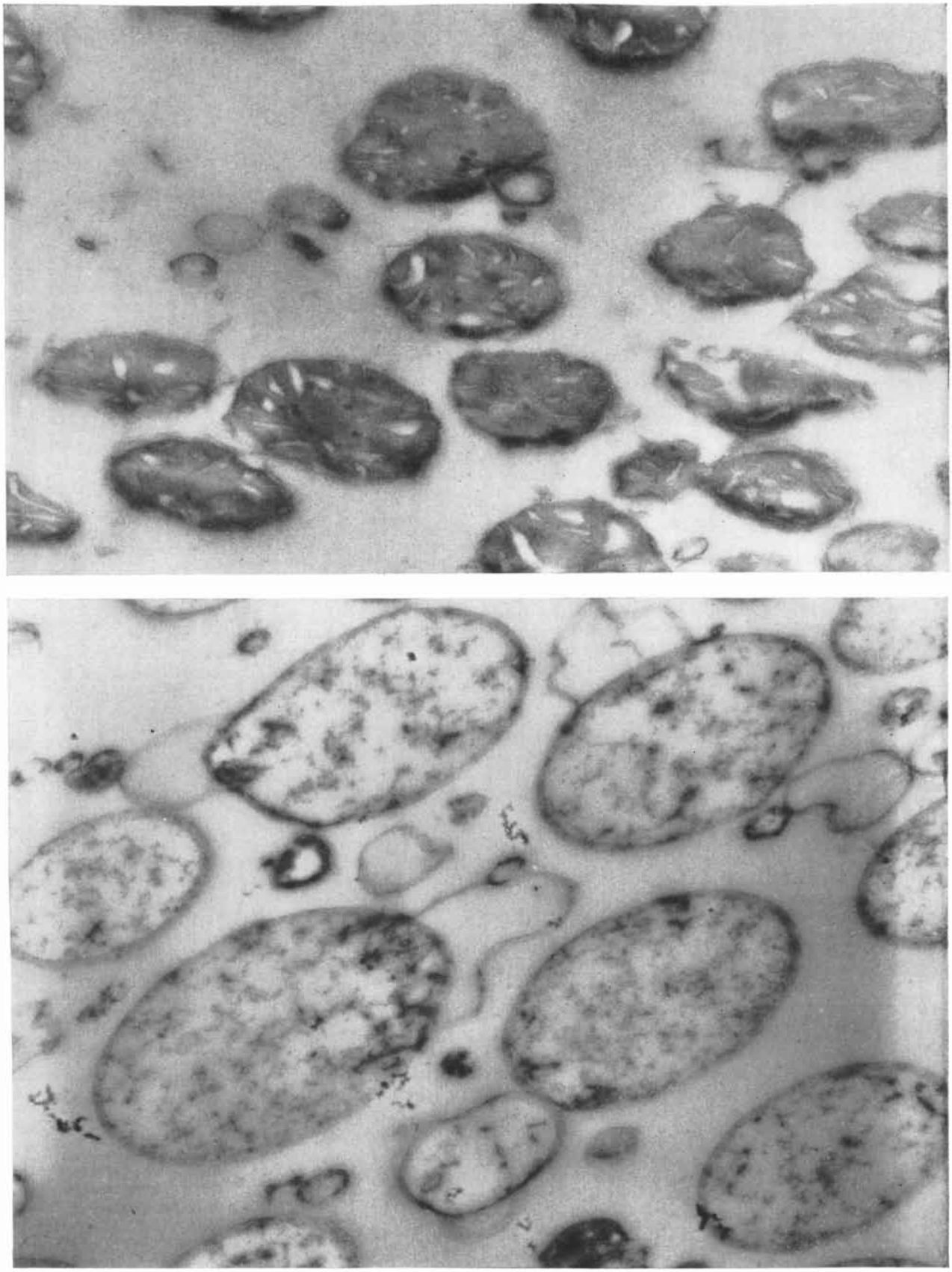


NORMAL AND SWOLLEN MITOCHONDRIA are contrasted in these electron micrographs. Mitochondria at top were isolated from cells and suspended in sucrose solution. Their appearance is somewhat distorted by the processes of isolation and fixation. At bottom are similar mitochondria suspended in distilled water which have swelled three to five times. The outer membranes of the mitochondria remain intact, but their inner structure changes. These micrographs, made by Watson, enlarge the sections 44,000 diameters.

on. The energy released by oxidation is not transformed into heat but into a form which can be utilized by the cell. The transformation consists in making the energy-rich compound adenosine triphosphate, or ATP. Most of the energy required by the cell is provided in this way, and most of it is produced in the mitochondria. Some of the energy of ATP is used in the mitochondrion, but most of the ATP is immediately shot out to power the other activities of the cell. Thus it can be said that the mitochondria "secrete" biological energy.

This singular function of the mitochondria appears to be reflected by their location within various kinds of cells. In muscle cells the mitochondria form rings around that part of the muscle fiber which actually contracts. In nerve cells they cluster around the junction of one cell and another, where the energy of the nerve impulse is transferred. In sperm cells they accumulate in the "neck" of the cell, where its head joins its whiplash tail. In cells which absorb substances from the blood, such as the cells in the convoluted tubule of the kidney, they are in the folds of the cell surface.

The complex anatomy of the mitochondrion itself is revealed by the electron microscope, notably in the studies of George E. Palade of the Rockefeller Institute for Medical Research and Fritiof Sjöstrand of the Karolinska Institute in Stockholm, Sweden. In the liver cell the rod-shaped mitochondria are about twice as long as they are wide, but in other cells they are much longer. The mitochondrion is bounded by a double membrane, the thickness of which is about a tenth or a twentieth of the mitochondrial diameter. In many cells the inner membrane is folded, apparently to increase its area. Within the mitochondrion are tiny bodies whose contents and function are entirely unknown. These features are similar in the mitochondria of all plants and animals examined so far, from single-celled organisms to man.

What does this anatomy mean? It may very well be a reflection of the complex chemical activities of the mitochondrion. If the production of biological energy is to be an efficient process, the enzymes involved in these processes must be part of some organization. Perhaps the enzymes are rigorously organized in a chain, so that the product of a reaction involving one enzyme is efficiently passed along to the next.

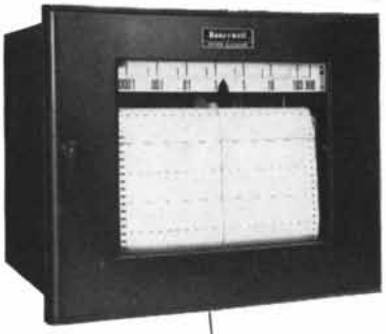
The meaning of this structure can be illustrated in various ways. When mitochondria are put in water, their con-

stituents tend to leak out and the water to leak in; they swell as much as five times their normal diameter. This swelling is remarkable because it indicates that the surface membrane of the mitochondrion can be stretched by a factor of 100 without breaking. The molecules of the membrane must be tightly coiled in their normal state.

The membrane appears to be semipermeable; that is, it will let some substances pass but not others. Large molecules like enzymes are held back by the membrane, but when it is stretched many of them leak out. The membrane is readily traversed by many small molecules. Some of this traffic, however, has nothing to do with the properties of the membrane; it is controlled by the mitochondrion as a whole. For example, pyruvic acid (the breakdown product of carbohydrate) can pass through the membrane in either direction, but it is concentrated in the mitochondria. Other small molecules are chemically bound to the structure of the mitochondrion. These processes which work against the natural tendency of the molecules to pass out of the mitochondrion require energy, which is of course made in abundance by mitochondria.

Experiments have shown that enzymes involved in oxidation are located both in the mitochondrion and elsewhere in the cell. For example, some of the enzymes which transfer electrons and hydrogen ions to form water are found outside the mitochondrion. Only the mitochondrion, however, contains all the enzymes required for this transfer. It would appear from these and other experiments that substances made in enzymatic reactions outside the mitochondria must enter it in order to continue their metabolic careers, or that substances made inside the mitochondrion must leave it to complete the processes outside. In this way the mitochondrion may regulate activities in other parts of the cell. Thus it may be not only a servant of the cell but also one of its controls.

But how is the activity of the mitochondrion controlled? The ceaseless motion of the mitochondria in a living cell is one of their most striking features; they not only change size and shape but also appear to divide and recombine. Are these changes in the structure of mitochondria related to changes in their chemical activity? There is much evidence to indicate that they are. For example, when mitochondria are placed in various solutions, they swell or change shape in a way that is characteristic of



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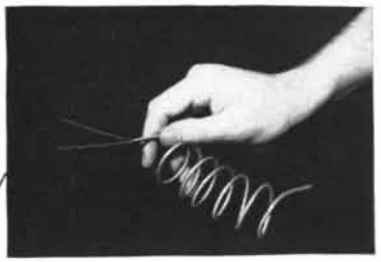

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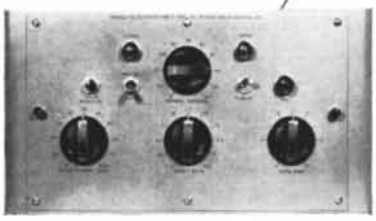

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the solution. These changes are accompanied by characteristic changes in the metabolism of the mitochondria. That these changes may be significant is indicated by the recent finding that thyroxine, a form of the thyroid hormone, causes mitochondria to swell more easily. It is known that the thyroid hormone somehow regulates the production or utilization of energy by cells; it could well be that it does so by affecting the structure of the mitochondria.

The swelling of the mitochondrion not only permits some of its molecules to leak out; it permits molecules of comparable size to leak in. Experiments have indicated that when the mitochondrion is made to swell to less than the full capacity of its membrane, it admits substances on which its enzymes can newly act. The swelling also activates certain enzymes and coenzymes, probably by releasing them from the structure of the mitochondrion. Obviously these events will affect the activity of mitochondria.

Certain enzymes in the mitochondrion are not only bound to the structure; they form an integral part of it. When mitochondria are broken up by swelling, or by subjecting them to intense sound waves, some enzymes pass into solution and others remain in the fragments of the structure. This in itself suggests that the latter enzymes are part of the structure. Mitochondria may be completely disintegrated with detergents, but even then small fragments remain insoluble. This insoluble residue has been found to contain a chain of the enzymes which transport electrons and hydrogen ions in oxidation. Electron micrographs have shown that the fragments are part of the mitochondrial membrane. In short, a functional unit (the enzyme system) is the same as a structural unit (the section of membrane).

These and many other experiments demonstrate that the functional units of the mitochondrion have a definite architecture. We may say the same of the entire living cell. We have come a long way from the time when a cell was considered a bag of loose substances freely interacting with one another. The cell, like the mitochondrion, has a rigorous and compartmented organization. Perhaps this is not surprising. When we build a factory, we do not park its raw materials and machines at random. We arrange matters so that the raw materials are brought in near the appropriate machines, and the product of each machine is efficiently passed along to the next. Nature has surely done the same in the living cell.

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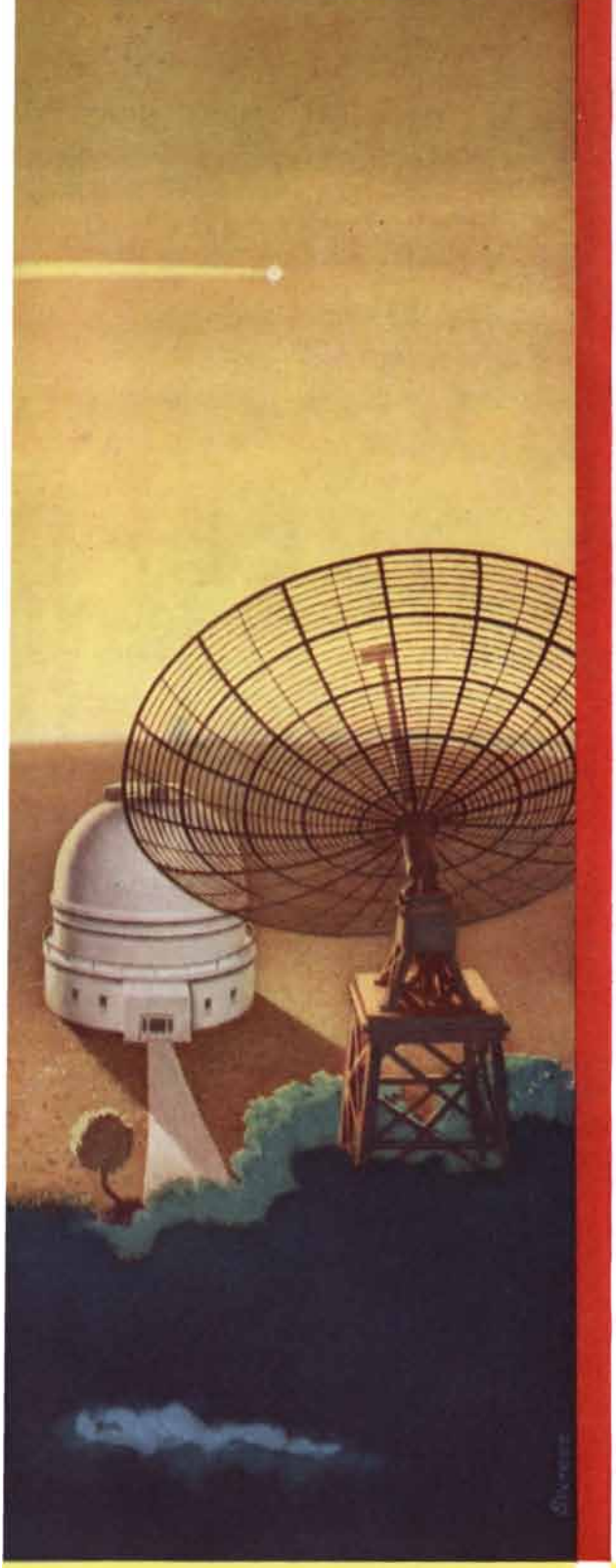

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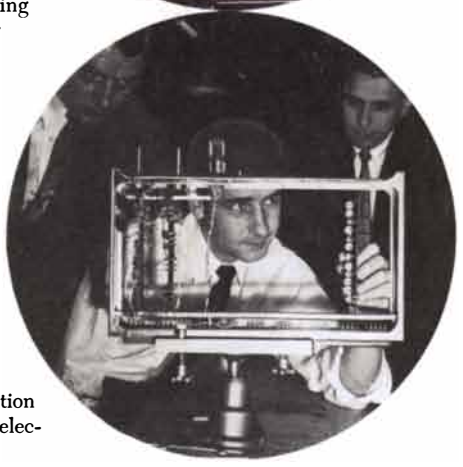

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MATHEMATICAL GAMES

Concerning the game of Hex, which may be played on the tiles of the bathroom floor

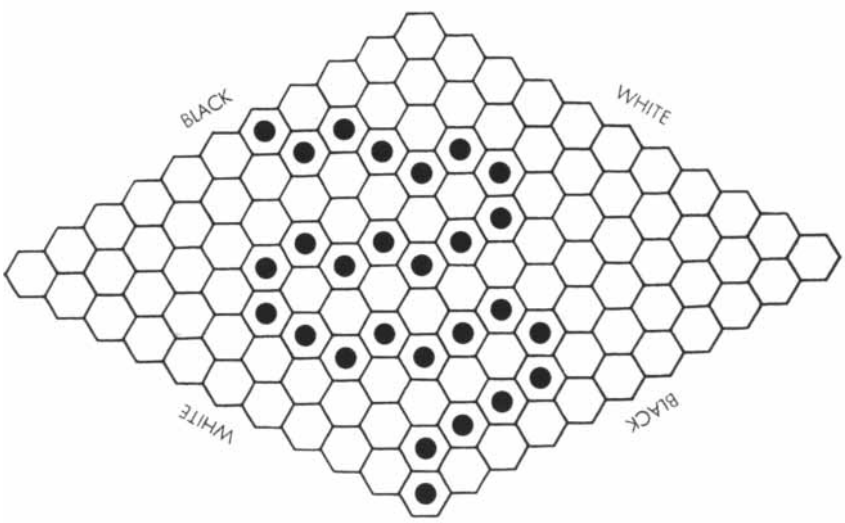
by Martin Gardner

It is something of an occasion these days when someone invents a mathematical game that is both new and interesting. Such a game is Hex, introduced 15 years ago at Niels Bohr's Institute for Theoretical Physics in Copenhagen. Hex may well become one of the most widely played and thoughtfully analyzed new mathematical games of the century. It swept the Scandinavian countries in the middle 1940s, and in 1949 it was taken up by game theorists in the U. S. Later Claude E. Shannon and Edward F. Moore of the Bell Telephone Laboratories designed and built an analogue computer capable of playing a moderately good game of Hex.

Hex is played on a diamond-shaped board made up of hexagons [*see illustration at the bottom of this page*]. The number of hexagons may vary, but the board usually has 11 on each edge. Two opposite sides of the diamond are labeled "black"; the other two sides are "white." The hexagons at the corners of the diamond belong to either side. One player has a supply of black pieces; the other, a supply of white pieces. The players alternately place one of their pieces on any one of the hexagons, provided the hexagon is not already occupied by another piece. The objective of "black" is to complete an unbroken chain of black pieces between the two sides labeled "black." "White" tries to complete a similar chain of white pieces between the sides labeled "white."

The chain may freely twist and turn; an example of a winning chain is shown in the illustration at the bottom of the page. The players continue placing their pieces until one of them has made a complete chain. The game cannot end in a draw, because one player can block the other only by completing his own chain. These rules are simple, yet Hex is a game of surprising mathematical subtlety.

Hex was invented by Piet Hein, who must surely be one of the most remarkable men in Denmark. Hein began his career as a student at the Institute for Theoretical Physics; then his industrial inventions switched him to engineering, where he remained until the Germans invaded Denmark in 1940. Because Hein was the head of an anti-Nazi group, he was forced to go underground. After the



A winning chain for "black" on a Hex board with 11 hexagons on each side

war he became well-known as a writer on scientific and other topics for *Politiken*, the leading Danish newspaper. He is also known, under the pseudonym of Kumbel, as the author of numerous volumes of epigrammatical poems. These books have sold 175,000 copies.

The game of Hex occurred to Hein while he was contemplating the famous four-color theorem of topology. (The theorem, as yet unproved, is that four colors are sufficient to make any map so that no two countries of the same color have a common boundary.) Hein introduced the game in 1942 with a lecture to students at the Institute. In December of that year *Politiken* published an account of the game; it soon became enormously popular in Denmark under the name of Polygon. Pads on which the game could be played with a pencil were sold, and for many months *Politiken* ran a series of Polygon problems, with prizes for the best solutions.

In 1949 Aage Bohr, son of Niels, introduced the game at the Institute for Advanced Study in Princeton, where it quickly captivated students of mathematics both at the Institute and Princeton University. The game was commonly called John because it was so often played on the hexagonal tiles of bathroom floors. It did not acquire the name Hex until 1952, when a version of the game was issued under that title by the firm of Parker Brothers, Inc.

Readers who would like to try Hex are advised to make mimeographed copies of the board depicted at the bottom of the preceding page. The game can be played on these sheets by marking the hexagons with circles and crosses. If you should prefer to play with removable pieces on a permanent board, a large one can easily be drawn on heavy cardboard or made by cementing together hexagonal tiles. If the tiles are big enough, ordinary checkers make convenient pieces.

One of the best ways to learn the subtleties of Hex is to play the game on a board with a small number of hexagons. When the game is played on a two-by-two board (four hexagons), the player who makes the first move inevitably wins. On a three-by-three board the first player may win easily by making his first move in the center of the board [*see illustration at left at the bottom of this page*]. There is no way in which his opponent can keep him from winning on his third move.

On a four-by-four board things begin to get complicated. The first player is sure to win if he immediately occupies any one of the four hexagons numbered in the illustration at the right at the bottom of this page. If he makes his opening play elsewhere, he can be defeated. An opening play in hexagon 2 or 3 ensures a win on the fifth move; an opening play in hexagon 1 or 4, a win on the sixth move.

On a five-by-five board it can still be shown that, if the first player immediately occupies the hexagon in the center, he can win on his seventh move. On larger boards the analysis becomes enormously difficult. So far as I know no one has fully analyzed the possibilities in a game of Hex played on a six-by-six board. Of course the standard 11-by-11 board introduces such an astronomical number of complications that a complete analysis seems out of the question.

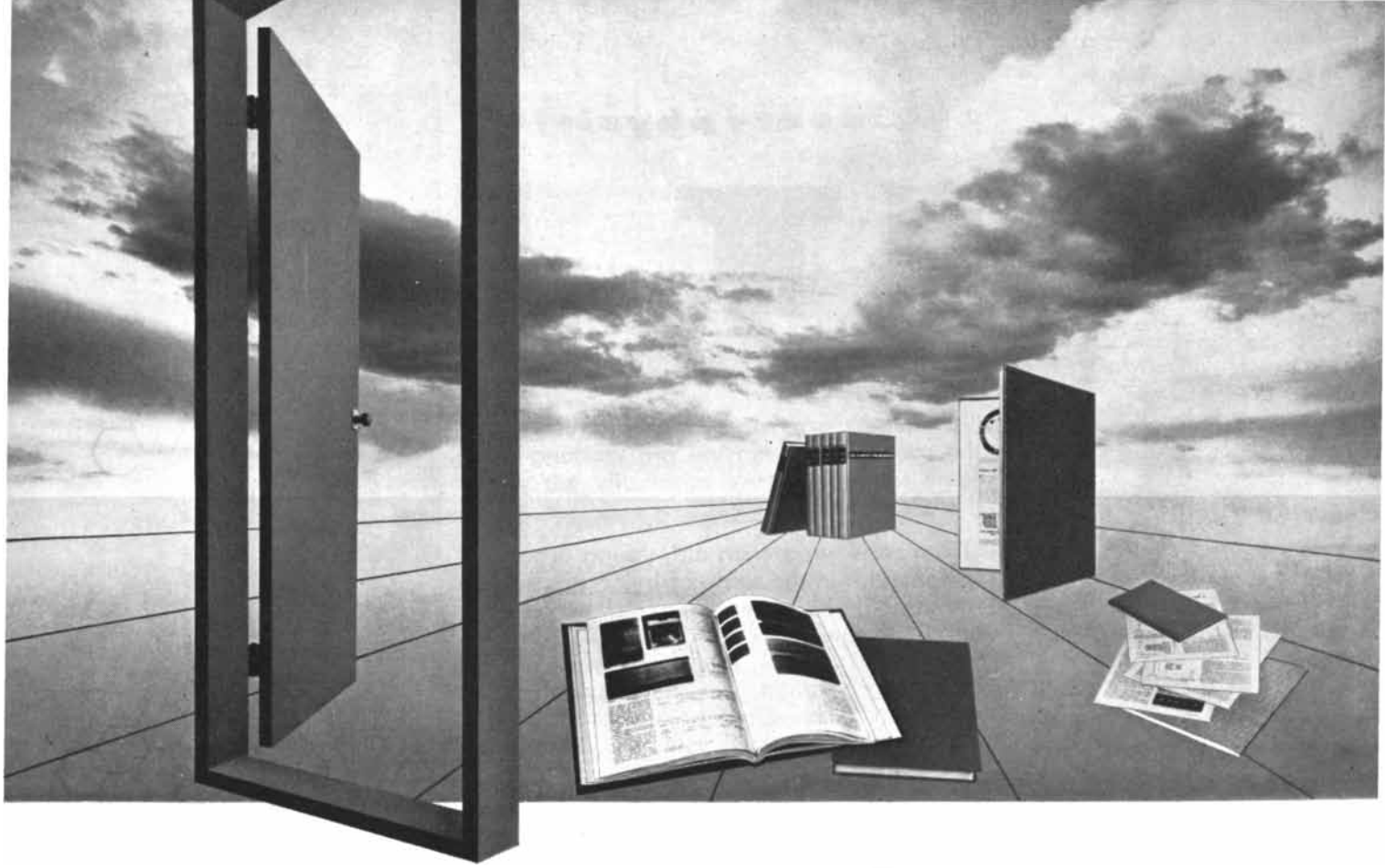
It is for this reason that game theorists find Hex particularly interesting. There is no procedure which will assure a win on a standard board, but there is an elegant proof that a winning strategy exists for the first player on a board of any size! The proof seems to have been discovered independently by Hein and several mathematicians both here and in Europe. The following is a condensed version of the proof (it can be formulated with much greater rigor) as it was worked out in 1949 by John F. Nash, now assistant professor of mathematics at the Massachusetts Institute of Technology.

1. Either the first or second player must win, therefore there must be a winning strategy for either the first or second player.

2. Let as assume that the second player has a winning strategy.

3. The first player can now adopt the

About first moves on three-by-three and four-by-four Hex board



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COMPRESSION OF SOLIDS BY STRONG SHOCK WAVES
M. H. Rice, R. G. McQueen, and J. M. Walsh, Solid State Physics—Advances in Research and Applications, Vol. **6** *(In Press).*

PRECISION FLASH X-RAY DETERMINATION OF DENSITY RATIO IN GASEOUS DETONATIONS
R. E. Duff and H. T. Knight, J. Chem. Phys. **25**, *1301 (1956).*

POLYMORPHISM OF IRON AT HIGH PRESSURE
D. Bancroft, E. L. Peterson, and S. Minshall, J. App. Phys. **27**, *291 (1956).*

IMAGE QUALITY CRITERIA DERIVED FROM SKEW TRACES
F. A. Lucy, J. Opt. Soc. Am. **46**, *699 (1956).*

VISIBLE RADIATION FROM HELIUM IN A STRONG SHOCK WAVE
G. E. Seay and L. B. Seely, Jr., Bull. Am. Phys. Soc. **II, 1**, *227 (1956) (Abstract).*

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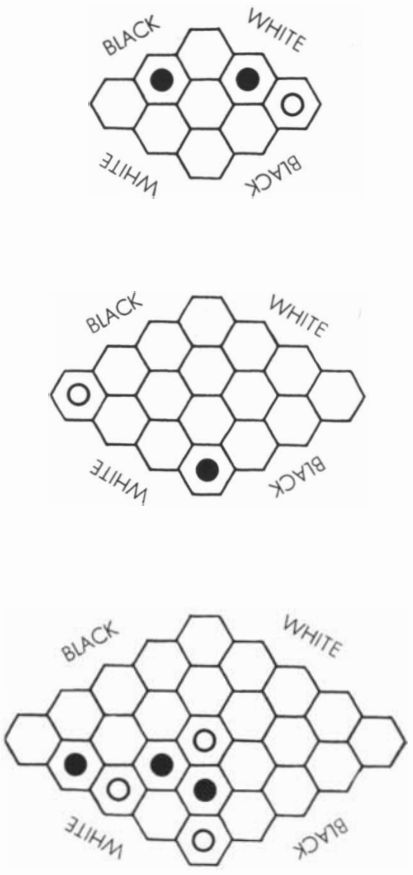

Three problems of Hex

following defense. He first makes an arbitrary move. Thereafter he plays the winning second-player strategy assumed above. In short, he becomes the second player, but with an extra piece placed somewhere on the board.

4. This extra piece cannot interfere with the first player's imitation of the winning strategy, for an extra piece is always an asset and never a handicap. Therefore the first player can win.

5. Since we have now contradicted our assumption that there is a winning strategy for the second player, we are forced to drop this assumption.

6. Consequently there must be a winning strategy for the first player.

There are a number of variations on the basic theme of Hex, including a version in which each player tries to force his opponent to make a chain. According to an involved proof devised by Robert Winder, a graduate student of mathematics at Princeton, the first player can always win this game on a board which has an even number of cells on a side, but he can lose on a board with an odd number.

After the reader has played Hex for a

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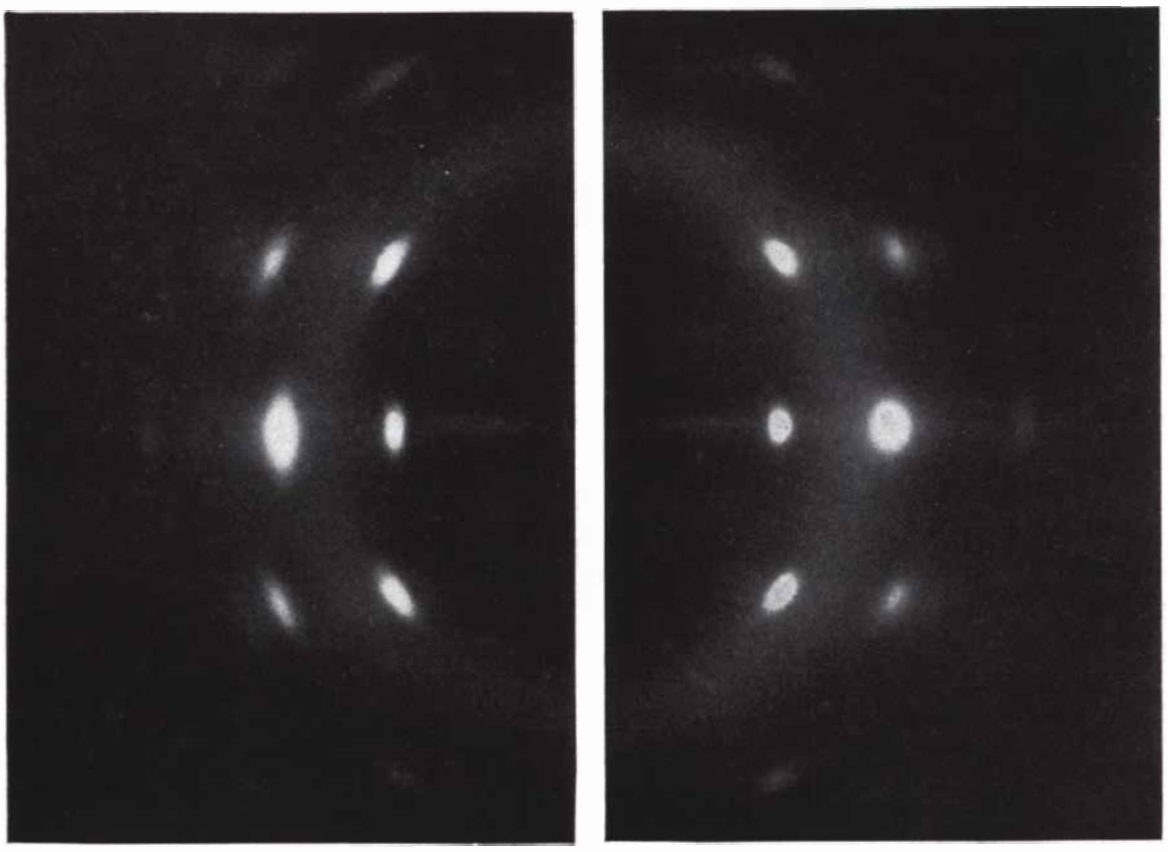

These two photographs compare the x-ray diffraction patterns of natural rubber (*left*) and a new synthetic rubber produced by the Firestone Tire and Rubber Company (*right*). As the patterns suggest, the new man-made high polymer successfully duplicates the structure of the polymer synthesized by the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

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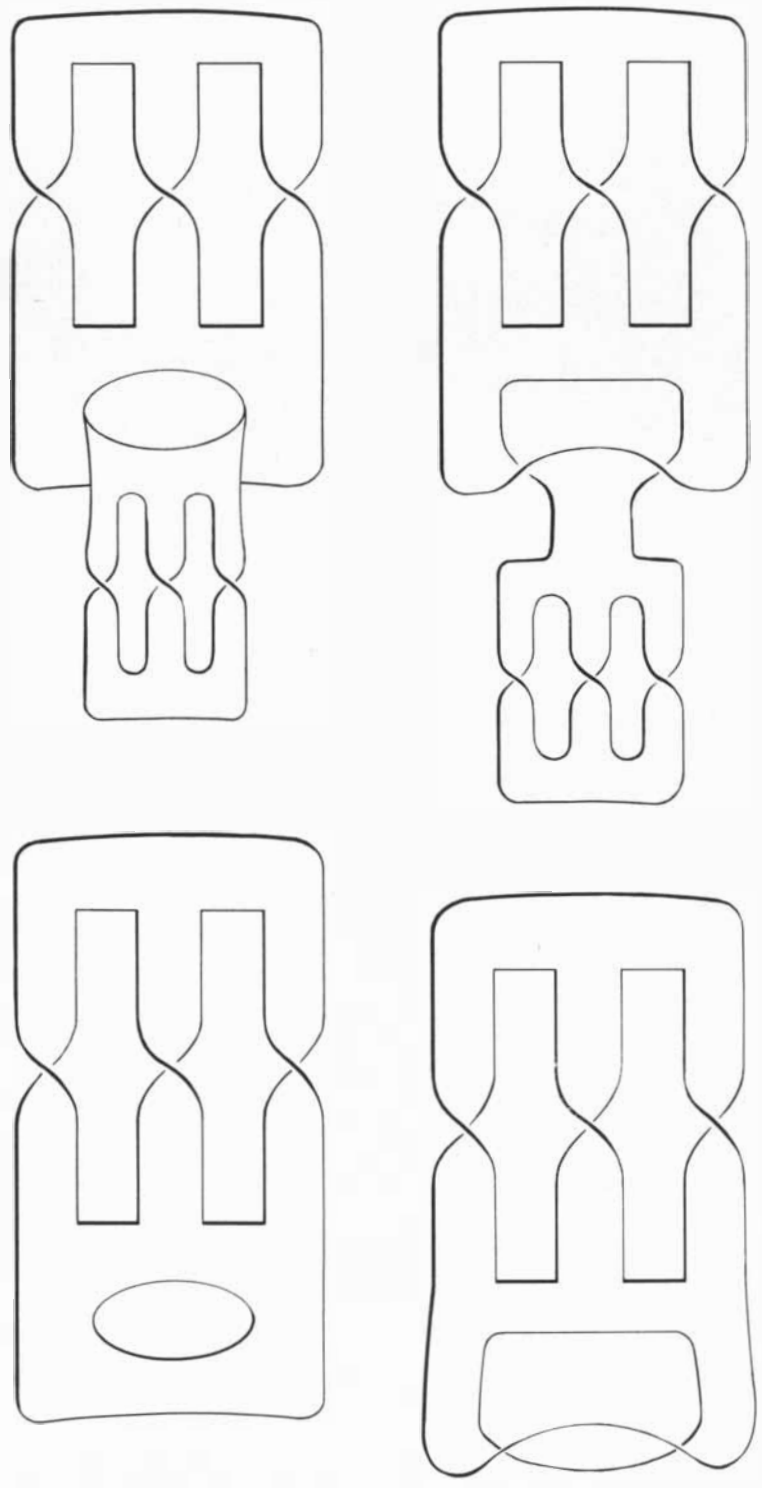
while, he may wish to tackle three problems devised by Hein. These are set forth in the three illustrations at the top of page 148. The objective in all three problems is to find the first move that will ensure a win for "white." The solutions will be published in this department next month.

Last month this department presented pictures of 12 of the 16 topological models that can be made with surfaces with no more than two edges, and edges which are a simple closed curve or a single knot. Readers were challenged to make the other four models. They are depicted below.



Four topological surfaces which the reader was challenged to make last month

U. S. Army Photo

Experimental rocket being launched from tower at DOFL's Maryland test facility.

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Electronic ordnance was born in World War II. Ammunition of this type, a DOFL specialty, senses the presence, distance, and direction of a target and causes the warhead to function at the instant when it will inflict the most damage. Electronic control can be compared to having a sharpshooter in every piece of ammunition. The accurate effect is devastating.

Many advances in ruggedness and miniaturization, pioneered by DOFL, are contributing significantly to peacetime technology. Typical industrial products which sprang from ordnance programs are printed electronic circuits, tough and tiny electronic tubes, and rigid mounting of components in solid plastic blocks. These valuable by-products have contributed heavily to the ability of DOFL's industrial teammates to design safer, smaller, and better components.

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THE AMATEUR SCIENTIST

Concerning simple and ingenious devices to record the waves made by earthquakes

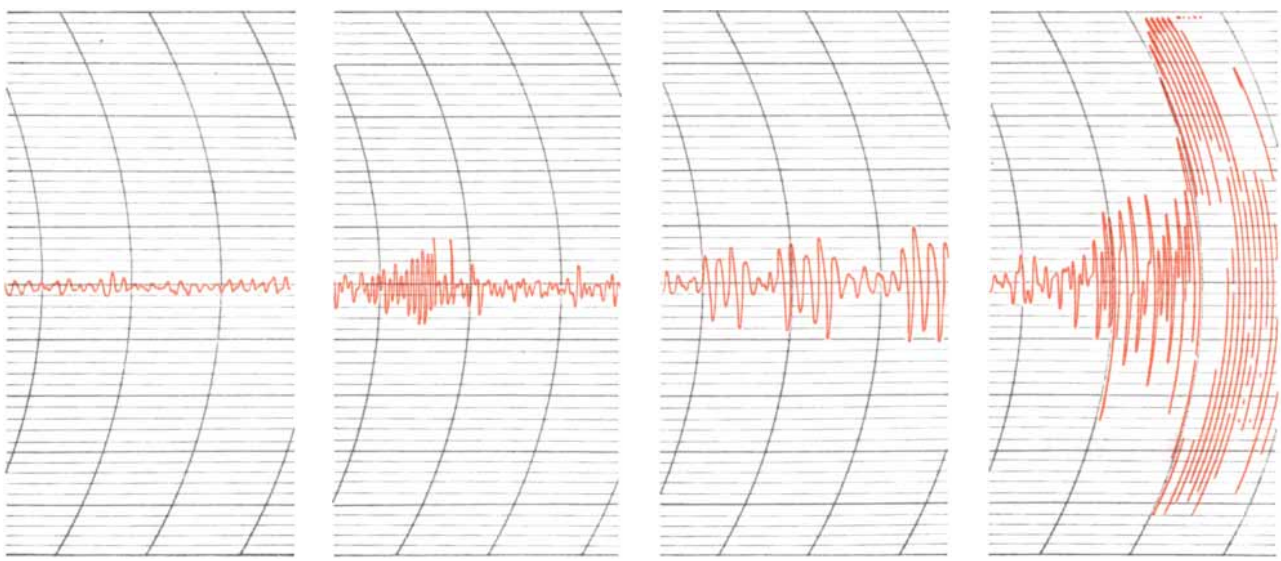
During the International Geophysical Year, which officially begins this month, the earth will conduct business as usual. Erosion will plane away at the uplands; volcanoes will erupt fresh lava; creeping masses of molten rock far beneath the surface will lift some mountains a little higher; rivers will distribute sediment over the floor of the oceans. All these shifting loads will exert new forces on rocks buried as deep as 400 miles. As the rocks crack and slide during the next 18 months the earth will liberate some 200 trillion trillion ergs of energy, which will touch off at least 160,000 earthquakes. Of these, some 15,000 will cause minor damage. Another 1,500 will locally shatter chimneys. Between 50 and 100 will be strong enough to register on every seismograph in the world. Some 15 or 20 will pack enough power to trigger local landslides, wreck bridges and level the most durable stone buildings. One of these quakes may be catastrophic.

If these predictions based on past performance are correct, there will be some impressive seismic events during the IGY. In anticipation of them a number of amateurs have built seismographs to observe the show from the sidelines. One of the best equipped is A. E. Banks, the proprietor of a stationery store in Santa Barbara, Calif. Banks has spent most of his free time during the past two years learning how to build simple versions of conventional seismographs and developing some not found in the textbooks.

Because two or three of Banks's instruments are always on the job, he has not missed a single earthquake of consequence during the past year. The most interesting sections of his record of the big Aleutian quake last March, which pounded beaches in Hawaii with five-foot waves, appear at the bottom of this page. The complete record of the quake covers four feet of record paper.

The first section of the record shows the faint and ever-present vibrations known as microseisms, which seem to arise from variations in atmospheric pressure, the pounding of surf and other minor sources of seismic energy. The next section shows the beginning of the quake, which is announced by the first and fleetest of three characteristic types of earthquake waves: the primary or "P" wave. The P wave vibrates in the direction of its travel like an opening and closing coil spring. It travels through the earth at an average speed of about five miles per second. The third section shows the arrival of the secondary or "S" wave. This wave travels at an average velocity of about three miles per second; it is often called the "shake" wave because it vibrates at right angles to the direction of its travel like an oscillating violin string. The trace made by S waves on the seismogram is not so jagged as that of P waves; moreover, the height or amplitude of the two are rarely equal. Hence P and S waves can usually be distinguished from each other without difficulty.

The fact that both P and S waves travel at characteristic rates provides a basis for calculating the distance between a quake's point of origin and the recording station. The more distant the



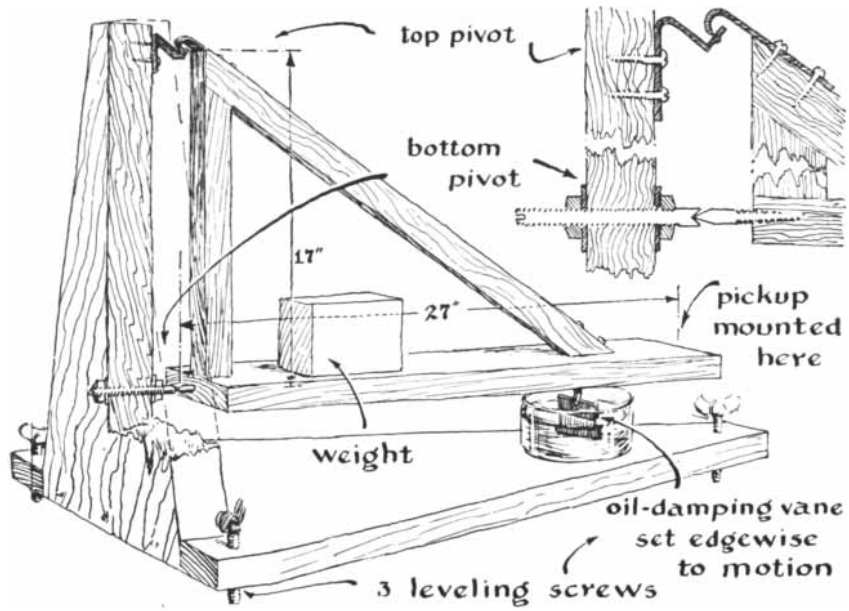
An amateur's seismogram of the Aleutian earthquake in March

quake, the longer the race and the longer the lead of the P waves over the S. The lead of the P waves does not vary, however, in direct proportion to the surface distance between the observing station and the location of the quake. This is primarily due to the fact that the waves take short-cuts through the interior of the earth. The waves are also refracted and reflected by discontinuities in the interior of the earth, and their velocity increases with the depth of their path. These and related factors complicate the calculation of distance, but the difficulties have been resolved by the compilation of "travel-time" charts. To determine the distance of a quake, one merely subtracts the arrival time of P waves from that of S waves and looks up the corresponding distance on the chart. This assumes, of course, that time signals have been recorded along with the quake. These are recorded on Banks's seismogram as equally spaced vertical arcs, each corresponding to an interval of one minute.

The fourth section of Banks's seismogram shows the final major wave of the Aleutian quake, the long or "L" wave. The L wave always makes a big, dramatic trace and, unlike P and S waves, travels largely through the earth's outer layers. P and S waves are accordingly most useful in investigations of the structure of the earth at great depths, and L waves are most useful in studies of its outer layers. The velocity of L waves is influenced by the character of the terrain but averages about 2½ miles per second.

The seismograph senses earth vibrations by taking advantage of Newton's first law, which states in effect that a body freely suspended and at rest in space will remain at rest until something gives it a push. If an experimenter could float in still air, his position would not be affected by an earthquake, however violent; if a sheet of paper were fastened to the ground, he could make a seismogram simply by reaching down and allowing a pencil to move across it during the quake. Because gravity rules out such ideal suspensions, the designers of seismographs settle for an elastic suspension such as a pendulum or a weight on a spring. A pendulum may be considered an elastic suspension because it behaves as though a spring were stretched between the pendulum bob and the center of the earth.

Galileo was the first to observe two interesting properties of such suspensions. First, they oscillate or swing at a characteristic rate. For example, when an iron ball suspended from a coil spring is pulled down and then released, it bobs up and down at a rate which depends on the size of the ball and stiffness of the spring. Second, when a pendulum is set in motion by a push it continues to oscillate for a time, the duration of which depends on how soon the energy imparted by the push is dissipated. This is why pendulums have historically been used to measure time. But if this property is prized by clockmakers, it is the bane of those who make seismographs.



A seismometer to detect horizontal motions of the earth

The ideal seismograph would respond equally to waves of all frequencies. The seismograph designer, however, must make do with a device which favors some frequencies and discriminates against others. Consider a simple seismometer consisting of a heavy iron ball suspended from a spring attached to a framework which rests on the ground. Let the ball and spring be chosen so that when the ball is disturbed, it bobs up and down once a second. Assume the ball is at rest when an earthquake strikes. If the quake shakes the frame faster than one oscillation a second, the ball will remain at rest while the spring expands and contracts. When the frequency of the shake corresponds to that of the ball and spring, the ball absorbs energy from each oscillation. It starts to bob up and down; the distance of its motion increases with each added oscillation. When the frame oscillates less than once a second, both ball and spring move up and down with it. Earth vibrations are detected by observing the motion of a pendulum bob with respect to its supporting frame. Such motion is accordingly apparent when the frequency of the frame is higher than that of the pendulum. It is almost totally absent when the frequency of the frame is lower.

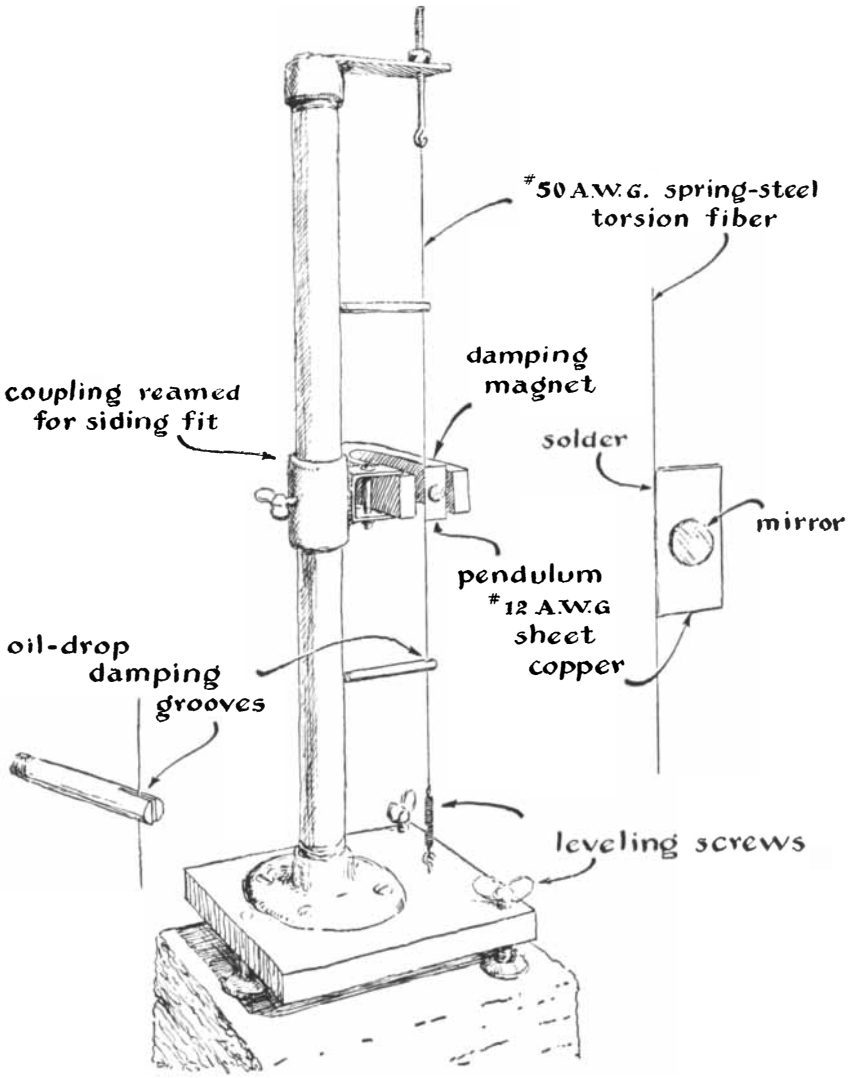
The most desirable seismograph would thus be one with a natural period of oscillation longer than any earthquake wave. It would require a pendulum capable of swinging only once in several minutes; ideally the pendulum should oscillate once in several hours. Such leisurely pendulums are either difficult to make or impractically large. Moreover, the most interesting earthquake waves have frequencies in the range of about three oscillations per second to one per minute. Seismological observatories usually record only the lower end of this range, and employ separate instruments tuned to oscillate at two, eight and 15 seconds. The two-second seismometer detects P waves and discriminates against microseisms, which lie in the two- to nine-second range. The eight-second instrument responds strongly to both P waves and microseisms. The 15-second instrument records these plus S and L waves. An instrument of this period is difficult to adjust; thus many amateur seismologists who have only one instrument compromise on a period of 10 seconds.

The second property of pendulums observed by Galileo—their tendency to continue swinging once they are set in motion—is controlled with friction or electrical resistance. This increases the rate at which unwanted energy is dissipated and so counteracts the pendulum's tendency to oscillate excessively at its

natural period. It is often accomplished by immersing a vane attached to the bottom of the pendulum bob in a bath of oil. The same result can be achieved by making the vane, or even the bob, out of copper and suspending it between the poles of a strong magnet. Eddy currents induced in the copper are transformed into heat by the resistance of the metal. Ideally the bob should be damped just enough for the pendulum to come to rest promptly. If the pendulum is damped too much, it will be sluggish and require more than one swing to reach equilibrium. If it is damped too little, it will swing several times before coming to rest. The best compromise, called "critical" damping, lies between these extremes and is determined experimentally for each instrument.

Unless they are in the immediate vicinity, earthquakes move the supporting frame of the pendulum only slightly—a thousandth of an inch or less. For the pendulum to make a useful record this motion must be amplified. The earliest seismographs were equipped with a system of amplifying levers, some of which turned on jeweled pivots. The short end of the first lever was coupled to the pendulum bob, the frame of the instrument providing the fulcrum. The long end of this lever drove another lever fitted with a stylus. The stylus made a trace on a cylinder of smoked paper rotated by clockwork. The mechanism required a heavy pendulum bob so that enough energy could be transmitted from the frame to the stylus without setting the bob in motion. The modern seismograph usually employs a combination of mechanical, optical and electrical amplifying elements; they are arranged in such a way that the seismic energy merely controls the movement of an electrically powered recording pen.

In essence, then, a seismograph consists of an elastically suspended weight which acts as the sensing element, a device to amplify the motion of the weight with respect to its supporting framework, and a pen or stylus to record the amplified motion. A fully equipped seismographic station employs at least nine sensing elements. Three sense vertical motions and are tuned to periods of about two, eight and 15 seconds. The second set of three, similarly tuned, responds to horizontal oscillations in the north-south direction; the third set, to oscillations in the east-west direction.



A seismometer which detects horizontal motion by twisting a vertical wire

Banks's example testifies that learning how to design, build and adjust seismographs can become a fascinating avocation. He writes: "I felt my first earthquake in 1914 while sitting in an Iowa farmhouse. Although that experience touched off my interest in seismology, it was not until September of 1955 that I attempted to build an instrument. I had had no previous experience and so had to start at the bottom and go as far as I could with the information I could dig out of books. Most of them were addressed to the specialist. I soon found that even an amateur seismologist should have majored in physics, geophysics, mechanical engineering and meteorology. Later I discovered that he must also be able to dig a ditch and mix a batch of concrete. A facility with hand tools and electrical circuits also comes in handy. But if the amateur is willing to settle for standards somewhat lower than those of the professional seismologist, the construction and operation of a seismograph turns out to be surprisingly simple.

"A so-called 'horizontal component' seismometer, one which detects lateral oscillations, can be made in a couple of hours if one has the materials on hand—a few scraps of wood, some screws, a bolt, a bit of strap iron and a small piece of sheet metal. The device essentially consists of a small triangular wooden frame hung like a garden gate from a larger frame [*see illustration on the preceding page*]. The upper pivot is made from two pieces of strap iron. As shown in the illustration, one piece is screwed to the hypotenuse of the frame, filed to a point and bent over like a fishhook. The point of the hook fits into an indentation made with a center punch in the second piece, which is fastened to the frame. The bottom pivot consists of a lag screw filed to a point. It fits into an indentation in the end of a stud bolt. The base of the frame is fitted with three leveling screws. These are adjusted so the beam swings to equilibrium in the center of the frame. The stud bolt provides a further means of adjusting the inclination of the beam and thus of altering its natural period.

"The period can also be adjusted over

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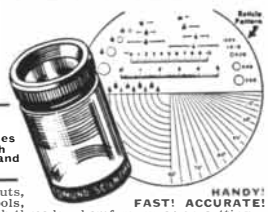

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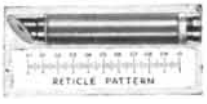

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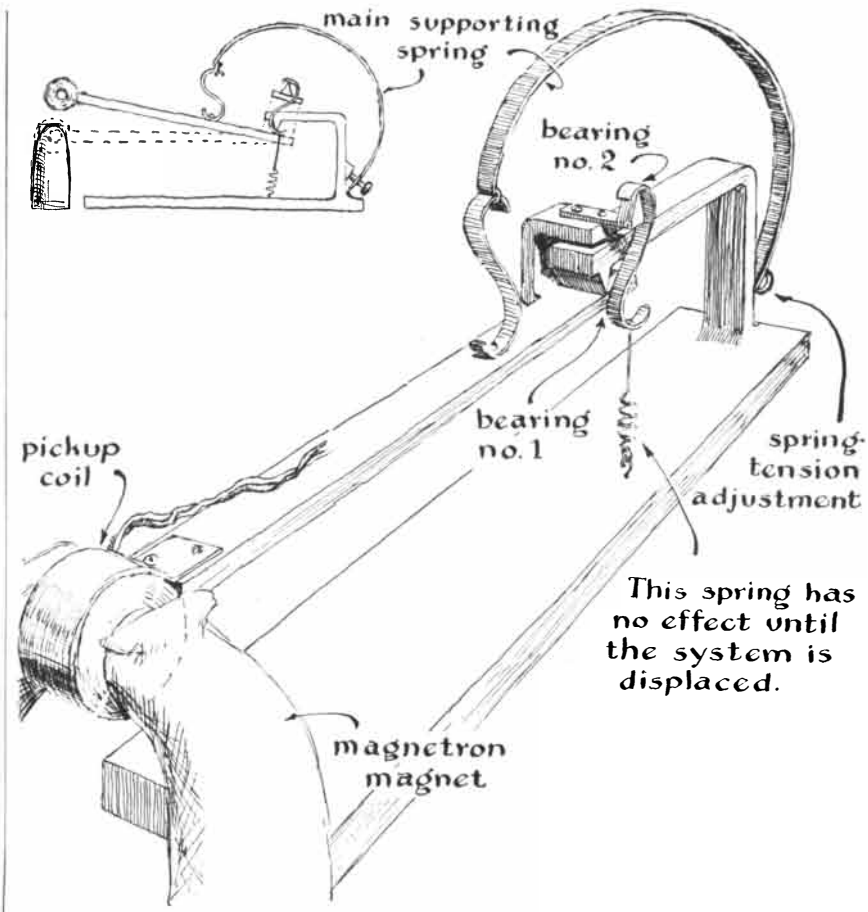


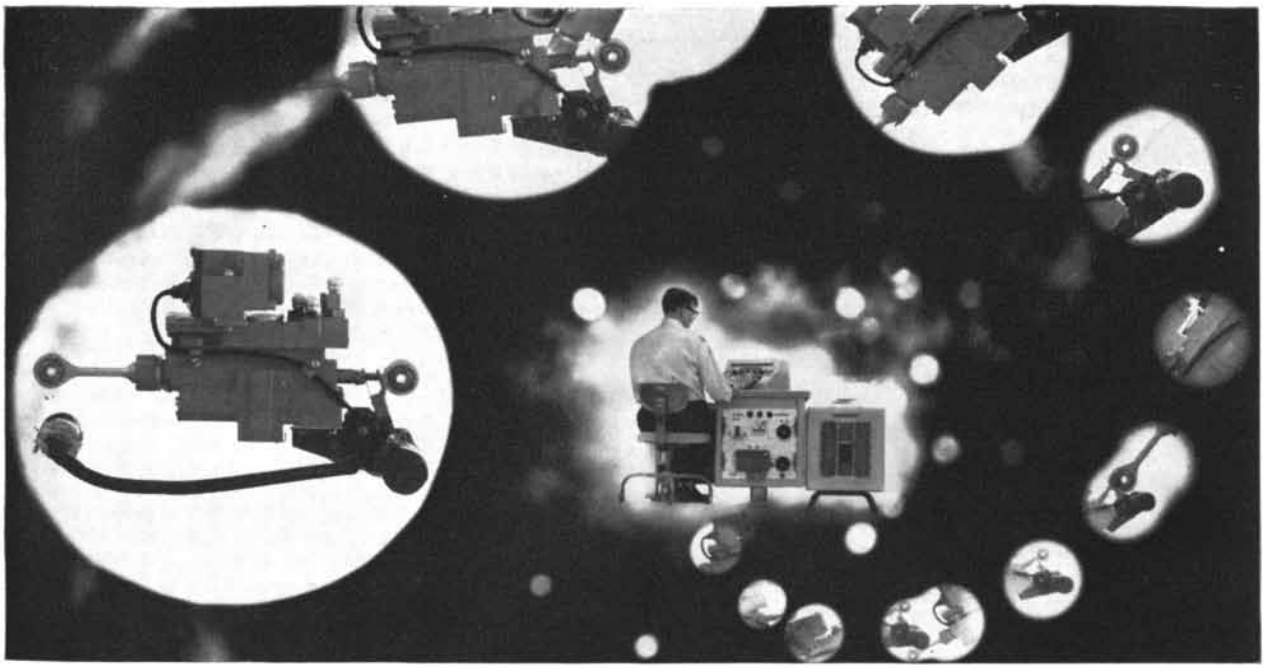
A seismometer to detect vertical motions of the earth

a wide range by placing a weight such as a brick on the beam. The brick serves as a pendulum bob, the period of oscillation increasing both with the weight of the bob and its distance from the pivots. The period is determined empirically by giving the pendulum a push and counting the number of seconds required for the beam to reach the limit of its swing and return.

"Finally the pendulum is fitted with a damping vane and housed to shield it from air currents. A piece of nonmagnetic sheet metal two inches square is soldered in the slot of a wood screw and screwed into the bottom of the beam. The vane is immersed in a bath of light machine-oil. The depth of immersion is adjusted until the beam makes about two full swings before coming to rest.

"A more elaborate version of essentially the same device is the Wood-Anderson torsional seismometer [*see illustration on page 154*]. Here the wooden frame is replaced by a heavy metal base and a 14-inch length of half-inch pipe. A 50-gauge wire (diameter .001 inch) is stretched between the bracket at the top of the pipe and the base. The long edge of a rectangular piece of sheet copper—about 1/2 inch wide, an inch long and 1/16 inch thick—is soldered or cemented to the middle of the wire. This serves as the pendulum. The pendulum is damped by a magnet which may be moved to adjust the degree of damping. The wire passes through oil-filled grooves in the ends of two studs supported by the pipe. These studs suppress the vibration of the wire. If the instrument is exposed to large variations in temperature, a coil spring must be inserted between the wire and its attachment to the base to compensate for differences in the expansion of the wire and its pipe support. Because an ordinary coil spring will twist the wire, it is necessary to use a double spring, one half of which is coiled in one direction and the other half in the reverse direction. Lateral movements of the earth shake the attached side of the vane with respect to its free edge. The wire, which corresponds to a hinge, twists slightly as the vane swings; this will account for the name 'torsional' seismometer.

"Seismometers to sense vertical vibrations usually consist of a pendulum hinged for vertical movement and supported in horizontal equilibrium by a



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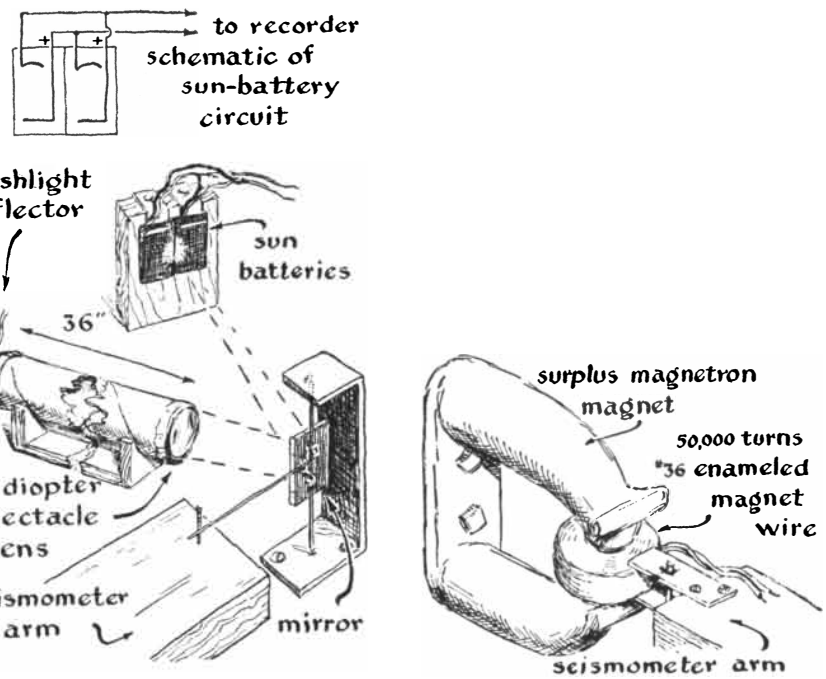
set of springs. One of many possible arrangements is shown in the accompanying drawing [*page 156*]. A mainspring supports the beam of the pendulum by holding it against a knife-edge. A second knife-edge is mounted on a short beam at right angles to the main beam. This knife-edge bears against an anvil linked to a second spring which opposes the force of the mainspring, depending upon the position of the pendulum and hence of the alignment of the two knife-edges. Adjustment of the second spring alters the natural period of the pendulum. Here the pendulum bob is a coil of insulated copper wire which moves between the poles of a war-surplus magnetron magnet. Current induced in the coil is dissipated by a resistance connected across the leads and so damps the motion by an amount which varies with the resistance.

"My first instrument was of the garden-gate type. The beam was a 27-inch piece of one-by-four-inch wood; bricks stacked on the beam acted as the pendulum bob. I found that the sensitivity of the instrument varies both with the angle at which the beam hangs and with the amount of damping. If the angle is too steep, the swing is imperceptible. If it is not steep enough, the beam will not return to equilibrium in the center of the supporting frame. The critical adjustment lies between these two extremes. To find it and at the same time find the proper weight and position of a bob which will oscillate at the desired rate requires some tinkering. This does not take long once you get the hang of it.

"The beam must of course be coupled to an amplifier. My first one consisted of an arrangement of levers. It worked after a fashion but was so full of friction that it would have taken a 100-pound pendulum to drive it effectively. So I built the electronic system which was described by E. W. Kammer in 'The Amateur Scientist' [SCIENTIFIC AMERICAN, June, 1953].

"In this arrangement I employ a coil of insulated copper wire at the free end of the beam, which swings between the poles of a magnet. The coil serves as the pendulum bob. Flexible leads connect it to Kammer's remarkable device, which can amplify frequencies from three cycles per second down to one cycle in 20 seconds. The amplifier drives an electrical pen recorder.

"The system has a number of advantages: the amplifier and recorder can be located away from the seismometer; their sensitivity may be controlled as easily as adjusting the volume of a radio; the assembly contains no delicate parts; one amplifier can be switched to several seismometers. Its disadvantage is that it responds to the velocity of the oscillations instead of their amplitudes; that is, the output of the system depends on the speed at which the magnet moves with respect to the coil. Regular seismographs show how much the earth moves, not how fast. Thus the recordings made with my seismograph differed from those in



Optical and electrical devices to link seismometers with amplifiers

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Here members of the Aerothermodynamics Staff discuss heating of jet control surfaces. Left to right: W. E. Brandt, thermodynamic analysis; M. Tucker, Aerothermodynamics Department head; R. L. Nelson, project aerodynamics; B. W. Marsh, aerodynamics; J. I. Osborne (back to camera), aerodynamics.

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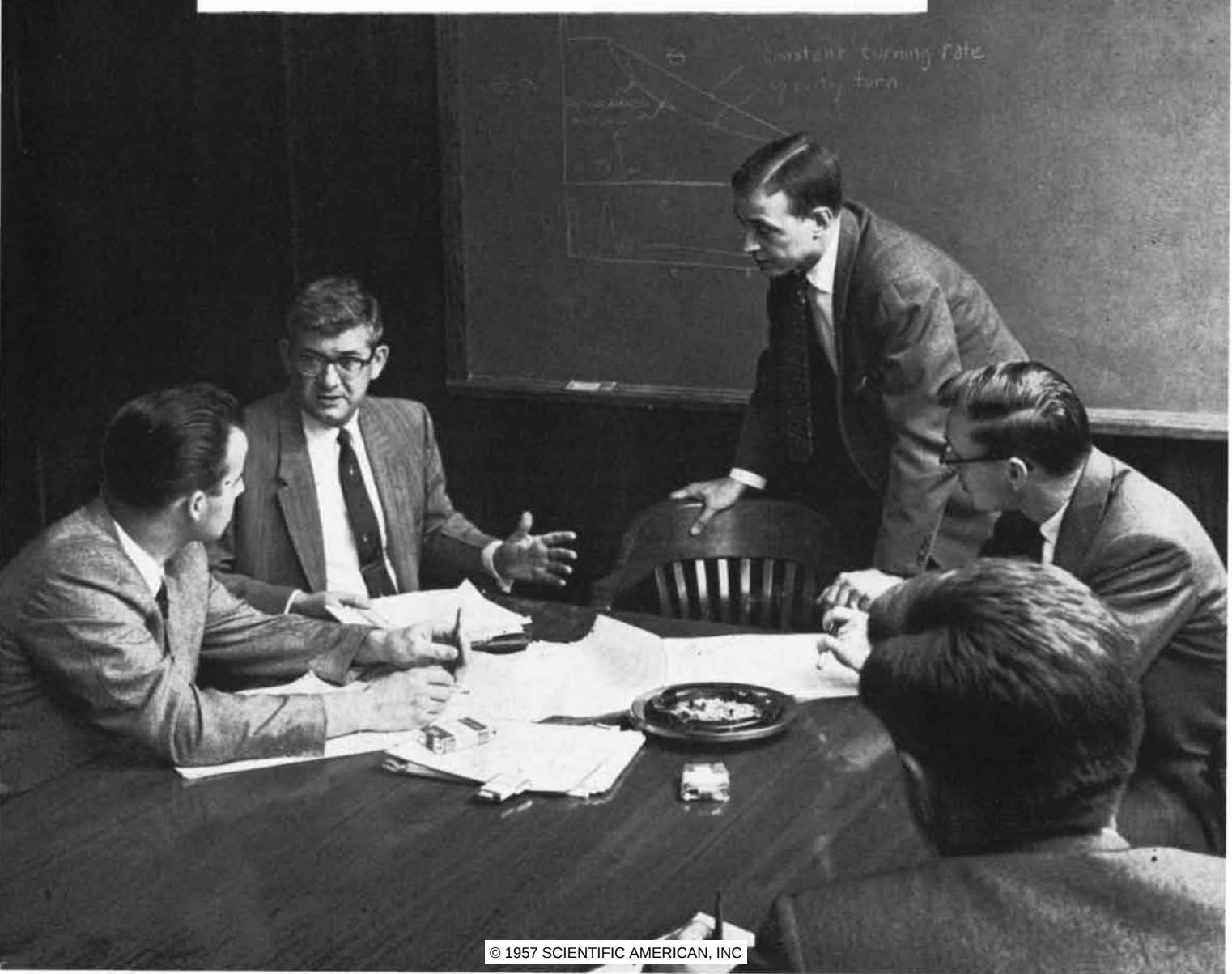

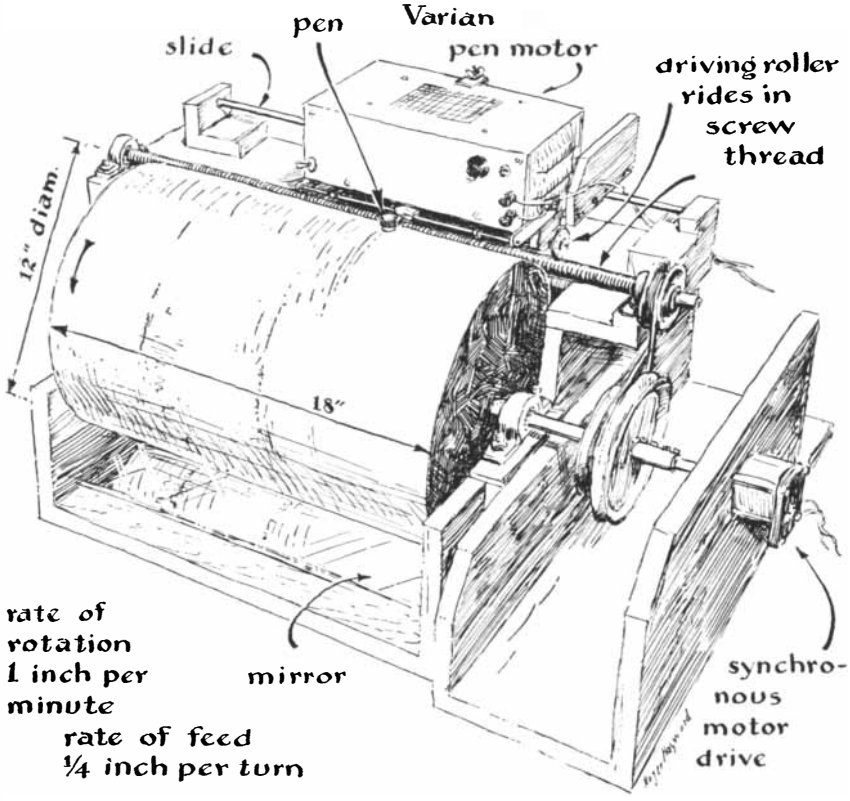

Recording drum and galvanometer for an amateur's seismograph

the textbooks, and I had difficulty in learning how to read them.

"I decided to make an amplifier that would indicate displacement rather than velocity. Most seismological observatories use an optical displacement amplifier, in which a pivoted mirror, either coupled to the pendulum through a lever or, in the case of the torsional instrument, mounted directly on the bob, reflects a beam of sharply focused light from a fixed source to a moving sheet of photographic paper. This arrangement is easy to set up and works nicely, but you pay for its simplicity with headaches. The instrument must be housed in a darkroom; you never know if it is working properly until the paper is developed. You also miss the thrill of watching a quake as it is being recorded. Finally, the large quantities of photographic paper required are expensive.

"There are a number of circuits which will translate the output of a velocity seismometer into its displacement equivalent, but all were beyond either my talent or my budget. I had just about concluded that the problem was hopeless when I came across the answer in a local radio store: a photovoltaic cell, the so-called 'sun battery' used in exposure meters. Why not substitute one of these for the photosensitive paper and drive the amplifier with its output? The principle has been used for years to amplify the deflection of galvanometers. Actually two photovoltaic cells are needed. They are arranged side by side so that the spot of light reflected from the mirror drifts from one to the other. The difference between the output of one cell and that of the other indicates the amount of deflection. The cells I use are made by the International Rectifier Corporation in El Segundo, Calif. They are called Type B-2-M and sell for $2.50 each. The system works with any convenient light source. A 35-millimeter slide projector works well. You can also make a source out of the reflector and socket assembly of a flashlight, a cardboard mailing tube and a spectacle lens [*see illustration on page 158*].

"Although a mirror silvered on the back surface will do, one silvered on the front surface will yield better results. The mirror can be mounted on two pivots which fit into indentations in a strip of metal bent into a U. The indentations are made with a center punch before the strip is bent. The lever linking the mirror to the pendulum can be a short length of magnetized piano wire. The wire is magnetically attached to and moved by a steel brad in the free end of the seismometer beam.

"The output of the sun batteries is directly connected to a Varian G-10

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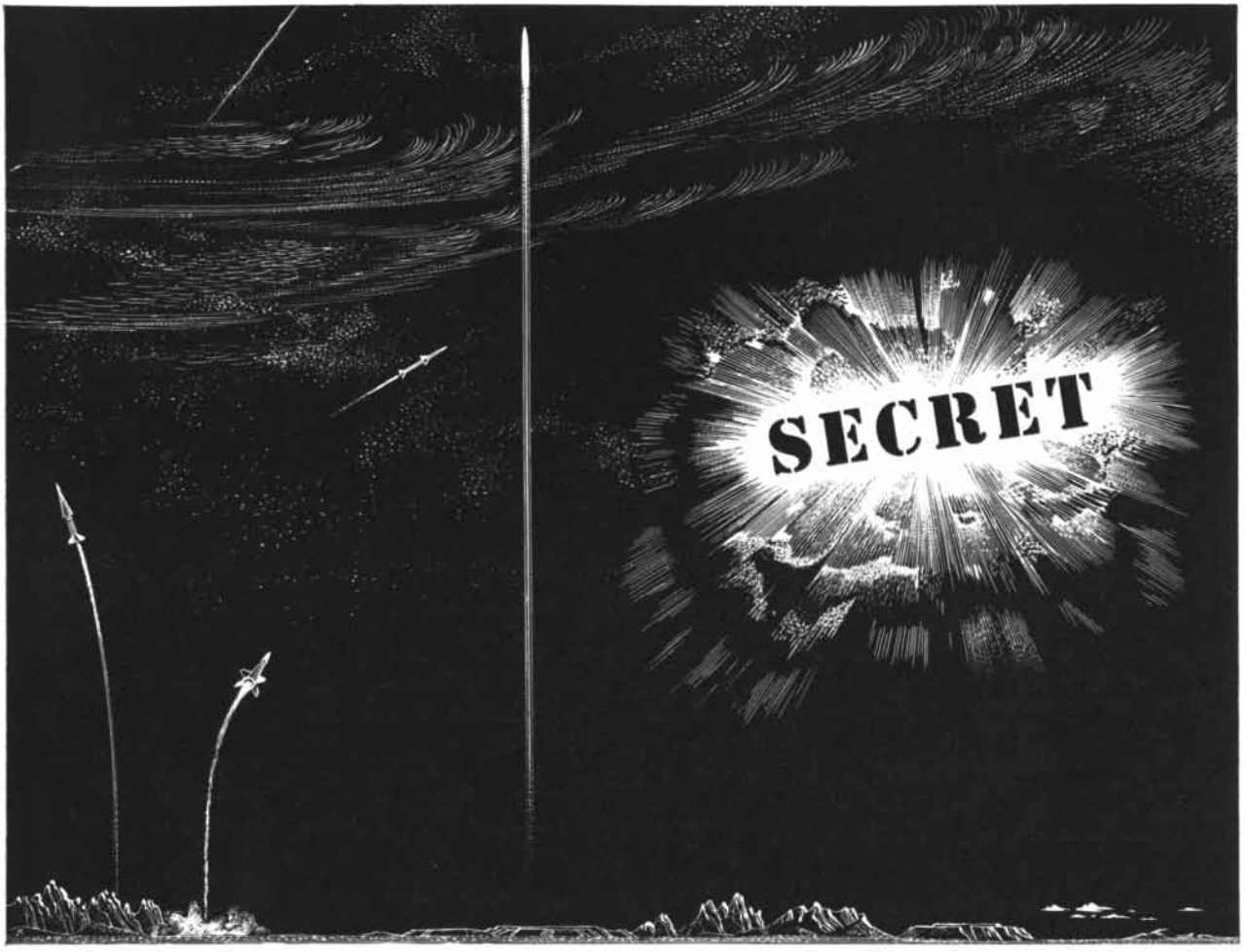

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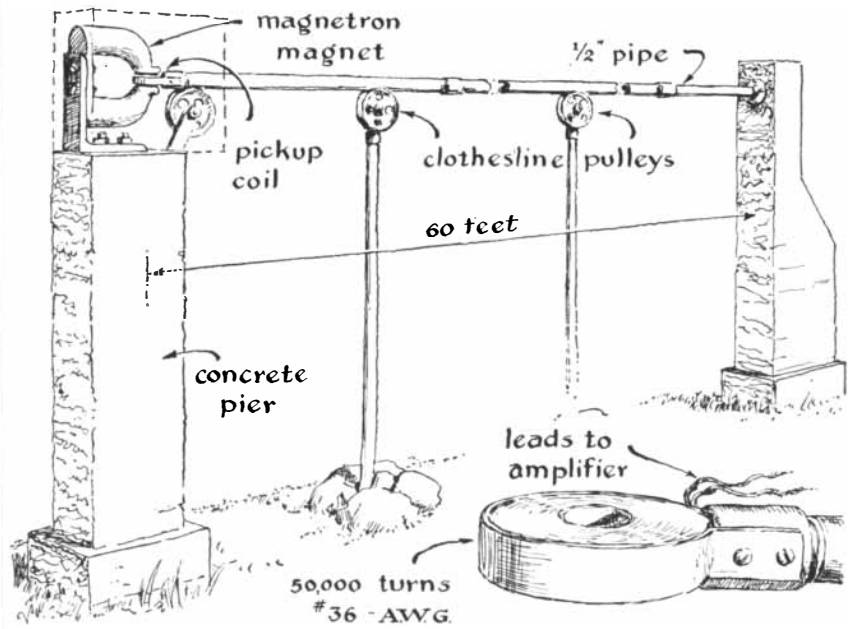
graphic recorder. This instrument includes a self-contained, high-gain amplifier with which the sun batteries can easily drive the recording pen to its full deflection. The recorder is manufactured in two units: the amplifier and pen motor comprise one and the chart drive the other. The units may be purchased separately.

"Although I have both units, I have replaced the chart drive with a homemade drum [*see illustration on preceding page*]. A seismograph eats up a lot of costly chart paper when it is driven fast enough to show the details of microseisms 24 hours a day. The drum is covered with a piece of common butcher paper 18 inches wide and 38 inches long. It turns two revolutions per hour. The pen is moved across the drum by a screw feed at the rate of 1/4 inch per revolution. Thus if the paper moves slightly more than an inch per minute, a 1,500-foot roll of it will keep the drum in continuous operation for three years! Butcher paper retails at $5 a roll.

"I used hand tools to build the whole assembly except for the drum, which must be true within 1/32 inch or the pen will skip. A local machine shop turned out the drum for me at a cost of $13.50 including all materials. The lead screw is a length of pre-threaded rod carried by most hardware dealers as stock for stud bolts. The threads are engaged by a pair of rollers from a Meccano set. The rollers support the plywood carriage on which the pen unit rides. I now have two drum assemblies and an Esterline-Angus chart recorder in operation.

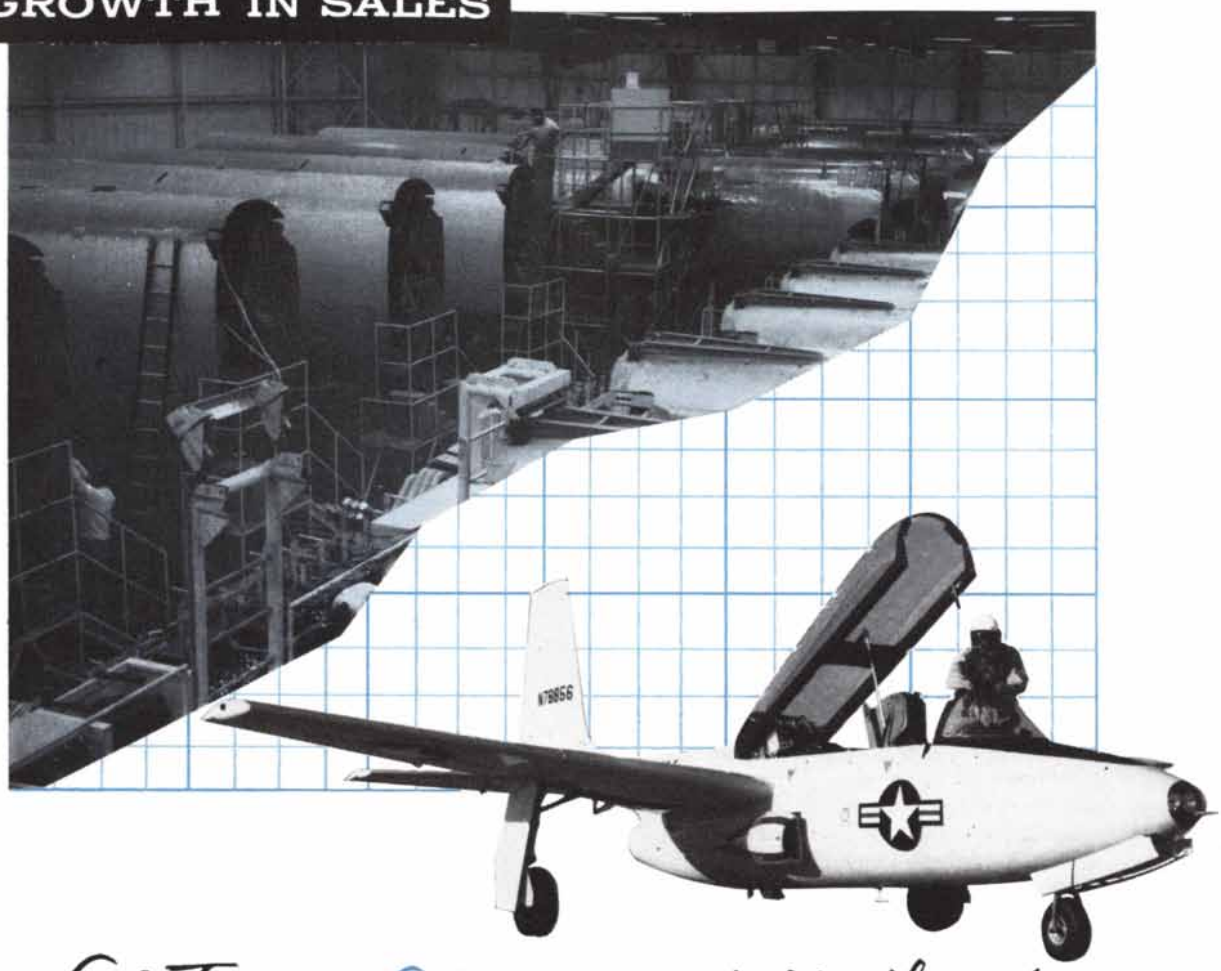
"Contrary to the impression this description may create, the construction of a seismograph is neither difficult nor time-consuming. A few days ago I started to build a seismometer at noon; by five o'clock I had used it to bag a quake, the epicenter of which was 5,400 miles away. Incidentally, my recordings are timed by an electric clock checked against station WWV. The second hand of the clock closes a switch once a minute, discharging a two-microfarad condenser through the pen motor and recording a short pip on the seismogram.

"The casual observer who wanders into a seismograph station may not be impressed by the opportunities for experiment which these slow-paced instruments provide. Firsthand experience will soon correct that impression. Building, testing and attempting to improve seismographs has kept me away from my television set for many a happy month; more projects are lined up now than when I started. I am still trying to debug an instrument of the strain type which I put together over a year ago. This instrument, incidentally, is built on two pillars 60 feet apart. Between the pillars is a long piece of half-inch pipe. One end of the pipe is fixed to the first pillar; the other end is fitted with a coil which moves between the poles of a magnet fixed to the second pillar. When a quake alternately compresses and expands the crust of the earth between the two pillars, the coil develops a voltage [*see illustration below*]. Unfortunately the setup is presently sensitive to wind and the rumble of nearby traffic."



An amateur's version of a seismograph

GROWTH IN SALES



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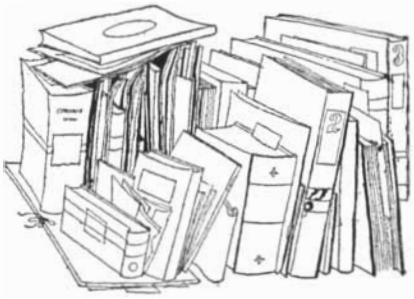


BOOKS

A study of a historic earthquake and its deep social consequences

by James R. Newman

THE LISBON EARTHQUAKE, by T. D. KENDRICK. J. B. Lippincott Company ($4).

At about 9:30 a.m. on November 1, 1755, a massive earthquake convulsed the great Portuguese city of Lisbon. There were three distinct shocks separated by intervals of about a minute. "The first alarm"—I quote from Sir Thomas Kendrick's description—"was a rumbling noise that many people said sounded like that of exceptionally heavy traffic in an adjacent street, and this was sufficient to cause great alarm and make the buildings tremble; then there was a brief pause and a devastating shock followed, lasting over two minutes, that brought down roofs, walls and facades of churches, palaces and houses and shops in a dreadful deafening roar of destruction. Close on this came a third trembling to complete the disaster, and then a dark cloud of suffocating dust settled fog-like on the ruins of the city. It had been a clear, bright morning, but in a few moments the day turned into the frightening darkness of night." The earthquake lasted about 10 minutes; but in that 10 minutes an era came to an end. After the shaking of Lisbon, Europe was not the same, as after Hiroshima the world was changed.

For the bicentenary of the disaster the Director and Principal Librarian of the British Museum has prepared this scholarly and engrossing study based upon an immense literature. Since the fall of Rome in the fifth century no other event had so shocked Western civilization. Not only in Portugal but throughout Europe there was an outpouring of diagnosis and commentary. Scientists offered explanations, preachers sermonized, philosophers speculated, poets lamented, theologians moralized and exhorted. One opinion evoked another and controversies multiplied. Sir Thomas reports the earthquake in vivid detail, but this is only the setting for his book. Primarily he is concerned with the effect of the calamity on men's minds: what light is shed on the deep questions of man's place in the world, of crime and punishment and the wrath of God, of duty to one's fellows, of competing faiths and creeds, of optimism and human prospects. Physical damage is soon repaired and the loss of human life easily forgotten, but the earthquake shaped the future by altering the course of thought.

For a few minutes of that dreadful day in November, Lisbon seemed to observers in ships on the Tagus River and on the higher ground around the city to "sway like corn in the wind." Then avalanches of falling masonry hid the ruins under a cloud of dust. But the violent tremors which collapsed some of the finest buildings and hundreds of smaller houses and shops were only the first ordeal. Within a quarter of an hour of the triple shock, fires broke out in different parts of the town, and as the conflagration mounted a third disaster occurred. The waters of the Tagus "rocked and rose menacingly, and then poured in three great towering waves over its banks, breaking with their mightiest impact on the shore between the Alcântara docks and the Terreiro do Paço [the palace square]."

Some 10,000 to 15,000 persons, it is said, lost their lives in the earthquake. Original estimates were wildly exaggerated and the official statistics, compiled with great difficulty afterwards, were not reliable. The careful historian Moreira de Mendonça thought that not more than 5,000 of Lisbon's 275,000 people were killed on November 1, but that the casualties were doubled or trebled during the course of the month. The loss of property was severe, the fire doing the most damage. Much could have been salvaged from the shattered buildings, but the flames destroyed pictures, furniture, tapestries, jewelry and enormous stocks of merchandise. The foreign traders alone—principally British and Hamburg merchants—lost about 10 million pounds worth of goods. Among the irreplaceable treasures incinerated in a single building, the palace of the Marquês de Louriçal, were 200 paintings (some by Titian, Correggio and Rubens), 18,000 printed books, 1,000 manuscripts, and a huge collection of maps and charts relating to the Portuguese voyages of discovery and colonization in the East and the New World. Seventy thousand books perished in the burning of the King's palace.

Measured by its toll of death and damage, Lisbon was not one of the greatest disasters of its kind. India, China and Japan have suffered much more terrible earthquakes. The Kwanto quake of 1923, which almost leveled Tokyo and Yokohama, killed 100,000. Nonetheless the earthquake of November 1, 1755, was in every sense a colossal seismic disturbance. It was felt over a very large area. It shook the whole southwest corner of Portugal heavily; there was a tremendous upheaval around the North African cities of Fez and Mequinez, with much loss of life; Spain, France, Switzerland and North Italy felt shocks; tidal waves were recorded in England, Ireland and the West Indies. Over almost all Europe, including Scandinavia, the water in rivers, canals and lakes was suddenly agitated. But while the ravages and astonishing side effects of this cruel day caused widespread alarm, there were other factors which had special effects on human behavior.

Consider, first, how "men of action" responded to the disaster. It must be said that they come off well. Lisbon was of course in a state of terror and panic. Corpses were everywhere. Men, women and children crept out of the rubble bleeding and mangled and searched frantically for others in their families. Suicidal attempts were made to escape from the upper stories of partly wrecked houses. The air was filled with screams and groans, and with the piteous cries of wounded horses and dogs. As flames roared through the town, it was soon enveloped in an impenetrable sulfurous cloak. And the earthquake continued. Brief aftershocks, some quite violent, kept hysteria alive. (In the week after

November 1 there were nearly 30 earthquakes, and by August, 1756, some 500 aftershocks had been recorded.) There was reason to believe, as many thought, that God would not desist until the city had been razed.

But the men of action wasted no time on such feckless speculation. Foremost among these energetic leaders was King José's Secretary of State, Sebastião José de Carvalho e Mello, the future Marquês de Pombal—the name by which he is remembered. Pombal, who was dictator of Portugal throughout the reign of José I, was troublesome, touchy and aggressive, but a man of exceptional ability. Where others, on learning of the catastrophe, wrung their hands and looked to heaven for succor, he saw the need for firm and immediate terrestrial steps to avert social chaos. When the unhappy King asked despairingly what was to be done, Pombal is said to have replied: "Bury the dead and feed the living."

This he did and much more. With the support of a group of high officials and of many plain, stouthearted Portuguese folk he restored order and confidence in a remarkably short time. He appointed special magistrates with ample power to deal with problems in the separate wards of the city. He ordered the corpses collected in barges, towed out beyond the bar of the Tagus and then weighted and sunk. He commandeered food supplies and wagons, pressed into service millers, bakers and cooks, constructed camp kitchens on the outskirts of the city, to which the population had fled. He controlled food and wood prices to prevent profiteering. He set up hospitals and shelters. He decreed the summary trial and prompt public execution of the many looters, robbers and other knaves who fattened on the public agony. Soldiers were brought in to fight fires, clear the streets and demolish dangerous structures. Salvage and rebuilding operations were so speedily put into effect that within the first year many public buildings were reconstructed and 1,000 private houses were restored to usable condition. Other towns, in particular Setúbal, had suffered extensive damage, and similar steps were taken for their relief.

It was not only to these emergency measures that Pombal gave his energetic attention. He took steps to alleviate the dislocation of money transactions and trading. He reduced the generous concessions that had been made to British merchants, and required the Junta de Commercio to levy a direct tax on all imports into Lisbon. The rebuilding of the city was of the utmost concern to him. Before the earthquake Lisbon was not noted for its architectural beauty; in fact, it had a "jumbled, partly medieval appearance." Thus the catastrophe presented an opportunity to institute a master plan of reconstruction involving public buildings and streets. An economical but handsome Pombaline architecture was imposed. As a result Lisbon is today "a classic example of 18th-century town planning, influenced by Turin and by Covent Garden." This famous rebuilding, says Sir Thomas, is Pombal's most magnificent achievement.

Dictator though he was, Pombal did not always find it easy to accomplish his purpose. Lisbon was a stronghold of the Church. The people were devout and the clergy powerful. The city lodged innumerable religious orders and swarmed with priests, monks, friars and nuns. Above all it was the city of the notorious Inquisition, whose barbarous persecutions had long offended the popes themselves. By disposition vehemently anticlerical, Pombal found reason after the earthquake to detest some of the clergy even more, for it seemed to him that at every turn they hindered his efforts at reconstruction. It would be unjust to condemn the whole of the Lisbon ecclesiastical hierarchy for these tactics, much less the ordinary parish priests who rendered heroic service in the time of greatest danger and confusion. But not a few of the clergy "exploited the earthquake in an alarmist and anti-social manner." As if the holocaust had not already produced enough suffering, as if fear and hysteria had not sufficiently fastened its grip on the population, the fanatical preachers now scourged their wretched flocks and frightened them out of the few wits they had left by prophesying greater horrors to come. The people of Lisbon were not deficient in superstition; they had been suckled on it. Pombal's task was hard but the zealots made it harder; to this point I should like to return.

It cannot be said that the men of science, such as they were, compared favorably with the men of action. Lisbon needed some plain truths about the earthquake to counteract monstrous exaggerations. But the very suggestion that the earthquake was a natural phenomenon, like an eclipse or a storm, shocked the devout and enraged their religious instructors. Even honest men deemed it prudent to hedge. A physician, José Alvares da Silva, was one of the first to venture the opinion that while the earthquake might be a judgment of God, it could also be naturally explained. He put forth several possible theories,

among them the notions that compressed air was responsible for the quake and that electricity—a fashionable phenomenon—was an important factor in it. It is our duty, he said, to find out how nature works before looking to supernatural causes. Lisbon is undoubtedly a wicked city, but to compare it with Babylon is absurd, and if God intended to make an example of it there are much more deserving candidates in other countries. A noteworthy aspect of da Silva's essay is his stress on how the researches of such men as Descartes and Newton had spiritually enriched the world. He proposed that their approach be emulated, and the physical sciences encouraged; God could not be expected to help man if he was too witless or too wayward to help himself.

Another Lisbonese author, Miguel Tibério Pedegache Brandão Ivo, took the same tack. However, he differed in his scientific diagnosis. He discoursed lengthily on subterranean fires but concluded that the real culprits were the moon and the heat of the sun. Of far greater significance than these writings was a medical treatise by António Nunes Ribeiro Sanches, a celebrated Portuguese doctor of Jewish origin who was living in France. His response to his country's ordeal was a long book on the maintenance of public health, intended for the use of the medical authorities of Lisbon. Pombal warmly approved the book, because it was full of sound advice and was an antidote to religious hysteria. Ribeiro Sanches laid down sensible rules for the prevention of epidemics, for ventilation and sanitation, for diet, exercise and personal cleanliness. The medical schools of Portugal, he said, needed to be improved, and he warned against allowing young doctors to practice without adequate clinical experience. No less valuable was his appendix on the causes of earthquakes. He made it clear that since ancient times every reasonable person who had studied the question had concluded that an earthquake is a natural event. It is dangerous and destructive, but so are tempests and lightning and gunpowder and war and fire and poison, all of which are accepted as ordinary hazards of life. Only the ignorant, timid and superstitious think otherwise, and by their primitive fears they spread alarm and a sense of hopelessness. God *may* use this instrument to punish our sins, but the majority of earthquakes "cannot possibly have a moral significance and we are very foolish to worry about them [on these grounds]."

The disputes proliferated. Dr. Juan Luis Roche, adroitly carrying water on both shoulders, expressed the opinion that while science can explain how an earthquake happens, when it does in fact happen a supernatural agency is in control. The evidence was plain. At Puerto de Santa Maria, for example, the Virgin Mary had repulsed a seismic wave; at Seville the 350-foot-high Giralda Tower, with a heavy belfry, had oscillated over an arc many times greater than that which had collapsed 30-foot towers. Why? Because God had protected it. The famous Spanish Benedictine Benito Jerónimo Feyzóo y Montenegro, respected, learned and outspoken, espoused the electrical theory and ridiculed the fear of earthquakes. This made a very great impression and prompted the aged Bishop of Guadix to reply. The electricity explanation was, he said, obvious nonsense. Fortunately the clergy were in a position to refute it, having been trained in a higher science of spirits—*pneumatologia*. With God's permission a company of evil spirits had given Lisbon a good shaking, which was exactly what it deserved. Of course they might do it again. Juan de Zuñiga, another savant, joined the Bishop in chiding Feyzóo, as did a learned young lawyer, Feliciano da Cunha França. Dr. José Cevallos of Seville came to Feyzóo's support and lectured the clergy on their duty to instruct the public on religious matters instead of spreading mischievous stories about devils lurking over the city and preposterous reports of the miraculous behavior of images.

In May, 1647, a heavy earthquake had shaken the Chilean city of Santiago. Its bishop, Gaspar de Villaroel, had been so disgusted "by the lies, false miracles, revelation, prophecies and so on that had followed the disaster that he boldly declared before all the world that he saw no reason to suppose that earthquakes were always punishments for the sins of the people who lived in the towns destroyed by their agency." The attitude of this prelate bore no resemblance, as I have indicated, to that of the clergy in Lisbon. Over the people hung a pall of religious despondency thicker and more lasting than the smoke of the great conflagration. The city was rich and wicked. God was wrathful. The people were contrite. Elaborate displays of this pervasive mood of humbleness, repentance and supplication were made. Great penitential processions were held. At the special request of the King, the Pope appointed St. Francis Borgia, who had died in 1572, as "special patron and protector of the realm against further earthquakes and similar disasters." Miracles blos-

somed. One of the many images of the Virgin was seen to weep over ruined Lisbon; another cried aloud, "It is enough, my Son, it is enough"; images of St. Anthony, the patron saint of the city, resumed their helpful services, which included retrieving lost objects.

Since God's ways are mysterious, even the most devout people craved instruction as to his method of working. Why, for example, had so many churches been destroyed but a street full of brothels spared? The answer, said the preachers, was obvious. Sacred buildings had been profaned. God had shown His terrible anger by abandoning His own altars. He could not pardon those who had sullied the temple but He could show pity for outcasts and wretches. The question was asked: Was God really a loving Father? Lisbon, it seemed, had suffered more than it deserved. Many good men and women had perished, to say nothing of a large number of innocent children. The clergy squirmed but managed an explanation. The earthquake was an act of love as well as chastisement. Its purpose, said the preacher António do Sacramento, was "to bring Portugal, as a beloved child, back into the comforting arms of Jesus Himself." Considering the offenses perpetrated against the Lord, Lisbon should have been destroyed, as were Sodom and Gomorrah. Yet the punishment had been "relatively light. Just think, for instance, what the Flood must have been like!"

The theme of God's anger and of retribution was endlessly repeated in sermons, tracts and poetry throughout Europe. In Lisbon, especially when the exhortations were insanely ferocious, the effect was to make the people apathetic and seriously to hamper the work of recovery. Should a man rebuild and start afresh, or should he, as the Jesuit Gabriel Malagrida urged, "set all this miserable worldly business aside and seek in what might well be his last hours to save his soul"? These extremes could not be reconciled; there was no conceivable compromise between the men of action and the men of God. The conflict was not confined to Lisbon: its repercussions sounded everywhere.

"One generation passeth away, and another generation cometh: but the earth abideth forever," said the preacher. But now man could not be sure that the earth would abide. We must recall the setting for this upheaval in thought. Looking backward from the first half of the 18th century, it is astonishing to see the change in outlook that had taken place in 200 years. Science, philosophy, politics, technology, trade and commerce

had transformed society. This life was no longer to be regarded as a mere preparation for the hereafter. Man was to enjoy what he had. He saw himself and the world about him as no medieval thinker could have imagined, as few of even the most ebullient philosophers of the Renaissance would have dared hope. Sir Thomas writes: "It is said that the first half of the 18th century with its enlightenment, its optimism, its cult of happiness and its content with the *status quo* was a fortunate age, so much so that it might be preferred to all other times in the past as the one in which a sensible man might elect to live." It was in all things an "age of stability." For the wealthy and educated, Basil Willey has said, it was "the nearest approach to earthly felicity ever known to man." Even the common man could share in this cozy feeling. Thus the Lisbon earthquake could scarcely have come as a more terrible shock. Suddenly the whole edifice of confidence began to crumble; in 10 awful minutes the world's sense of security was lost. There is nothing like an earthquake to make men feel helpless, to remind them of their mortality, of the vanity of all they covet and acquire, of the ridiculous insubstantiality of what they have made and built. If the ground itself will not stand firm, what remains? Even today earthquakes strike terror; how much more shattering the experience must have been in an age when earthquakes were not understood as natural events but regarded as occurrences "instinct with deity."

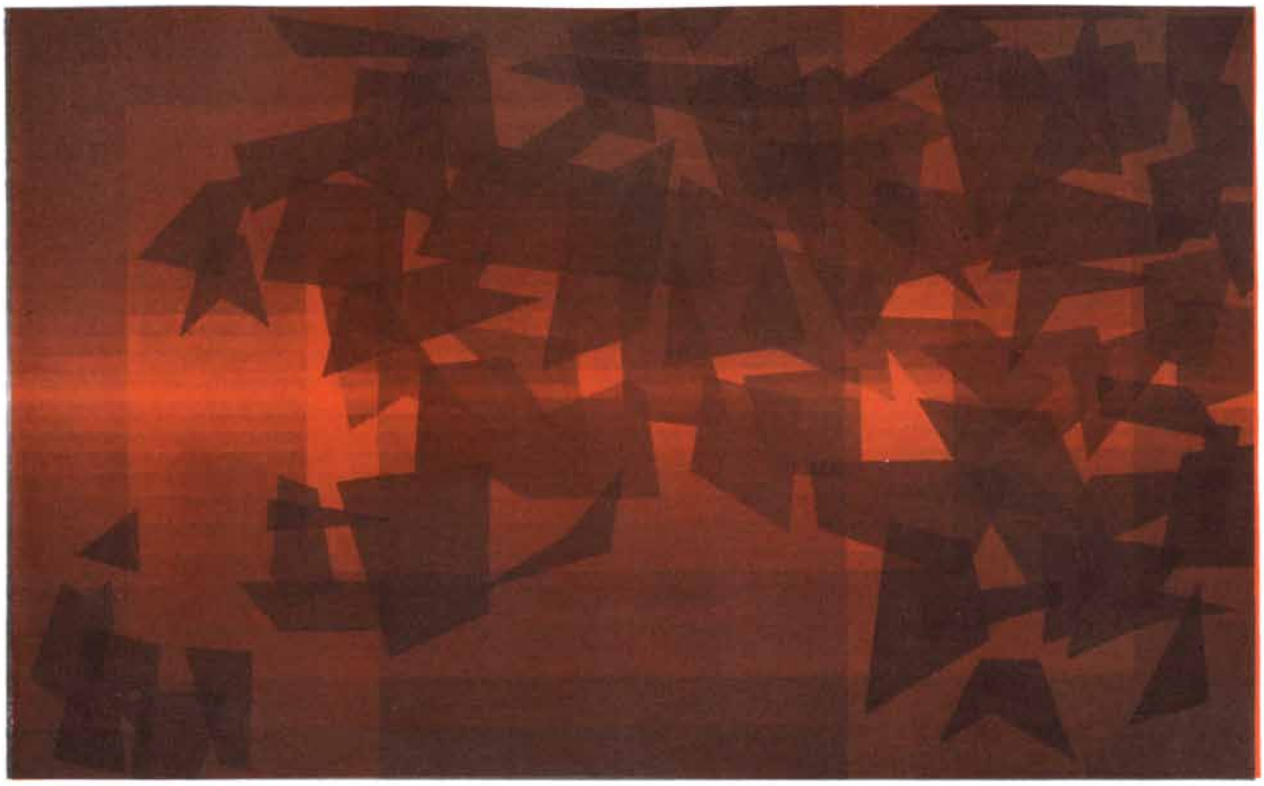
Voltaire was the foremost figure among contemporary thinkers who seized upon the Lisbon earthquake as an opportunity to attack the climate of optimism. The chief target of his attack was what he called the "*tout est bien*" philosophy, expressed 20 years earlier in Alexander Pope's *An Essay on Man*. In the preface to his *Poème sur le désastre de Lisbonne* he made some devastating points. What if, when Lisbon was destroyed, the philosophers had said to the wretched survivors: "Whatever happens is for the best; the heirs of the dead will benefit financially; the building trade will enjoy a boom; animals will grow fat on meals provided by the corpses trapped in the debris; an earthquake is a necessary effect of a necessary cause; private misfortune must not be overrated; an individual who is unlucky is contributing to the general good"? Would not such a speech be as cruel as the earthquake was destructive? We must admit, said Voltaire, that there is injustice and evil in the world, that there is inexcusable suffering, that there are inexplicable calamities. It is stupid and self-deluding to pretend that every misfortune is a benefit in disguise. It is folly to believe that Providence will assure safe conduct to the virtuous. Man is "weak and helpless, ignorant of his destiny, and exposed to terrible dangers, as all must now see." Optimism must be replaced by realism; at best, by an "apprehensive hope that Providence will lead us through our dangerous world to a happier state."

The poem was widely read and discussed. Voltaire himself was a little apprehensive as to the offense it might give in religious circles and for that reason tinkered with some of the lines. It was scarcely calculated to nourish the belief in a kind and loving God. Nor, on the other hand, did it support a blind faith in a just God whose ways might be hard but whose over-all scheme could not be questioned. Jean Jacques Rousseau was one of those who strongly opposed Voltaire's pessimism; Immanuel Kant, while less cheery, took the position that "the only possible theodicy is a practical act of faith in divine justice."

In 1759 Voltaire published his immortal satire *Candide*, which was far more influential than his poem. It blew the *tout est bien* philosophy to bits. The philosopher of the novel, Dr. Pangloss, is a German "primed with a complete apparatus of clichés and jargon derived from [Gottfried Wilhelm von] Leibniz's *Théodicée*"; for it was Leibniz who had invented the doctrine that this is the best of all possible worlds. No one could miss the point of the story. The hapless Candide suffers every conceivable misfortune, including being caught in the Lisbon earthquake, but having to listen to Pangloss is almost the worst of all:

"Some falling masonry had hit Candide, and he lay flat in the [Lisbon] street covered with debris. He said to Pangloss, 'I am dying. Get me a little wine and oil.' 'An earthquake is nothing new,' Pangloss replied; 'Lima in America had the same experience last year. Similar causes, similar effects. Obviously, there is a train of sulfur running under the earth all the way from Lima to Lisbon.' 'Nothing is more probable,' said Candide, 'but for God's sake get me a little oil and wine.' 'What do you mean by probable?' asked Pangloss indignantly. 'I maintain the case is proved.' At this point Candide lost consciousness and Pangloss brought some water from a fountain close at hand."

Optimism never recovered from Lisbon and *Candide*. "There was no more to be said; the case was finished and the case was lost." Not, of course, that it vanished all at once. "A doctrine," the



"ECLIPSE" a recent painting by Simpson-Middleman, gifted artistic interpreters of the physical sciences. About this new expression they write: "'Eclipse' was painted as a result of watching an actual eclipse of the sun. We were particularly struck with the curious light that was both dim and glowing and the unusual pattern of the shadows on the leaves of the trees around us. We had never seen anything like it before." Painting courtesy of John Heller Gallery, Inc.

French literary historian Paul Hazard wrote, "lives on for a long time, even when wounded, even when its soul has fled." But within a few years the wounds proved fatal, and a French poet could say that the age of optimism had degenerated into the Dark Ages.

Short Reviews

ARCHIMEDES, by E. J. Dijksterhuis. Ejnar Munksgaard (68 Danish crowns). About Archimedes, the greatest mathematician of antiquity, little is known. Greek mathematics itself is shrouded in obscurity and the information about the lives of its makers is paltry as well as undependable. Already in ancient times Archimedes was a legend. The stories grew and multiplied. A biography of him was written by Heraclides, but it is lost and we do not even know who Heraclides was. All that modern scholars can do is to piece together a not altogether implausible story from the various reports of Arabian historians, of Tzetzes, Diodorus, Pappus, Cicero, Lucian, Ptolemy, Macrobius, Vitruvius, Plutarch and others, and to indicate the evidence bearing on their reliability. This was done by Sir Thomas Heath in his study *The Works of Archimedes.* The present volume, by a noted Dutch historian of mathematics and the natural sciences, recapitulates the relevant data and evaluates them; but this is only a small part of the book. Dijksterhuis presents a new edition of Archimedes' work, which attempts "to bring it nearer to the understanding and appreciation of the modern reader." The exposition follows the Greek text closely, but the propositions are given in a literal translation. The proofs are set forth "in a symbolical notation specially devised for the purpose, which makes it possible to follow the line of reasoning step by step." The entire work has been translated into English by Miss C. Dikshoorn. This is a well printed, very attractive edition which students of Archimedes will cherish, but it must not be supposed that, despite the new symbolism and the editor's very helpful comments and explanations, this text opens Archimedes for the millions.

THE COLLECTED PAPERS OF PAUL EHRLICH, VOL. I, compiled and edited by F. Himmelweit and Martha Marquardt. Pergamon Press (complete set of four volumes $85). Paul Ehrlich, who died in 1915 at the age of 61, was one of the builders of modern medicine. He laid a large part of the foundations of hematology, immunology and chemotherapy; he contributed to neurology and biochemistry; he made pioneer studies of transmissible malignant tumors. A connecting link in his wide-ranging work is identified by Sir Henry Dale, under whose editorial direction this lavish edition of Ehrlich's papers was compiled. His primary interest was in the chemical properties and structure of living cells, and "in their consequent variable affinities which they exhibit for other chemical substances of different kinds." Especially brilliant was his use of the then new aniline dyes, whose distribution among the organs of the body could be visually observed. Ehrlich is remembered for his tissue stains, his refined description of red blood corpuscles and their pathological variations, his marking of tubercle bacilli, his introduction of methylene blue as a biological reagent, his establishment of quantitative standards for the administration of serums and other therapeutic agents, his measurement of the avidity of the different organs of the body for oxygen. He was the discoverer of the salvarsan arsenicals, the pioneer chemotherapeutic agents, long of the first importance in the treatment of syphilis but now superseded by antibiotics. Arsphenamine was known as 606 because that many experiments preceded its synthesis. When a friend congratulated Ehrlich on his discovery, he replied, "I've had 10 years of undeserved hard luck, and now, all at once, I've got a piece of undeserved good luck." This impressive volume deals with histology, biochemistry and pathology; the editors intend to present all of Ehrlich's scientific publications in four volumes. The second volume is to comprise Ehrlich's work on immunology and cancer; the third, his achievements in chemotherapy; the last, tributes to Ehrlich and a complete bibliography. Where a paper is outstanding, it appears not only in the original German but also in an English translation. Some of the papers have never before been published.

UNESCO SOURCE BOOK FOR SCIENCE TEACHING. United Nations Educational, Scientific and Cultural Organization ($3). The purposes of this book are clearly stated at the outset: "There are many places in the world where both facilities and equipment for science teaching are at present inadequate. Such places are to be found in areas that are more advanced in the applications of science, as well as in other regions. This volume has been produced to help the trend of upgrading science instruction in schools and training colleges

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everywhere by basing it more and more on observation and experiment." Much usable information is crammed into 220 pages. There are directions for making general pieces of equipment such as balances, heat sources, filters, pumps, tweezers, ring stands. Experiments and materials for the study of plants are described. Directions for the study of animals tell how to make a collecting net, cages, a wormery, homes for spiders and ants, aquariums. Astronomy, meteorology, hydrology, machines, mass and force, heat, sound, light, electricity and magnetism are covered by a wide range of simple, inexpensive apparatus and revealing experiments. Every item is clearly illustrated; there are convenient tables and bibliographical lists in the appendixes. UNESCO's little guide will make conscientious science teachers from Ghana to Georgia happier, and their students more knowledgeable.

WEATHER, by Paul E. Lehr, R. Will Burnett and Herbert S. Zim. Simon and Schuster ($1). WEATHER MAP, prepared by the British Meteorological Office. Her Majesty's Stationery Office (10 shillings, sixpence). THE BOOK OF STORMS, by Eric Sloane. Duell, Sloan and Pearce ($3.50). These three volumes should enable you to do something about the weather; if not to change it, at least to talk about it as knowledgeably and to predict it as dependably as the average television forecaster. The manual by Lehr, Burnett and Zim (in the Golden Nature Guide series) ranges over many topics: the effects of heat, pressure, wind and moisture; the different types of clouds; the relation between the earth's motion and weather; the origins of rain, snow, dew and frost; pressure cells; fronts; forecasting; reading weather maps. Each of these matters is clearly and succinctly treated with the help of some 300 illustrations in full color. This is an ideal pocket companion, introduction and curiosity stimulator. The Meteorological Office volume, now in its fourth edition and for many years a very popular book in Britain, provides one of the best brief accounts available of the history and modern practice of weather forecasting. It is a *tour de force* to make weather phenomena so lucidly comprehensible with the aid of only a few weather maps; the anonymous civil servants who prepared this primer deserve the highest praise. But the book would be even better if some diagrams and pictures of cloud formations were added. Eric Sloane's book of storms is neither as professional nor as comprehensive as the first two monographs. It is a modest effort, easy to read, and dependable. It will help you to tell whether that distant object in the sky, no bigger than a man's hand, is an upcoming fair-weather cumulus or the precursor of a full-grown, pleasantly menacing cumulonimbus.

STUDIES IN ANCIENT TECHNOLOGY, VOL. IV, by R. J. Forbes. W. S. Heinman ($6.50). Professor Forbes, a noted scholar of science in antiquity, continues in this volume his series of essays on the industrial arts of classical societies. He summarizes the history of textile fibers: how they were spun, processed and woven. There are many fine illustrations and copious (but at times curiously incomplete) references to the literature. Seven more installments of this illuminating survey are to appear in the next two years.

HAILSTORMS OF THE UNITED STATES, by Snowden D. Flora. The University of Oklahoma Press ($3.50). The author of *Tornadoes of the United States* gathers in this companion study varied information on a not so furious but even more destructive weather phenomenon. Hail damage in the U. S. during a 10-year period ending in 1953 averaged more than $50 million per annum; hurricanes are more mischievous, tornadoes a little less. Hailstones are usually spherical in shape, "with more or less concentric layers of compact snow and solid ice about a nucleus of partially melted snow or possibly a large raindrop in which freezing has already begun." There are many variations to the pattern, some stones being shaped like pyramids, some like disks or lenses, some being covered with spikes. The size of hailstones, like the size of the fish that got away, is apt to be exaggerated. Still, they come pretty big at times. Flora's book reproduces pictures of Oklahoma stones that are four inches in diameter and weigh seven ounces, of Missouri stones as large as baseballs, and of a super-hailstone that fell in Troy, N.Y., in 1949, which measured five by five and a half inches and weighed four pounds. The enormous accumulation of hail from a severe storm is hard to imagine. In 1951 hail piled up to a depth of 12 inches in an area in southern Kansas; drifts up to six feet deep have been recorded in Iowa. The hazard of hail to crops, property and aircraft has stimulated the study of forecasting methods and of the suppression of hailstorms by breaking up their clouds as they form. In the latter department little progress has been made, but a breakthrough is

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possible. Flora writes on the causes (which are still in dispute) and distribution of hailstorms, on forecasting, hail insurance, the hail hazard by states, hailstorms in other countries. Tables, maps and plates.

THE BIRD BIOGRAPHIES OF JOHN JAMES AUDUBON, selected and edited by Alice Ford. The Macmillan Company ($10). From Audubon's multivolume *Ornithological Biography*, a text to his magnificent folio *The Birds of America*, the editor has selected some 80 biographies which she regards as the "most interesting and characteristic" of the bird biographies. Many of the biographies are of undeniable interest, but Miss Ford's edition of the text is flawed with zoological and other inaccuracies. The most desirable feature of the book is reproductions of 12 beautiful watercolor and chalk drawings by Audubon in the collection of the Harvard University Library. These have never been reproduced before.

GREEK SCIENCE IN ANTIQUITY, by Marshall Clagett. Abelard-Schuman, Ltd. ($4.75). Greek science has had a long and eventful life. It was born several centuries before the Christian Era, reached its high point in the works of Euclid, Archimedes and Apollonius of Perga, and was eclipsed in late antiquity. It was revived in the Middle Ages when students turned to Islam, which had preserved the great body of classical Greek learning. It is almost superfluous to mention the debt of modern science to the ancient Greeks. In this concise survey, written for the adult or student reader without specialized scientific background, Clagett covers the fate of Greek science in late antiquity. The author is engaged in a study of medieval science which will pick up where the present work ends.

THE ENJOYMENT OF MATHEMATICS, by Hans Rademacher and Otto Toeplitz. Princeton University Press ($4.50). This attractive book, known in the German edition for more than a quarter of a century, is now for the first time available in English. It moves lightly and informatively over a wide range of topics. These include prime numbers, problems of maxima and minima, the theory of sets, factorization, the four-color map problem, the regular polyhedrons, Fermat's theorem, linkages, approximating irrational by rational numbers, Euler's proof of the infinity of primes, periodic decimal fractions, combinatorial problems, arithmetic and geometric means, perfect numbers, Waring's problem, compass constructions, traversing nets of curves, curves of constant breadth. Many of the selections are easy for anyone who remembers a little algebra and geometry; but when the authors cut below the surface, the amateur to whom they claim their book is addressed had better not be a novice.

Notes

VENOMS, edited by Eleanor E. Buckley and Nandor Porges. American Association for the Advancement of Science ($9.50). Papers presented at the First International Conference on Venoms held at Berkeley, Calif., in 1954.

THE IDLER AND HIS WORKS, AND OTHER ESSAYS, by George Santayana. George Braziller, Inc. ($4). Twelve essays on various subjects, from Americanism to the ethics of Spinoza, never before published in book form.

ATLAS OF EUROPEAN HISTORY, edited by Edward Whiting Fox. Oxford University Press ($7). Sixty-four pages of maps presenting Europe's past in geographical terms.

THE PSYCHOLOGY OF INSANITY, by Bernard Hart. Cambridge University Press ($1.75). This little book, which has sold tens of thousands of copies since its publication in 1912 and has never been materially altered or revised, remains a model introduction to the complex, doctrine-ridden, flourishing field of mental illness.

INTELLIGENCE IN THE UNITED STATES, by John B. Miner. Springer Publishing Company, Inc. ($4.25). A survey of U. S. intelligence levels based on a sample of 1,500 persons aged 10 and over.

A SYMPOSIUM ON THE CHEMICAL BASIS OF HEREDITY, edited by William D. McElroy and Bentley Glass. The Johns Hopkins Press ($12.50). This substantial work consists of papers and informal discussions presented by geneticists, virologists, biochemists, physiologists, biophysicists and physical chemists at a 1956 Johns Hopkins symposium under the sponsorship of the McCollum-Pratt Institute.

THE PHYSIOLOGY OF NERVE CELLS, by John Carew Eccles. The Johns Hopkins Press ($5.75). A technical monograph describing the investigation of nerve cells by electrical methods.

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DIDYMIUM

A plentiful and economical rare earth mixture

a report by LINDSAY

You have often watched a welder at work, watched briefly that is, because the intense glare, even at a safe distance, forced you to turn your eyes away. And you wondered perhaps how it is that a welder, even with protective goggles, can focus his eyes on a welding spot for minutes at a time.

The secret, of course, is *Didymium*. The lenses in the welder's goggles, and in the glass blower's goggles, too, are made with didymium which completely absorbs yellow sodium light, thereby reducing glare and eye fatigue.

WHAT IS DIDYMIUM?

In 1842, a European chemist named Mosander separated from a crude rare earth mixture some material he called "didymium." He thought it was a new element. Actually it was a mixture of rare earths predominantly neodymium and praseodymium. Classically, didymium means a mixture of Nd and Pr. However, commercially, the name didymium is restricted to the cerium-free group of rare earths extracted from monazite ore, since the composition of the mixture is reasonably constant.

Didymium is the basic material from which all the other rare earths except cerium are produced. Lindsay produces didymium in various forms for different applications. For example:

Didymium Carbonate—pink powder, insoluble in water, soluble in acids.

Didymium Oxide—brown powder, insoluble in alkalis, soluble in acids.

Didymium Chloride—pink lumps, soluble in water and acids.

TYPICAL APPROXIMATE COMPOSITION OF RARE EARTHS IN DIDYMIUM MATERIAL

La_2O_3	45%
Nd_2O_3	38%
Pr_6O_{11}	11%
Sm_2O_3	4%
Other rare earths and yttrium oxides	2%

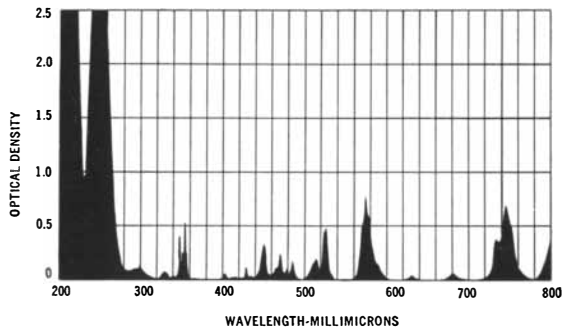
Didymium is one of the most economical forms of rare earth mixtures and is available for prompt shipments in carload quantities. It is useful for the coloring characteristics of Nd and Pr and for some of the other rare earth properties where purity is of secondary importance.

In addition to its extensive application in the production of lenses for welders' and glass blowers' goggles, didymium has other important uses. In coloring and decolorizing of glass. As a porcelain coloring agent. In light filters for calibration of instruments. To control the temperature coefficient of capacitance in barium-titanate ceramic condensers for radio and electronic use (U.S. Pat. 2,398,008). In stainless steels which are forged hot (U.S. Pat. 2,553,330).

We'd like to tempt you to investigate didymium and other rare earth salts as possible materials for use in your chemical and manufacturing processes. The very fact that important companies in a wide cross-section of industry, through their own research, have discovered profitable applications for the rare earths may intrigue your own research people.

We can be helpful to you and will be pleased to supply any information we can. Please keep in mind that we produce rare earths in purities up to 99.9% and higher in some cases (which is an achievement in itself). Shipments, depending on the salts you may need, can be made to fit your schedules in quantities from a gram to a carload.

Absorption Spectrum of **DIDYMIUM CHLORIDE SOLUTION** *from monazite containing 1 g. rare earth oxide/100 ml. compared with water in 5 cm. cells*



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