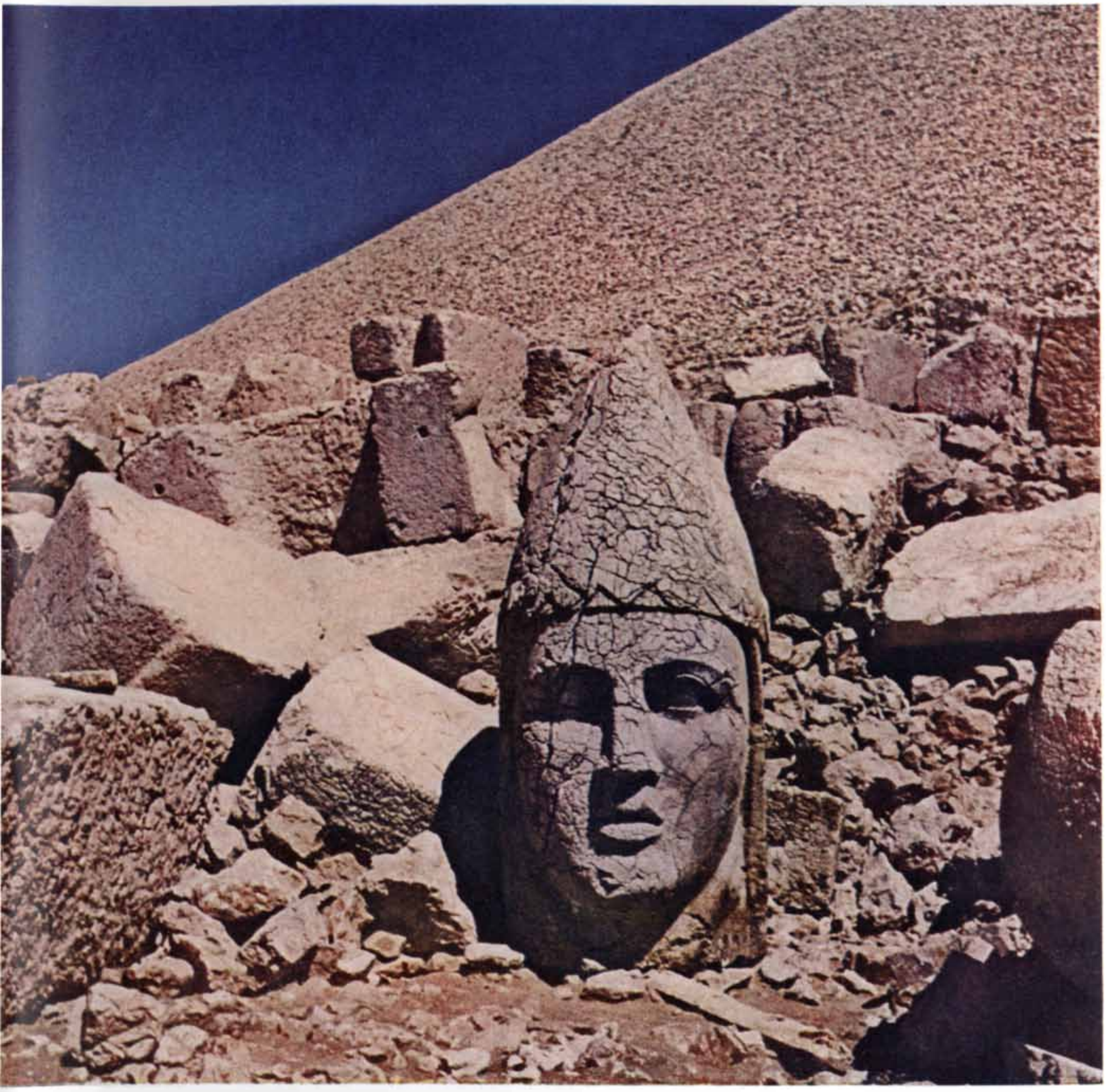
SCIENTIFIC AMERICAN



ANTIOCHUS I, KING OF KOMMAGENE

FIFTY CENTS

July 1956

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Warp-free wood panel—Novoply—is a 3-ply laminate with faces of specially prepared wood flakes and a core of wood chips—all resin-impregnated and molded under heat and pressure to form a dense, hard, flat panel. Novoply is extremely rigid, dimensionally stable. In thicknesses from ⅜" to 1"; sizes up to 4' x 16'. Used as core stock for furniture, as sliding doors, and wardrobes. NOVOPLY®.

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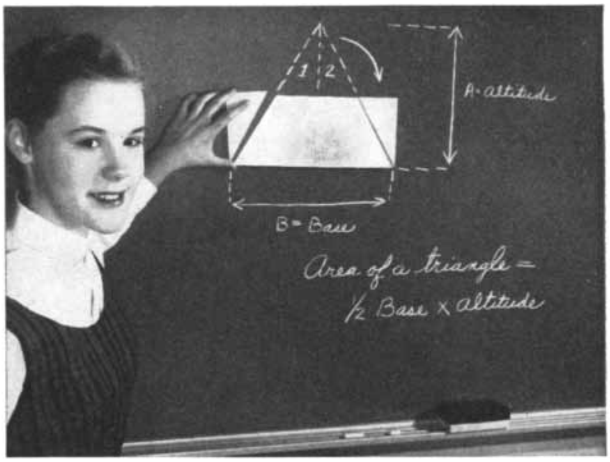
Metal-clad plywood—Armorply—has permanently bonded faces of copper, aluminum, stainless steel or any other metal on one or both sides. Plywood backing gives strength and rigidity. Lightweight, verminproof, waterproof, easy to work. Sizes to order. Used for cold storage rooms, sectional electrical shielded rooms (shown above), truck bodies, carrying cases. ARMORPLY®.



New double-duty visual aid—Chalkboard—is writing surface and magnetic display board in one. Made of plywood with porcelain-on-steel face, and backed with steel. Magnets cling to surface to hold displays or demonstration material. Available in gray, green or blue; and in "projection white" for use as movie screen. Sizes to order, (max. width: 4'; max. length: 10'). CHALKBOARD®.

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- ☐ Duraply
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Established 1845 **SCIENTIFIC AMERICAN** July, 1956 Volume 195 Number 1

ARTICLES

DEPARTMENTS

THE COVER

Antiochus I, whose stone portrait appears on the cover, ruled over the tiny Near Eastern kingdom of Kommagene from about 69 to 34 B.C. During his lifetime he built a remarkable monument to himself on the summit of Nemrud Dagh, a 7,500-foot mountain in what is now southeastern Turkey (*see page 38*). The monument consists of a huge mound of loose stones surrounded by three terraces decorated with reliefs, altars and colossal statues of Antiochus and his curious hybrid gods. In the photograph on the cover the slope of the mound may be seen at the upper left. The head of Antiochus stands amid the rubble of fallen statuary on the West Terrace of the monument. Made of limestone, it stands about eight feet high. It was originally part of a statue between 24 and 30 feet high.

THE ILLUSTRATIONS

Cover photograph by Heinrich Buerger, Nemrud Dagh Excavations

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32	Eric Mose
33	Ohio State University
34-35	Ohio State University (*top*), Eric Mose (*bottom*)
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amorphous nickel alloy coating

Number 5 In A Series

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

BASIS MATERIALS THAT CAN BE KANIGEN COATED

METALS

Virtually all of the alloys of iron, copper and aluminum, wrought and cast, can be satisfactorily Kanigen coated. In certain instances, particularly with regard to aluminum alloys, special pre-coating preparation techniques are required which may cause some alteration of the basis material. Aluminum alloys are slightly etched in pre-coating treatment, and Kanigen coatings on these surfaces usually will display a satin finish appearance. In most cases, however, Kanigen coatings will reproduce accurately the surface finish as it is supplied.

Tin, lead, zinc, cadmium, antimony and bismuth *cannot* receive Kanigen coatings directly, and if immersed in the coating solution, will retard the coating reaction. This precludes the use of tin-lead solders on parts intended for Kanigen coating; silver solders are acceptable if they can be used.

Kanigen alloy coatings are utilized on small *and* large metal parts. For example, Kanigen coatings have been applied to components measuring $\frac{1}{16}$ inch maximum dimension, and to the interior surfaces of vessels 50 feet in length.

NON-METALS

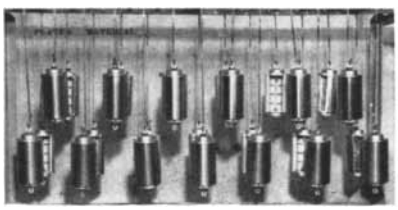
Glass, ceramics and thermosetting plastics can be Kanigen coated. These materials are chemically or mechanically roughened prior to coating, and while Kanigen deposits on these non-metals are adherent and continuous, they will reproduce the roughened surface, displaying a modified "orange peel" appearance.

Should a polished surface be required, electrolytic copper plating may be deposited on the Kanigen coating, buffed to the desired finish and followed with additional Kanigen or electro-plated metals.

Kanigen nickel alloy coatings are applied directly to the non-metals to provide the following:

- solderable surface
- conductive surface
- wear resistant surface
- moisture barrier
- base for electrodeposition

Kanigen-coated 10-inch valve body (cast steel)



Kanigen-coated cast-iron rolls

Kanigen-coated aluminum parts

Kanigen-coated brass fitting

Kanigen-coated stainless steel cylinder

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

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LETTERS

Sirs:

In the marvelous article "Ancient Masters of the Desert" [SCIENTIFIC AMERICAN, April] the Nabataeans are called an Arab people. This agrees with the usual assumption, but it is incorrect.

The Nabataeans were an Aramaic nation. The inscriptions of the eighth century B.C. found in Arabia Petraea are Aramaic. Theodor Mommsen (*History of Rome*, Book V, Chapter 4, Section 69) wrote: "The Nabataeans, this remarkable nation, has often been confounded with its eastern neighbors, the wandering Arabs, but it is more closely related to the Aramaean branch than to the proper children of Ishmael."

WILLIAM SIEGEL

New York, N. Y.

Sirs:

Although a long-time reader and admirer of *Scientific American*, I have never before felt compelled to write to the editors. However, Robert P. Knight's review of Ruth Munroe's *Schools of Psychoanalytic Thought* [SCIENTIFIC AMERICAN, April] moves me to some comments which I feel are worth printing, not so much to challenge directly Dr. Knight as to indicate to the rest of your scientifically oriented readers that there are other more logically defensible posi-

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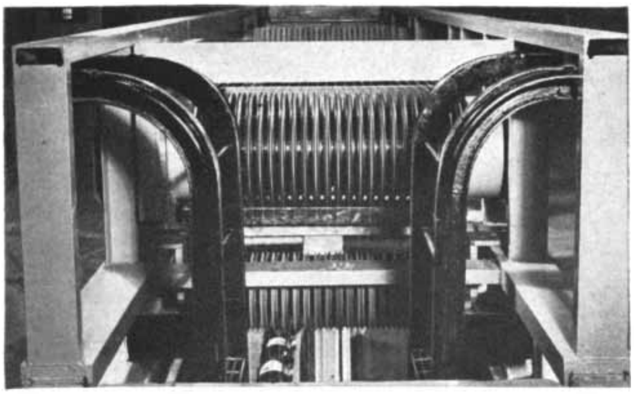
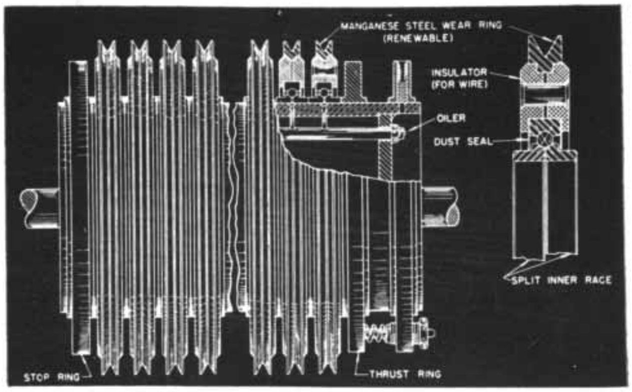
tions than the one embraced by the reviewer.

Dr. Knight starts with the quite defensible premise that Freud devised and developed the psychoanalytic theory and technique, and he properly concludes that the mainstream of psychoanalysis is "Freudian." However, he then proceeds to use "Freudian" and "libido theory" interchangeably and exclusively in spite of his previous assertion that the term "psychoanalysis" has a threefold connotation: a research technique, a growing body of empirical data and collection of specific hypotheses, and a special technique of therapy. All the other therapies discussed in Dr. Munroe's book would more or less fulfill these requirements, except for the "specific hypothesis" of the libido theory. Dr. Knight is left very much in the position of a churchman who would restrict the use of the term "Christian" to Roman Catholics.

The question of labels is not, however, as disturbing as his later inferences about the personal neuroses of the "dissenters." Dr. Knight cavalierly dismisses Karen Horney's schism from the New York Psychoanalytic Institute, completely dismissing the theoretical issues involved, and ignoring the fact that she did not leave "with a few faithful students" alone, but with a group of mature colleagues who have since made a considerable imprint on the psychoanalytic scene. Most important is his assumption that rebellion against the established theoretical formulations is, *per se*, neurotic. This is based on two major misconceptions: first, that there is any validity in discarding a man's theory on the grounds of his personal neurosis, and, second, that dissent is necessarily neurotic and undesirable. The first point is, I think, self-evident: a theory stands or falls on clearer and more dispassionate evidence than the peculiarities of its founder. Second, the concept that dissent is unhealthy is a position more appropriate to the Victorian authoritarianism of Freud's day than to the more hopeful permissiveness of our own. Most significant change results from the dissent against the established system of beliefs; this is the history of the Western world. If dissent is treated with respect, then new ideas may result which will be of benefit to the community at large. If it is squelched, the dissenter has no choice but to submit and substitute variations on the old theme for original thought, or to take his ideas elsewhere, to a more receptive climate. Both the dissenter and his opponent then lose the opportunity of interchanging ideas, a



After processing in 600-foot electroforming tanks, band of 25 wires is delivered via battery of tensioning sheaves (upper) to reels on lower floor of plant.



Split-race ball bearings utilized in tensioning sheaves as *friction* rather than *anti-friction* elements helped to solve the problem of wire tensioning.

Solved: Automatic Production of Telephone Wire

There's an example of automation in a Western Electric factory in Baltimore which is a monument to an idea for making better telephone wire – in this case, conductor for the wire which runs from the telephone pole to your house.

The idea, conceived and made a reality by engineers of Western Electric boiled down to this: Develop a process in which successive coats of copper, lead and brass will be deposited on steel wire in one continuous operation from supply spools to take-up reels.

In carrying out the idea, quite a few problems were encountered. For example: the copper-clad wire must have uniform conductivity and the coatings must be deposited upon the steel core wire successively in one uninterrupted operation; the plating solutions must not drag along the wires and so contaminate any one solution with a previous one in the process; controls must be established to provide increase or decrease of copper deposition rate in order to maintain a standard resistance value.

Solutions to the electrical, chemical and metallurgical problems are interesting – and have been written-up elsewhere. But the ingenious answer to one of the mechanical problems has, thus far, not been described. That problem: how to advance and uniformly tension 25 strands of steel wire as they are (1) paid out by a constant speed capstan at one end of a series of plating tanks 600-feet long and (2) drawn through by a tensioning capstan at the other end. Minute irregularities in the wires and in capstans of conventional design cause some wires to run tighter than others.

The challenge to Western Electric engineers: Find the most effective design for a battery of 25 tensioning sheaves – each capable of adjusting automatically to unpredictable variations in wire speeds and, simultaneously, of maintaining any predetermined pull on the wires between the limits of 1 and 15 pounds.

Paradoxical Use of Ball Bearings

The solution lay in the application of a basic physical principle: *Elastic deformation of matter requires the expenditure of work.* Thus, heavy loads increase the rolling resistance of ball bearings by distorting the balls and raceways – in much the same way that soft tires and roadbeds increase rolling resistance of an automobile.

Western Electric engineers applied the principle in a design that took this form: Twenty-five tensioning sheaves, each equipped with a ball bearing that features a split inner-race assembled side-by-side on a common driving drum, as shown in the drawing above. Adjustable thrust, applied to the inner races of the stack of bearings, with compression springs acting against the thrust, brings the complementary halves of the races together and forces the balls against the one-piece outer race. The load so applied distorts the balls and raceways. Consequently the amount of torque transmitted from driving drum to sheave varies in proportion to the thrust applied by the compression spring. Thus, contrary to previous conceptions, ball bearings are put to work under controlled conditions to increase rather than decrease rolling resistance – a seeming paradox.

In operation, the driving drum rotates at a rate which would cause the wires to be overdriven if the sheaves were keyed rigidly to it. The bearings roll just enough to compensate for the difference – and transmit just enough torque to maintain the desired tension.

When all the problems were solved a plant was built to accommodate two giant electroforming machines, engineered to operate around the clock with a minimum of labor. The result: better, stronger wire at lower cost.

Since the Bell System uses over 300,000 miles of this kind of wire annually, the new process adds up as an important contribution to the economy and efficiency of Bell telephone service.

For over 73 years Western Electric has been coming up with improvements like this which, because we are a part of the Bell System, is reflected in the good, dependable service enjoyed by Bell telephone users at low cost.

Problems of significance such as this are being solved right along at Western's 22 plants. Sure, we're on the lookout for qualified engineers to help us!

Western Electric

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM necessary catalyst for scientific growth. Any good father knows he can establish a better relationship with his son by permitting and respecting his dissent than by attempting to repress it. It is no wonder that some libido theorists are so concerned with the "castrating father"—they have created him in their own image.

I feel that it is vital that any scientific forum reaffirm the right to dissent and even the precious right to be wrong. It is only fair that your other readers, in fields where this scientific axiom is more respected, be apprised of the "dissentist" case.

EDGAR A. LEVENSON, M. D.

New York, N. Y.

Sirs:

With reference to your April issue, in which you show a set of stereo views of the moon on page 164 and label one method of viewing them as the "cross-eyed" method, I believe that the following is a more relaxing method.

Holding the page at about a foot or so from the eyes and then relaxing them, or focusing on the wall or floor behind the page, also yields four images, and the two "inner" ones will converge to give the stereo effect.

Since the most natural position for the eyes is with their focus at infinity, or both eyes straight ahead (or parallel), this method imposes less strain on the eye muscles.

ENSIGN ROBERT FABRIS

Fleet Post Office
San Francisco, Calif.

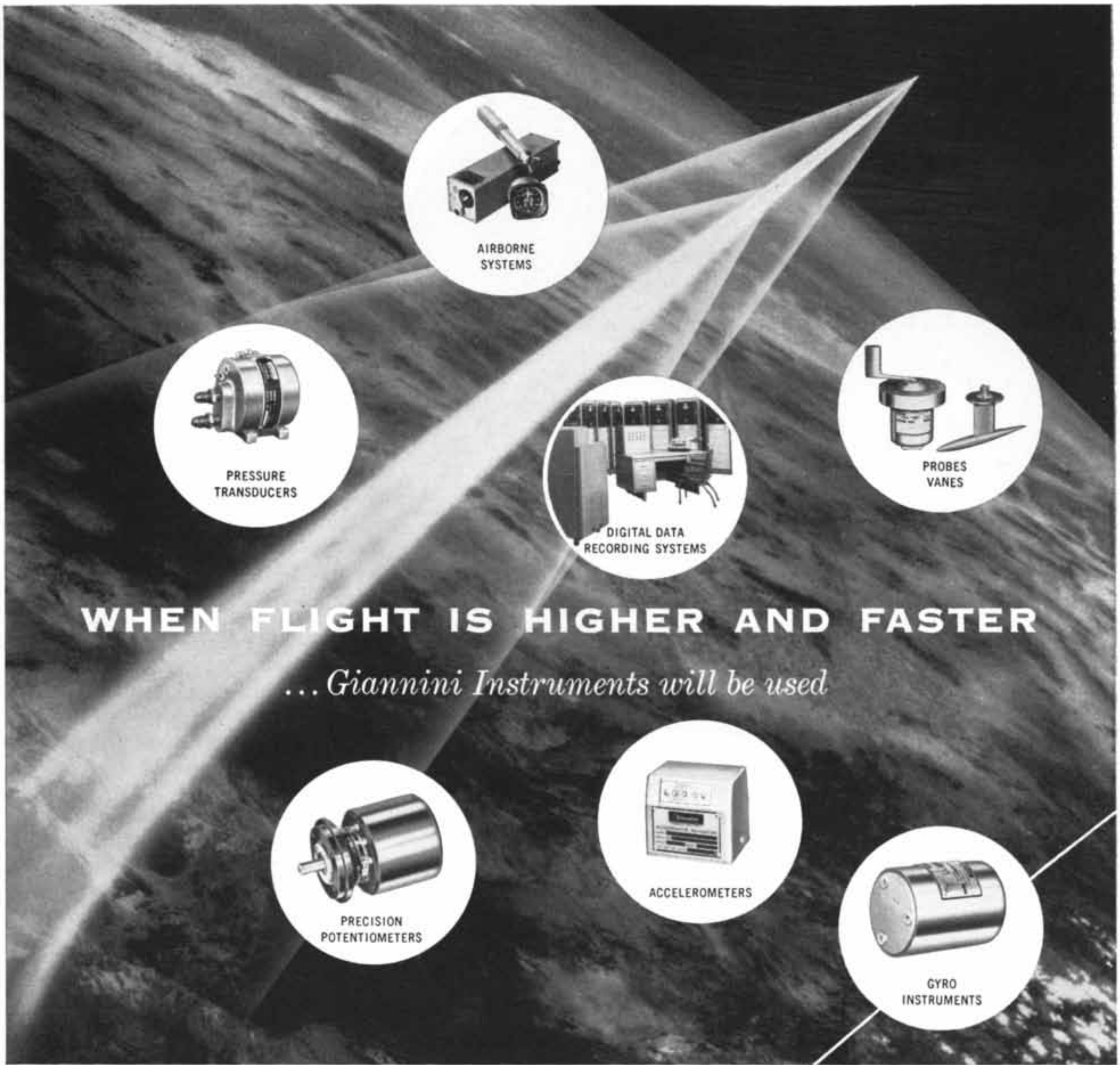
Sirs:

Regarding your discussion of Murphy's Laws in the April *Scientific American*, our engineering department has found that all of these laws can be deduced by the most rigorous logic from a single elegant principle which we call simply "The First Principle." It is: All inanimate objects follow the line of maximum perversity.

We feel that this statement of the law would be still more elegant if it could be generalized by dropping the word "inanimate," and present studies indicate that this can probably be done.

PHILIP R. GEFFE

Chatsworth, Calif.



Scientific achievement in the field of aircraft and missile development is literally attaining new horizons ... Keeping pace with those milestones of progress, Giannini, too, is advancing—both in theory and in practice.

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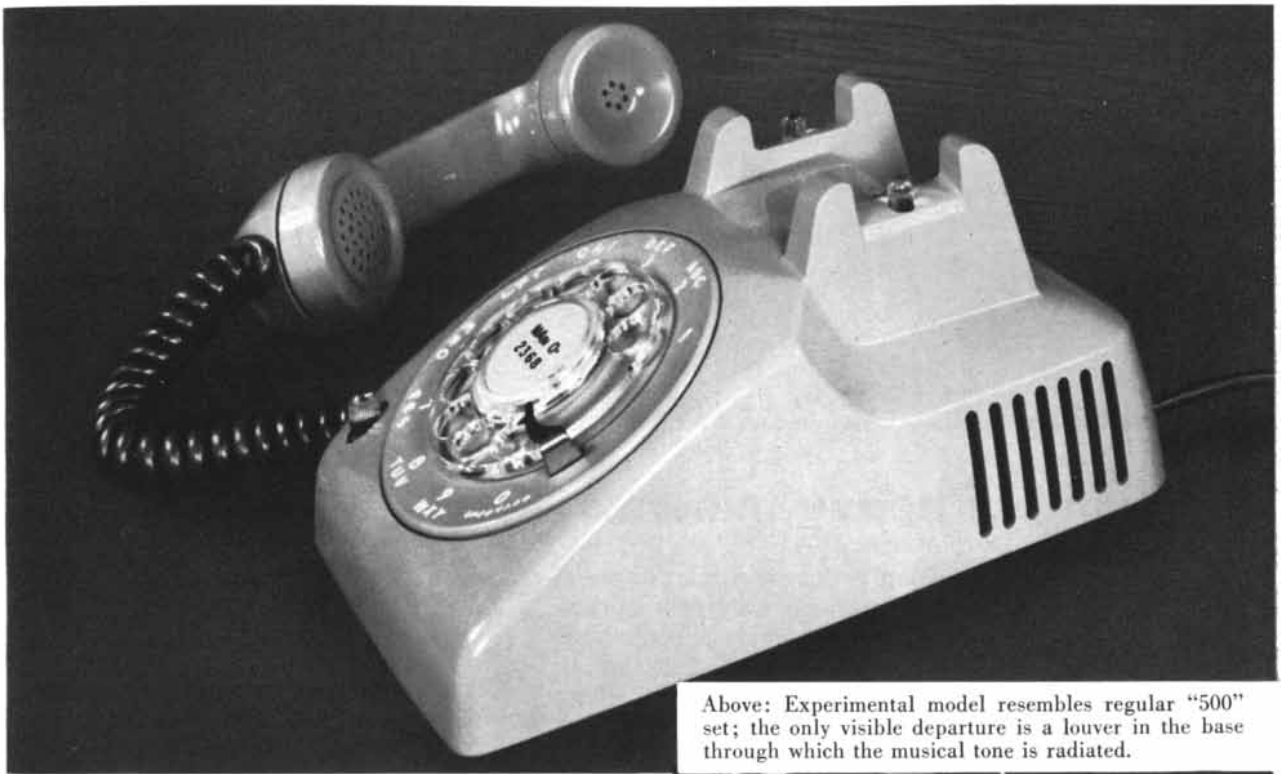
50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

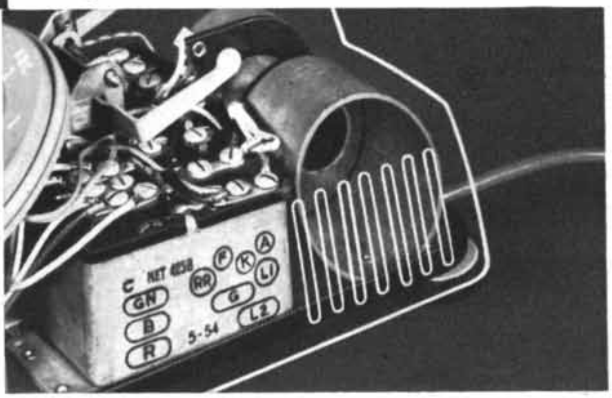
JULY, 1906: "At a recent congress of the French Academy of Sciences, the Prince of Monaco exhibited a newly designed instrument intended for deep-sea research, which instrument he is utilizing in connection with his marine biological investigations. The device consists of an ingeniously contrived glass vessel, which can be safely let down to the lowest known depths, the sounding wire with which it is connected at present being 18,000 feet in length. When the requisite depth has been attained, the water present at that level is admitted into the receptacle, and remains a pure, uncontaminated specimen, since no further water can enter while the vessel is being hauled through the upper levels to the surface."

"In the *Proceedings* of the Berlin Academy W. Kaufmann has repeated his measurements of the mass of the electron at various speeds with greatly increased accuracy, in order to decide, if possible, between the rival theories of Abraham, Lorentz and Bücherer with regard to the structure of the electron. As a source of electrons he used radium, and instead of an electro-magnet he used two highly aged permanent magnets. He photographed the magnetic and electric deflection curves on films cast on plate glass, and compared them with the curves demanded by the three theories. The final result is stated as follows: The value of e/m for infinite slowness, as derived from cathode-ray experiments, is 1.885×10^7. The curves of deflection of the β-rays of radium, interpreted according to the theories of Abraham, Lorentz and Bücherer, respectively, give 1.823, 1.660 and 1.808×10^7 for the same ratio. The theory of Lorentz, according to which the electron in motion is reduced in the direction of motion, but not laterally, is, therefore, least probable. The experiments do not, however, decide between the theory of M. Abraham, who assumes an absolutely rigid electron, and that of Bücherer, who assumes that the electron in motion becomes a Heaviside ellipsoid with un-

Transistorized telephone summons you with a musical tone



Above: Experimental model resembles regular "500" set; the only visible departure is a louver in the base through which the musical tone is radiated.



Bell scientists have developed a new musical tone device which may some day replace the telephone bell, if it meets technical standards and customers' approvals.

Because the musical tone equipment uses transistors, the tones will be transmitted with the same amount of power required to transmit a telephone conversation — considerably less than is needed to make a telephone bell ring.

The experimental telephone sets resemble the current "500" sets; the only external difference is a louver at the side of the base through which the tone is radiated by a small loudspeaker mounted inside the telephone's base.

Tests have shown that the musical tone can be heard at great distances. It stands out above general room noise and can be distinguished from such sounds as ringing of doorbells, alarm clocks, and home fire alarms.

This new low-power signaling technique is expected to play an important part in the electronic switching system now under development at Bell Laboratories.

Above: Bell ringer has been displaced by a small loudspeaker in transistorized telephone. Left: L. A. Meacham heads the team of engineers that developed the musical tone ringer. Mr. Meacham holds a B.S. in Electrical Engineering from the University of Washington, Class of '29. He became affiliated with Bell Labs a year after his graduation. In 1939 Mr. Meacham won the "Outstanding Young Electrical Engineer" award of Eta Kappa Nu.

BELL TELEPHONE LABORATORIES

World center of communications research and development changed volume, and thus incompressible. But so far the figures support Abraham's theory."

"During the earthquake and the subsequent days of fire marking the awful calamity which all but swept the city of San Francisco from the map, and when every single telegraph, telephone, and cable wire was interrupted, the only direct means of communication with the burning city was by wireless telegraphy. The wireless station on the top floor of the Merchants' Exchange Building in San Francisco was rendered inoperative for lack of current, originally derived from the lighting mains, and on the second day it was consumed by the flames. Within a very few minutes after the earthquake the line of government wireless stations extending from Mare Island Navy Yard to San Diego had received wireless tidings of the city's distress. The flagship *Chicago*, accompanied by the cruisers *Boston* and *Marblehead*, were at sea when these same dispatches were received by the ships' operators. Immediately forced draft was put on, and the fleet headed with all possible speed to the relief of the stricken city. Upon the arrival of the naval vessels, the flagship anchored off Fort Mason at the foot of Van Ness Avenue and within a stone's throw of the shore. For the next two weeks the cozy little wireless office on the *Chicago* presented a very businesslike appearance. Without hitch or delay an enormous lot of telegrams were handled. Learning that it was possible to reach the outside world by the *Chicago*'s wireless, many of the refugees made their way to the water front and filed messages of their safety. From the *Chicago* came in telegrams to every point of the Union and cables to foreign parts. A private wireless station in Alameda, tapping the aerial bulletin service, supplied the anxious people there with news of the disaster."

"The recent summer meeting of the American Association for the Advancement of Science at Cornell University was rendered memorable by the dedication of the largest and best-equipped physical laboratory in America. Prof. E. L. Nichols gave an account of the new Rockefeller Hall of Physics, which has 478 rooms and will accommodate 2,000 students. Among the large number of papers read at the meeting was one by Prof. Wallace C. Sabine, who spoke of neglected factors in determination of musical quality. When a complex tone is sounded, the fundamental tones do not die away so soon as the overtones, and

New trends and developments in designing electrical products . . .

How General Electric Permanent Magnets help designers miniaturize products by supplying constant magnetic field energy in a fraction of the space required by electromagnets

WHERE constant magnetic field energy is necessary, powerful G-E Alnico permanent magnets offer the designer many advantages no electromagnet can match.

The most important of these advantages — from the designer's viewpoint — is the permanent magnet's superior volumetric efficiency. An Alnico permanent magnet can supply a given magnetic field in a fraction of the space required by even the best designed electromagnet.

Since miniaturization has become so vital in the electrical and electronics industries, it is important to see just why and how a permanent magnet utilizes space so much more effectively.

Figure 1 shows a typical magnetization curve of an electromagnet with a flux density of 20,000 gausses, when the polarizing force is 200 oersteds. (The curve has been displaced into the magnetizing quadrant for comparison purposes.)

In a well-designed electromagnet, approximately half the total area is occupied by conductors, and half is flux - conducting core material.

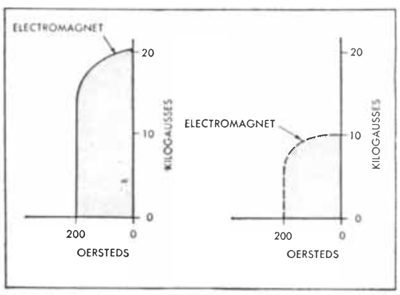


FIGURE 1 FIGURE 2

Therefore, to make the comparison valid, the residual induction of the electromagnet must be reduced to 10,000 gausses (Figure 2).

The area under the curve now represents the approximate external field energy available on a volume basis. When the equivalent demagnetization curve of Alnico 5 is plotted against the corrected electromagnet curve (Figure 3), the true capabilities of each type of magnet become immediately apparent.

The area under the Alnico 5 curve is about three times the area under the electromagnet curve. Thus, to produce a given field requirement, the permanent magnet will occupy a volume one-third that of an equivalent electromagnet.

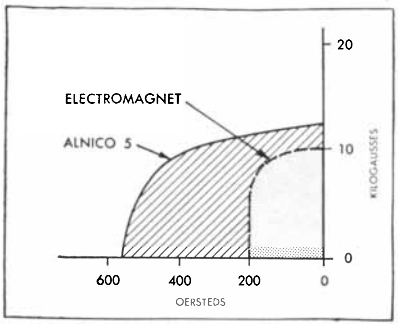


FIGURE 3

The above comparison is somewhat theoretical; under many circumstances, permanent magnets will show to even greater advantage. For example, consider the two TV-tube focusing magnets in Figure 4, at the top of the next column.

At the left, is the electromagnet previously used. It weighed 2 lbs. 13 ounces, and took up 16.35 cubic inches. At right, is the G-E Alnico 5 permanent magnet which replaced it. The new magnet weighs just 15 ounces, and occupies only 1.30 cubic inches — a space saving of 87%!

These savings in size and weight result from permanent magnets' inherent volumetric superiority. In addition, permanent magnets provide equally impressive savings in both initial and service costs because of four other inherent advantages.

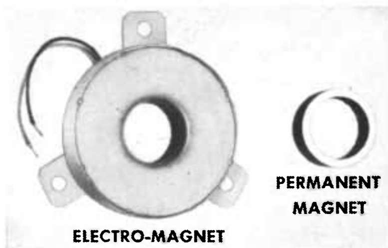


FIGURE 4

First, no power source is required with permanent magnets, because no energy is consumed. Once magnetized, the field is permanently retained.

Second, permanent magnets operate continuously. There can be no interruptions of the field due to power failure.

Third, permanent magnets are extremely stable under changing temperature conditions. They are unaffected by conditions ruinous to electromagnet installations.

Fourth, permanent magnet assemblies are easier to install, and cost nothing to maintain. There are no moving parts to break down, no wiring to burn out, no costly, time-consuming repairs to make.

These are but a few of the many reasons why designers are turning to G-E Alnico magnets for products for which only electromagnets had been previously considered.

If you have a problem where constant magnetic field energy is required, one of the G-E Alnico compositions may well be your solution. For more design data or technical assistance from our magnet engineers, write: *Carboloy Department of General Electric Company, 11199 E. 8 Mile Road, Detroit 32, Michigan.*

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GENERAL ELECTRIC

it is found that the material of which the walls of an auditorium is constructed has a material effect in deadening the overtones, and thus changing the quality of the music or of the voice. Hence it seems that more attention should be paid to the material with which the walls are covered."

SCIENTIFIC AMERICAN

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THE AUTHORS

EVON Z. VOGT and JOHN M. ROBERTS ("A Study of Values") are anthropologists who have worked together on the study described in their article. Vogt grew up on a ranch in western New Mexico, where he early came to know the Navahos, Zuñis, Spanish-Americans, Mormons and Texans who were his neighbors. In 1931 he set out to become a mining engineer and spent a year working in the gold-mining camps of Nevada. He soon discovered that he was more interested in his Shoshone Indian companions on the mining crews than in the technical problems of mining gold. With money saved in the mining camps he entered the University of Chicago in 1937, graduated in geography and stayed on for graduate work in anthropology. After serving in the Navy in World War II he re-entered the University of Chicago, and in 1947 returned to his native countryside to study Navaho veterans for his Ph.D., which he took in 1948. He has since been with the Department of Social Relations of Harvard University, where he is now associate professor and assistant curator of American ethnology, as well as director of the values study project which Harvard started in New Mexico in 1949. Roberts also came to anthropology while seeking another career. After graduating from the University of Nebraska in 1937, he enrolled for the fall term at the law school of the University of Chicago, but found himself so much interested in anthropology and so little interested in law that he shifted to graduate work in anthropology. In 1939 he took an assistantship in the Institute of Human Relations at Yale University. He later served in the Army, did field work among the Ramah Navaho and, in 1947, took a Ph.D. in anthropology at Yale. From 1948 to 1953 he was with the Harvard Department of Social Relations. In 1953 he went back to the University of Nebraska, where he is now professor of anthropology and curator of anthropology in the University museum. He and Vogt worked together on the values study from 1949 to 1953, while Roberts was coordinator of the study; Vogt has had the responsibility since then.

JOHN D. KRAUS ("The Radio Sky") is professor of electrical engineering at Ohio State University. His progress from antenna designer to radio astronomer was sketched in the March, 1955, issue of SCIENTIFIC AMERICAN, in which his article "Radio Telescopes" appeared.

THERESA GOELL and FRIEDRICH KARL DOERNER ("The Tomb of Antiochus I") are, respectively, an archaeologist and a classicist who have collaborated on the excavations which they describe. Miss Goell was born in New York City and was graduated from Radcliffe College. She took up architecture and archaeology at the School of Architecture of the University of Cambridge. For several years she was an interior architect with the Hearn Department Stores in New York City; later she took up further studies in the Graduate Institute of Fine Arts at New York University. In 1953 she conducted a preliminary survey of the tomb of Antiochus I, and in 1954 returned there for a full-scale excavation. Doerner joined her in 1953 to decipher inscriptions and to collaborate in field work. He has since invited her to collaborate with him at *his* excavations at the sanctuary of Mithradates, which he had discovered in 1951 at Arsameia-on-the-Nymphaios. He is associate professor of Greek and Latin epigraphy and of ancient history at the University of Münster in western Germany.

ROBERT HOFSTADTER ("The Atomic Nucleus") is professor of physics at Stanford University. He grew up in New York City, and while in high school was interested in literature and philosophy. "On entering the College of the City of New York," he writes, "I found that although physics was less alive than literature, the physics instructor was much more stimulating. At his suggestion I took some advanced mathematics and physics. I liked to be at the source of things, and felt that physics was fundamental to everything else, except possibly mathematics. I was also stimulated by the lives of some of the great physicists and mathematicians. At this time I felt that the laws of physics could be tested and those of philosophy could not. Halfway through college my mind was made up that I wanted to teach and do research in physics." Hofstadter graduated from City College in 1935 *summa cum laude*. A Coffin fellowship, awarded by the General Electric Company, enabled him to do graduate work at Princeton University. "I was pushed into experimental work," he recalls, "by the Coffin requirement that a man must do research even in his first year. In my second year there seemed to be an open place in the infrared laboratory and I moved into that branch of physics, again

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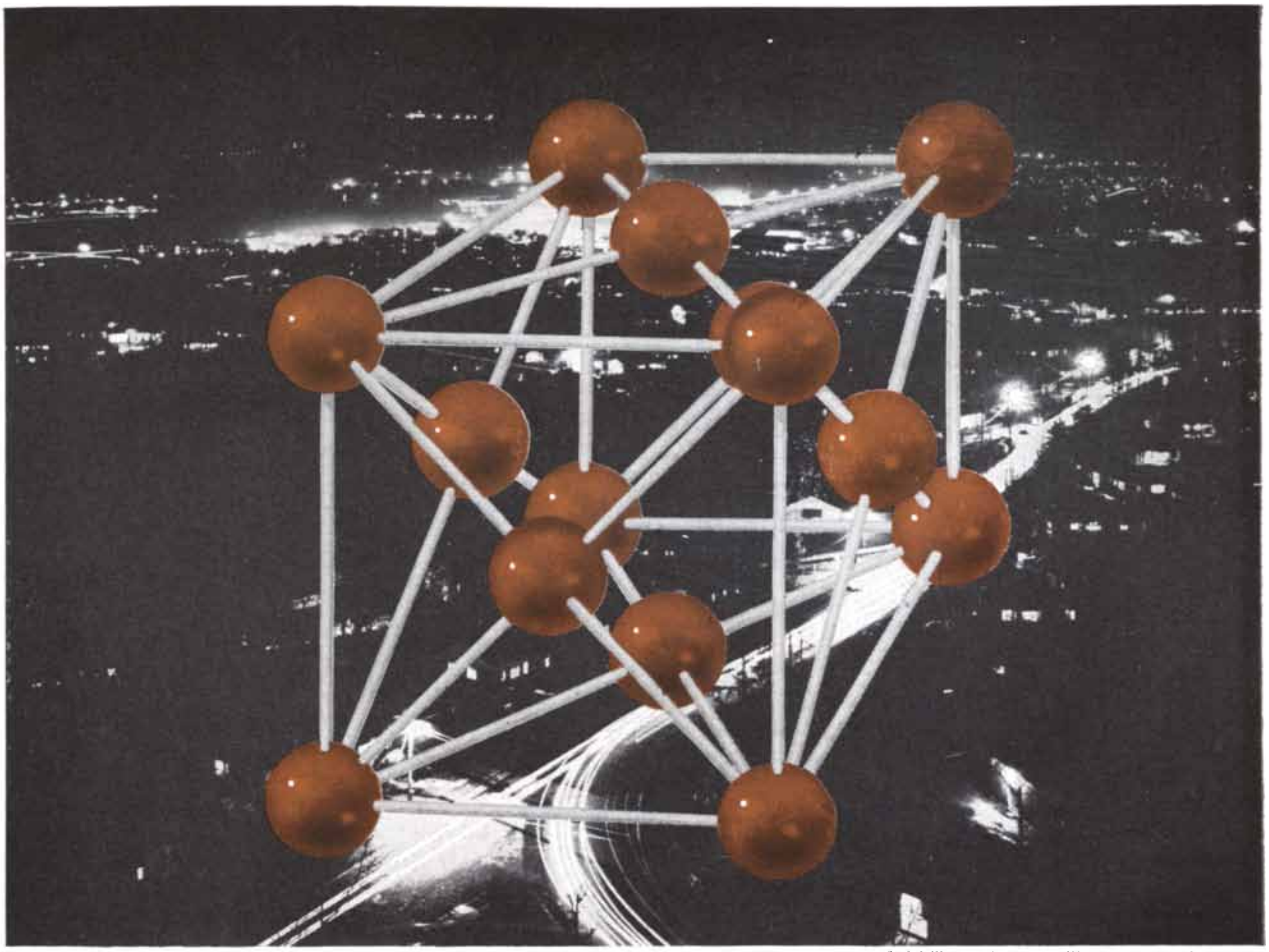
IN CANADA: SUN OIL COMPANY LIMITED, TORONTO AND MONTREAL not exactly because I wanted to." Studying simple organic molecules by means of infrared spectroscopy, he helped to elucidate the nature of the hydrogen bond; he took his Ph.D. in 1938. During the first years of World War II he worked on the proximity fuze at the National Bureau of Standards; he later helped develop servomechanisms at the Norden Laboratories Corporation. In 1946 he became assistant professor of physics at Princeton, where in 1948 he discovered that sodium iodide activated by thallium made an excellent scintillation counter. "I was extremely lucky. Throughout the eight years since that time people have searched intensively for a better material but so far none has been found." In 1950 he went to Stanford, where he built the first magnetic spectrometer for the Stanford linear accelerator.

ECKHARD H. HESS ("Space Perception in the Chick") is associate professor of psychology at the University of Chicago. This year he is a fellow at the Center for Advanced Study in the Behavioral Sciences at Stanford, Calif. He received his Ph.D. for work in physiological psychology from the Johns Hopkins University in 1948. Most of his research deals with the basic problems of vision and the effects of early experience on perception and behavior.

PHILIP H. ABELSON ("Paleobiochemistry") is Director of the Geophysical Laboratory of the Carnegie Institution of Washington. He was born in Tacoma, Wash., and graduated from the State College of Washington in 1933. He started out as a nuclear physicist, doing graduate work with Ernest O. Lawrence at the University of California. He took his Ph.D. there in 1939; in 1940 he and several other workers discovered the synthetic element neptunium. At the Naval Research Laboratory during World War II he developed a liquid thermal diffusion process for separating uranium isotopes on a large scale; the process was later used at Oak Ridge. In 1946 he began a new career in biochemistry and microbiology at the Department of Terrestrial Magnetism of the Carnegie Institution and acquired an interest in comparative biochemistry, evolution and the origin of life.

HARRY TABOR ("Progress in Solar Power") is the director of Israel's National Physical Laboratory in Jerusalem. He was born and educated in England and graduated from the University of London in 1937, taking honors in phys-



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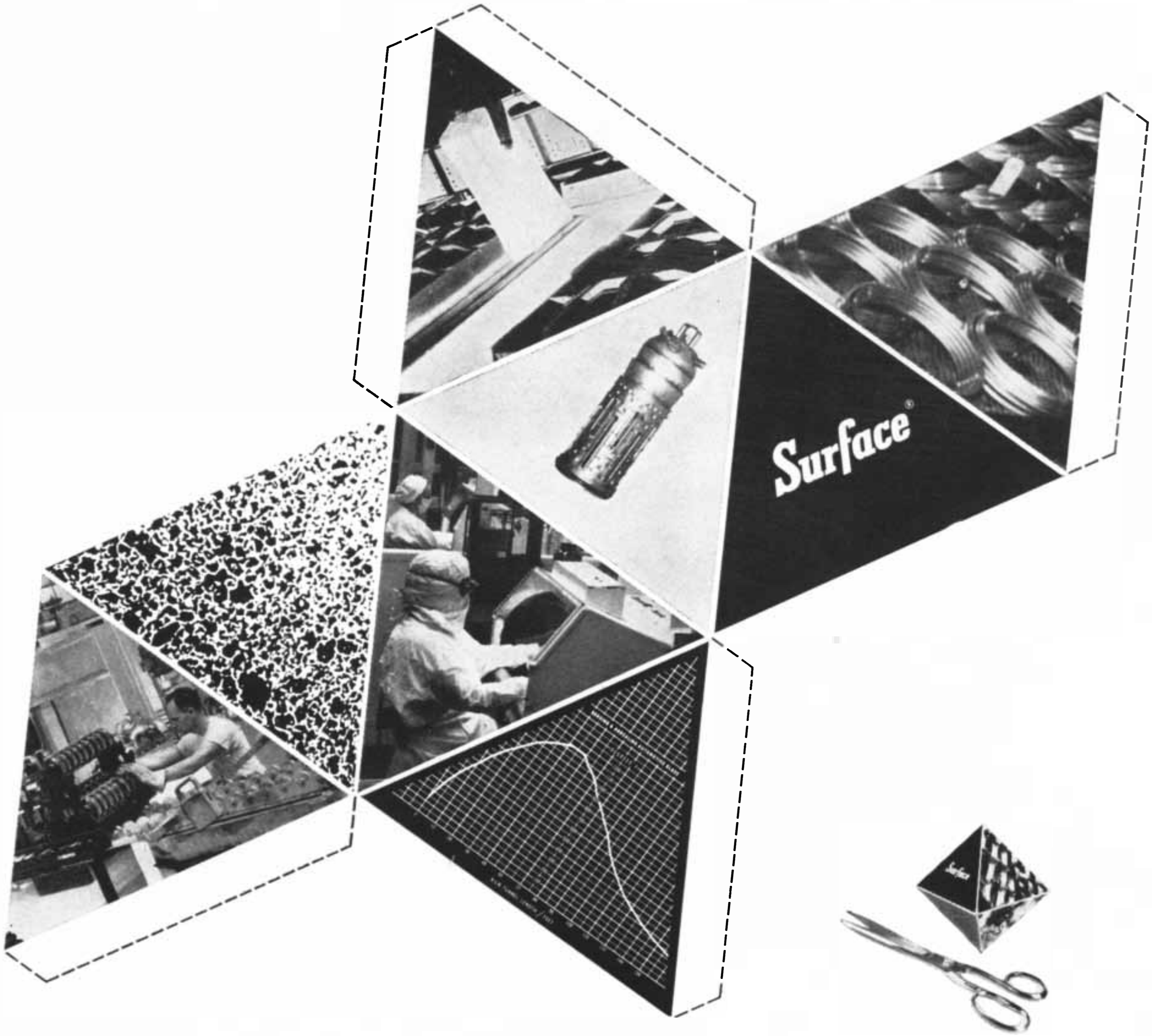
ics. He was particularly interested in automatic control; for 10 years he worked in England on the design and development of industrial instruments. In 1949 he settled in Israel. There he joined the Research Council of Israel, which assigned him the task of setting up a National Physical Laboratory and encouraging applied physics research and development. Israel is without coal, and Tabor's compatriots never tired of sending the Laboratory rather visionary suggestions for tapping solar energy. Tabor, however, tired of reading them, and about two years ago decided to investigate the problem himself.

ELIE L. WOLLMAN and FRANCOIS JACOB ("Sexuality in Bacteria") are both *chefs de laboratoire* at the Pasteur Institute in Paris. Wollman's parents were themselves microbiologists at the Pasteur Institute, and Wollman studied medicine and biology at the University of Paris until he was drafted during the war of 1939-1940. He finally took his M.D. at Lyon. France was at the time occupied by the Germans, who killed both his parents. Wollman became a physician in the resistance forces, and later in the French Army. These events, he points out, retarded his start in research. In 1945 he entered the Pasteur Institute, where he worked in the department headed by André Lwoff, author of the article "The Life Cycle of a Virus" in SCIENTIFIC AMERICAN for March, 1954. From 1948 to 1950 he was a Rockefeller Foundation fellow with Max Delbrück at the California Institute of Technology. Since then he has been mainly interested in the genetic aspects of the relationship between bacterial viruses and their bacterial hosts. Jacob, who was born at Nancy in Lorraine, had entered the medical school of the University of Paris with the idea of becoming a surgeon when the events of 1940 caught up with him. He escaped from France and joined the Free French forces in England. He fought against Germans and Italians in Africa and France and was severely wounded. After the war he returned to Paris and acquired his M.D., but then decided not to go into surgery. In 1950 he entered the Pasteur Institute as an assistant to Lwoff, and in 1954 he took a D.Sc. at the Sorbonne.

HARRY L. SHAPIRO, who reviews two new sociological studies of secrecy and loyalty, is chairman of the department of anthropology at the American Museum of Natural History in New York City.



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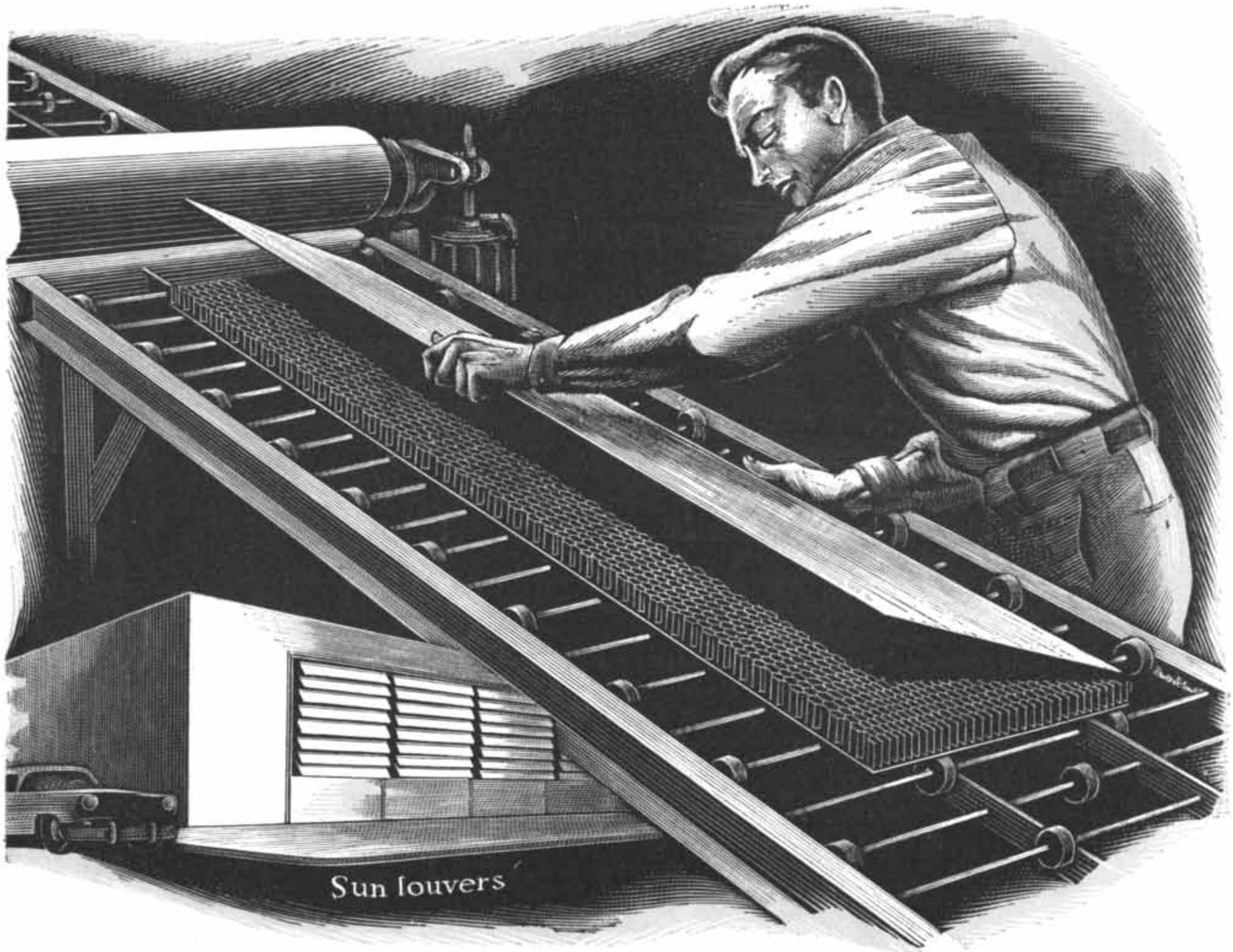

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A Study of Values

In the same semi-arid region of western New Mexico the people of five entirely different cultures lead different lives. A long-term study seeks the connections between their values and their ways of life

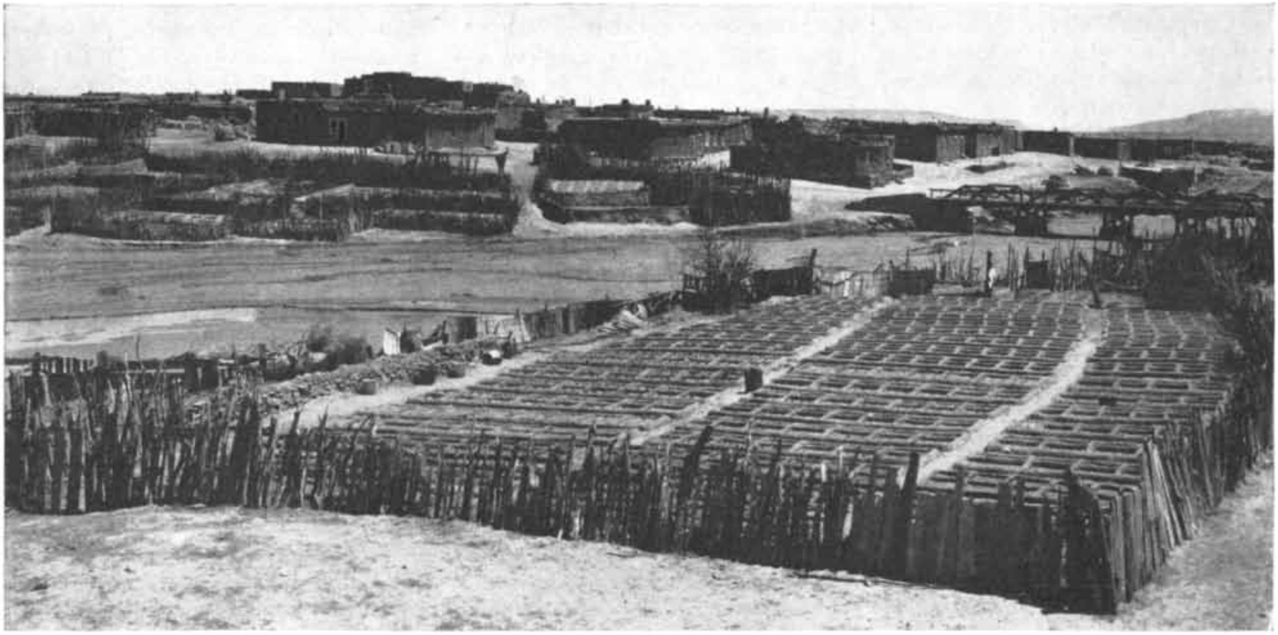
by Evon Z. Vogt and John M. Roberts

"No tenet of intellectual folklore has been so damaging to our life and times as the cliché that 'science has nothing to do with values.' If the consideration of values is to be the exclusive property of religion and the humanities, a scientific understanding of human experience is impossible."

In these words the anthropologist Clyde Kluckhohn recently defined a major challenge and frontier of social research. The forming and choosing of values is a central concern of all men and societies. Conceptions of the desirable, the fitting and the good vary widely among the world's 3,000 or so cultures. They strongly influence the selection of the modes, the means and the ends of human behavior. The social scientist cannot view "man in culture" as conditioned only by economic forces and biological impulses. People see the world through cultural lenses compounded of particular combinations of values; they respond in different ways in accordance with their differing values. We must recognize that people are not just "driven" by situational pressures; they are also "pulled" by the ideals and goals of their cultures.

As we advance the frontiers of the social sciences it becomes increasingly clear that values must be studied as a part of our actual subject matter and not left entirely to the humanists and philosophers. Values are, in fact, the subject of an increasing number of investigations today. But how can values be brought under the same kind of objective study as linguistic systems and the techniques of salmon fishing?

The apparent difficulty is reduced if we recall that the object of such study



PUEBLO OF ZUÑI expresses in its density of construction the strong community feeling of the Zuñi people. "Waffle" pattern in garden (*foreground*) conserves water carried from the Zuñi River just beyond. Chile beans, onions and other vegetables are the crop.

MORMON CHURCH at Ramah was built by labor of its members. The substantial structure and the landscaping around it, in this arid country, bespeak the Mormon community spirit.

COOPERATIVE PROJECT at Ramah in 1952 added a high school and gymnasium to

is not to make an ethical judgment of goodness or badness. We want to know, rather, how values function in organizing behavior. Since it is virtually impossible to experiment with human cultures, the social scientist must find his laboratory situation ready-made. Preferably he should be able to observe and compare the role of values in one or two cultures other than his own. Ideally he will find a situation where he can observe variations in values against a background in which other variables are relatively constant.

This article is concerned with a long-term project of the Harvard University Laboratory of Social Relations known as "The Comparative Study of Values in Five Cultures." The study is centered in the region south of Gallup, N. M., where communities of five different cultural traditions—Zuñi and Navaho Indians, Mormons, Catholic Spanish-Americans and Protestant-American homesteaders from Texas—all contend with the same high-altitude semi-arid environment. Since our research has not yet reached the phase of synthesis and final theory construction, it is still too early to summarize the project's over-all results. At this stage, however, we are able to report that the Gallup region has given us a practically ideal laboratory for investigation of the manifold questions presented by the role of values in human life.

The values study project was initiated in 1949 with a grant from the Rockefeller Foundation. To date its field program has engaged the collaboration of 30 investigators from the disciplines of anthropology, sociology, psychology, philosophy, history, government and law. They have approached their common concern with values through a wide variety of topical interests, such as religion, cultural change, politics, land use, child rearing, adult personality, mythology, music and graphic arts. The full battery of research techniques—direct observation, participant observation, personal interviews, group discussions, interaction analysis, psychological tests and questionnaires—is represented in the immense documentation now assembled. Since the populations of the five communities are small (3,000 Zuñis, 650 Navahos, 700 Spanish-Americans, 250 Mormons, 250 Texans) it has been possible to emphasize intensive methods and reduce the problems of sampling and statistical analysis which attend so much social research. The extensive existing literatures on some of the cultures have helped to give the study historical depth.

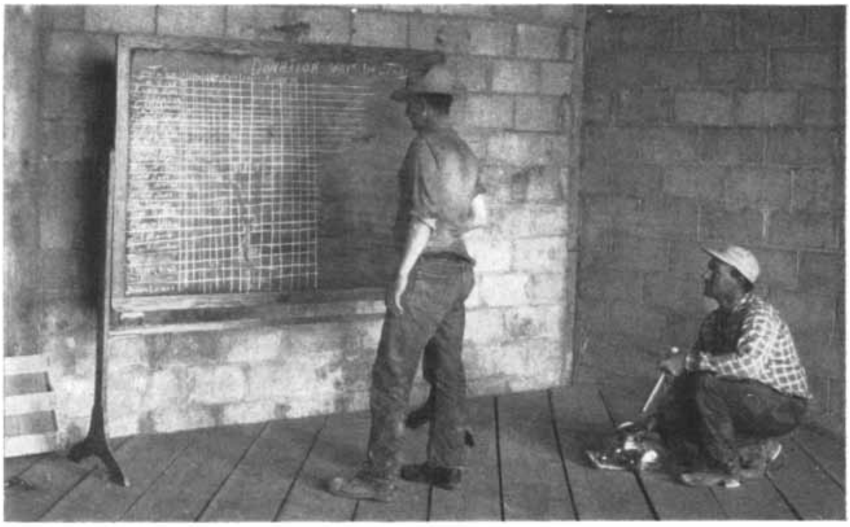
In all its undertakings the values study has been faced with the delicate problem of rapport and public relations in the five communities. No research could be conducted that might endanger future investigations. Among the Zuñi, for example, it has so far not been politic to study prayers, ceremonials and other religious matters at close range. Because we have had to be careful to protect individuals and groups in every way, this is the first over-all account of the project to be published outside a few specialized professional journals and monographs.

The geography of the Gallup region establishes some much-needed constants for a study that is otherwise bedeviled by a multiplicity of uncontrolled variables. Each of the peoples of the five cultures see the same plateau and mesa country, sparsely covered with grama-grass, sagebrush, pinyon and juniper, and with stands of ponderosa pines at the higher elevations. All of the people must contend with the same fluctuation in rainfall, averaging only 12 to 15 inches per year, and with the short, changeable growing season typical of the American Southwest at this 7,000-foot altitude. There are permanent springs in the region, but the small Zuñi River, a tributary of the Little Colorado, is the only year-round stream. Soils, however, are fertile and productive when watered.

To meet the problems of making a living in this landscape, each of the five communities has essentially the same technology available to it. In face-to-face contact with one another for a generation or more, all have been subject to markedly similar historical pressures. These pressures have mounted during the last 10 years, as hard-surface roads, telephone lines and public power have spread through their country. The five communities remain distinct, however, and present significant contrasts.

Each of the cultures, for example, has worked out its own solution for the problem of physical survival. The Zuñis, oldest of the peoples in the region, conduct a long-established irrigation agriculture, supplemented by stock-raising and by crafts, notably the making of silver jewelry. The Navahos were originally roving hunters and gatherers and came into the region only a century ago; they have become dry farmers and sheepherders, with wage work providing an increasing percentage of their income as contact with our American culture becomes

the assets of the Mormon community. Volunteers here mix concrete for foundations.



VOLUNTEER LABOR on new high school at Ramah is charted on blackboard. The community spirit of Mormons' culture is closer to that of the Zuñis than any other in study.

more extensive. Livestock ranching and wage work provide the principal income for the three Spanish-American villages, which were settled about 75 years ago. The Mormons, also established in this region since the 1880s, have been conspicuously successful at irrigation farming; they also engage in livestock ranching and wage work. The Texans staked out the last Homestead Act lands in the region during the 1930s, as refugees from the dust bowl to the east; they raise cattle and carry on a commercial and largely mechanized dry-land farming, with pinto beans as their principal crop.

The five cultures present corresponding contrasts in their community organization and family life. The sedentary Zuñis spend their winters in the stone houses of their large central pueblo, moving in the agricultural season to three farming villages. Their social structure is based on the matrilocal household (with the husband living with his wife's kinfolk), matrilineal clans, and various priesthoods and other religious groupings. The Navahos also have matrilocal extended families and matrilineal clans. They are less tightly organized, however, and families dwell in widely scattered hogans: hexagonal log houses with dirt roofs. As compared to the other two non-Indian cultures, the Mormons resemble the Zuñis in having a strong sense of identity with their community. Their life centers around the single village of Ramah, where the values study maintains its field headquarters. For the Spanish-Americans the family and the Catholic church are paramount institutions. The Texan homesteads are scattered over several townships; their identity is loosely maintained by competing Protestant churches and cliques.

The values study seeks answers to a number of questions that are suggested by the differences among these five cultures. It has set out to define, first of all, the value system of each of them and to establish the role that values play in making these cultures different from one another. The changes in values that are occurring in each culture represent another important line of inquiry. Of equal challenge is the question of why their different value systems persist, despite their contact with each other and their exposure to the same environmental pressures.

One of the most promising areas of investigation is the connection between the values and the social structures of the various communities. For example, the Spanish-Americans lay strong emphasis upon "lineality"—the view that social relations are desirable when they are consistent with the hierarchy of their society. In their communities younger relatives are subordinate to older kinsmen, females to males, and the *peon* to his *patron*. The secular structure gears into the hierarchically arranged Catholic church with its offices extending from the parish priest through the bishops, archbishops, cardinals and on up to the Pope. Much the same type of hierarchy is found in the sacred world of the Spanish-Americans, from the local images of the saints up to the Deity.

The Texan homesteaders, in marked contrast, place a strong American-frontier stress upon individualistic social relations in which each man is expected to be self-reliant and to be "his own boss." The social order of the community is composed of relatively isolated families, each living on its own farm and competing with other families for position and prestige. Instead of the single, hierarchically arranged church, the homesteaders subscribe to no less than 10 competing Christian denominations, each distinguished by a slightly different doctrine and type of service.

The Texan homesteaders fail to understand why "anybody wants to live all bunched up in a little village and take orders from the big landholders and the priests." The Spanish-Americans say of the Texans that "everybody tries to be his own *patron*."

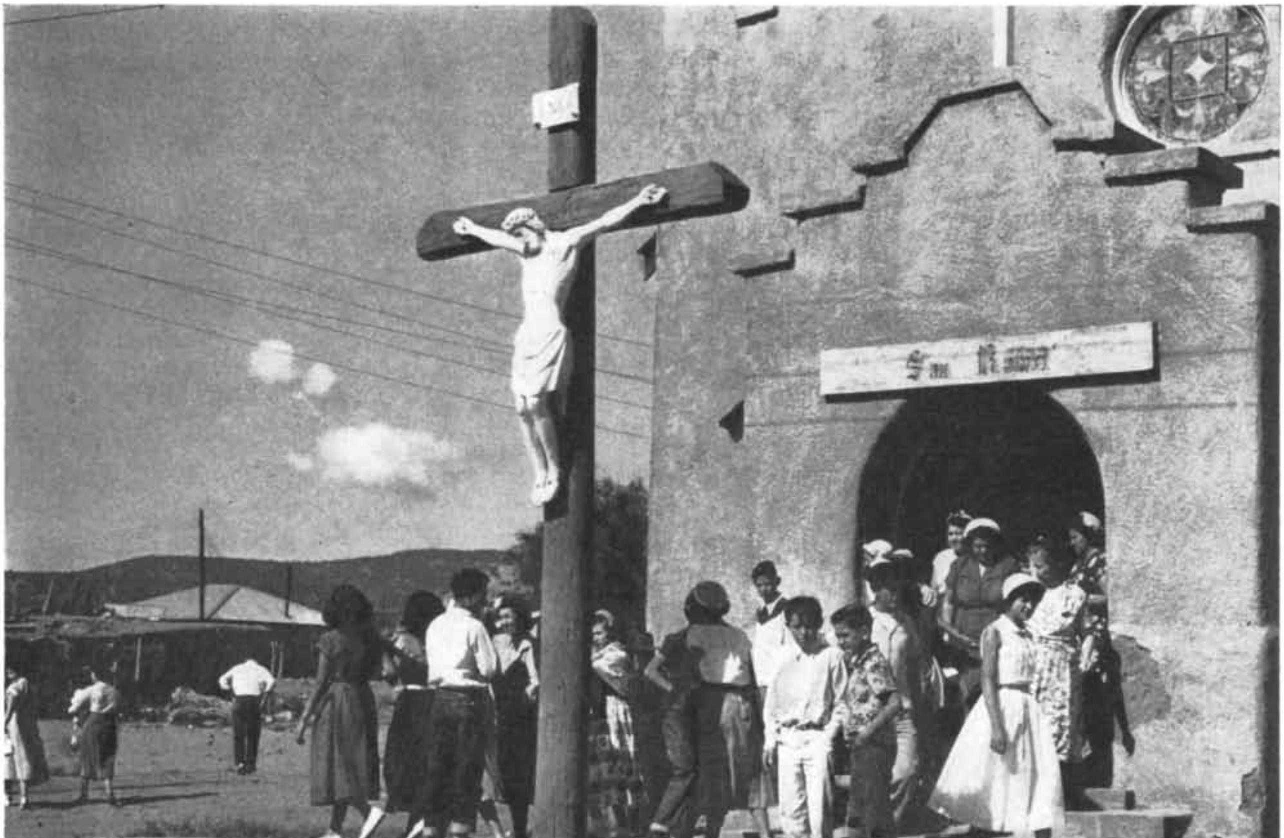
The Mormons present still another picture. The formal structure of the Mormon church has hierarchical aspects with lines of authority running upward from the local ward bishops through the state presidents to the 12 apostles and church president in Salt Lake City, Utah. But within this framework the local community enjoys much autonomy to work out its own affairs, and great value is placed upon collateral, cooperative economic and social relationships. Around the village and the large cohesive family system there is a proliferation of cooperatives in economic affairs. The little village of Ramah boasts a mutual irrigation company, a cooperative land and cattle company and a cooperative dairy. The spirit of individualistic competition which pervades the Texan community is consciously suppressed in favor of the values of cooperation in the Mormon village.

These values have deep roots in Mormon history. Joseph Smith, the founder of the church, proposed the "law of consecration" which required that all who had surplus wealth must impart it through the church to the poor. Although this "law" was abandoned as early as 1838, the values it expressed lent a strong cooperative bias to much of later Mormon activity. The compact village settlement was a social invention of the Mormons, motivated by a sense of urgent need to prepare a dwelling place for the "Savior" at "His second coming." Through the years cooperation became a strong defense against "persecution" by the "gentiles," first in the Middle West and later in the Far West, when the political and legal movements to stamp out Mormon polygamy came to a head. The cooperative spirit was also strongly reinforced in the arid West by the requirements of irrigation agriculture—the construction of storage reservoirs, the building and maintaining of networks of ditches, and the necessity of organized arrangements for the distribution of scarce water supplies among the various farms within a village.

The Spanish-Americans, Texans and Mormons, different as they are, belong to a single major historical tradition which contrasts with that of the Zuñis and Navahos. In former times Zuñi was ruled by a theocracy. Today personal relationships among the Zuñis are organized in a complicated series of interlocking religious, kinship and secular units, in which the individual strikes a delicate balance with external authority. No true Zuñi wishes to live away from Zuñi, particularly in the wintertime. The Zuñis have been characterized as having a kind of "middle of the road," "avoidance of excess" approach to life, in the manner of the ancient Greeks. Although this characterization must be qualified, it still symbolizes the Zuñi ideal.

While both Mormons and Zuñis can be characterized as "cooperative" and both societies manifest important linkages between their cooperative value systems and the requirements of irrigation agriculture, there are some interesting differences between them. In the Mormon community the values of cooperation are propounded by a single organized church which embraces the entire community. The Zuñi spirit of cooperation is expressed and institutionalized in the activities of a whole series of priesthoods, dancing groups and curing societies, in which the individual Zuñi may hold two or more memberships. Cooperation is stressed also as a matter of Zuñi kinship obligation. Kinship is important to the Mormons, but sustained kinship-based activity seldom goes beyond the closest relatives. In Zuñi there are large groups of near and distant relatives to whom one owes duties and from whom one derives benefits and position.

The Navahos, with their scattered hogans are more like the Texans in their settlement pattern. Except near agencies and railroad towns, they have no villages. From the core of the extended matrilineal family the Navaho views his relationships as reaching outward to include an ever-widening circle of kinsmen, some of whom he may rarely, if ever, see during the course of a year or more. Until recent times the Navahos have had no organized political leader-



SPANISH-AMERICANS leave their church at San Rafael after Mass. San Rafael is one of three such villages in the area of the values study. The people of the other two, however, have been scattering in search of wage work in larger towns of the Southwest.

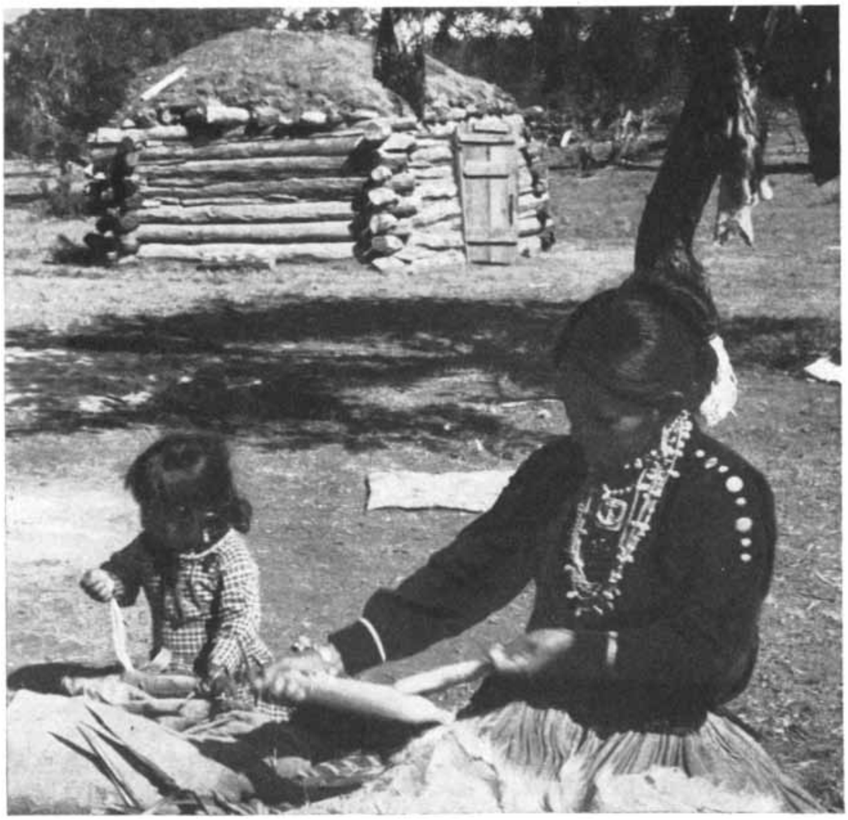
ship, the "tribe" consisting merely of a series of local bands which shared the same language and customs.

Although the Texans and Navahos can be characterized as being less communally inclined and more "individualistic" than the Mormons and Zuñis, there are, again, interesting differences in pattern and emphasis. The Texan focus is upon the individual farmer and his immediate family engaged in a competitive struggle with others for economic wealth and social prestige within the community. The Navaho sense of kinship involves no idea of striving and competing. Navahos cooperate easily with kinsmen and neighbors when the occasion arises, such as the work of putting on the larger ceremonials. But there are no organized and regular cooperative activities on a community-wide basis, unless these are actively promoted by Indian Service officials or other whites.

Differences in culture can thus be related to differences in values. The relationship comes into sharper focus when we consider the varying cultures in the context of their adjustment to their relatively unvarying natural environment, the constant in our laboratory situation. First we shall describe the general orientations of the five groups toward nature and time. Then we shall see how the values thus expressed relate to the way each of the groups reacts to the environmental problem of drought.

The Spanish-Americans have what might be called a "normal curve" view of the workings of nature. Out of so many children born, so many die before maturity; from every row of seeds, only so many plants come up; and out of every 10 or so summers, two or three are bound to be without rain. One can do little but accept what comes. Corresponding to this view of nature is an orientation in time that lays stress upon the present, as opposed to the past, which slowly recedes into obscurity, or to the even more elusive future. Life flows secure in the traditional familial mold; the important thing is the present, with its immediate drama, color and spontaneity. It is foolish to work too hard, and to worry about the future is even more ridiculous. About the mysteries of the world neither curiosity nor knowledge extend much beyond a shrug of the shoulders and a "*Quién sabe?*" These Spanish-American values find concrete expression in the traditional fiesta, a combined religious and recreational affair which is conducted each year in honor of the patron saint of the

NAVAHO FAMILY walks across sun-baked cornfield on a hot, late-summer day. In contrast to the cooperative Zuñi, Navaho families work their separate farms, have little irrigation.



CORN IS HUSKED by Navaho mother and child. In the background is their hogan, typical of the dirt-roofed structures in which Navaho families live in sparsely settled communities.

village. Catholic Masses and processions, combined with drinking, dancing, singing and visiting, express at once the solemn traditionalism and the love of present excitement and drama in the life of the small Spanish-American village.

By contrast the Texan frontier homesteaders manifest a drive for mastery over the workings of nature. Nature is defined as something to be controlled and exploited by man for his own ends and material comfort. The homesteader therefore equips himself with the most modern type of tractor, practices modern farming methods and attempts to extend even further his control over nature in the face of great odds in this semiarid environment. The past can be forgotten, even rejected, and the present is merely a step along the road to the future. If the crops fail, there is always the hope that "next year we'll make it." There is strong perennial optimism that "progress" will continue and that their crossroads will eventually grow into a modern city. While the homesteaders feel that their Spanish-American neighbors are lazy and "not getting any place," the latter feel just as strongly that the homesteaders are senselessly working themselves to death in a life in which one should live fully in the present.

The Mormon villagers share with the Texan homesteaders the view that mastery over nature is desirable. Indeed, in some respects they carry this idea much further, for they hold the theological view that the Mormon people have "put on the uniform of the flesh" and live out this earthly life in order to learn about and attain mastery over gross matter. "The Latter-Day Saints," as the Mormons call themselves, have developed a work-health-education-recreation value complex to guide their activities: work to gain mastery over the world; health to keep man effective in the struggle for continuing progress; education to accelerate his progress; and recreation to strengthen both man's body and the community he lives in. Like the Texans, they emphasize the future, but not so much for the purpose of economic development as for participation in the eternal progress of the universe in which man himself progresses toward godhood.

To the Zuñi the universe looks very different. He neither feels that he is a master of nature nor that he is its victim. In his colorful and beautiful religion he has developed techniques of co-operating with nature. This attitude is of course sustained by a body of realistic information on ways to make a living in a difficult environment. The Zuñi equivalent of the Spanish-American fiesta has an important place in his life, but he is less taken with its recreational aspects. He lives in the present, but in many things, much more than any of his neighbors, he looks back to the past. It is a glorious past, an ancient mythological time when Zuñis came up from the "wombs" of the earth, wandered around, and finally settled at "the middle place," where their descendants to this day still maintain a shrine to mark the center of the universe.

The Navahos resemble the Spanish-Americans and the Zuñis in their orientation to nature and time. Like the Zuñis, the Navahos view man as having an integral part to play in a general cosmic scheme. But they see the universe as more powerful than man and profoundly threatening. In dealing with nature circumspection is the best guide to action, and fear is the dominant emotional theme. Yet the Navaho is not completely fatalistic. There are small things one can do to maintain and restore harmony in the scheme. Thus individual curing ceremonials, performed with care, can keep matters from becoming worse. The present is the important time-dimension, but the Navahos also recall a "holy people" who came up from the underworld, created four sacred mountains and the "earth surface people" and then departed for their permanent homes in the six directions: east, south, west, north, zenith and nadir.

For all five cultures the annual drought is a serious common concern. Each group responds differently to this problem in terms of its distinctive value-orientation. The Zuñis increase the intensity and tempo of their ceremonial activity; they give more attention to the planting of prayer feathers and to the fasting and prayers of the rain priests. This is in line with their view of the ultimate harmony of nature; man need only do his part and the gods will do the rest. With centuries of summer rains to testify to the soundness of this view, Zuñi is deeply opposed to rainmaking with airplanes and silver iodide.

The Navahos also tend to respond to drought by increasing ceremonial activity. But they are not so certain of the efficacy of their rainmaking ceremonies. They direct less ritual to that purpose and are more humble in the face of a more threatening universe.

The Spanish-Americans, on the other hand, seem to do little or nothing about drought beyond collecting in small groups on the plaza to talk about it. In their view, to attempt to alter the course of natural events by ceremonial is as useless as trying to alter it by rainmaking.

Against the ceremonial responses of the Zuñis and Navahos and the fatalistic response of the Spanish-Americans, the behavior of the Mormons and Texans draws a dramatic contrast. They actively support the artificial rainmaking projects; they reduce their livestock herds and crop acreages, and they organize to enlist government aid in meeting the drought conditions. The Navahos and Zuñis, in contrast, have to be forced by the government to practice acreage restriction in bad years.

Ceremonial and ritual responses are not entirely lacking, however, in the Mormon and Texan communities. Mormons occasionally say prayers in church for rain. The Texans have held special prayer meetings during droughts; indeed, the governor of Texas set aside a special day for such meetings during the recent severe Southwestern drought. A minority within each community also feels that seeding the clouds is "interfering with the work of the Lord." But the majority responds in the vein expressed by one of the more articulate farmers in the Texan community, who declared: "The Lord will look down and say, 'Look at those poor ignorant people. I gave them the clouds, the airplanes and the silver iodide, and they didn't have the sense to put them together.'"

Thus systems of values may promote and justify radically different modes of behavior among people confronted with the same objective problem. Why do such different values persist in the same tiny region among peoples living so close to one another? There appear to be at least two basic aspects to this question. First, we know that the values are intricately related to the total structure of each culture. Accordingly, unless the structure breaks down completely, values will tend to persist as functional parts of the whole. Second, we have also discovered that face-to-face contacts between the five cultural groups have not always encouraged the easy communication and interaction which might eventually level the differences between them. In fact, some of the intercultural contacts appear to have reinforced, rather than changed, the original value systems. There is, for example, good evidence that Navahos and Zuñis cling tenaciously to certain of their aboriginal values precisely because missionaries and other agents of white culture bring strong pressure upon them to change.

TEXAN HOMESTEADER CHURCH is one of 10 to which 250 homesteaders in the Gallup region belong, and is a cruder structure than the Mormon temple shown on page 26. Texan homes are not concentrated in village settlements, and their churches are scattered.

DRY-LAND FARMING of the Texan homesteaders contrasts with the diversified irrigation agriculture practiced by the Mormon and Zuñi communities. Here tractor-driven four-row cultivator works field of pinto beans, typical of one-crop economy of Texan farms.

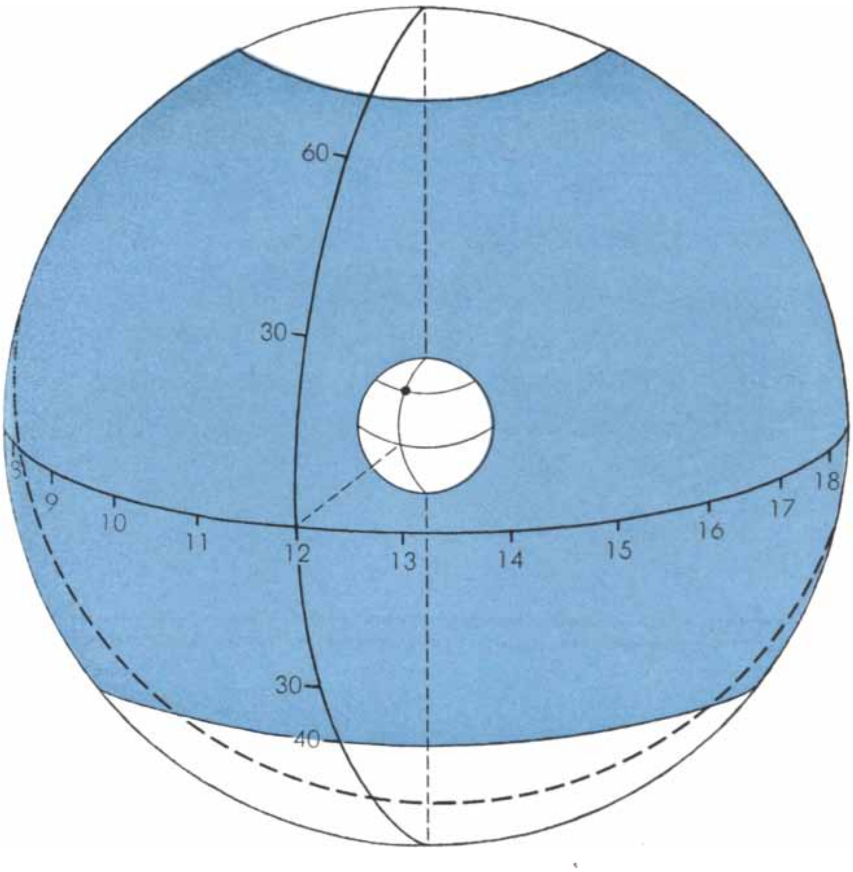
The Radio Sky

If our eyes were sensitive to radio waves rather than to light waves, we would have an entirely different view of the heavens. Presenting the panorama of the sky "seen" by a radio telescope

by John D. Kraus

The brief history of radio astronomy is one of rapidly accumulating observations. It is just 25 years since the first faint radio waves from outer space were detected. They seemed to be coming from a broad region in the general direction of the Milky Way. Then, as more and better radio telescopes were built, signals were found in other parts of the sky. Some of them came from separate, well-defined directions, so they were said to represent radio stars.

In the past five years or so there has been a rapid advance in the quality of radio telescopes. The new instruments have higher power (their radio receivers are more sensitive) and higher resolution (their antennas receive radio waves in a sharper and narrower beam). As they scan the heavens a radio "picture" is emerging that rivals the visual one in richness and variety.

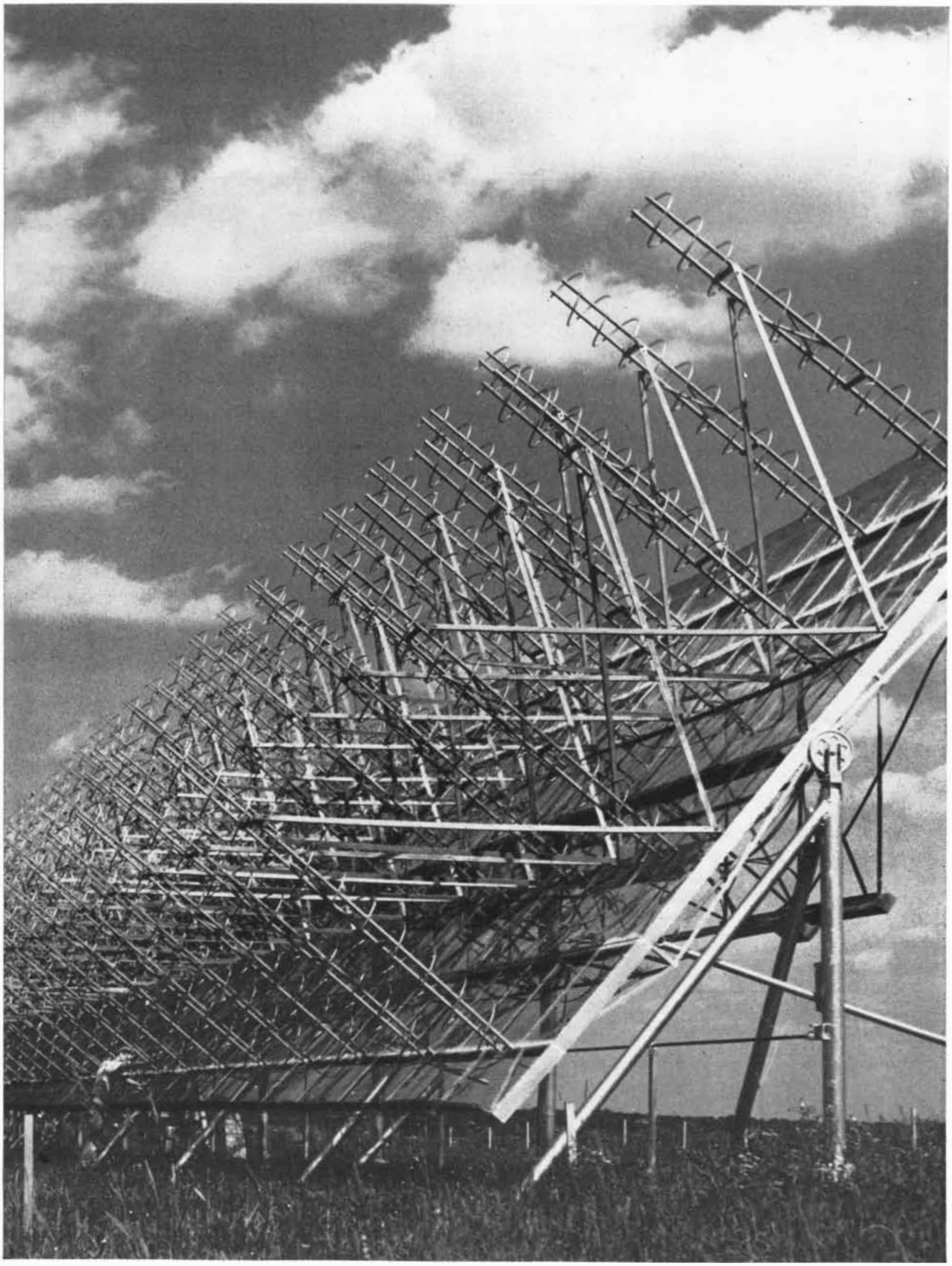


REGION OF SKY covered by the panorama is shown in color on the celestial sphere. Coordinates give right ascension in hours around equator and declination in degrees along meridian. Inner sphere represents the earth. Dot shows location of observatory in Ohio.

On the whole the two pictures are quite different. We cannot detect radio waves from the visible stars, with the exception of the sun. Conversely many radio sources emit too little light or are too far away to be detected with a light-gathering telescope; others are hidden from visual observation by great clouds of interstellar dust and gas. Radio waves are a million times longer than light waves and easily penetrate clouds that are completely opaque to light.

There is a slight resemblance between the two views in that the Milky Way is a feature of both. However, the Milky Way is much more prominent in the radio picture, where it stretches like a brilliant band across the entire sky and blazes with exceptional intensity in the region of the galactic center. The other objects in the radio sky form completely unfamiliar patterns or constellations which bear no resemblance to the familiar groupings of visual stars. In fact, no radio object has as yet been found to correspond with any visual star, although a few have been identified with very faint visual objects of an unusual character.

A panoramic view of the radio sky is presented on pages 34 and 35. Prepared from observations with the Ohio State University radio telescope, this picture suggests how the sky would appear if our eyes were sensitive to radio waves instead of to light. The bright

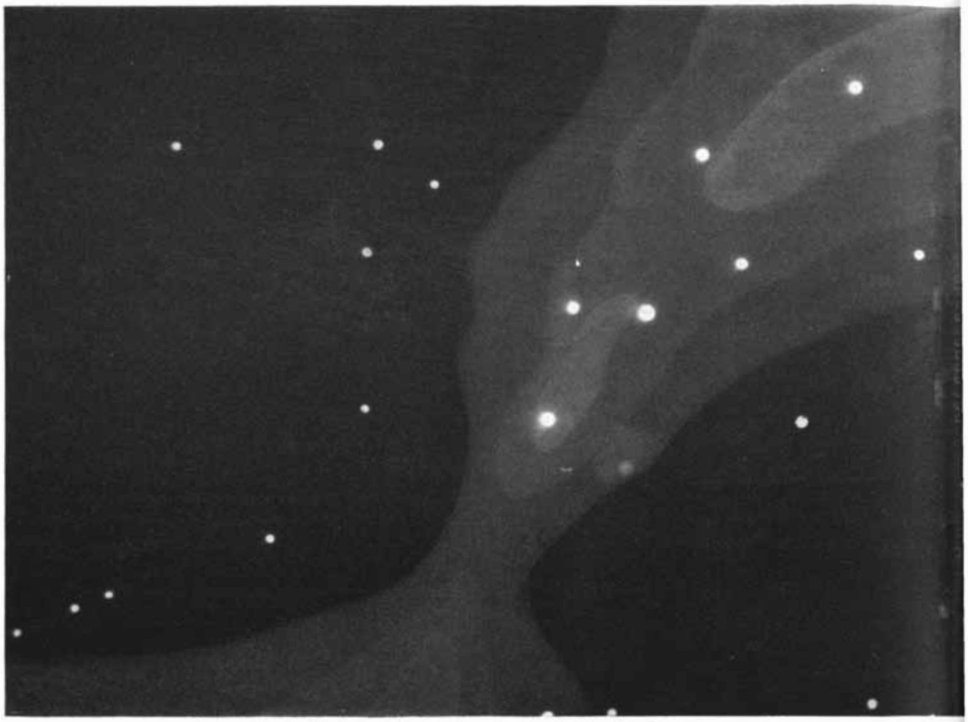


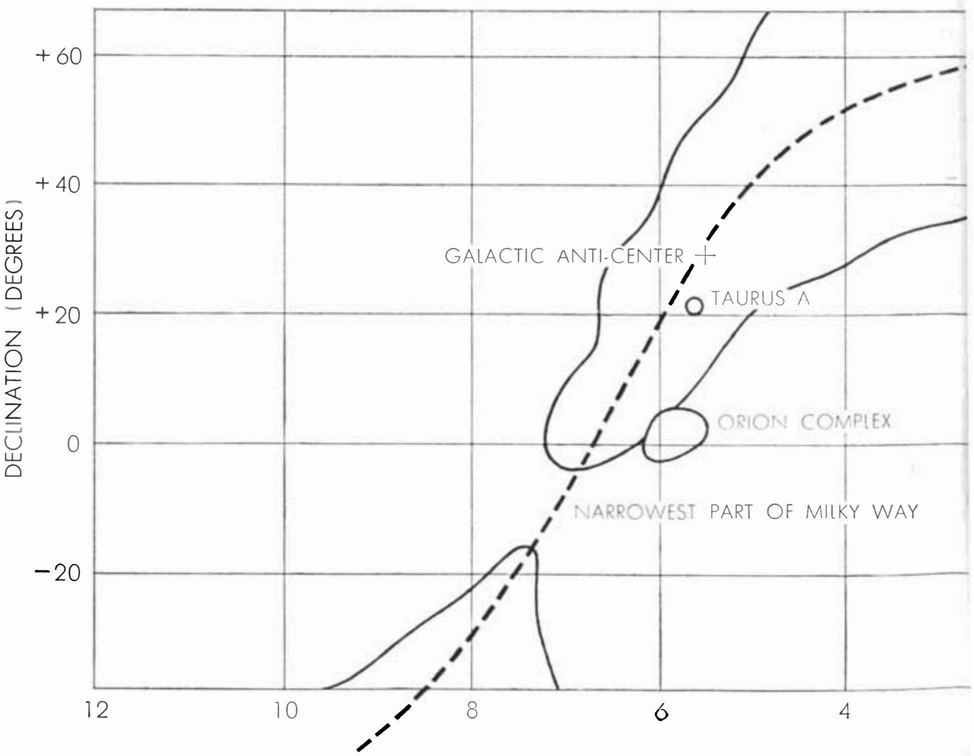
RADIO TELESCOPE at Ohio State University was used to make the panoramic view of the sky on the next two pages. Its antenna consists of an array of 96 helical coils. This arrangement receives a fan-shaped beam that is one degree thick and eight degrees wide.

areas represent regions from which strong radio emission is received; the dark areas indicate regions of weak emission. The white dots represent the strongest radio stars. The map below the panorama identifies its important features.

The panorama is a Mercator projection of a portion of the celestial sphere—the imaginary spherical surface on which celestial objects appear to be located even though they may all actually be at different distances from us. The diagram on page 32 shows the relationship of this sphere to the earth and the portion of the sky covered by the panoramic view. To understand how the Mercator projection is obtained, imagine that the colored area on the sphere in the diagram is cut along a vertical line, peeled off, flattened out, and its top and bottom edges stretched to the same length as the widest portion, which is the perimeter of the sphere at its equator. This operation shows that the left and right edges of the panorama are the same line (the line of the cut on the sphere). You can obtain a more realistic impression of the radio sky by imagining that the left and right edges of the panorama are joined behind your head so that the panorama extends completely around you in a circular wall. Now you cannot see the entire panorama at once but must turn your head, just as an observer on the earth must wait for the earth to rotate in order to see all the way around the celestial sphere.

The panoramic view covers nearly 80 per cent of the entire sky. About 3 per cent of the sky is omitted near the north celestial pole (above the top of the panorama) because of difficulties of observation. Another 18 per cent is omitted (below the bottom of the panorama) because it lies close to or below the horizon at Columbus, Ohio, where the observations were made.



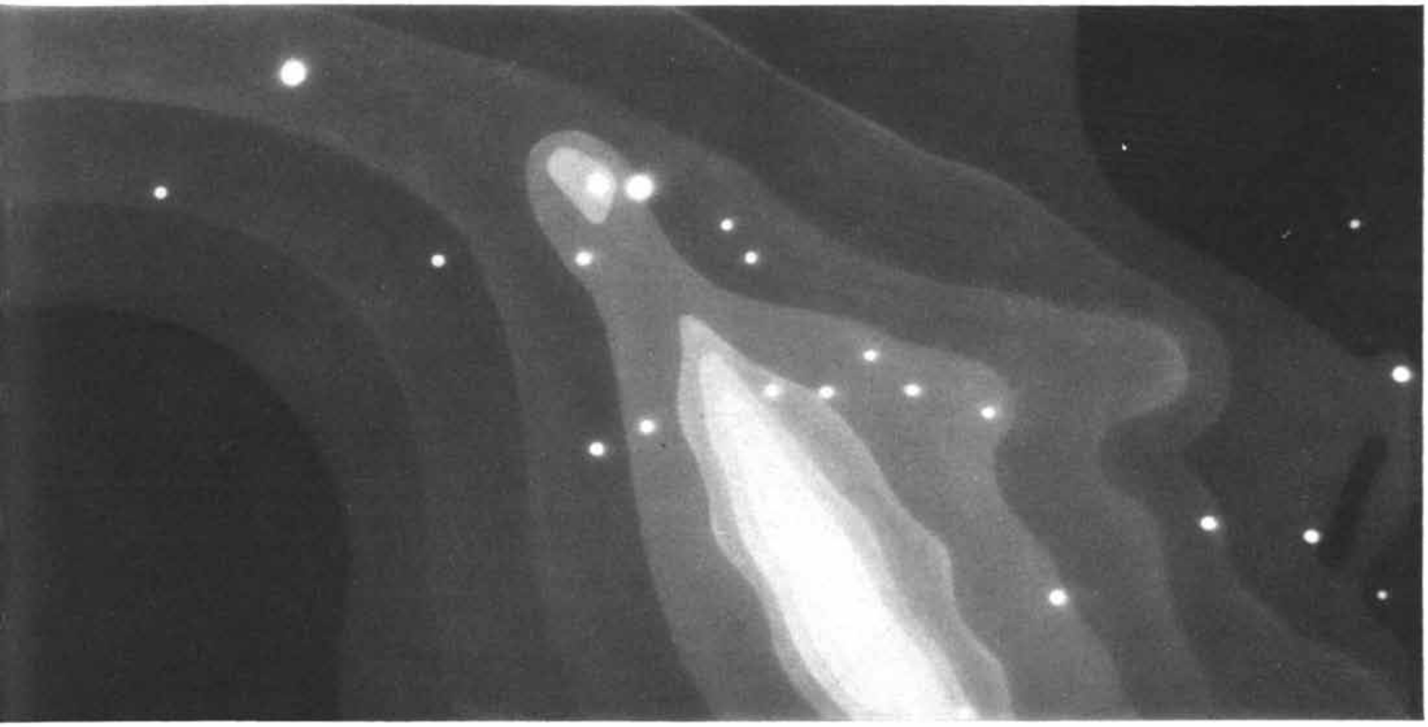


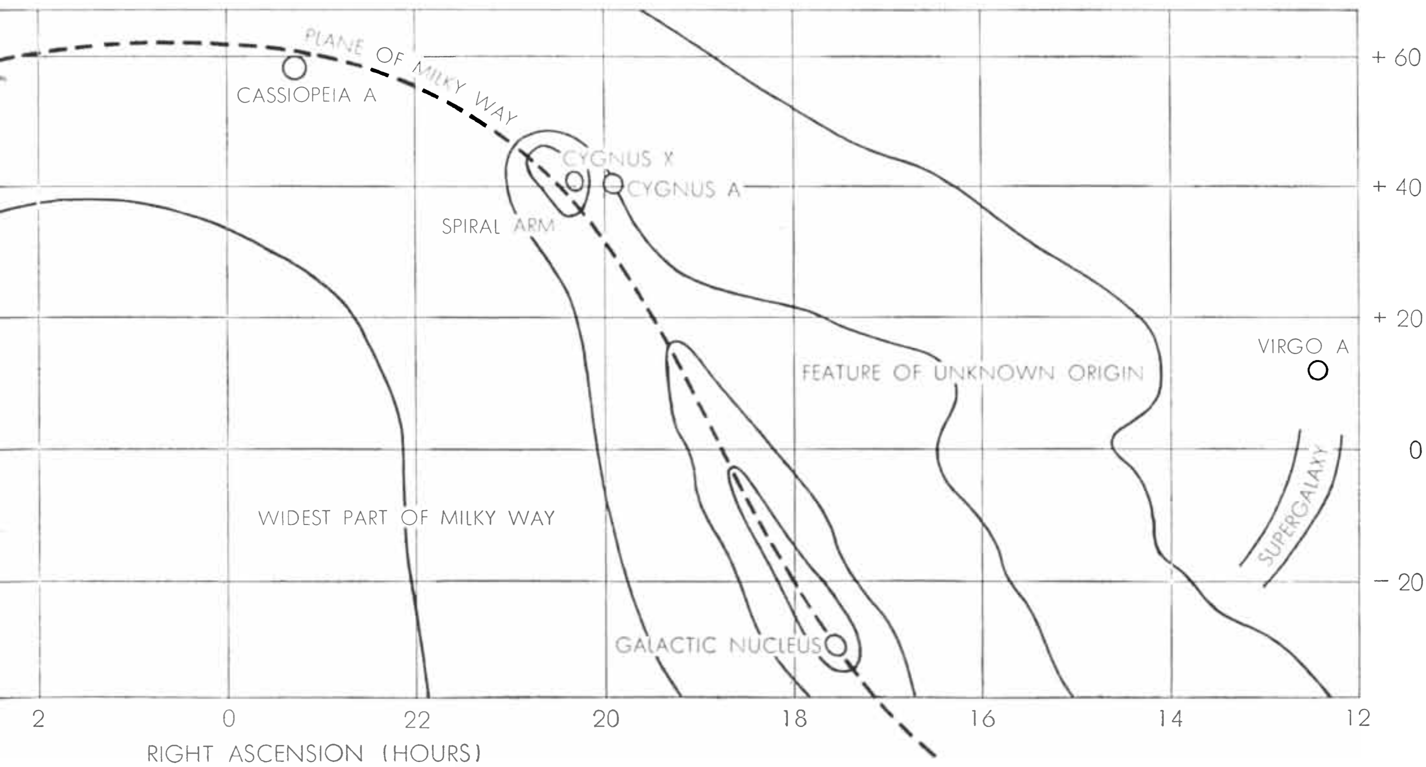
PANORAMA across the middle of these two pages shows how the sky would appear to us if our eyes were sensitive to radio waves 120 centimeters long. The map at the bottom identifies the main features of the panorama. A "view" of the sky obtained at any single wavelength corresponds to a visual view through a color filter. The range of radio wavelengths coming from the heavens is much broader than the range of visible light, so that the radio pictures at various wavelengths may differ considerably more than the visual ones. At shorter wavelengths, for example, many of the features seen here would disappear. There would be considerably fewer radio stars. On the other hand, new elements would be added to the picture. In particular, a view at a wavelength of 21 centimeters would reveal the underlying structure of our galaxy much as an X-ray photograph shows the skeleton of an animal. Hydrogen gas sends out a single-frequency radiation at this wavelength, which permits the distribution of interstellar hydrogen to be mapped. This distribution outlines the trailing arms of our galaxy.

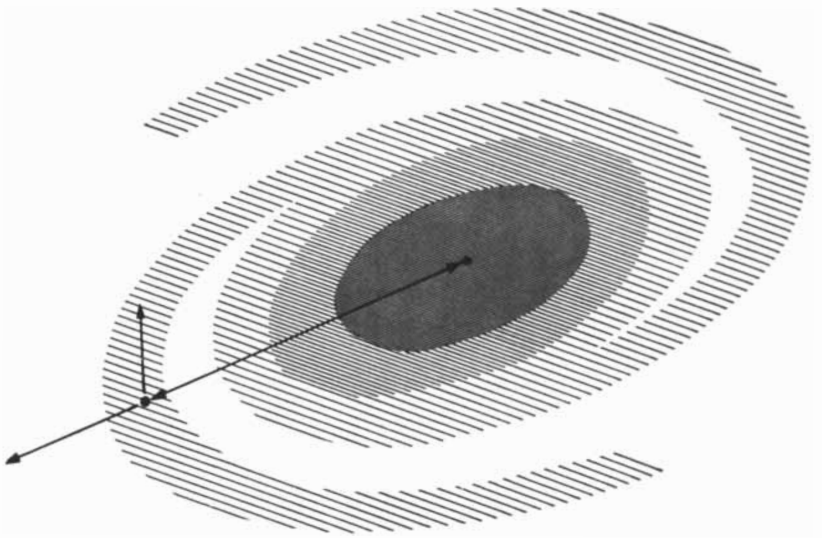
The map is incomplete in that the sun and moon are missing. The sun is a strong radio source and the moon is readily detectable. However, their positions change from day to day, the sun moving completely across the sky once a year and the moon once a month. Because of their rapid motion they have been omitted. The objects shown, although not fixed, are so far away that their motion from year to year is almost imperceptible.

Although the Milky Way appears like a great arch in the Mercator projection, its central plane is actually flat; it cuts the celestial sphere in a great circle around the sky. The lower portion of the circle is cut off in the panorama because it lies below the horizon at Columbus.

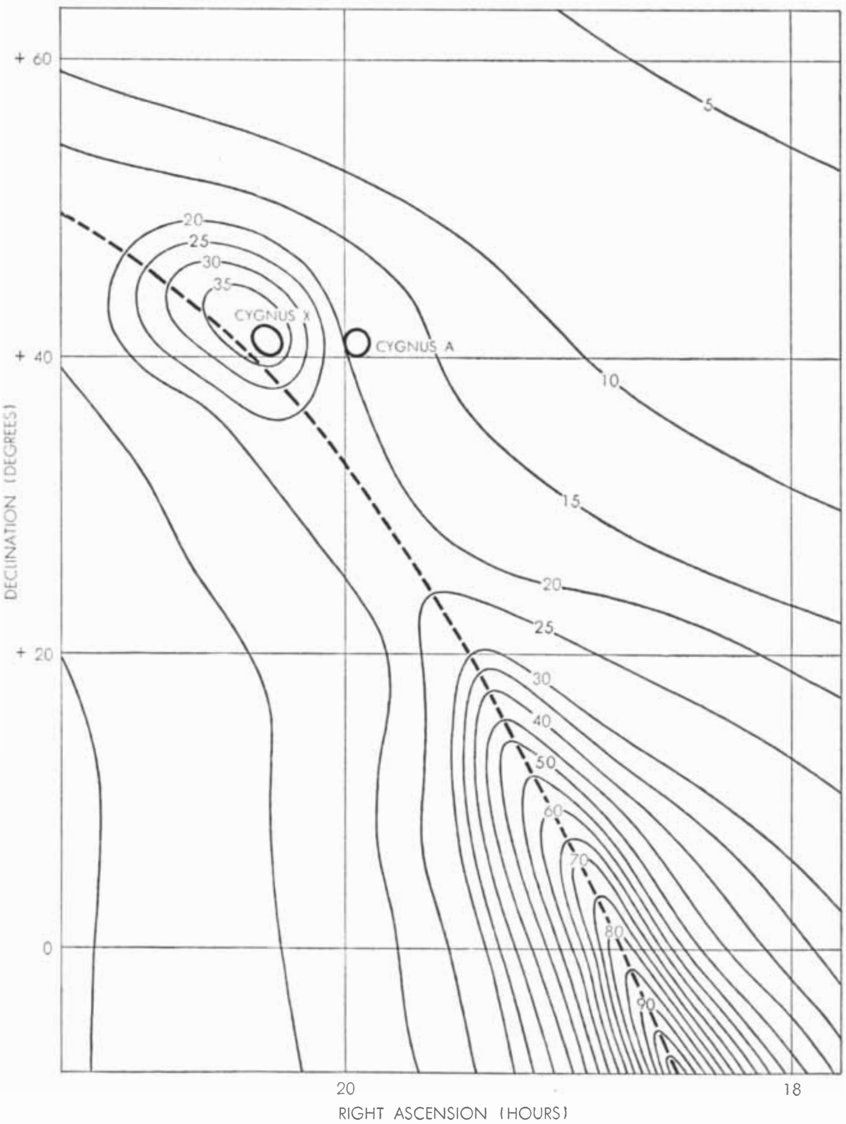
As almost everyone knows, the Milky Way is an island universe composed of







OUR GALAXY is shown as it would appear from above its central plane. The dot at left locates our sun. Arrow at left points away from galactic center; arrow at top, toward Cygnus.



RADIO CONTOUR MAP of part of the sky is obtained by combining many profiles of the kind shown on the opposite page. Numbers indicate relative intensity of received radiation.

millions of stars grouped in the shape of a flat disk that turns like a great wheel in space. An observer far outside could see that gigantic spiral arms trail out from the central disk. The sun and all its planets would be an infinitesimal speck situated in one of the arms at a distance of about 30,000 light-years from the center of the galaxy [*see drawing at the left*]. The entire galaxy is some 100,000 light-years in diameter.

The galaxy is thickest at its center and grows steadily thinner toward its edges. As we view it from our spiral arm we see it edge on. Hence the radio view of the galaxy is brightest and widest in the direction of its center and faintest and narrowest in the opposite direction, away from the center.

Radio telescopes show the structure of our galaxy much as an X-ray photograph reveals the skeleton of an animal. The hydrogen gas associated with the structure emits a single-frequency radiation at a wavelength of 21 centimeters. From studies of this hydrogen line the paths of the spiral arms can be traced out. This tracing can only be made in a rudimentary way with optical telescopes.

The general galactic radiation in the panoramic view is probably a composite of radiation from interstellar gas and from large numbers of localized radio sources too close together to be resolved by existing radio telescopes. Many of the resolved radio stars lie close to the plane of the Milky Way, which suggests that they are objects within our galaxy.

One of the most striking features of the radio sky is the intense radiation from the region near the galactic center. Right at the center there is a sharp peak of radiation that may indicate a dense nucleus. Extending out to the right somewhat above the center is a prominent feature of the radio map which corresponds to no known optical structure of the galaxy.

In the Cygnus region we are looking inward along our spiral arm, and the extended patch of bright radiation outlines the arm in cross section. Right next to the patch is the bright radio source called Cygnus A. This is the object that has been identified with two colliding galaxies which are 200 million light-years distant. Although a very strong radio source, Cygnus A is so faint photographically as to be near the limits of detection of the 200-inch Hale telescope on Palomar Mountain. If these colliding galaxies were about 10 times farther away, they would lie beyond the range of the 200-inch but would still be readily detectable with a radio telescope. Thus it may be seen that radio telescopes may open to exploration regions of space that lie beyond the range of any photographic instrument. Indeed, some of the radio stars in the panorama may lie in these outer regions.

At left center in the panorama is the strong source Taurus A, which has been identified with the Crab Nebula—the billowing gaseous remnant of an exploded star or supernova. Although the Crab Nebula is a strong radio source, it is now a faint photographic object. When Chinese astronomers saw it explode in 1054 A.D., however, it flared up so brightly that it could be seen in broad daylight.

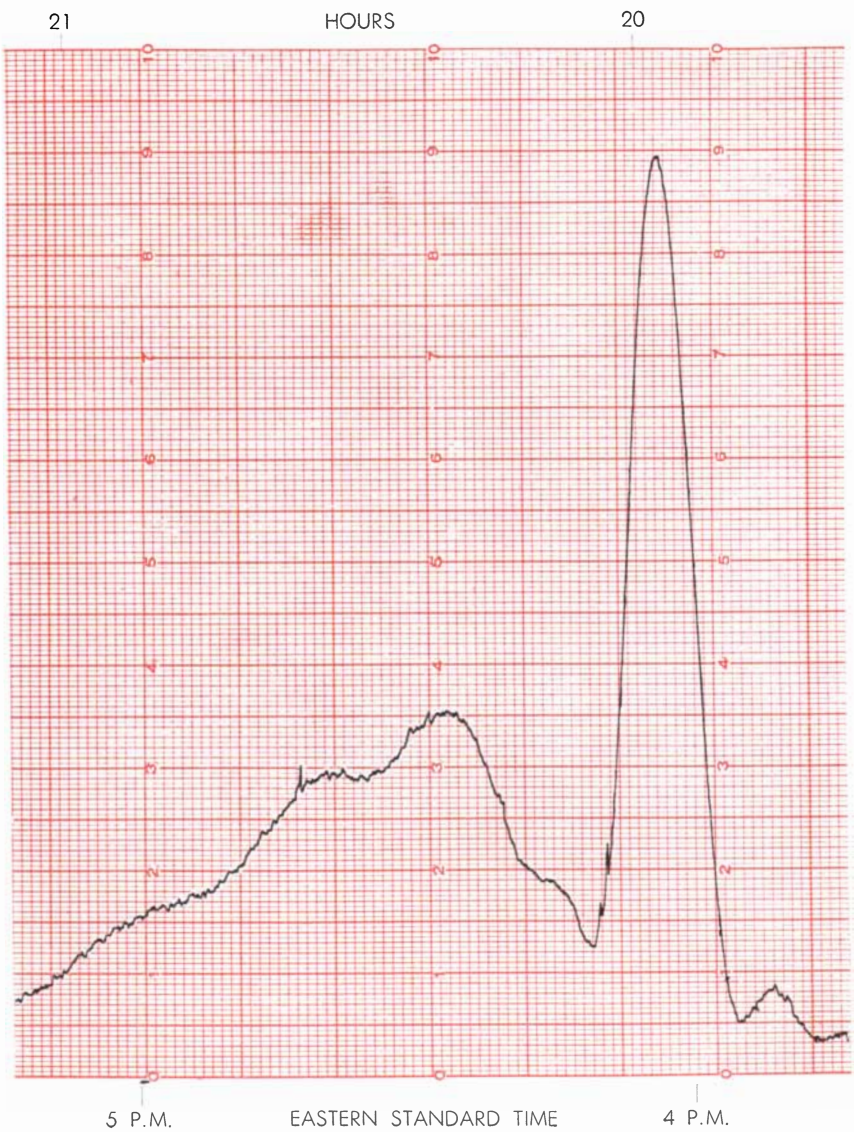
Near the upper center is the strongest radio source in the sky, called Cassiopeia A. It has been identified with some wisps of nebulous material several thousands of light-years distant. They may be the remnants of another supernova.

In the lower right-hand corner can be seen part of a faint belt which coincides with the plane of a supergalaxy (a galaxy of galaxies) of which our own galaxy is one member.

The dark regions on the panorama, where the radio radiation is at a minimum, center around the poles of our galaxy. Even here the intensity of the radiation is far from zero. It probably comes from vast numbers of distant galaxies. The observations from which the panorama was assembled were made at a wavelength of 120 centimeters. Although radio radiation from the sky has a broad continuous spectrum, the sky picture changes significantly with wavelength differences of a few octaves. At shorter wavelengths fewer radio stars are detectable. The radiation from the galactic plane or Milky Way becomes much weaker except where there are clouds of ionized hydrogen gas, and these show up more prominently than at long wavelengths.

The range of radio wavelengths reaching the earth's surface from outer space is very broad. It extends from about one centimeter to several hundred meters. The ratio of the longest to the shortest wavelengths is some 20,000 to one, which represents an enormous window looking out on the sky. By comparison the visual window extends from about 4,000 to 8,000 Angstrom units—a ratio of only two to one. Recently the pioneer radio astronomer Grote Reber has measured galactic radiation at wavelengths as long as 600 meters. These waves penetrate to the earth's surface only for limited periods of time, when the ionosphere develops a hole. Ordinarily this layer of ionized gases cuts off wavelengths as long as 600 meters. The limit to the radio spectrum at the short end is set by the molecules of the atmosphere, which strongly absorb wavelengths below one centimeter.

A word now about how the panoramic view was made. As the antenna beam of the radio telescope scans the sky, the radiation it receives is recorded by a pen on a moving paper chart. A sample trace through the Cygnus region is shown on this page. The trace passes directly through the strong radio sources Cygnus A and Cygnus X and crosses the plane of the Milky Way. By taking such traces for 24-hour periods and at various angles of elevation, a contour map was constructed where each observed trace represents a cross section through the map. A portion of the sky mapped in this way is presented at the bottom of the opposite page. The contours are lines of equal radio brightness. This map is similar in appearance to a topographic map, the contours with large values corresponding to hills or mountains and the contours with low values corresponding to the plains or lowlands. To make a panoramic view from such a contour map one merely replaces contour lines by shades of light and dark.



PROFILE through Cygnus was taken by letting the radio telescope sweep across an arc through this region. The trace shows the variations in the strength of the received signal.

CENTRAL MOUND of the monument is seen from the southeast on the summit of Nemrud Dagh, a 7,500-foot peak in the Anti-Taurus Mountains of southeastern Turkey. Barely visible at the foot of the mound are the statues of the monument's East Terrace.

COLOSSAL STATUES of Antiochus and his gods are viewed from the floor of the East Terrace. The mound is in the background. From left to right the statues represented Apollo Mithra Helios Hermes, the fertility goddess or Tyche of Kommagene, Zeus Oromasdes, Antiochus and Herakles Artagnes Ares. The statues stood 24 to 30 feet high. At the bottom are three of their fallen heads.

The Tomb of Antiochus I

On a mountaintop in Turkey stands one of the most remarkable monuments of ancient times. Built during the first century B. C. by the king of Kommagene, it is a link between the East and West

by Theresa Goell and Friedrich Karl Doerner

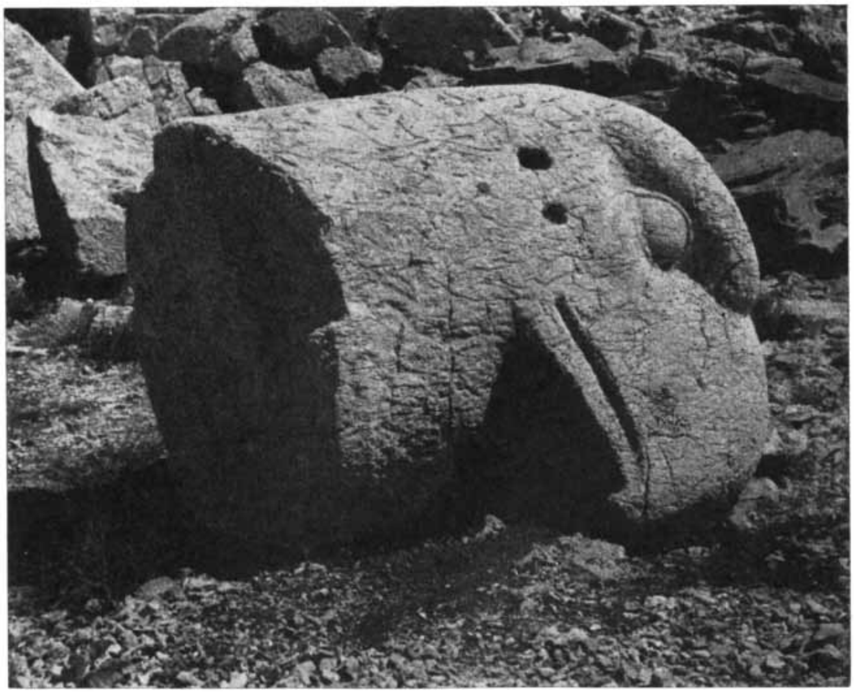
One of the most impressive and least known works of the ancient world is located in the Anti-Taurus Mountains of southeastern Turkey. At the summit of the 7,500-foot peak called Nemrud Dagh stands the tomb and outdoor temple of Antiochus I, who ruled over the kingdom of Kommagene from about 69 to 34 B.C. This fantastic monument consists of an imposing mound of loose stones, flanked by three spacious terraces hewn out of solid rock. Today the terraces bear the desolate gray remains of altars, colossal statues, limestone reliefs and long inscriptions in Greek.

According to these inscriptions, Antiochus considered himself a god during his lifetime. He sought to establish a sacred precinct where, after his death, his corporeal remains would rest "in close proximity with the heavenly thrones." He was admirably accommodated by the design of his monument: the mound to protect his body; the terraces to hold multitudes of worshiping pilgrims; the altars for the ritual of his priests; the statues of his gods to be crowned with golden wreaths; the reliefs to record his ancestral, spiritual and astronomical preoccupations. He also provided for slave musicians with hereditary privileges, and for sanctuaries to be placed throughout his kingdom for those who could not come to Nemrud Dagh. We know from the inscriptions that Antiochus was born on January 16 and ascended the throne on July 10. He prescribed that these events should be celebrated on the 16th and 10th of each month. Unfortunately we do not know the exact years in which he was born, ascended the throne and died.

Kommagene was a small but strategic region in the first century B.C. According to the Greek geographer Strabo, who lived during the first centuries B.C. and A.D., it was a land rich in natural resources. Although its borders shifted with political events, and are not known for any specific time, we may state in general that it was bounded on the north and west by the mountains of what is now the south-central part of Turkey, and on the east by the Euphrates River. On the south it lay open to Syria. Kommagene was the hub of many roads from the West to Mesopotamia, Persia and India. Any power intent on gaining a foothold in the East had to possess or control this small kingdom.

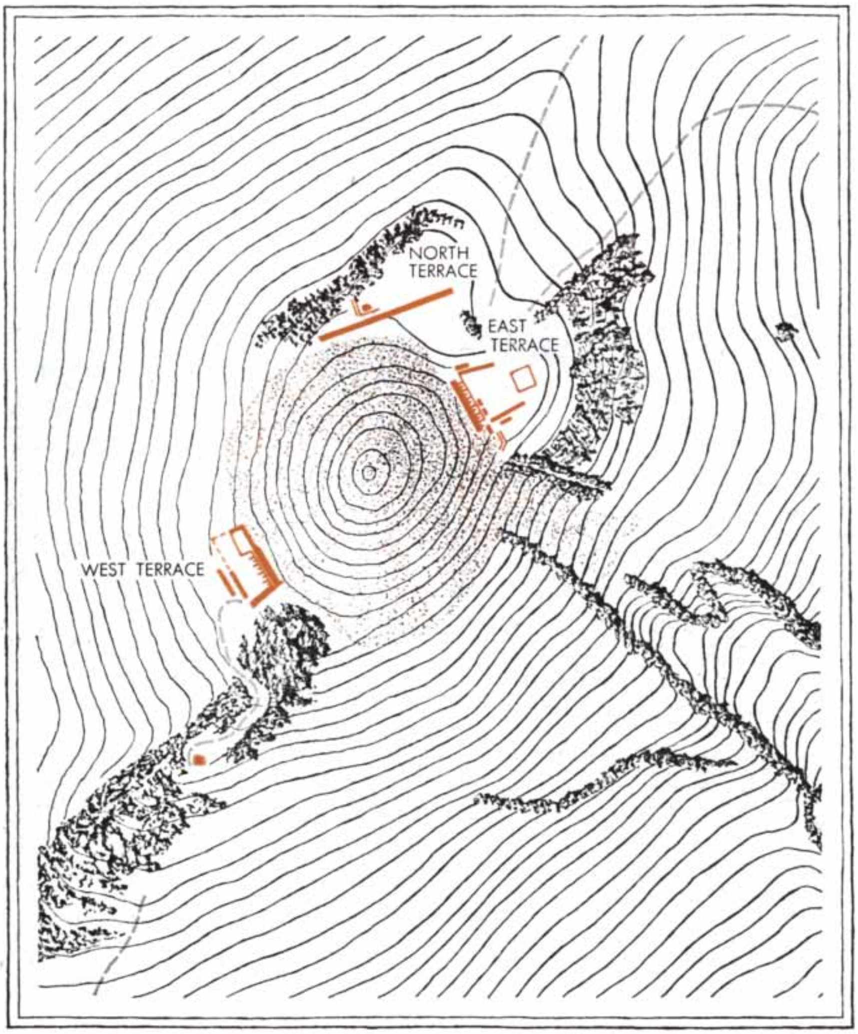
The Romans coveted Kommagene both for its wealth and its position as a buffer against the formidable Parthians across the Euphrates. In 62 B.C. Antiochus signed a treaty with the Roman general Pompey, who was reorganizing the East after successful Roman military campaigns. The treaty allowed Antiochus to keep his throne as an ally of Rome, and spared him the humiliation of marching with other conquered kings in Pompey's triumph.

Lying across the land routes between East and West, Kommagene had been deeply influenced by the ebb and flow of foreign cultures. Antiochus clear-



EAGLE'S HEAD lies on the floor of the West Terrace. A lion and an eagle stood at each end of the row of statues on this court. Similar lions and eagles guarded the statues of the East Terrace. The feet of one lion are visible at the right end of the row on the opposite page.

RELIEF MAP locates Nemrud Dagh. Kommagene lay roughly to the south and west of the peak. For the Romans Kommagene was a buffer against the Parthians across the Euphrates.



PLAN VIEW of the peak shows the mound, its three terraces and limestone outcroppings. The main structures of the terraces are outlined in color. The contour intervals are 15 feet.

ly felt spiritual and ancestral ties with both worlds. He asserted that through his mother, Thea Philadelphia, he was descended from Alexander the Great; through his father, Mithradates Kallinikos, from the Achaemenid rulers of Persia who were overthrown by Alexander. Antiochus refers to himself as a Philhellene and Philromaios: a lover of Greece and of Rome. The gods of his pantheon on Nemrud Dagh are neither Greco-Roman, Persian nor local, but hybrids of all three.

Antiochus indicated his devotion to these gods by enthroning himself among them after his death. He was succeeded by a brief line of Kommagenian kings. In 72 A.D. Antiochus IV was dethroned by the Roman Emperor Vespasian, allegedly for plotting with the Parthians, and Kommagene was formally incorporated into the Roman Empire. From then on the West had scant interest in the Kommagenian dynasty, and it faded into obscurity until 1881. In that year Carl Sester, a German engineer surveying roads for the local Turkish government, happened upon the sacred precinct of Antiochus. His discovery aroused the interest of German scholars, and in 1882 and 1883 the site was explored by Karl Humann and Otto Puchstein. In May of 1883 the monument was also examined by the Turkish scholar Osman Hamdy Bey, although at that time the mountaintop was covered with as much as 12 feet of snow.

These pioneering efforts contributed richly to our knowledge of the ancient world in the first century B.C., but they were not followed up. Classical perfection was an ideal of the 19th century; the monument of Antiochus was considered too Oriental, barbaric and imperfect for classical scholars, and too classical for Orientalists. Such appraisals overlooked the significance of Nemrud Dagh as a link, shaped by indigenous influences, between the cultures of East and West. It was this aspect of the monument which attracted us to the mountain. We made a preliminary survey in 1953 under the auspices of the American Schools of Oriental Research, with funds provided by the Bollingen Foundation and the American Philosophical Society. The excavations in each succeeding summer have been supported by the Bollingen Foundation.

Nemrud Dagh is approached by jeep, by animal and on foot through parched sandy plains, silted river beds, rocky gorges and rugged limestone slopes. When one first arrives at the

WEST TERRACE is viewed from the top of the mound. On the floor of the terrace are two colossal heads. The one at the left is the same eagle that appears on page 39, which was later set upright. At the right is a head of Herakles Artagnes Ares. The bases of the original statues may be seen against the slope of the mound. At left center are fallen reliefs and the sockets which held them.

peak, one succumbs to a powerful urge to climb to the top of Antiochus's mound. Partly composed of loose stones about the size of a fist, this artificial cone is about 500 feet in diameter and 150 feet high. From this height one can easily see the plan of the monument. At the base of the mound are three terraces—to the east, west and north. The terrace to the east is some 300 feet higher than the one to the west.

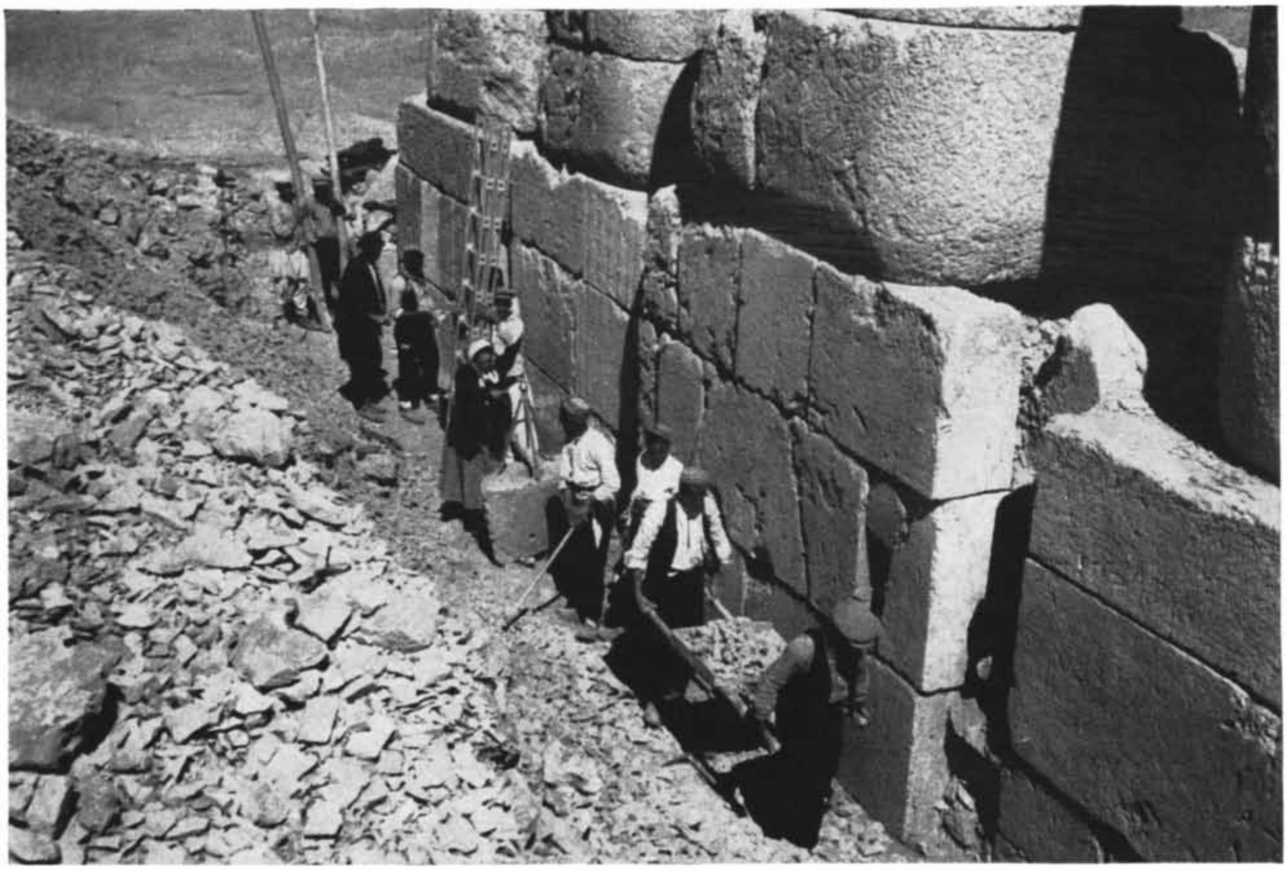
The East Terrace is the most unified and monumental of the three. It is distinguished by a row of five colossal statues of Antiochus and his hybrid gods: Zeus Oromasdes, Apollo Mithra Helios Hermes, the fertility goddess or Tyche of Kommagene, and Herakles Artagnes Ares. Originally these majestic figures, facing east away from the mound, were from 24 to 30 feet high. Now the crowned heads of all except Tyche, wearing her symbolic turban of fruit, have been thrown down to the terrace by earthquakes or by vandals looking for treasure. At each end of the row of statues is a pedestal which supported a massive guardian lion and eagle. The north and south sides of the East Terrace were flanked by 10-foot walls resting on a stepped foundation which bore reliefs of Antiochus's Macedonian, Persian and Kommagenian ancestors. In front of each relief was a small incense altar. At the eastern side of the terrace was a large stepped pyramid which was surmounted by at least two lions and two eagles, probably flanking a relief portrait of Antiochus. We conjecture that a fire altar also stood on top of the pyramid, following the Persian custom.

The West Terrace follows roughly the same plan but omits the stepped pyramid. Here the statues and reliefs have all been toppled from their bases. On this terrace Humann and Puchstein found a remarkable relief bearing the horoscope of Antiochus. According to Otto Neugebauer of Brown University and the Institute for Advanced Study, the relief is not astrological but the astronomical representation of a date in July. Neugebauer has shown that the symbols of 19 stars, a crescent moon and a lion on the relief depict the conjunction of Jupiter, Mercury and Mars on July 7 in 62 B.C. Thus the relief might represent the year in which Antiochus was confirmed in his throne by Pompey. To us it seems unlikely, though not impossible, that Antiochus commemorated his subjugation by the Romans or his status as an ally. He may have celebrated the date for another reason.

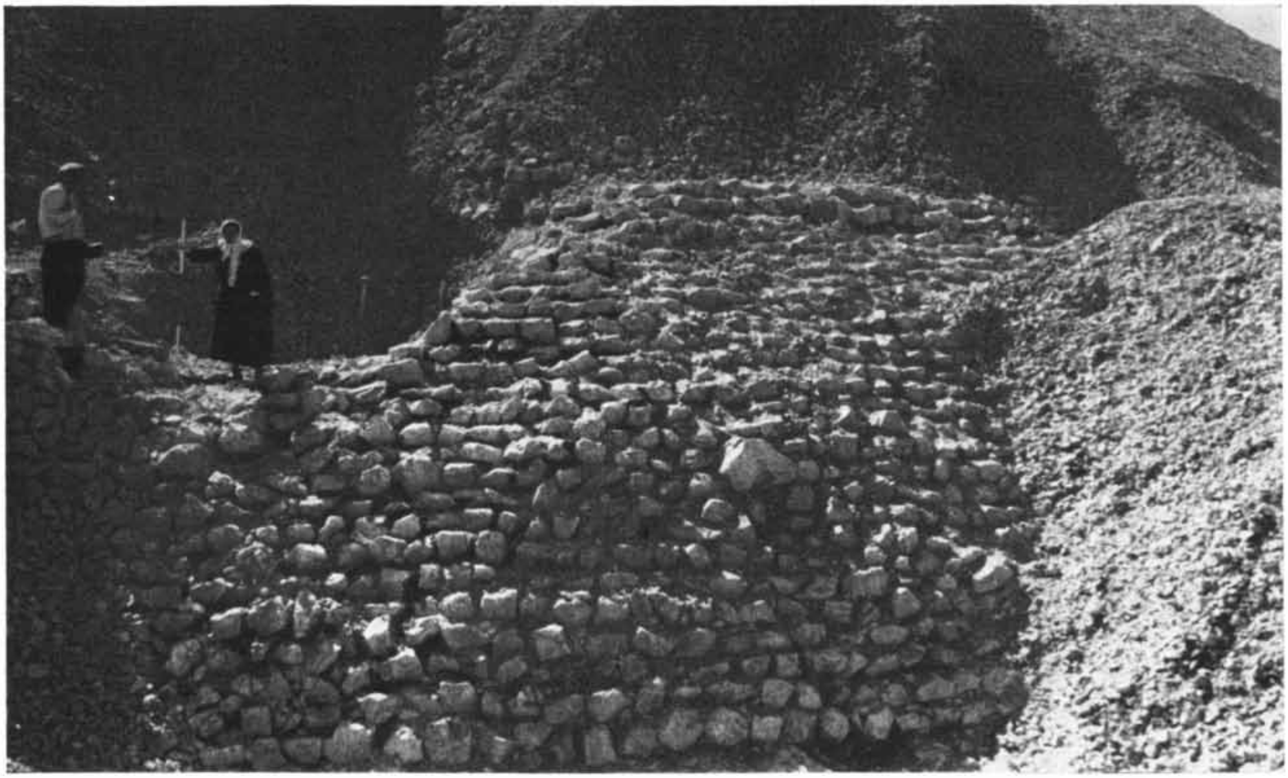
The southern side of the West Terrace represents an impressive feat of engineering. Because an outcropping of limestone blocked a passage to the south, the builders hewed a broad cleft through the rock. At several places on the southern side of the mound there are other outcroppings, indicating that the peak of Nemrud Dagh forms the core of the mound. Thus the remains of Antiochus may be in a chamber hewn out of solid rock.

The North Terrace lacks the monumental plan of the East and the West Terraces. Its most prominent feature is a long wall of sandstone slabs about 10 feet high, now fallen. This wall separates the North Terrace from the valley below. The sandstone slabs bear no reliefs or inscriptions, which suggested to Humann and Puchstein that the North Terrace had been left unfinished. We believe the slabs were not adorned for another reason. Outside the wall, and on the slope of the mountain below the terrace, we found the remains of other walls suggesting a complex of rooms. They may be the remains of the living quarters and storage rooms of the priests, musicians and slaves who maintained the cult of Antiochus and served the participants in his celebrations and feasts. Our supposition can only be confirmed by further examination of these crumbling ruins.

The plan of all three terraces is obscured by the rubble of their decay. The monument has been subjected to 2,000 years of earthquake, heat and cold, rain and wind, snow and ice. Even during the summer the temperature sometimes drops to freezing at night,



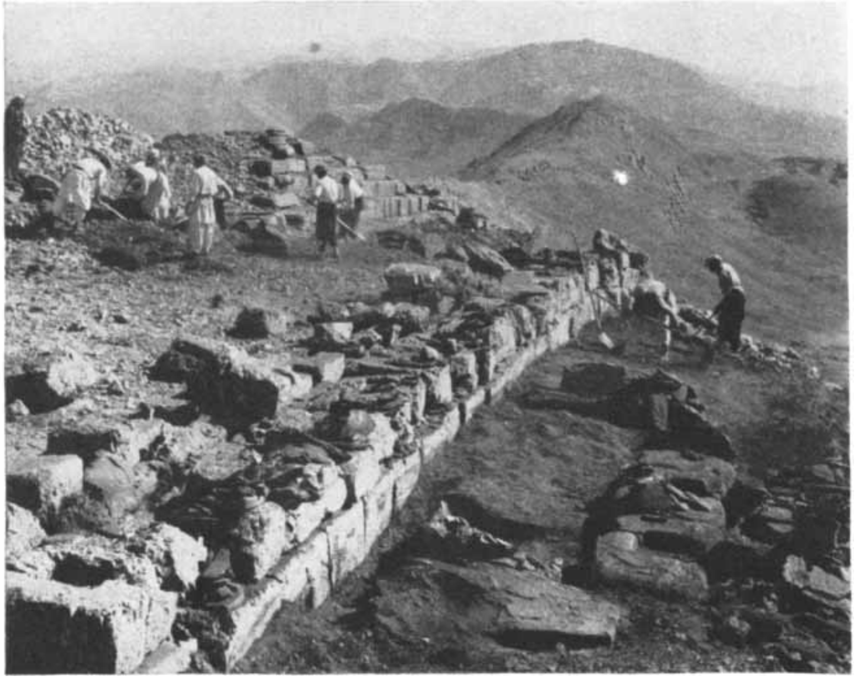
PASSAGE IS CLEARED behind the bases of the statues on the East Terrace. This laid bare the long Greek inscriptions on the bases. At left center, wearing a kerchief, is Theresa Goell. The inscriptions to her left have been covered so that they may be copied.



REVETMENT IS EXPOSED by the removal of the loose stone of the mound. At left Miss Goell stands before a trench dug in an attempt to find a passageway to the tomb of Antiochus, which is presumably cut into the mountain. The passageway has not been found.

and often rises to more than 150 degrees Fahrenheit during the day. We have seen snow fall in September, and the wind blows so furiously that our local workers consider us *bir tahtasi eksik*—"a board missing"—to go to the mountain at all. Fortunately the monument has largely been spared the even more destructive effects of man. Throughout the ancient world, monuments in such famous cities as Ephesus, Pergamum, Philadelphia and Tarsus were quarried to build their cut stone into new structures, and to burn their limestone in kilns. The remoteness of Nemrud Dagh prevented such depredations. The principal damage inflicted by man evidently results from the fact that shepherds grazing their flocks have whiled away their time by flinging stones at the statues, reliefs and inscriptions. The noses of the figures have been their favorite targets.

The loose stones of the great mound have slipped down against the bases of the colossi on the East and West Terraces. From the awakening of our interest in the monument we surmised that beneath this rubble the mound was encircled by a retaining wall and processional pathways leading from terrace to terrace. One of our main objectives has been to discover these features. During our preliminary survey of 1953 we dug a narrow trench behind the statues of the East Terrace, primarily to disclose the inscriptions on their bases and to determine what excavating equipment we would need in later seasons to locate the burial of Antiochus. Kermit Goell of our party made latex "squeezes" of the inscriptions, which comprise the sacred edict prescribing the ritual of Antiochus and providing for the perpetuation of his cult. In 1954, with the assistance of a tunnel expert (Heinrich Buerger of the Victoria Mine in the German province of Westphalia), we widened and lengthened the trench, and found that the rock of the mountain had been chiseled away to form a low wall with a platform above it. This formed a passage behind the inscriptions. We also found traces of a passage into the core of the mountain, which suggested that we were approaching the tomb chamber. In 1955 we continued to enlarge the trench, and we laid bare the foundation of the mound about a third of the way to its summit. The suspected passage to the tomb did not materialize. It proved to be the remains of a cavity dug by earlier explorers who had tried to find the burial chamber. We doubt very much that our predecessors ever reached the chamber, if it is on this side of the mound at all, because the



STEPPED PYRAMID on the East Terrace opposite the statues is cleared by local workmen at the upper left. In the middle is a wall which was surmounted by a long row of reliefs.

"SQUEEZE" COPY of a Greek inscription is held up by Kermit Goell. Such copies are made by covering a piece of burlap with liquid latex and pressing it against the inscription.

RELIEF found on the West Terrace shows Antiochus (*left*) shaking hands with Herakles Artagnes Ares (*right*). At the bottom is the tongue which held the relief in its stone socket.

HOROSCOPE of Antiochus was also found on the West Terrace. It has been interpreted as representing a date in 62 B.C., the year Antiochus was confirmed in his throne by Rome.

rubble cascades violently when it is disturbed by shoveling.

In 1954 and 1955 we also located the processional ways leading to the East and West Terraces from the valleys below. They were marked by inscribed slabs set in rock-cut sockets. We brought to light many significant fragments of statues and reliefs, including a second horoscope relief on the East Terrace.

Earlier investigators thought that a broad stairway ascended to the platform of the colossi enthroned on the western side of the East Terrace. After clearing the rubble covering we found not a stairway but a two-tiered monumental platform, partly cut from the living rock. On the lower tier are five sockets which held a wall of reliefs depicting Antiochus being greeted by his deities.

The disclosure of the double platform is of first importance because it provides evidence that the plan of Antiochus's precinct was not the caprice of an eccentric monarch, but that it was deeply rooted in tradition. Only a few miles away, at the tomb of Antiochus's father Mithradates, we find similar stepped platforms. Sunk into the platforms were sockets which held colossal reliefs of Mithradates and his gods. We consider these stepped platforms to be prototypes which were extended and monumentalized by Antiochus.

The deeper significance of the monument is that it reflects not only the influences of ancient local cultures but also those of the Greco-Roman and Eastern worlds. As an example, the lion of the horoscope reliefs found on the East and West Terraces is generally conceived in the realistic Greek tradition. But the head of the lion, with its open mouth and schematic mane, has affinities with lions found at the celebrated Hittite sites of Boghaz Köy and Carcemish. The astronomical objects in the relief suggest the earlier Babylonian astronomy.

Viewed in this light, the tomb of Antiochus bears on one of the main questions of Middle Eastern history: What became of the Hittite culture after the eighth century B.C., when the Assyrians had conquered the last Hittite city-states in what is now southeastern Turkey? Obviously the people of the region did not vanish from the face of the earth, yet we have no record of them until seven centuries later. The art and architecture of Nemrud Dagh provide a clue to this mystery. They represent Hittite traditions shaped by Greco-Roman, Mesopotamian and Persian influences. Thus remnants of the local culture survived at least until the time of Antiochus.

Kodak reports to laboratories on:

how to make alignment decisions that don't take so much out of a man . . . acrylic fiber and spectroscopic plates . . . a long haul from wheat germ oil

No knots

Take the Great Pyramid of Cheops at Gizeh. Take the Eiffel Tower. Take the *Nautilus*. Take one of those gigantic atom smashers. Take even a little thing like a million dollar turbine in a power generating station or a 70-foot planer bed. Always there comes a moment when the engineer-in-charge has to say, "OK, boys. She'll never be lined up any better than she is right now. Let's get on with the job." And the irrevocable next step is taken. Making a decision like that can take a lot out of a man.

Any gadget that puts such a decision on firmer ground ought to be worth quite a bit in peace of mind alone, to say nothing of the time cards of all those men standing around waiting, waiting for the word.

Right here we could make a big mistake by overplaying our hand. Let's better make plain where the new *Kodak Axicon* stands in relation to the art of aligning long axes.

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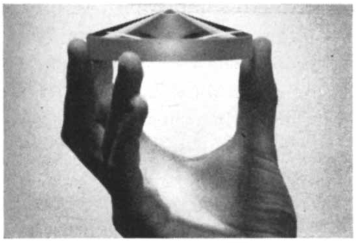

No, it's not a lens. It's not curved in a plane containing the axis of symmetry.

this simple new class of axially symmetric optical element, which, with the study of optics a couple of millenia old, he was lucky and smart enough to invent. An axicon images a point source of light along the axis as a straight line in space. No wire, however tight, can be so perfectly free of kink and sag. What of a telescope, you say?

A telescope objective forms its image at a different little knot in space for each successive target along the line of sight. In following these images with the cross hairs, there is a chance for error of parallelism between the focusing motion and the axis. There is also doubt about how much of the observed displacement is real and how much of it is parallax because of inability to locate the knots exactly. With an axicon there is no focusing. Anywhere along a length of 40 feet—100 feet or more, if you like—the line of light is equally thin, forms an equally hard little point of light where intercepted.

A procedure for aligning lower turbine shells with a Kodak Axicon Aligner *has been worked out in full detail and even timed. The friends with whom we worked out this procedure certainly know the turbine trade as well as anybody alive. That they, with all their experience, like the axicon method encourages us to believe that the booklet prepared for their operating personnel might make interesting reading for others faced with awesome alignment problems. For a copy, write Eastman Kodak Company, Military and Special Products Sales, Rochester 4, N. Y.*

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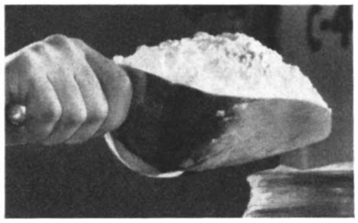
We expect to sell quite a few million pounds of *Verel* staple at $1.10 a pound (the delivered price east of the Mississippi River). On Dr. Humason's order we should gross perhaps as much as $27. It is hard to say which is more important, and that is no joke.

Remember that there is today no basic shortage of any type of fiber, natural or man-made, but a considerable shortage of objective information from which to spin theories about where the world came from and where it is going. Before Dr. Humason retires a few months from now, he expects to photograph spectra of the farthest galaxies within the grasp of the largest optical telescope that may ever be built. That "103a" emulsion is not as fast for ordinary or for high speed photography as the far better known *Kodak Tri-X Film;* its *forte* is the ability to respond in as little as 50 hours of exposure to the feeble trickle of billion-year-old photons.

Remember also one reason why gifted men can be allowed to draw good pay for time spent increasing the speed of Dr. Humason's plates. It is that many people who don't know a galaxy from a galvanometer (and couldn't care less) demand, when a fabric comes along that feels a little nicer because of proper moisture retention, wears a little better, holds shape and color a little better, that they have it on their backs *pronto.*

Pilot plant quantities of Verel *staple fiber are available for evaluation from Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company). Plates that respond to light too dim for any eye are available from Kodak dealers after correspondence with Eastman Kodak Company, Professional Sensitized Goods Division, Rochester 4, N. Y.*

Dry E



From something in wheat germ oil that could rectify a certain experimentally induced reproductive dysfunction in rats to this crystalline *d*-alpha-tocopheryl acid succinate, it has been a long haul for vitamin E. The purpose of this newest vitamin E product of ours is to meet the pharmaceutical industry's need for the pure vitamin in a form convenient for tablets and dry-fill capsules. The burgeoning pharmaceutical demand for vitamin E is generated almost entirely at the physician's prescription pad.

It is unwise in a journal such as this to indulge in discussion of medical rationale. However, there is an entirely different case to be made for vitamin E in feeding chickens and turkeys. If you have any of them to feed, there is no reason why we can't send you a recent review article from our laboratories that appeared in Poultry Science. *A copy of "Role of Vitamin E in Poultry Nutrition and Disease" may be obtained from Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

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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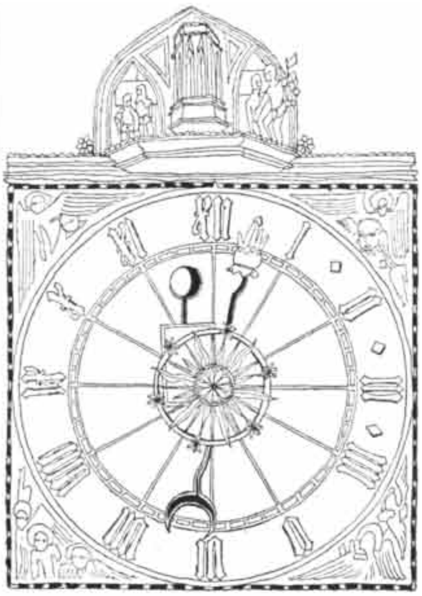


Radiation Study

In the peacetime development of atomic energy, man has been lucky. Except for some tragic accidents to a relatively few people, he has suffered little biological damage from the immense radiation he has already released. As the atomic age advances at an accelerating pace, man must learn how best to cope with the inherently dangerous radioactivity he is releasing in ever-increasing quantities. This is the principal message of a report on the biological effects of atomic radiation that was released by the National Academy of Sciences last month.

The report is the first publication in what is to be a continuing study sponsored by the Academy and financed by the Rockefeller Foundation. For the past year six scientific committees have been investigating radiation problems in the fields of genetics, pathology, meteorology, oceanography, agriculture and the disposal of radioactive waste products. Each committee has issued a report summarizing present knowledge in its field and outlining the areas in which further research is most urgently needed.

The Academy has also issued a popular summary of the reports. The purpose is to provide the layman with technical background against which he can consider the "ethical, political, economic or military questions" which he will be called upon to decide in connection with atomic energy.

The genetics committee emphasizes the importance of the total amount of radiation absorbed by the human population. The cumulative effect of radiation on future generations is likely to be the same whether a great many people are exposed to tiny doses or a few people receive considerably larger amounts. In either case the total number of mutations will be the same.

A child's genetic make-up can be affected by any mutations in its parents' genes from the time they are born until it is conceived. For this reason the report recommends that, as an average for the population as a whole, the amount of radiation to which an individual's reproductive glands are exposed from conception to the age of 30 be limited to 10 roentgen units. (To give the reader an idea of the size of this unit, the average dental X-ray delivers five roentgens to the patient's jaw, but only five thousandths of a roentgen of stray radiation to such remote parts of the body as the reproductive glands.) The 10-roentgen figure is over and above the unavoidable "background" radiation that comes from naturally radioactive elements in the earth's crust and from cosmic rays. The average 30-year exposure from background in the U. S. is 4.3 roentgens.

As a maximum for the exposure of individuals, the report sets a gonad dose of 50 roentgens before the age of 30 and not more than 100 before the age of 40. It also recommends that a record be kept for every individual showing how much radiation he has accumulated in his lifetime. The geneticists advise physicians to use X-rays as sparingly as possible.

The pathologists of the National Academy study call attention to the fact that radiation shortens the span of life. Aside from the specific diseases, such as cancer and leukemia, that can be triggered by radiation, there are more diffuse effects. Radiation appears to lower immunity, damage connective tissue and generally to accelerate aging. There is no evidence that doses up to about 100 roentgens spread over years can shorten human life. Nevertheless, the pathologists warn that if very large numbers of people were exposed to a gradually accumulated dose of 100 roentgens or even less, statistics might show that their life expectancy had been reduced.

A picture of how radiation may reach the human population, and of the steps necessary to minimize the amount that does, is provided by the committees on meteorology, oceanography, agriculture and waste disposal. So far as atmospheric contamination is concerned, the chief problem comes from atomic explosions. The immediate fallout of radioactive particles covers an area that is comparatively small and, for controlled tests, closely predictable. However, the lighter material remains in the air for long periods and spreads over most of the earth. Some of it is washed out of the air by rain or snow, and so may be unevenly distributed, depending on variations in local precipitation. Following a single bomb explosion in Nevada, rain showered the cities of Albany and Troy, N. Y., with one tenth of a roentgen of fallout. It is unlikely that a single region would be so unlucky more than once, but it is possible.

The lightest particles are blown up into the stratosphere, where they remain for years. Meteorologists know little as yet about how, when or where this material gets back to the lower atmosphere and to the ground.

The report states that weapons tests have not produced dangerous worldwide levels of radioactivity, nor should they do so in the future if continued at the same rate as in the past. Nevertheless, the geneticists point out, any increase in radiation levels is genetically undesirable and should be held to an absolute minimum.

Fallout from weapons tests has measurably raised the "natural" level of radioactivity in plants. The amount is biologically negligible thus far. But no one yet knows what levels of radiation can be tolerated in plants that serve as animal or human food. Research in this field is urgently needed, the agricultural experts say.

They also sound a reminder that the biological effects of radiation are not all bad. In their science, as in many other branches of biology and medicine, controlled use of radiation is leading to remarkable advances, both in fundamental knowledge and in applied work.

As the atomic power industry develops, some of its accumulating radioactive wastes will almost certainly be dumped into the oceans. Before this happens, the oceanographers warn, we need to know much more than we do about circulation patterns and the rates of mixing between different parts of the seas. It may be that some sections of the ocean deeps mix so slowly with the surface

waters that radioactive material dumped there would have a chance to "cool" before it entered the general circulation.

The problem of ocean contamination is complicated by the fact that marine life concentrates many of the elements in sea water. Radioactive substances are taken up by the smallest plants and animals, which in turn serve as food for larger creatures and so on up to the fish eaten by man. Each stage may result in an increase in concentration. Thus a comparatively low level of contamination of the oceans' surface waters could cause comparatively high contamination of food taken from the sea.

Radioactive tracers will be valuable in charting ocean currents and in studying marine life. But this research must be undertaken at once. "Because of the increasing radioactive contamination of the sea and the atmosphere," the oceanography committee points out, "many of the necessary experiments will only be possible within 10 or 20 years."

The report makes several recommendations for controlling waste disposal. Techniques for monitoring world-wide fallout should be further improved. Measurements of the storage of radiation in the stratosphere should be continued and extended. A national agency should control and record the dumping of radioactive material in the ocean. An international body should set up safe standards for the disposal of radioactive materials. As long as reactors remain potentially hazardous, those that are built near populated areas should be sealed so that in the event of an accident no radioactive materials can escape.

"The development of atomic energy is a matter for careful, integrated planning," the report concludes. "A large part of the information that is needed to make intelligent plans is not yet at hand. There is not much time left to acquire it."

The chairmen of the study committees are: Warren Weaver of the Rockefeller Foundation (genetics), Shields Warren of the New England Deaconess Hospital in Boston (pathology), A. Geoffrey Norman of the University of Michigan (agriculture and food supplies), Roger Revelle of the Scripps Institution of Oceanography (oceanography and fisheries), Harry Wexler of the U. S. Weather Bureau (meteorology), Abel Wolman of the Johns Hopkins University (disposal and waste).

Moscow Open House

The 14 U. S. and seven British physicists who attended last month's high-energy nuclear physics conference in Moscow were impressed by the congeniality of their hosts and the absence of secrecy. For the first time since the war Soviet scientists entertained Western visitors in their homes and discussed a wide range of technical subjects.

A highlight of the conference was a trip to the new Institute of Nuclear Problems at Ivankovo, 80 miles north of Moscow. There the visitors saw a 680-million-electron-volt proton synchrotron. They also got a glimpse of a new 10-billion-volt proton synchrotron which, when it goes into operation soon, will be almost twice as powerful as the largest comparable U. S. accelerator. Jack Steinberger of Columbia University judged that the facilities he saw will insure the Soviets world leadership in high-energy physics for the next decade. According to H. W. B. Skinner of the University of Liverpool, the scientific resources for nuclear physics in the Moscow area alone are "comparable with those in the whole of Britain."

The visitors were asked what they wanted to see in addition to the Ivankovo laboratories. Their requests were granted; their questions were answered; they were allowed to take pictures.

The relaxed atmosphere seemed at least partly due to political changes within the Soviet Union. Victor F. Weisskopf of the Massachusetts Institute of Technology reported that Soviet research was already benefiting from the return to universities and institutes of many scientists who had been held in labor camps. The release of prisoners, he said, has gone far to eliminate the atmosphere of fear in the Soviet Union.

WHO Reunited

Since 1949 there has been doubt concerning how many nations were members of the World Health Organization. At that time the U.S.S.R., the Ukraine, Byelorussia and Bulgaria announced their withdrawal from the organization. The next year Rumania, Albania, Czechoslovakia, Hungary and Poland also withdrew. But since the constitution of WHO does not provide for secession, all nine countries were kept on the membership list as "inactive" members.

This year the defectors applied for reinstatement. At the Ninth World Health Assembly at Geneva in May they were restored to active membership by a vote of 51 to 0, with five abstentions. Three other countries—Morocco, Tunisia and the Sudan—were advanced from associate to full membership. Associate membership was granted to the Gold Coast, the Federation of Nigeria, and Sierra Leone, bringing WHO's total membership to 88 nations.

Nuclear Power Warm-up

The first atomic reactor designed to produce electricity on a large scale is now operating at the Calder Hall station in Cumberland, England. One of the two piles being assembled there has been loaded with enough uranium to sustain a chain reaction. By October both reactors will be supplying a total of 50,000 to 70,000 kilowatts to Britain's national electric network.

The Calder Hall station is a project of the British Atomic Energy Authority. The nationalized Electricity Authority plans to build an additional 12 atomic power stations. By 1965 they are expected to have a capacity of 1.5 to 2 million kilowatts.

Salk Serum for the Soviets

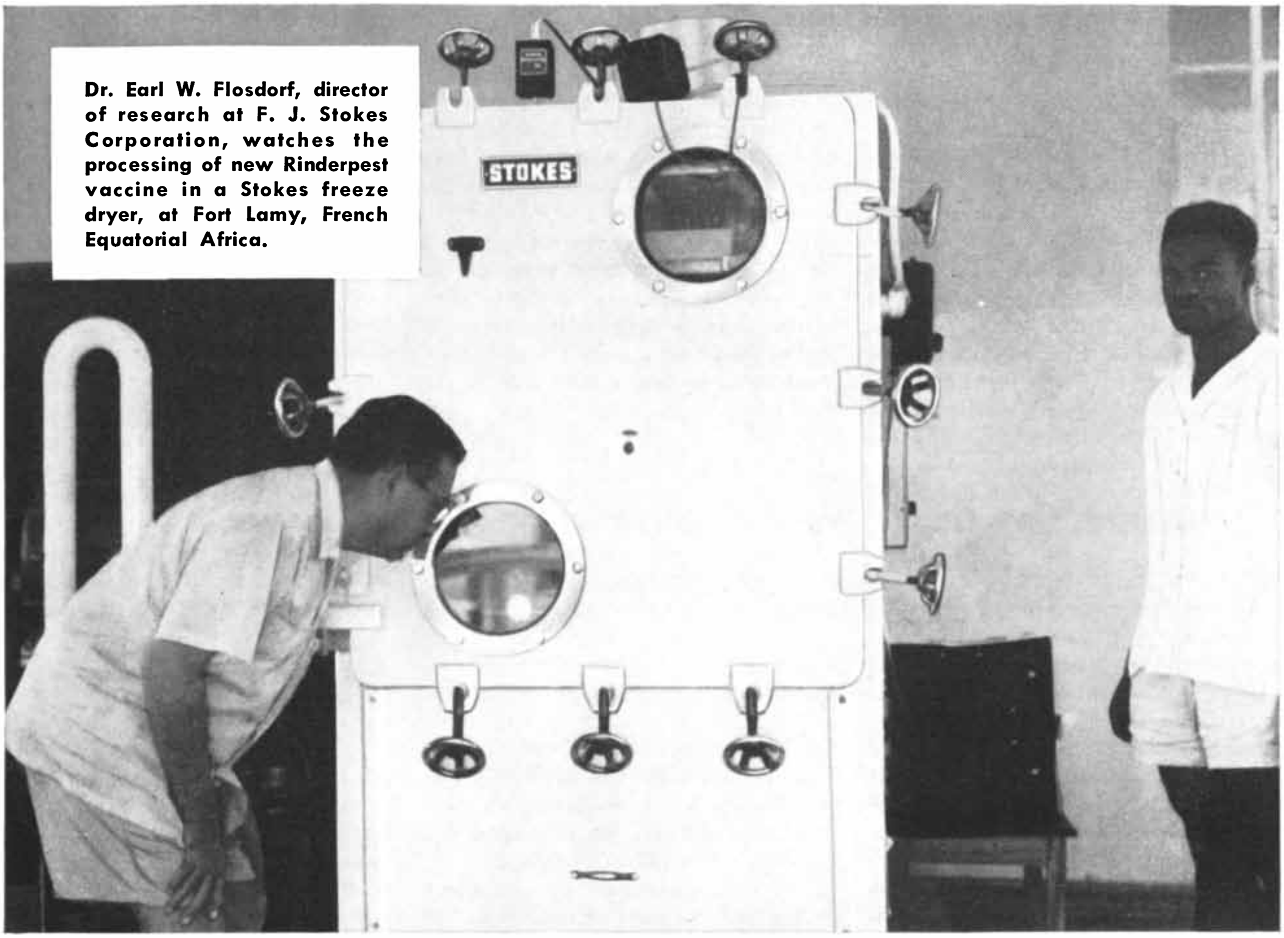
It has been noted that the incidence of poliomyelitis in a nation generally corresponds to indexes of its standard of living. In the U. S., Denmark and Sweden, for example, polio is a major health problem, while in India and China the disease is rare.

If this thesis is true, citizens of the U.S.S.R. are apparently enjoying an increasingly higher standard of living—and paying for it. Writing in a recent issue of the illustrated weekly *Ogonyok*, the director of the Soviet Union's Institute for the Study of Poliomyelitis described a "crash" program to produce a Salk-type vaccine. He observed that during the past 10 years the frequency of polio outbreaks in the U.S.S.R. has increased. He called upon the Ministry of Health to help make adequate supplies of vaccine promptly available.

AD-X2 Again

Another chapter in the story of the controversial storage-battery additive AD-X2 closed last month when the Federal Trade Commission agreed unanimously that the chemical had not been advertised unfairly.

As early as 1948 and again in 1952 tests made by the National Bureau of Standards had condemned AD-X2 as worthless. Then its maker, Jess M. Ritchie of Oakland, Calif., had enlisted the sympathies of 28 Senators and the Senate Small Business Committee. As a result of hearings before the Committee, Secretary of Commerce Sinclair Weeks had forced the resignation of Allen V.



Dr. Earl W. Flosdorf, director of research at F. J. Stokes Corporation, watches the processing of new Rinderpest vaccine in a Stokes freeze dryer, at Fort Lamy, French Equatorial Africa.

New vaccine for African cattle virus preserved by Stokes Freeze Drying

A significant forward step has been made in the fight to control Rinderpest, an infectious virus disease of cattle. A new live virus type vaccine has been developed at the Chad Livestock and Veterinary Service, at Fort Lamy in French Equatorial Africa.

The vaccine, prepared from goat spleen, is non-infectious to cattle but still capable of giving immunity. Previously, goats were transported to the range, the spleen removed on the spot and the vaccine prepared for immediate use. Today, however, the vaccine is preserved by processing in a Stokes freeze dryer. Now it can be kept for many weeks unrefrigerated . . . even in climates where daytime temperatures average 120° F. in the shade. When refrigerated, it can be stored indefinitely.

The installation and initial operation of the Stokes equipment at Fort Lamy was personally supervised by Dr. Earl W. Flosdorf, Stokes director of research.

Freeze drying is typical of the new techniques in which Stokes' 30 years of experience in high vacuum engineering is being applied today. Long a leader in developing and building vacuum equipment, Stokes offers a diversified line, including vacuum furnaces for melting and casting metals . . . vacuum dryers . . . vacuum impregnating systems . . . TV tube aluminizers and vacuum metallizers.

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Astin, director of the National Bureau of Standards. This move caused widespread protest among scientists, and Astin was reinstated. Then a committee of the National Academy of Sciences approved the Bureau's tests and its findings, and the FTC leveled a complaint of false advertising against Ritchie.

In dismissing this complaint the FTC rejected Ritchie's assertion that the NBS had acted on bias. Despite the fact that the bulk of scientific evidence failed to support claims made for AD-X2, the commissioners felt compelled to condone Ritchie's claims because so many users of the product testified that it restored the life of spent batteries and prolonged the usefulness of others.

It's a Smaller World

The U. S. Army Map Service has just finished computing the length of the longest line ever surveyed: a 5,777.5-nautical-mile stretch from Finland to the southern tip of Africa. As a result of this measurement the map makers have revised their estimate of the size of the earth. They calculate that its radius at the Equator is 6,378,260 meters—128 meters shorter than the previously accepted figure.

The European section of the arc was finished by 1951. Then, with high-precision shoran, a radio-echo technique akin to radar, the Map Service men extended the line across the Mediterranean. In Egypt they roughly followed a 435-mile arc surveyed by the Greek mathematician Eratosthenes in about 200 B.C. South of Egypt they were hindered by grass fires and aroused buffaloes. The last gap, from Khartoum to Uganda, was filled by 1954. Since then the data has been reduced to summary form with the aid of a large computer.

Being twice as long as any arc previously surveyed, the arc theoretically should increase the accuracy of maps fourfold. The new measurement will be applied to plotting the course of the earth satellites to be launched during the International Geophysical Year.

The survey was reported at a recent Washington meeting of the American Geophysical Union by Bernard Chovitz and Irene Fischer of the Map Service.

Mapping the Pancreas

A new way to examine the pancreas from outside the body has been devised by William V. McDermott, Jr., and George L. Nardi of the Harvard Medical School and the Massachusetts General Hospital. They feed a patient radioactive zinc one day and radioactive copper the next and then analyze the radiation that emanates from his abdomen. Because zinc concentrates in both the liver and the pancreas, the result of the first day's analysis is a composite map of the two organs. But only the liver takes up the radioactive copper; on the second day they get a picture of the liver alone. By subtracting the radiation counts of the liver from those of the liver plus the pancreas, they get a map of the pancreas alone. Since cancers of the pancreas do not absorb zinc, they show up as non-radioactive spots in the final map.

Age of Life

The calendar of life on earth has been extended back two billion years by the discovery that some rocks containing fossils are as much as three billion years old. Arthur Holmes, the distinguished University of Edinburgh geologist, says that life must have existed even earlier, for in the ancient rocks are embedded fossils of algae, protozoa and fungus spores, presumably the descendants of still simpler forms. According to most previous estimates, life originated not more than 800 million years ago.

Holmes bases his conclusion on recent radiochemical dating of rocks found in South Africa, Canada and Southern Rhodesia. The fossil-bearing sedimentary rocks are sandwiched between younger layers of pegmatite. The age of the pegmatite, which is radioactive, has been accurately measured by its proportion of lead isotopes into which heavy radioactive elements have decayed.

The most ancient fossil-bearing rock Holmes and his colleagues have yet studied is a granite pebble from Southern Rhodesia. Chemists at the British Government Chemical Research Laboratory and the University of Minnesota attest that this pebble is 3.3 billion years old. Another sample found on the northern shore of Lake Superior is 1.3 billion years old, according to measurements made at the Massachusetts Institute of Technology.

Reserpine Synthesized

Robert B. Woodward of Harvard University, who first synthesized quinine, strychnine, cortisone and lysergic acid, has now synthesized another drug: the tranquilizing agent reserpine. His work on this compound was spectacularly fast; only a year earlier chemists had still not determined the structure of the complex reserpine molecule.

The synthesis was reported in *The Journal of the American Chemical Society* by Woodward and his associates: F. E. Bader, H. Bickel and A. J. Frey of Switzerland and R. W. Kierstead of Canada. Almost simultaneously two other groups of chemists at Ciba Pharmaceutical Products, Inc., and the Squibb Institute of Medical Research, succeeded in synthesizing reserpine by similar methods.

Woodward's synthesis starts with the simple coal-tar derivative quinone, proceeds directly and yields an abundance of reserpine. It is doubtful whether the drug can be produced more cheaply by synthesis than by extraction from Rauwolfia root. From another viewpoint the synthesis is more promising: it enables chemists to make a series of compounds related to reserpine. These may have medical value, and they should prove useful in showing how reserpine works.

Mock Tuberculosis

An unfamiliar microorganism is responsible for a rapidly growing number of cases of a lung disease that resembles tuberculosis. The infection, first recognized two years ago, is apparently widespread in the U. S. Fragmentary reports on the nature of the new disease and ways of treating it were made last month at the 52nd annual meeting of the National Tuberculosis Association in New York City.

Horace E. Crow of the Battey State Hospital in Rome, Ga., observed that the disease does not appear to infect young people so frequently as tuberculosis does, nor is it as contagious as tuberculosis. His study of 69 cases showed that patients generally responded poorly to tuberculosis drugs and lung surgery.

Marie L. Koch reported that the number of fresh cases at the Veterans Administration Hospital in Wood, Wis., had jumped from 185 in the last three months of 1954 to about 1,000 in the last quarter of 1955.

Emanuel Wolinsky of Saranac Lake, N. Y., announced that the American Trudeau Society has formed a committee to investigate the new disease, its association with tuberculosis, how it is transmitted and how it can be treated.

Hybrid Tombs

The great pyramids of Egypt are architectural hybrids derived from tomb designs developed before Upper and Lower Egypt were united about 5,000 years ago. This is the conclusion of Walter B. Emery of the University

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Emery bases his notion on a study of the recently discovered tomb of Queen Her-Neit, who died not many years after the first Egyptian dynasty was established. The Queen's tomb is surmounted by a brick-covered rectangular mound typical of Upper Egyptian burials. Around the mound is a brick wall, which is characteristic of Lower Egyptian tombs. Emery believes that in the course of architectural evolution tomb builders elevated the mounds and filled in the gaps between mounds and walls, thus producing the steplike motif of the later pyramids.

Down Water, Up Oil

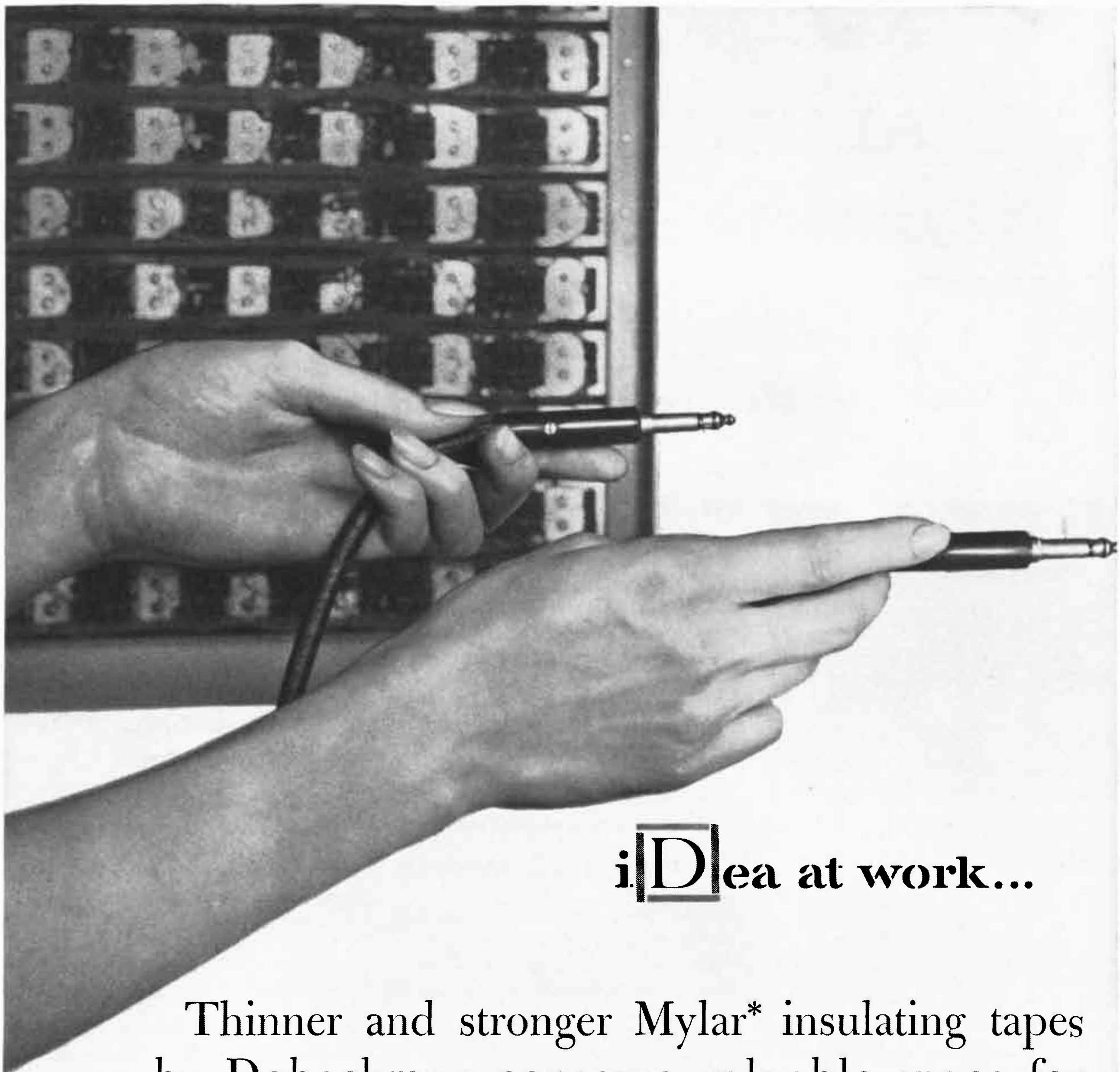
Many oil wells must be abandoned when the pumps start bringing up a great deal of water and very little oil. Frequently this failure can be traced to "water coning": underlying water rising in the oil-bearing sand and gathering at the base of the wall.

To counteract water coning Alan S. Michaels of the Massachusetts Institute of Technology Soil Stabilization Laboratory has been experimenting with a detergent mixture that makes sand attract oil and repel water. By forcing this mixture down an oil well, he hopes to destroy the capillary forces that help the water rise. As yet he has not tested his technique in an actual well, but in barrels of sand containing water and kerosene it has greatly increased the amount of oil that can be pumped up through a pipe sunk in the sand.

Dielectric Pumps

Liquid insulating materials react strangely to a strong electric potential. When two solid electrodes are partially immersed in such a liquid, the liquid rises between them. And when the electrodes are screens and are completely submerged, the liquid flows from one toward the other.

A research group at the University of Cincinnati is taking advantage of this peculiar behavior to develop a new kind of pump. Like the magnetic pumps used in the atomic energy program to circulate molten metals, the so-called dielectric pumps are compact, leakproof and have no moving parts. As reported in *Chemical and Engineering News*, the same techniques may also prove to be useful in separating mixtures of nonconductive liquids. Glenn H. Brown, J. F. Dreyer, H. R. Lubowitz and W. H. H. Middendorf are the investigators.



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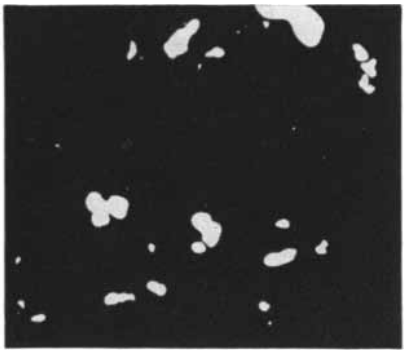
ALCOA ATOMIZED ALUMINUM POWDER now readily available

Reduced military demand frees large quantities for growing list of industrial and chemical uses



Photomicrograph of ALCOA Atomized Aluminum Powder No. 120 at 100x. Non-leafing. Average mesh size—100% through 40 mesh, 40% through 325 mesh. Average particle diameter, 26 microns. Specific gravity approximately 2.72. Bulking value .0441 gal/lb.

ALCOA® Atomized Aluminum Powder is a finely divided, granular aluminum powder produced by blowing molten aluminum through fine atomizing nozzles and collecting the product in a dust collector. Particles are more or less spherical or tear shaped, with a relatively low surface area.

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APPLICATIONS

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THE ATOMIC NUCLEUS

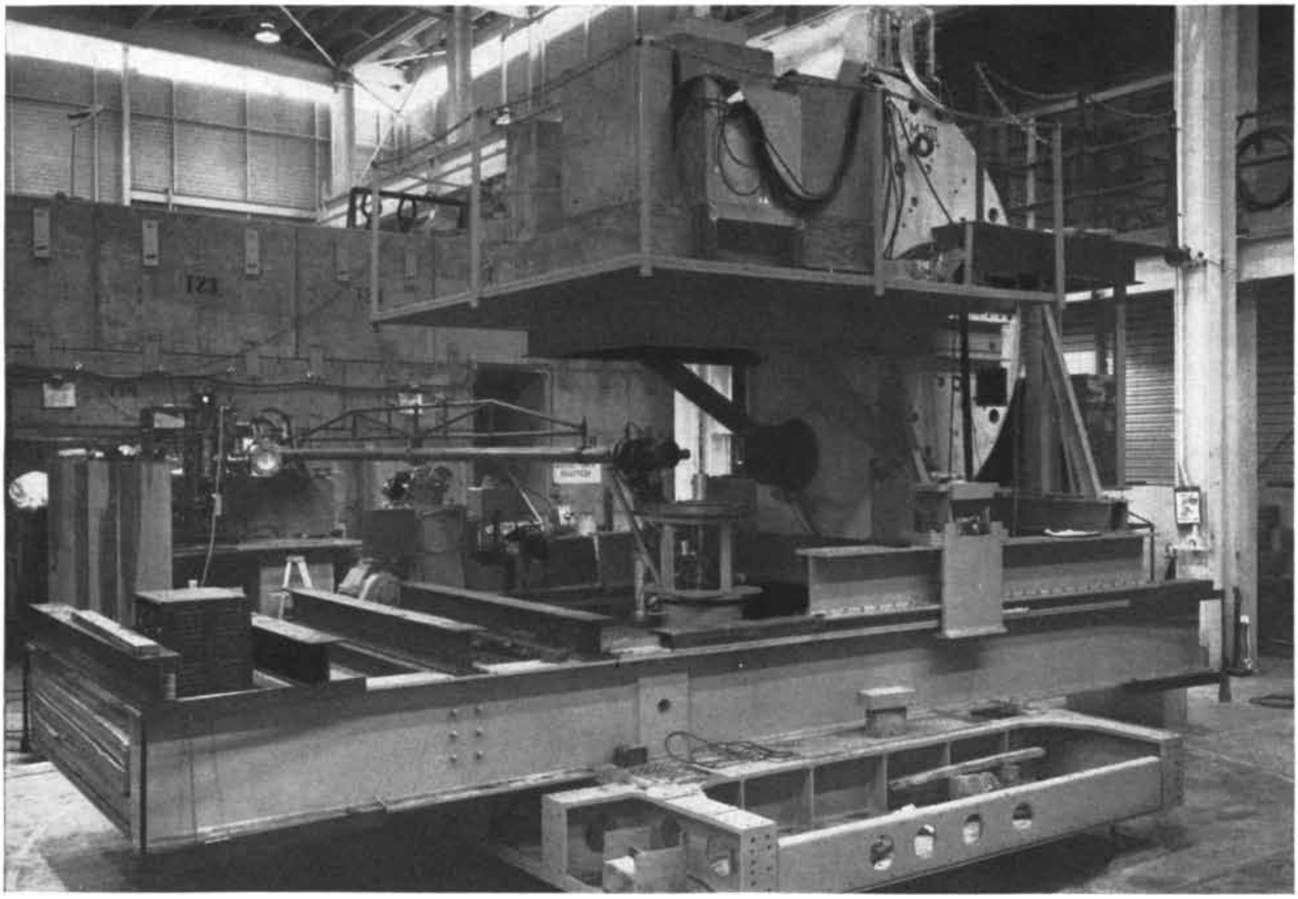
Its structure, when examined with beams of high-energy electrons, is characterized by a fuzzy "skin," the density of which decreases from the inside out. Even individual protons have this construction

by Robert Hofstadter

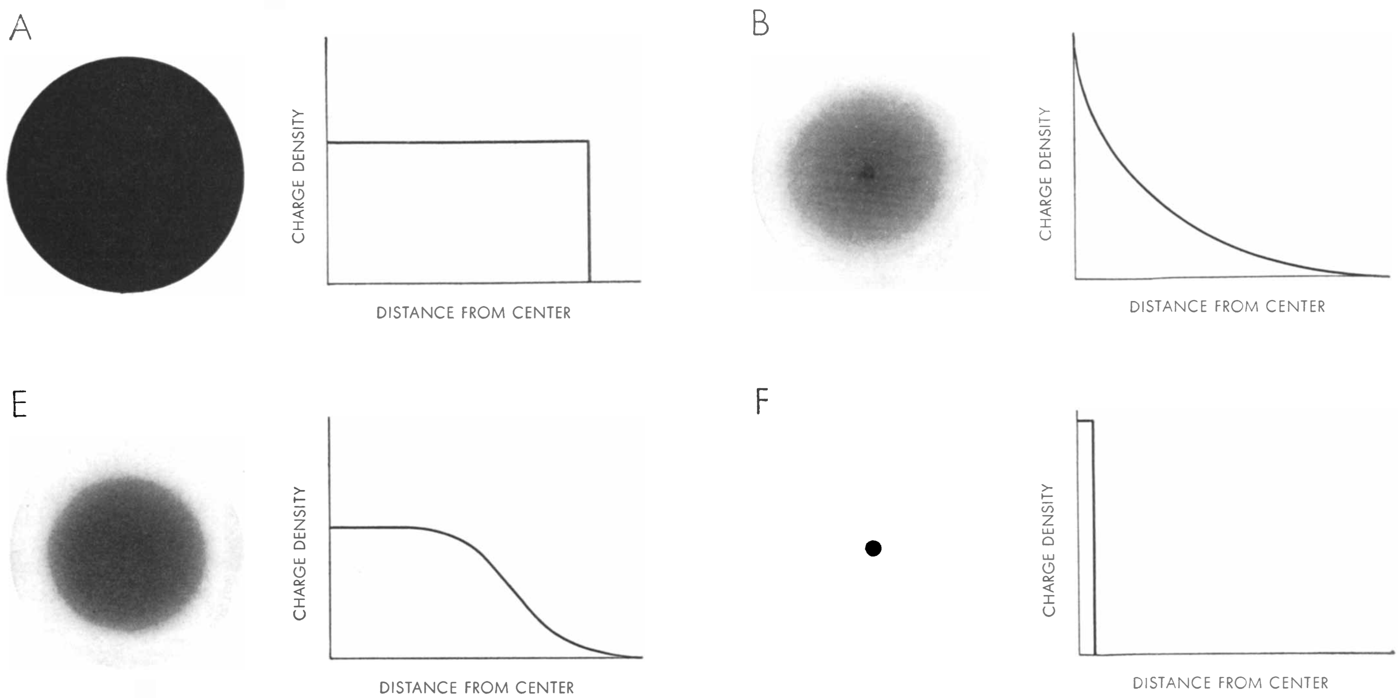
Not much more than 50 years ago it was still possible for leading physicists and chemists to argue over whether atoms really exist. Today the most backward schoolboy knows that atoms are real. He even knows what they look like. The picture of a little round nucleus surrounded by a cloud of electrons is practically the trademark of our time.

It is not just a popular emblem. Physicists also have a mental image of the atom which is much like this one. In fact, they have gone farther. For the past 20 years or so they have been trying to draw mental pictures of the inside of the nucleus.

That physicists can even dream of perceiving details in so minute an object is a tribute both to their imagination and to the delicacy of their experimental



MAGNETIC SPECTROMETER measures the scattering of high-speed electrons from target nuclei. Electrons from the Stanford University linear accelerator enter through the thin pipe which extends from the left background to the center foreground. The target material is suspended in the ladder-like holder in front of the pipe. The huge, D-shaped magnet which focuses the scattered electrons can be seen at the far right. It is carried on a naval gun mount which moves it to various angular positions around the target.



MODELS OF THE NUCLEUS, showing various conceivable distributions of electric charge within it, are illustrated here. The graphs show how the density of charge varies from the center of the nucleus outward for each model. To the left of each graph is an imaginary rendering of what the model would "look like" in cross section. Model A is the liquid drop, with its constant density and

technique. The smallness of the nucleus has been pointed out many times, but it is always worth emphasizing when one is trying to appreciate what nuclear physics is about. The diameter of the nucleus is a few ten-trillionths of a centimeter. If the nuclei of all the atoms in the earth could be stripped of electrons and packed together, they would make a ball only 200 feet in radius. We usually think of an atom as a very small object indeed. Yet if an atom could be expanded so that its outer electrons enclosed an area the size of New York City, the nucleus at its center would be about as big as a baseball.

That it is possible to peer within this speck of matter is one of the most impressive feats of modern physics. It underlines the genius of Lord Rutherford and other early investigators, who accomplished the feat with the relatively crude methods which were available to them. Recently the author and his colleagues at Stanford University, using the advanced technology of present-day experimental physics, have developed a new and very powerful instrument for examining nuclei. With it we are getting a look at details that have never been seen before, and which show that older pictures of the nucleus must be revised. We have even begun to penetrate the interiors of the "ultimate" particles—the protons and neutrons of which nuclei are made!

Models of the Nucleus

The significance of our work is best understood against a background of ideas about the nucleus that have been developing since the early 1930s. In the first place, it should be said that terms like "looking" into the nucleus or forming "pictures" of it are pure metaphor. The nucleus is utterly and hopelessly invisible. In fact, the physicist does not speak of "pictures" but of "models." This word is better because it reflects the indirect approach he is obliged to take. His experiments, as we shall see, do not yield a direct representation of the nucleus. The physicist must consider separate sets of experimental results and then try to imagine a model of the nucleus that would account for all of them.

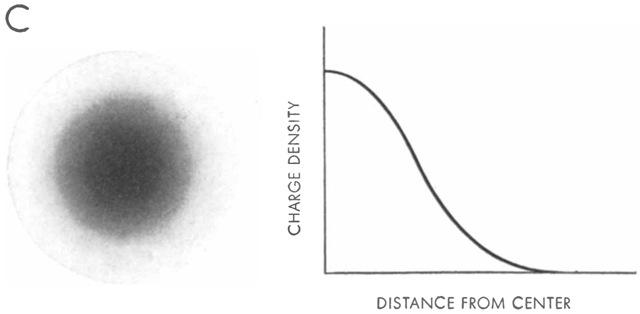
Probably the oldest model—and for some purposes still a very useful one—is the "spherical drop" or "liquid drop." Here the protons and neutrons (collectively called nucleons) which make up the nucleus are considered to be packed together like the molecules in a drop of water. On this model the nucleus has a uniform density everywhere in its interior, and a sharply defined surface. Furthermore, all nuclei, large or small, have the same density. Just as large drops of water contain more molecules than small drops but have the same density, so large nuclei have more nucleons, but these are no more nor less tightly packed than they are in small nuclei.

If this view is correct, there must be a rather simple rule governing the relative sizes of various nuclei. Their volumes obviously must be proportional to the number of nucleons they contain. And since the volume of a sphere depends on the cube of its radius, the radii of different nuclei must vary as the cube root of their numbers of nucleons. For example, if a large nucleus contains eight times as many protons and neutrons as a small one, it will have twice the radius.

It is possible to go further and get a figure for actual as well as relative sizes. On the assumption of the spherical-drop model, various experiments indicate that the radius of a nucleus, measured in "fermis" (units of 10^{-13} centimeters), is 1.45 times the cube root of its number of nucleons. Thus the radius of the gold nucleus, which contains 197 nucleons, is $1.45 \times \sqrt[3]{197} \times 10^{-13}$, or 8.45 fermis.

In addition to size and mass the nucleus has electric charge. This charge is positive, and is due only to the protons

C



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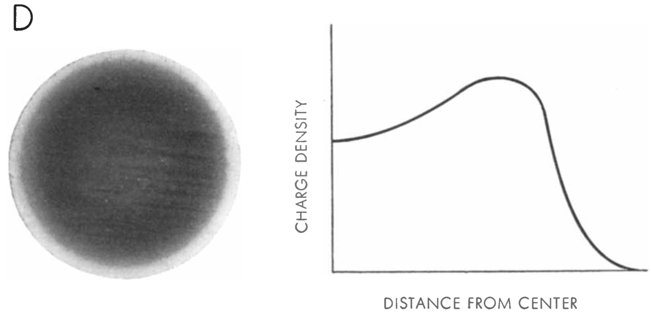

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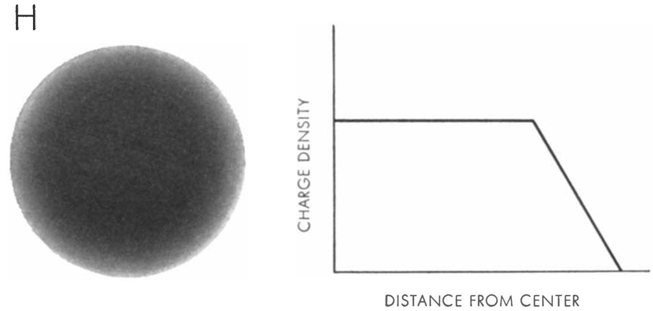


sharp boundary. Other possible structures with sharply bounded surfaces are the point nucleus (F) and the shell (G). The electron-scattering experiments of the author and his colleagues indicate, however, that the nuclear boundary is not sharp. Their results suggest a skin, the density of which falls off gradually. Models such as E or H give the best agreement with the experimental findings.

which the nucleus contains. The uncharged neutrons contribute to size and weight but not to electric charge. Now on the spherical-drop model the charge is also thought to be uniformly distributed throughout each nucleus. But the "charge density," that is, the amount of charge concentrated in a given volume, must vary from one nucleus to another, depending on the ratio of protons to total nucleons. The nucleus of ordinary hydrogen, which consists of just one proton and no neutrons, obviously has the highest possible charge density. In a nucleus where half the nucleons are protons (which is approximately the case for most light nuclei) the charge density will be half as great. In heavier nuclei the ratio of protons to total particles goes down to .39, so that the charge density is somewhat smaller.

There is no doubt that a number of important nuclear properties are reflected by the liquid-drop model. But there is also no doubt that an actual nucleus cannot be exactly like a liquid drop. It is extremely unlikely that the nuclear surface can really be sharp, with its density dropping from the constant interior value abruptly to zero. Modern quantum theory predicts that the density should fall off to zero smoothly, from the high interior value through an outer layer or "skin." This has been realized for several years, but there seemed no way to find out how thick the skin was.

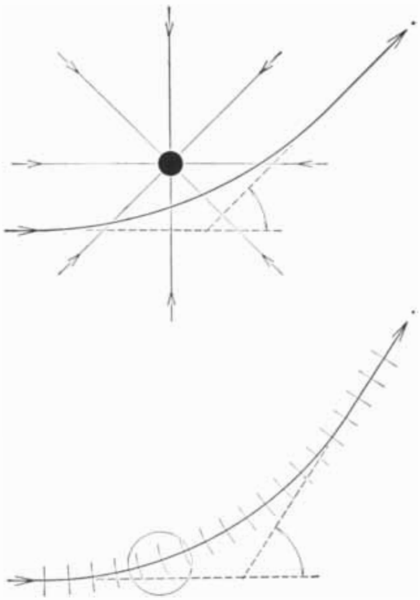
As a matter of fact, when one moves away from the simplified picture of the spherical drop, it is possible, in the present uncertain state of nuclear theory, to imagine a variety of models. Some calculations show that the nucleus may be a "soft sphere," whose density decreases steadily from the center outward. According to other theories the mass and charge may be concentrated in concentric shells. Some of these possibilities are illustrated in the drawings on these two pages. No one knew how seriously they should be taken.

Electron Probes

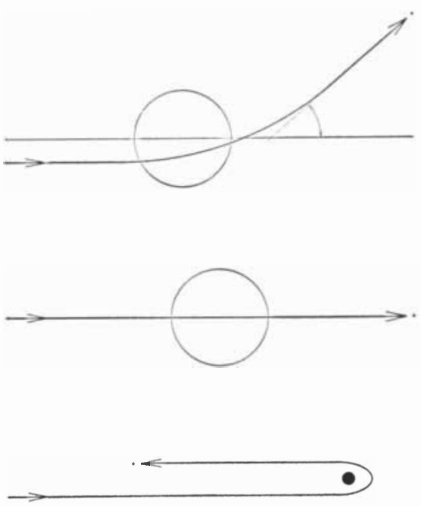
These questions were in the air in 1951 when the author began to think about a new way of examining nuclei. The idea was to shoot very high-speed electrons at them and see how the electrons were deflected, or, as the physicist says, scattered. Now scattering experiments are a classical technique of atomic physics. It was by observing the scattering of alpha particles that Lord Rutherford first discovered the existence of the nucleus. Later another British physicist, G. P. Thomson, used electron scattering to study the structure of molecules and atoms. In 1951 E. M. Lyman and his collaborators at the University of Illinois tried electron scattering on nuclei. With the moderate energies at their disposal, they were not able to make out any detail, but they did get an indication that heavy nuclei are somewhat smaller than had been thought.

To understand why high energy is necessary to reveal nuclear detail it is easier if we think of electrons as waves rather than as particles. Like all other subatomic bits of matter, electrons have wavelike as well as particle-like properties. (The rules of quantum physics tell us that the length of the waves depends on the energy of the particles; the higher the energy, the shorter the wavelength.) In many cases the behavior of electrons can be as well described from one point of view as from the other. For example, we can as well say that electron waves are diffracted by nuclei as that electron particles are scattered.

The electrons used by Thomson in his work on atoms had energies of a few tens of thousands of electron volts, which means that their wavelengths were on the order of 10^{-8} centimeters, which is 100,000 fermis. These waves cannot "see" the nucleus at all. Since they are about the same size as the atom's entire



SCATTERING, or deflection, occurs whenever an electron passes through the force field of a nucleus. If it passes near the nucleus, its deflection results chiefly from the electric attraction between its negative charge and the positive nucleus (*top*). If it enters the nucleus, the situation is better pictured in terms of waves. The electron wave is refracted by the nuclear material (*bottom*), much as a train of light waves is refracted when it passes through a raindrop.



SCATTERING PATTERN depends on the structure of the target nucleus. An extended, diffuse nucleus (*top and center*) tends to give small deflections when the electron passes near its center. In fact, a particle passing exactly through the center is not deflected at all. A point nucleus, on the other hand, gives large deflections (up to 180 degrees) when an electron passes near the center (*bottom*). Thus relative degrees of scattering at small and large angles reflects some of the details of nuclear structure.

electron cloud, the nucleus in the cloud's interior will be entirely shielded from them. In Lyman's electron beam, at 15 million electron volts, the waves were hundreds of times shorter and could penetrate the cloud. But they were still considerably longer than the diameter of the nucleus, and hence could not show it in any detail.

But at Stanford in 1951 a great linear accelerator was being built that would produce an intense beam of electrons at energies approaching a billion electron volts. The corresponding wavelength would be measured in a few fermis. This is short enough to reveal nuclear structure in considerable detail. Thus it appeared that electrons could soon be used to examine the innermost part of the atom.

This was an exciting prospect. Until that time the chief nuclear probes had been protons, neutrons and alpha particles (which are made up of two protons and two neutrons). That is to say, the particles used to examine the nucleus were the same as those which compose it. This raised a difficult problem. One of the deepest mysteries that confronts physics today is the nature of the force that acts between nucleons. In a sense all of nuclear research is directed toward clearing up this fundamental question. Thus if we shoot protons or neutrons into a nucleus, we can interpret what happens only in terms of their interaction with the other nucleons. Yet this is the very problem we are trying to solve.

Electrons, on the other hand, are not nucleons; they are not subject to the mysterious nuclear force. When they pass near protons or neutrons, they are affected only by electric and magnetic forces, and these are as well known as any in physics. Calculations of electromagnetic interaction can be made with great confidence.

Scattering

Let us consider in some detail what happens to electrons that are fired at nuclei, and what can be learned from their behavior. The electron may be thought of as a negatively charged speck which, like the earth, is spinning on an axis through its center. The motion of the charge gives rise to a magnetic effect. Hence the electron is at the same time a tiny charge and a tiny magnet. A nucleus is a positively charged ball. It may or may not be magnetized depending on how the protons revolve within it. In some cases the motions give a net magnetic effect, in others they cancel each other out. For elements above an atomic weight of 10 the nuclear charge is so much greater than the magnetic strength, if any, that the latter is negligible. In this case the interaction between electrons and the nucleus is purely electrostatic. Lighter elements with magnetized nuclei exert both electric and magnetic forces on a bombarding electron, and to separate their effects is rather difficult. Marshall Rosenbluth, now at the Livermore Laboratory of the Atomic Energy Commission, has made the separation possible by calculating the pure magnetic scattering pattern.

In any case, an electron that passes through the force field of a nucleus is deflected. If it merely passes nearby, the situation can be pictured in terms of two attracting particles, as in the deflection of a comet by the sun. If the electron actually enters the nucleus, it is more convenient to think in terms of waves and diffraction rather than deflection [*see diagrams at upper left*].

The scattering pattern will depend on the nature of the target nucleus. If it is a point, or a small, densely packed sphere, then the closer a bombarding electron passes to its center the larger its angle of deflection. An electron passing very close to the target could be so strongly attracted that it would loop around and return in the direction from which it came. That is, its scattering angle would be 180 degrees [*see diagram at bottom left*].

A diffuse or smeared-out nucleus would give a different result. An electron directed at the center of such a structure would see as much positive charge on one side of its path as on the other. Hence it would not "know which way to turn," and would pass straight through.

Here we have come to the heart of the electron-scattering method. With a dense, tightly packed nucleus we expect a considerable amount of scattering at large angles, up to 180 degrees. With a diffuse, "soft" nucleus the large-angle or backward deflection will be very much reduced in favor of forward scattering. The two curves in the diagram on page 61 show what is expected theoretically when electrons are scattered from a point charge and from a uniform soft cloud. It is also possible, although in some cases very difficult, to compute the scattering pattern for more complicated models, as we shall soon see.

A reduction in the deflections at large angles is not the only effect of a soft nucleus. Its scattering pattern is also marked by a series of ups and downs or diffraction "wiggles." To appreciate their significance we may compare the

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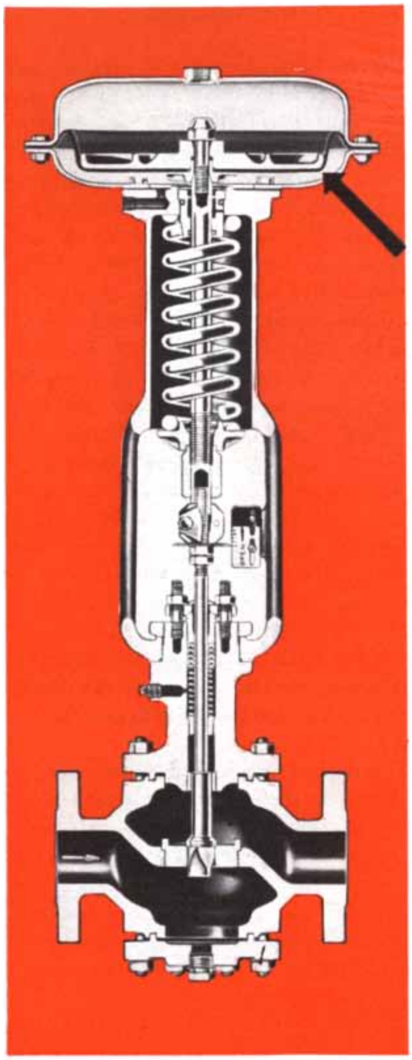

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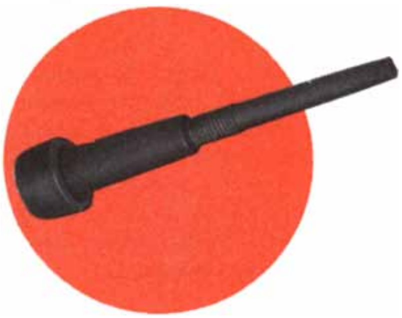

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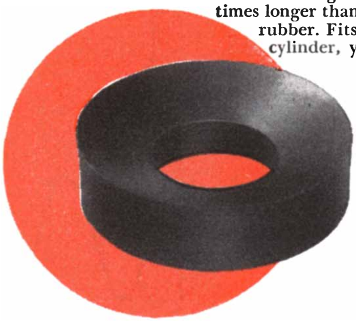

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diffraction of electrons by the nucleus with the diffraction of a beam of light when it passes through a small circular hole in an opaque barrier. A screen on which the light is allowed to fall after passing through the barrier shows a bright spot directly opposite the hole, surrounded by alternating dark and light rings, the light rings growing fainter as they get bigger [*see diagram at the bottom of this page*]. If this pattern were translated into a graph showing brightness at various angles from the forward direction, the result would be a curve with diffraction wiggles resembling those in the electron-scattering curve, although more pronounced.

From the spacing of the rings or wiggles in the light-diffraction pattern it is possible by the methods of theoretical optics to figure out the diameter of the hole. Similarly, the spacing in the electron patterns gives information about the size of the diffracting nucleus.

The analogy is not quite exact. To make it better we should have to imagine that the hole in the light experiment contains a lens made of nonuniform glass, so that the refractive index is not the same throughout the lens. The effect of such a lens would be to distort the normal pattern. The analogous problem would then be to figure out from the irregular diffraction rings both the size of the hole and the exact make-up of the lens. In the actual case we must calculate the size of the nucleus and its internal distribution of charge. As may be imagined, this can be extremely difficult. Without the aid of high-speed computers it would in many cases be impossible. However, it has now been done for a large number of nuclei, and a striking new picture has emerged.

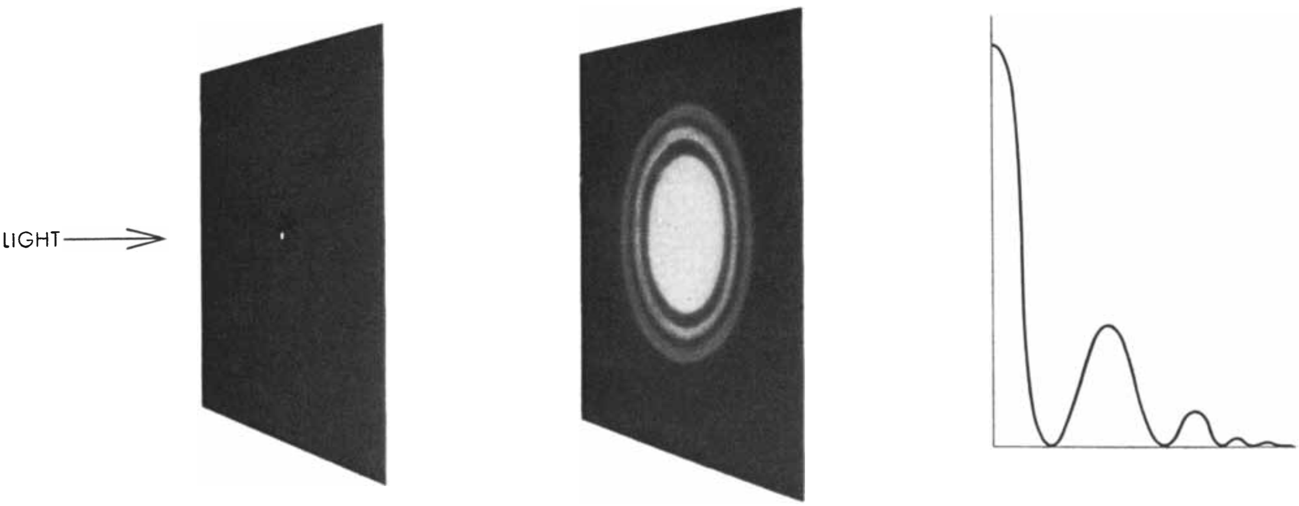
The Apparatus

Before turning to the results, let us see how the diffraction experiments are made. The Stanford linear accelerator shoots electrons at a rate of 60 bursts per second; each burst lasts a millionth of a second and contains about 10 billion particles. The machine will accelerate electrons to an energy of 700 million electron volts, but our analyzing apparatus cannot handle particle energies over 550 Mev. For reasons that will soon be apparent, the conditions of the experiment require that the particles striking the target nuclei have a very sharply defined energy. The electrons emerging from the accelerator are already at nearly the same energy—the spread is only five to 10 Mev. This is further reduced by letting them pass first through a magnetic field and then a narrow slit [*see diagram on pages 62 and 63*]. The magnet bends electrons of different energies in different directions and the slit picks out those that are traveling in one direction.

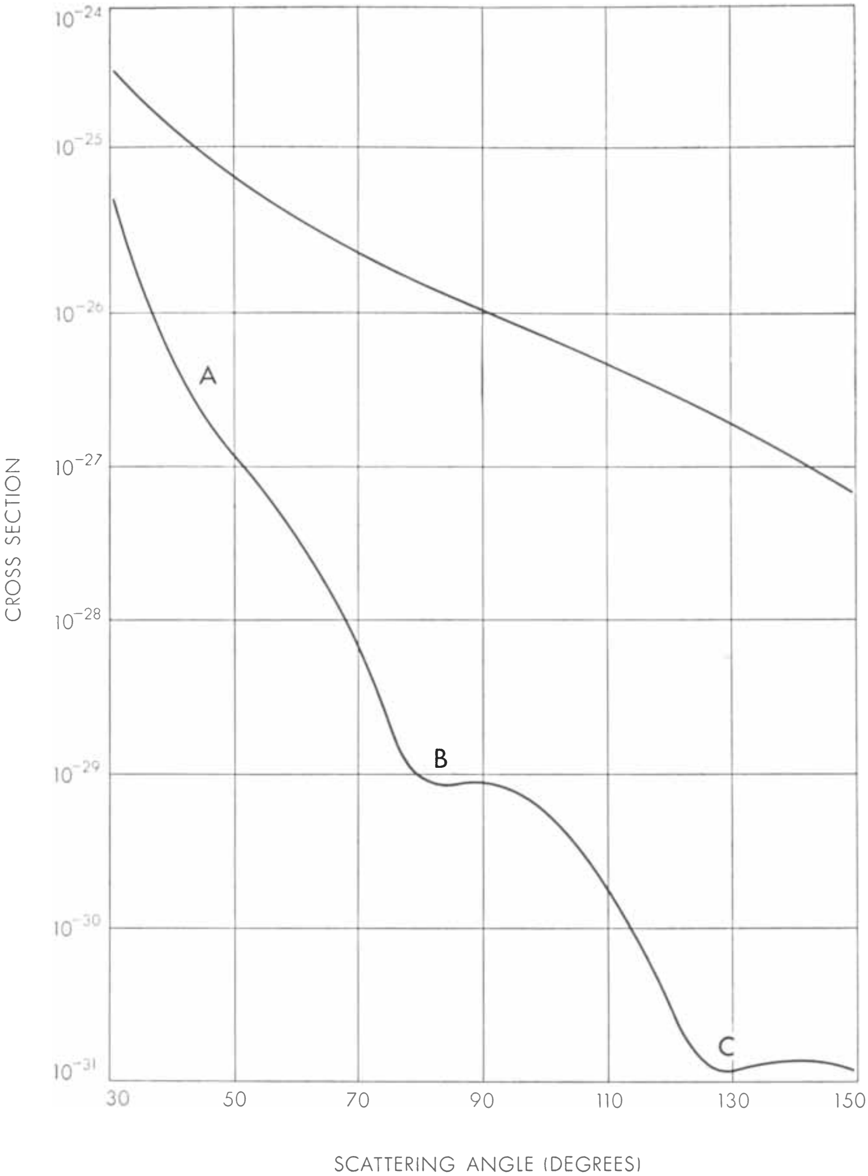
The narrow beam of uniform-energy electrons is then directed against the target material—for example, a gold foil about two thousandths of an inch thick. To determine the scattering patterns, one might suppose that it would only be necessary to move a detector around the foil and count the number of electrons deflected at various angles. It would be nice if this were so. It would make our apparatus some $200,000 cheaper and 45 tons lighter. The weight and the money represent an enormous D-shaped magnet which sorts out the scattered electrons by energies.

Why is this necessary? Why not, in fact, simply count the total electrons scattered at each angle? The reason is that all the particles deflected at a particular angle have not undergone the same type of interaction with a target nucleus; hence they do not convey the same information. In some collisions the electron and nucleus behave like a pair of billiard balls bouncing off one another, or, rather, like a ping-pong ball bouncing off a cannon ball. That is to say, the total energy of motion (kinetic energy) of the particles after the collision is the same as before. These are known as elastic collisions. A large nucleus, being so much heavier than the electron, does not recoil appreciably, so that in an elastic collision the electron bounces off with just about the same energy it had on its approach.

In other cases, the electron gives up some energy which is not accounted for by recoil motion of the struck nucleus. That is, the energy exchanged does not remain kinetic. Instead the nucleus becomes "excited" from its normal or "ground" state to a state of higher internal energy. (We may crudely picture what happens by saying that the individual nucleons go into more energetic motion.) When this happens, the collision is said to be inelastic.



DIFFRACTION PATTERN obtained when light is passed through a small hole resembles the patterns of the electron-scattering experiments. The curve at the right shows how the intensity of light varies, starting at the center of the inner bright spot and moving outward across the pattern in a straight line. This is analogous to measuring the numbers of electrons scattered at various angles from the target. The dips in the scattering curves, although shallower than those in the light pattern, convey the same sort of information.

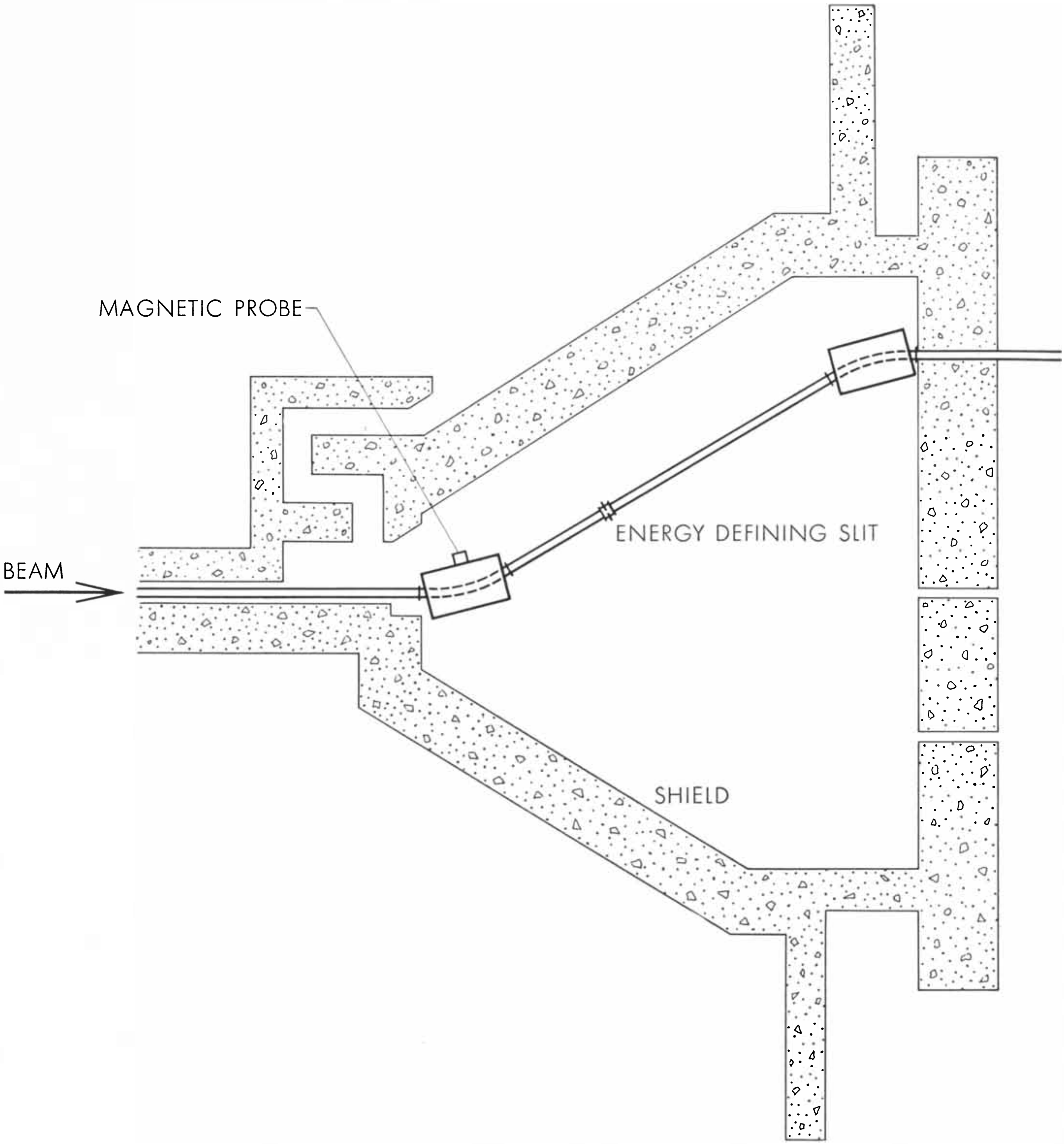


THEORETICAL CURVES show the scattering patterns expected from a point charge (*top*) and a uniform soft cloud (*bottom*). The vertical scale is a measure of the percentage of the incoming electrons which would be detected at the various angles on the horizontal scale.

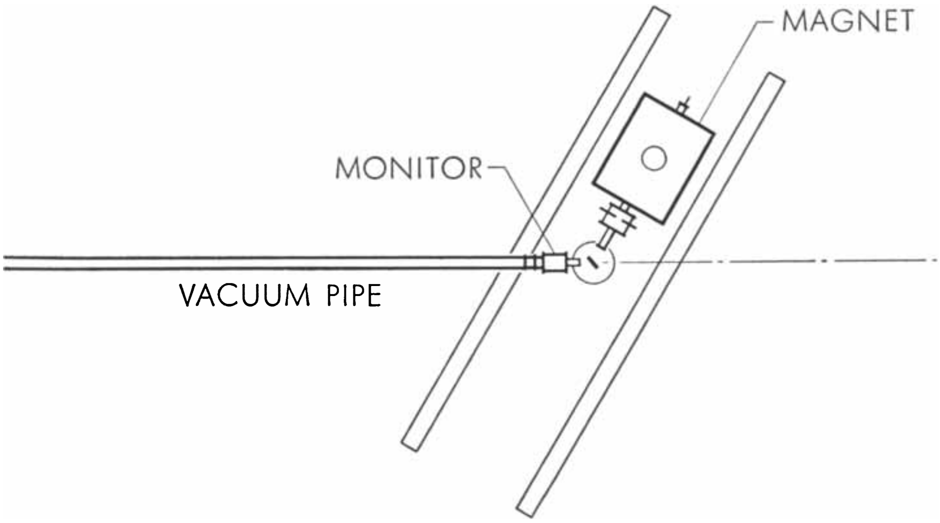
If we are interested in examining the nucleus in its normal condition then the electrons scattered inelastically are no help. They have "seen" the nucleus in an excited state. Hence we wish to pick out the elastically scattered electrons—the electrons emerging from the collision with the same energy they had going in. This is what the magnet does. Scattered electrons enter the semicircle on one side of the center and are bent 180 degrees by the magnetic field so that they emerge at the other side. Particles of different energies follow different paths, so that it is possible to focus those of a particular energy at the detector. The reason the magnet must be so big and powerful is that high-energy electrons are hard to deflect. The first apparatus we built had a magnet weighing two and a half tons and could handle electrons only up to 190 Mev. The new device, in use for about a year, can force 550 Mev electrons around its semicircular track. It is also sensitive enough to select an energy band only .8 Mev wide at 400 Mev. In other words, it can separate electrons whose energies differ by one part in 500.

Our detector is a small piece of lucite that glows momentarily when a fast electron passes through it. A photomultiplier tube picks up the light flashes and produces a corresponding series of electric pulses which are fed into a counter.

The actual number of scattered elec-



EXPERIMENTAL ARRANGEMENT for electron-scattering measurements is shown diagrammatically. The magnetic probe and energy-defining slit pick out a narrow energy band from the incoming electron beam. Electrons striking the target are picked up and focused onto the detector (*not shown*) by the magnet, which can be moved to different angular positions. The monitor records the total number of electrons that pass through the target material. A 10-ton shield around the detector cuts out background radiation.



trons counted at any angle is, of course, of no significance unless the total number of incoming particles is known. What matters is the fraction of the total that is scattered in a given direction. Each incoming electron knocks a burst of secondary electrons out of the plates of a monitor material, and a count of these bursts indicates the number of particles in the incident beam.

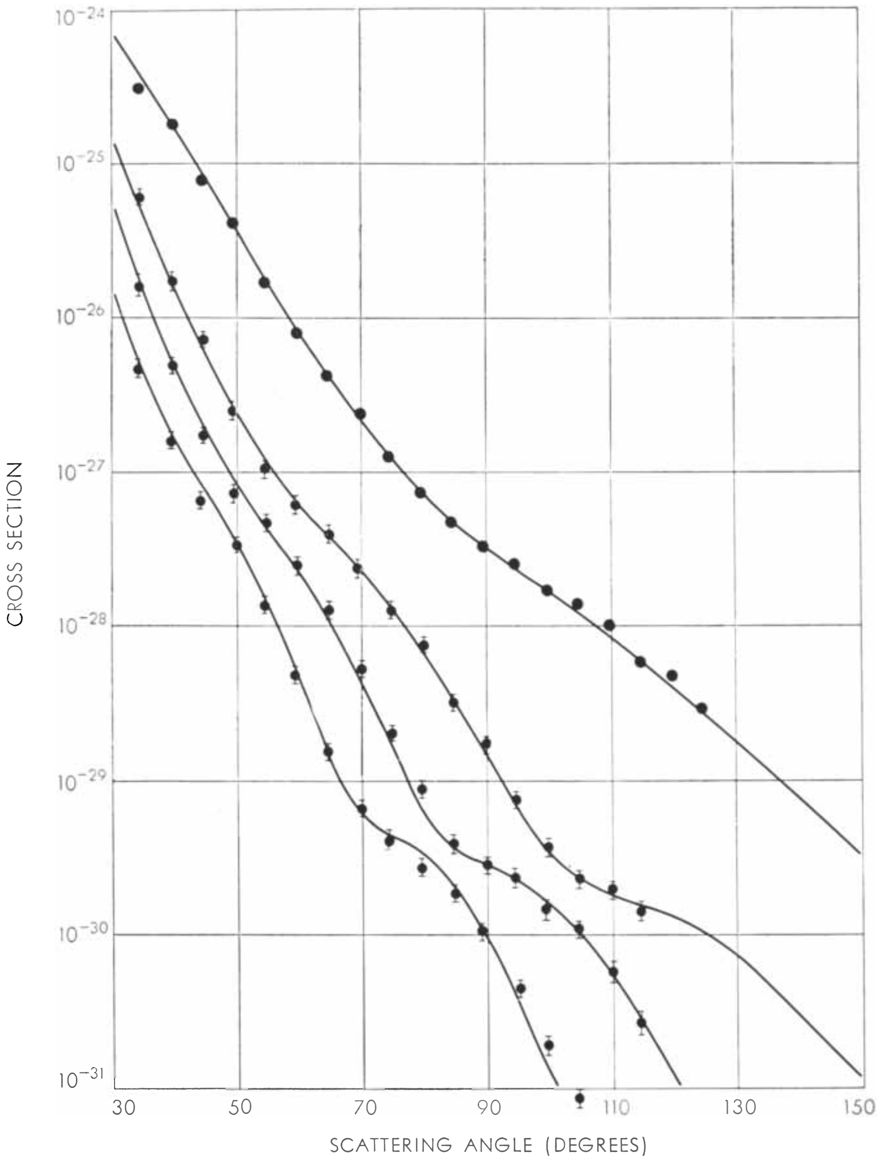
The magnet, the detector and a 10-ton lead and concrete shield which surrounds it are all mounted on an obsolete five-inch naval gun base provided by the U. S. Navy. On this movable platform the apparatus can be swung to various angles around the target. A remote-control arrangement can position the gun base to an accuracy better than a tenth of a degree.

Our apparatus operates in many ways like an optical system, and has even been called a nuclear microscope. Just as a lens collects light scattered by an object, the magnet collects electrons bouncing off a target. The lens focuses the collected light to a spot; so does the magnet in the electron analogy. However, the magnet does more, since it sorts electrons into separate energy ranges. The optical analogy would be a spectroscope or spectrometer, sorting colors or wavelengths of light. The magnet performs the operations of collecting, bending and refocusing the electrons just as a spectroscope collects light waves, separates their various colors with a prism or diffraction grating, and refocuses them.

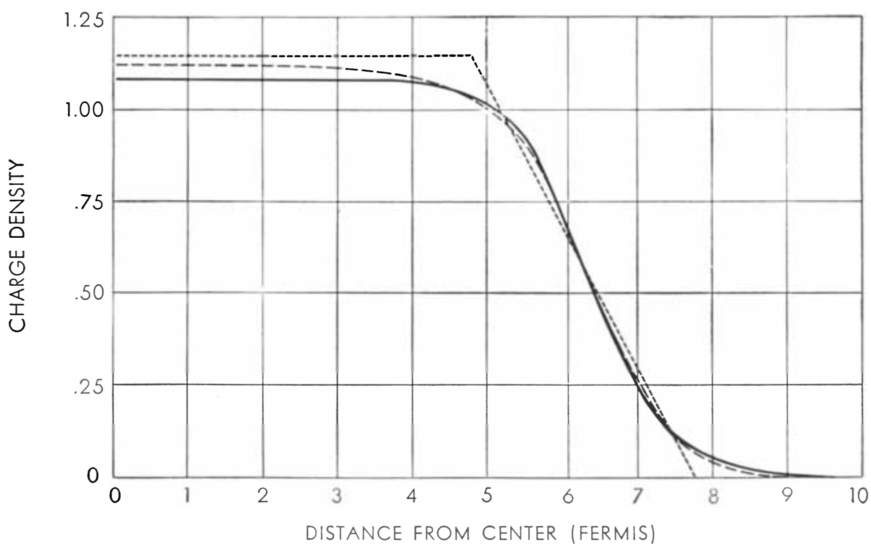
New Nuclear Models

Let us now look at some of the results that have been obtained with this apparatus. The experimental procedure is, as has been pointed out, quite simple in principle. We simply set the accelerator for a given energy, and count the percentage of elastically scattered electrons at various angles around the target. The dots in the chart at the top of the next page show the result of a number of such runs on gold nuclei at energies ranging from 84 to 183 Mev.

While the experimental group was making these measurements, a team of theoretical physicists including D. R. Yennie, G. D. Ravenhall and R. N. Wilson was busy calculating the expected diffraction pattern for various nuclear models such as those illustrated on pages 56 and 57. One specific model of the gold nucleus has a dense core extending about four fermis from the center, and then a rapidly thinning "skin" which drops away to nothing at around nine fermis [*see chart at bottom of next page*]. The theoretical diffraction pattern at various energies from 84 to 183



GOLD NUCLEI give scattering results shown by points on the graph. Solid curves are calculated patterns for a particular model. Different curves represent different electron energies.



MODEL OF GOLD NUCLEUS which gives close agreement with experiments is shown as a solid curve. Dotted lines represent alternative models that might give nearly the same results.

Mev for this model are also shown on the chart at the top of this page, as solid curves. The agreement between the experimental and theoretical curves is nothing short of astonishing. Evidently the distribution of charge in the gold nucleus must be very much like the one in this model. Since protons and neutrons are presumably distributed in the same way, this distribution should also apply to the total mass of the nucleus.

If we define the skin thickness of the gold nucleus as the distance between the point where the charge density is 90 per cent of the maximum and the point where it has fallen to 10 per cent, we find that the thickness is close to 2.4 fermis. Taking as a measure of nuclear size the distance from the center to the point where the density is 50 per cent of the maximum, this turns out to be approximately 6.3 fermis.

Now, when we turn to investigate other nuclei, a surprising regularity appears. Together with Ravenhall and Beat Hahn, the author has made a systematic investigation of selected nuclei from mass number 40 to 238. Throughout this entire range the skin thickness is 2.4 fermis! The size of the dense inner core varies, but the fuzzy outer layer is the same thickness for all these nuclei.

As a measure of nuclear size it is more convenient for many purposes to use another average value for the radius rather than the distance from the center to the 50 per cent density point. This average is known as the "root mean square." When it is used, the value for the radius of a heavy nucleus obeys a simple law: its value in fermis equals 1.18 times the cube root of the mass number. This rule is reminiscent of the cube-root law for the liquid-drop model, but it implies a smaller nucleus than that suggested by the older view.

In nuclei below mass number 40 we find that the inner core practically disappears, and that the density decreases from the center out. These lighter nuclei obey a slightly different size rule: the root mean square radius is 1.35 times the cube root of the mass number.

At just about the time when we first obtained these results Val Fitch and L. James Rainwater at Columbia University were measuring nuclear sizes (but not skin thickness) by an entirely different method. They found the same law as we did for nuclei above mass number 40. For the lighter nuclei, however, their results were 1.18, as against our 1.35.

The Proton

Having proved that our electron beam could indeed see into nuclei, we began

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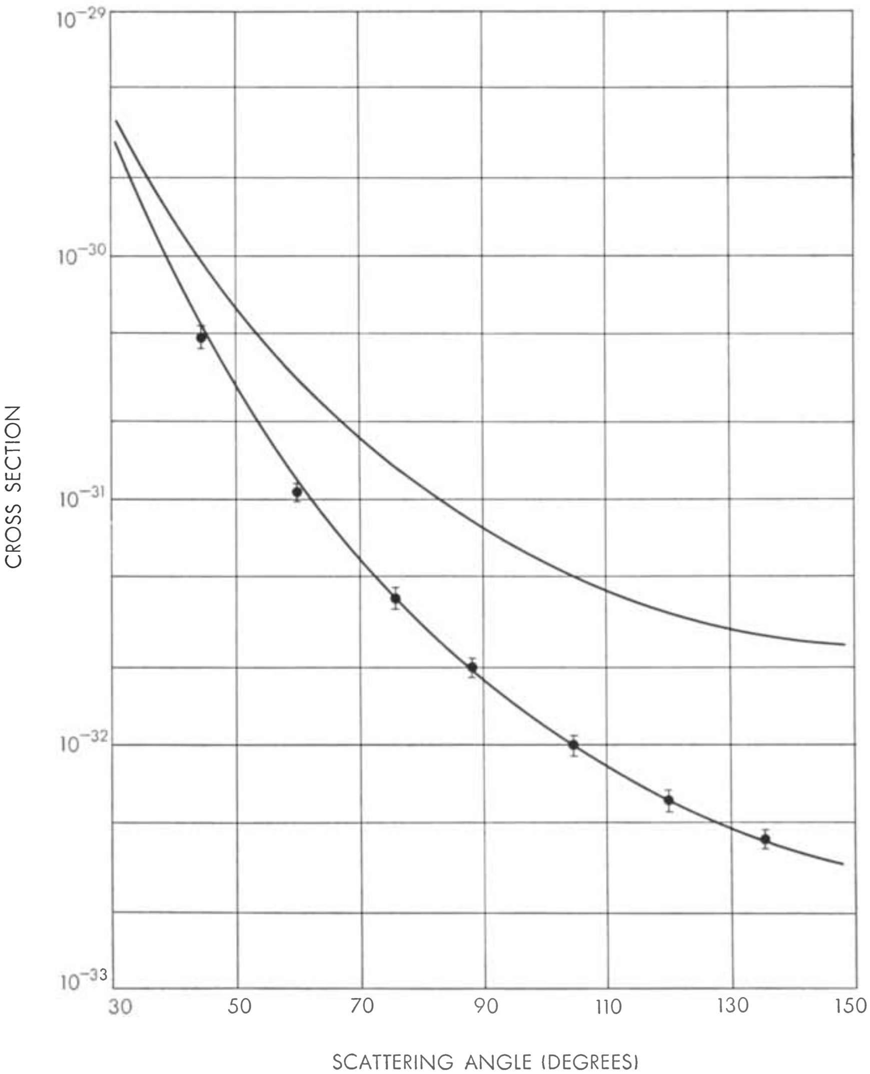
to wonder about still smaller particles. What about the proton itself? Is it a dimensionless point? Or does it too have a finite size and an internal structure?

To find out, we placed a target of gaseous hydrogen in the electron beam and again proceeded to measure elastic scattering. As the chart on this page shows, the results were quite clear. The amount of backward scattering is much less than would be obtained from a point proton. Again, one particular theoretical curve fits the actual results very closely. The charge distribution which gives this curve is bell-shaped or "Gaussian" [*see diagram at top of next page*]. It can also be proved that the proton's magnetic field is similarly distributed.

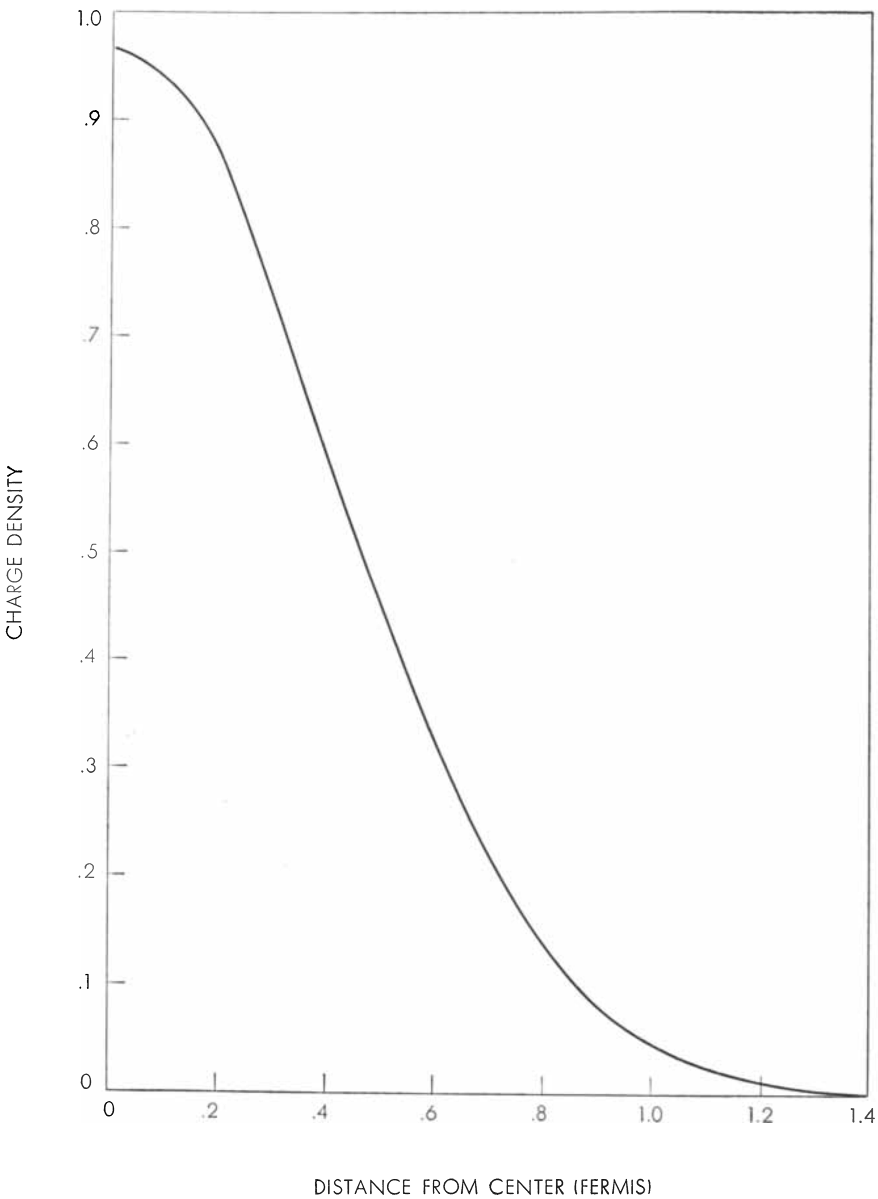
Thus the proton must be considered an extended body, and our electrons have for the first time actually seen inside it. The charge falls to zero only at a distance of 1.4 fermis from the center. The root mean square radius is approximately .75 fermis.

The proton experiments are quite recent, and we cannot say that the charge distribution shown is absolutely the only one that would give a close agreement with the experimental results thus far. But we feel that further experiments will specify a true model not basically different. It is likely that the central features will change more than the outlying ones.

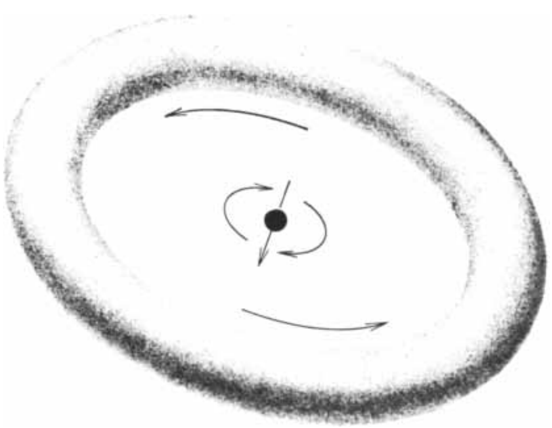
The extended charge distribution of the proton may explain the apparent discrepancy between radii as measured by electron-scattering experiments and by the older measurements based on the interaction of neutrons and protons with nuclei. If a gold nucleus and a proton are placed with their centers separated



PROTON-SCATTERING PATTERN would be as in the upper curve if the proton were a dimensionless point. If its charge were spread over a finite region, then one particular distribution would give pattern of lower curve. Points show actual scattering measurements.



MODEL OF PROTON shown above gives a theoretical scattering pattern very close to the one observed. The density of charge falls off from the center outward in a "Gaussian" curve.



MESON THEORY suggests that the proton may actually consist of a spinning "bare nucleon" which is essentially a point, surrounded part of the time by a rotating meson cloud.

by 8.45 fermis (the old value for the gold radius) there will be a considerable overlap of charges. The outer portions of the skins are already in contact. Thus the proton finds itself, at this distance, in a situation not radically different from that of an outer proton in the gold nucleus. There is no apparent reason why it should not interact strongly with the other nucleons of gold. Hence we may expect that a radius measured by nuclear methods that involve the strong nucleon interaction will appear to give a larger value than the electromagnetic radius measured with electrons.

According to present theory, the model of the proton obtained from the scattering experiments may not really represent a single, smeared-out particle. Instead, the proton may actually consist of a pointlike "bare nucleon" intermittently surrounded by a cloud of mesons [*drawing at lower left*]. It is probably the meson cloud that we are probing.

The theory says that the proton erupts from time to time, emitting a meson which whirls about for an unimaginably short period and then is sucked back into the proton again. The process of emission and reabsorption is considered to be an ever-present, essential activity of the proton (and the neutron as well). One problem has been to decide what fraction of the total time the meson spends outside the proton. Our measurements can be interpreted as indicating that the fraction is a few tenths or more. This is a higher value than had been previously estimated.

It is thought that the mysterious nuclear force arises from an exchange of mesons between nucleons. If electrons can be used to "see" the mesons, they may help clear up the mystery.

As this is written our group is busy with new scattering experiments. We are refining our observations on the proton. Preliminary investigations of the alpha particle show that it has a charge distribution like the proton's and is unexpectedly compact. It is only a little larger than its two protons together, despite the fact that it also contains two neutrons. Experiments with the deuteron (the heavy hydrogen nucleus, containing one proton and one neutron) show that it is bigger than the alpha particle. The deuteron observations may also give some information about the distribution of the neutron's magnetic field. It may soon be possible to tell whether the neutron and the proton are, as current theory says, alike except for their charge.

This is only a partial list of the exciting problems that are waiting to be investigated with high-energy electrons.

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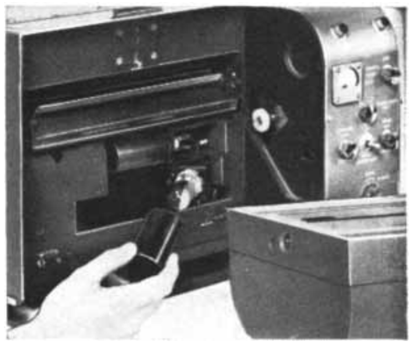

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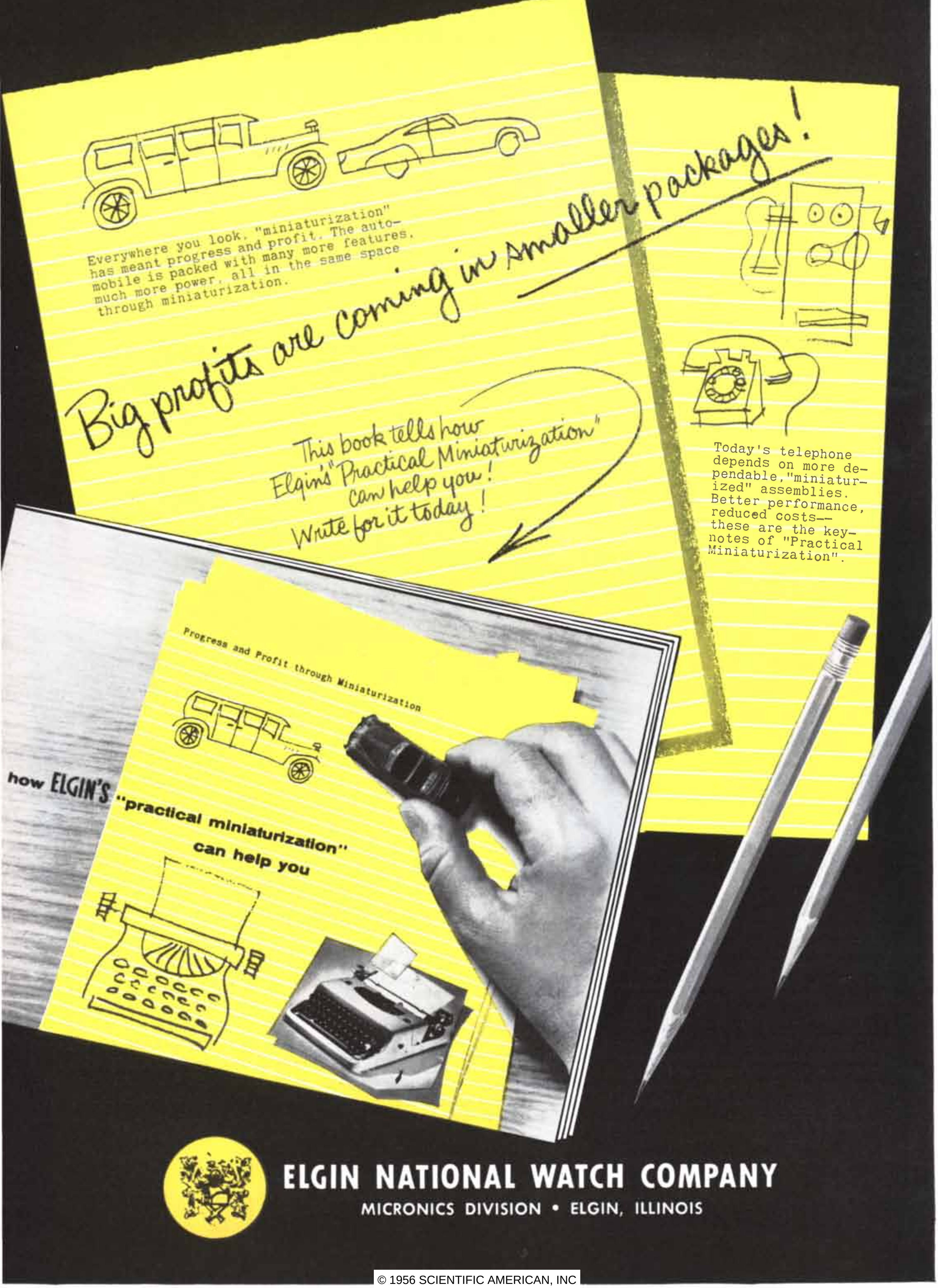
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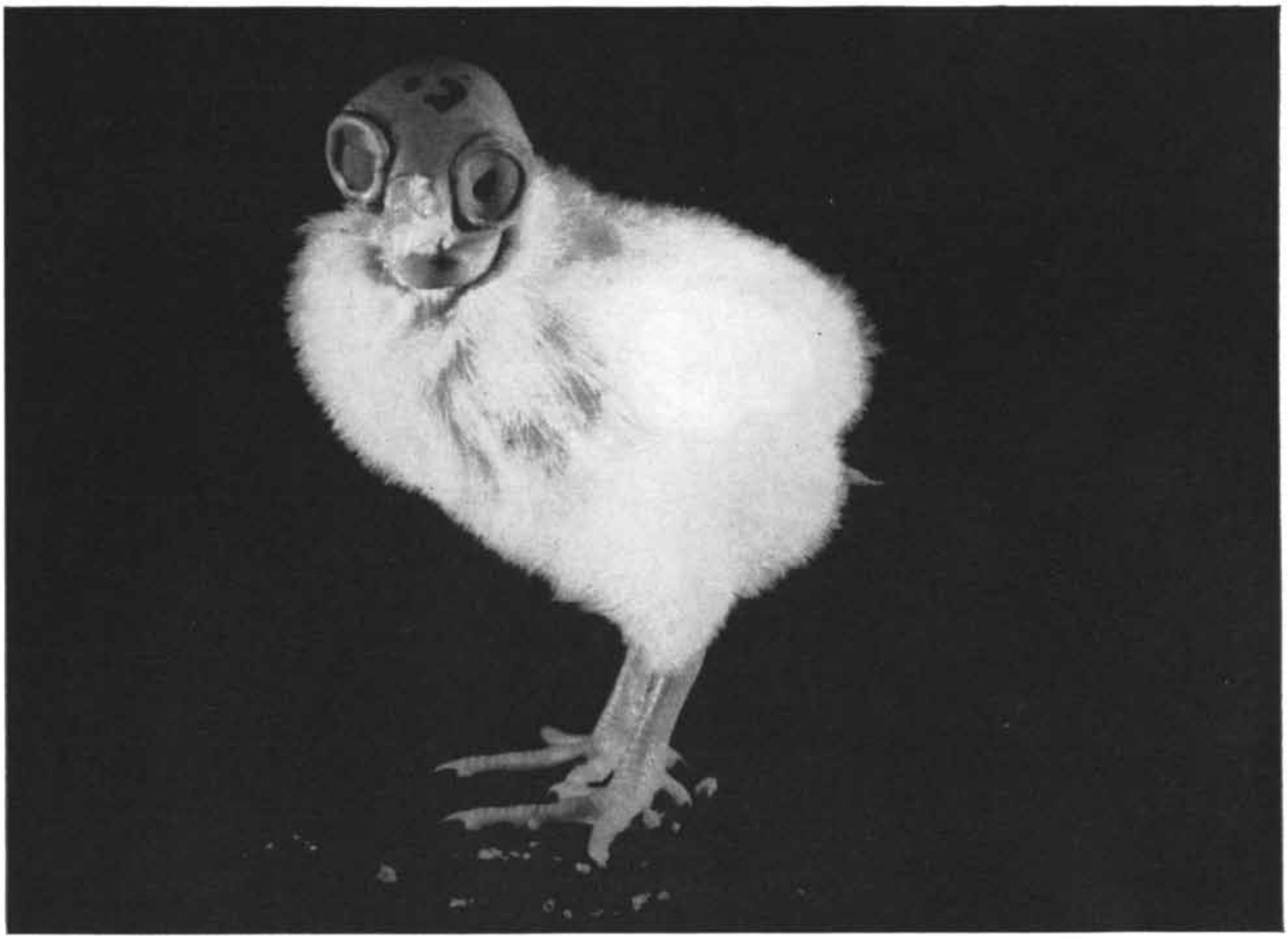
SPACE PERCEPTION IN THE CHICK

In which the sight of newborn chicks is manipulated with tiny hoods to determine whether the ability of the birds to locate objects is learned, innate or due to the process of maturation

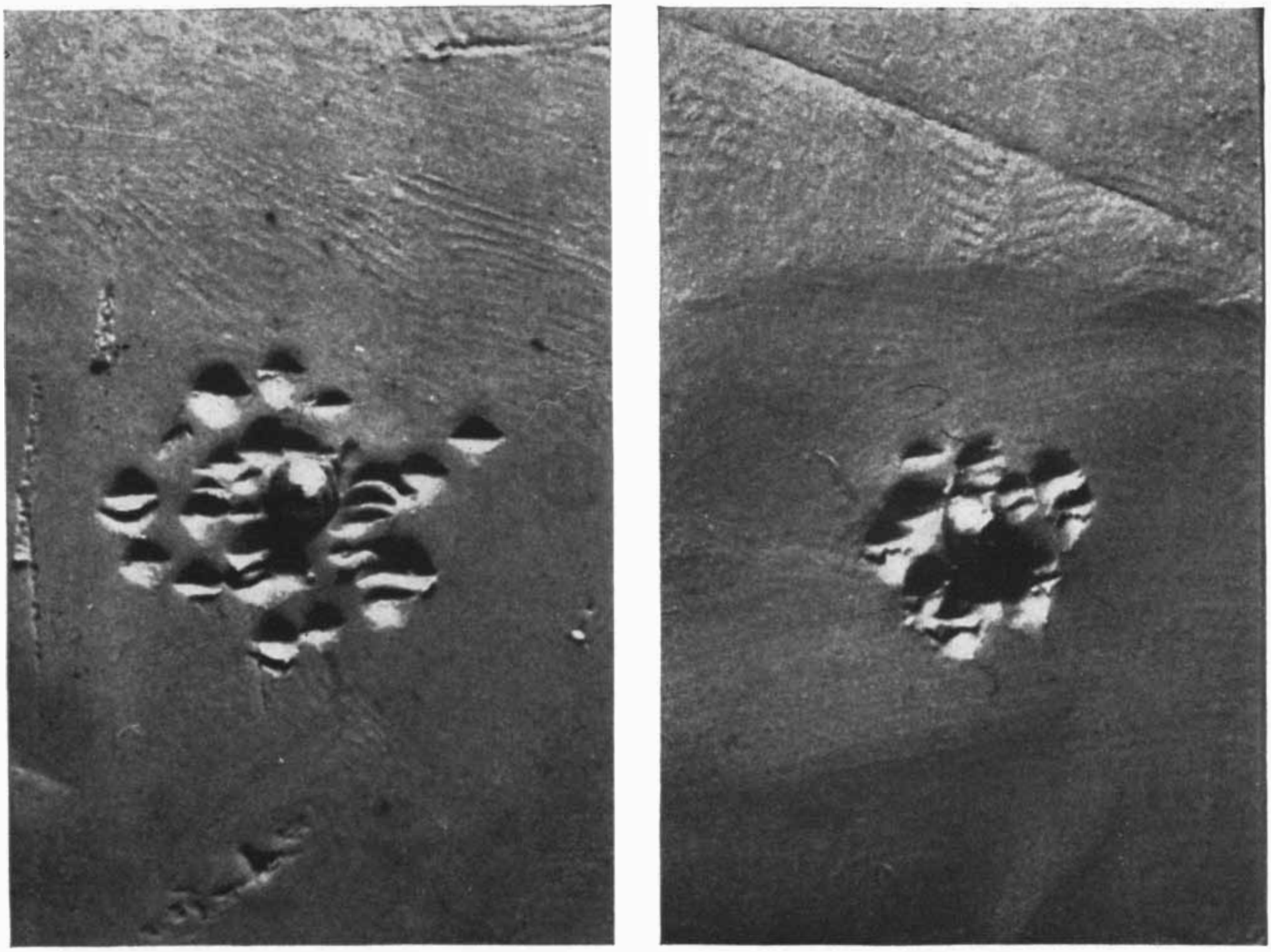
by Eckhard H. Hess

Suppose we observe that members of a particular species of birds always sing the same song. Is the song of this species innate or is it learned through the young bird's imitation of its parents? Let us isolate some young of this species from the adults so that no opportunity for learning is allowed. Will the young sing the song of their species? If the species selected is the nightingale, we shall discover that the young birds do not sing in the same way that the adults normally do, showing that the song is ordinarily learned through imitation. If, on the other hand, we isolate young robins, we shall find that they still sing the song of their kind, indicating the existence of an innate ability.

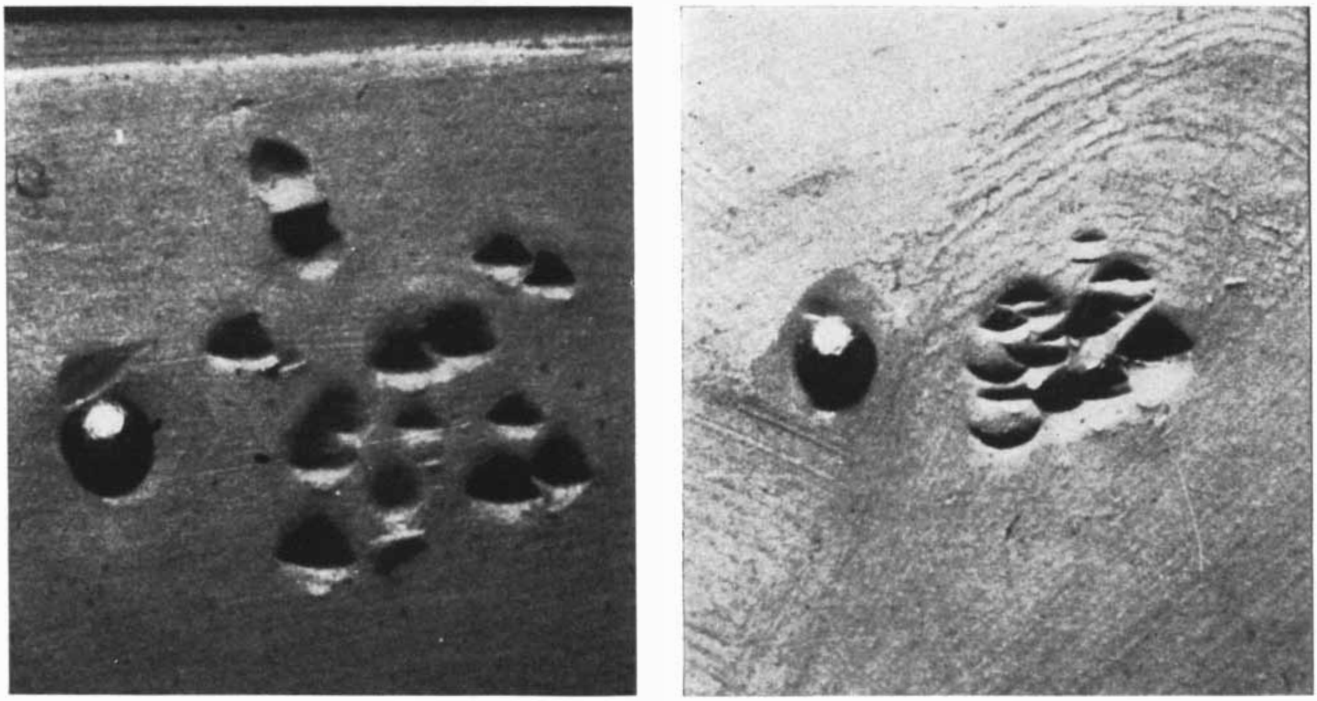
Why does a duckling or a gosling tag along after its mother? Until recent years it was believed that the young of a species possessed an inborn capacity for following only their own parents. It has now been shown for many species that the young animal will become attached to other objects in place of the parent if those objects are present during a critical



HOOD holds experimental goggles over the chick's eyes and leaves its beak free for pecking and eating. In one experiment the hood was fitted with prisms that caused the chick to see everything as though it were seven degrees to one side of its actual position.



CONTROL CHICKS, wearing hoods fitted with pieces of flat plastic, were allowed to peck at a brass nail embedded in modeling clay. A chick one day old made the pattern at left; a chick four days old, the pattern at right. The patterns are centered on the nail.



EXPERIMENTAL CHICKS wore hoods fitted with prisms that displaced objects seven degrees to the right. A chick one day old made the pattern at left; a chick four days old, the pattern at right. The pecks are more tightly clustered, but still displaced to right.

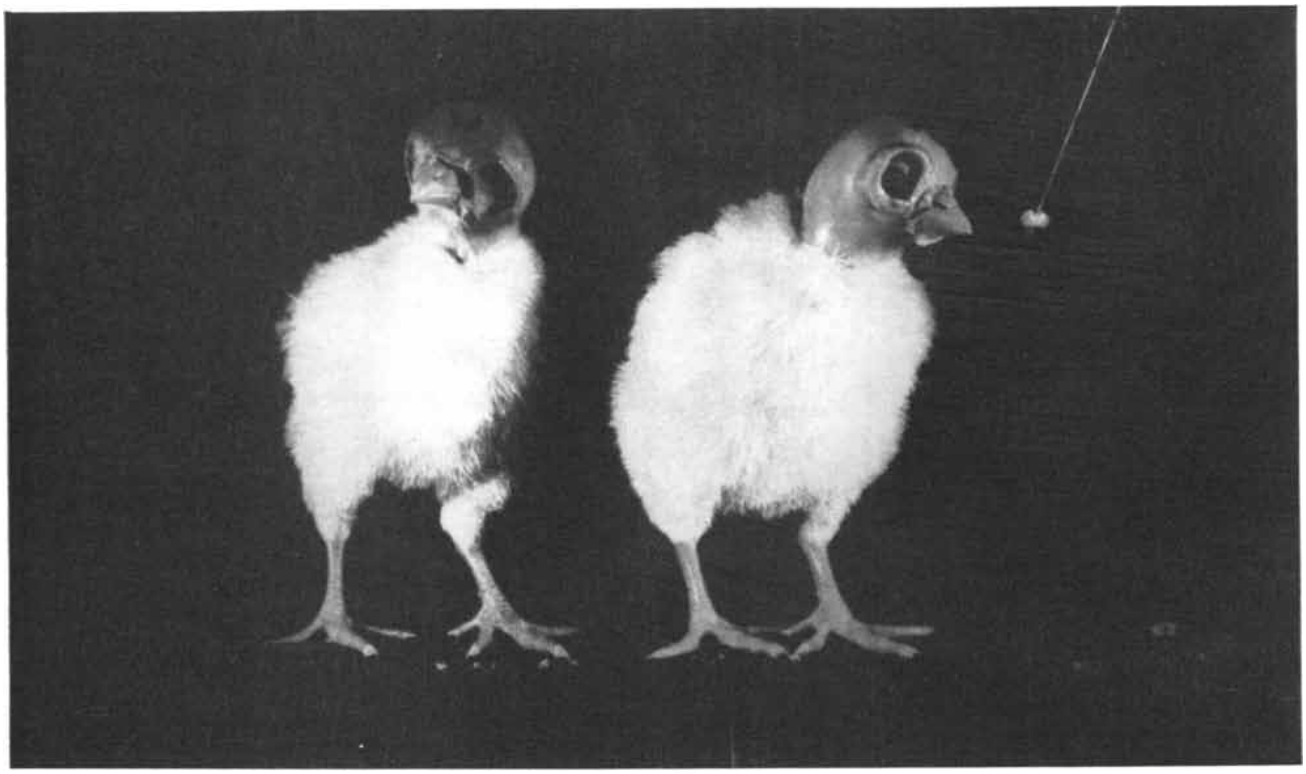
period shortly following its birth. A duckling may learn to follow a wooden decoy, a goose or even a human being if exposed to one of these objects instead of to its parent during this critical early period. Later it will follow that object in preference to its own mother.

Why is it important to know whether a certain behavior pattern is learned or innate? One reason is that once we have this information, we are well on our way to knowing under what circumstances the behavior can be changed. If it is learned, then we may alter the physical or psychological environment so that another behavior is learned in its place. If it is innate, we may not be able to modify the behavior unless we use the innate behavior pattern as a foundation upon which to build additional responses, so that the resulting composite behavior appears to be different.

Many psychologists believe that the ultimate aim of animal studies is to provide us with a better understanding of human behavior. Such an objective is not attained by generalizing from animal to human behavior—a practice of which comparative psychologists are commonly accused—although it is true that some hypotheses about man are occasionally suggested by the extension of behavioral trends observed in the progression from the lower to the higher animals. More likely, however, the understanding of human behavior is served through animal research in quite another fashion. That is to say, the animal laboratory is a testing ground for the evolution of techniques and the development of criteria which may ultimately be applied with ease and safety to humans.

If we can discover which of man's behaviors are learned and which are innate, we will know which ones may be readily changed and which can be modified, if at all, only within narrow limits. Such findings might explain why some experiences in an individual's early life affect his subsequent behavior whereas other early experiences apparently do not. We may learn how to create an environment in which desirable behaviors will be promoted and undesirable behaviors will be modified.

A further word should be said regarding innate and learned behavior. The simple fact that a behavior appears later than infancy does not necessarily mean that it is learned. It may represent the natural unfolding of innate processes occurring along with the individual's physiological development. We call this process maturation, and we may classify



CONVERGING LENSES were also placed in the hoods, causing the chicks to peck short of objects. These chicks learned to peck accurately at objects on the ground, presumably benefiting from muscular cues, but continued to peck short at objects in the air.

it as a special kind of innate behavior. Behavior which develops through maturation possesses, in all probability, the same resistance to modification that characterizes ordinary innate responses.

One problem which has for some decades been of interest to the comparative psychologist is the accurate localization of objects in space. When an organism first perceives the environment, can it accurately see where things are? A large number of experiments have been carried out on the development of pecking accuracy in chicks. The results, however, have been far from clear. Some investigators concluded that their experiments indicated a maturational process, others assumed that practice through trial and error led to this accuracy, and still others thought the entire process to be innately determined.

The experiments to be described were undertaken to ascertain whether a chick's visual perception of space—as measured through its accuracy in pecking at grain—depends upon learning or upon the maturation of an innate ability. One possible method for deciding this question would be to raise chicks to adulthood without permitting them the opportunity for normal visual experience and then expose them to a situation in which they might demonstrate their pecking ability. Prior to the experiment described here, experimenters who undertook this problem prevented young chicks from practicing the sensory-motor coordination involved in pecking by means of keeping them in dark enclosures or covering their heads with little hoods which masked their eyes but left their beaks free for eating. The results of these experiments were later laid open to question when it was suggested that in the absence of stimulation by light the eyes may fail to develop normally. Any inaccuracy in pecking might well have been the result of degeneration in the retina or the nerves.

To overcome this difficulty the author sought a method that would prevent normal visual experience and yet would not interfere with the normal physiological development of the eye. A solution to this problem was found in the technique of fitting the chicks' eyes with prismatic lenses which would displace the visual image to the right or to the left.

Suppose that a chick first sees the light of day wearing prisms which cause a displacement of the visual image seven degrees to the right. If the exact visual localization of objects in space is a totally learned ability, the chick's performance should be unaffected by the fact that it is wearing displacement prisms. When the chick sees a food object, it should start pecking but in a random fashion until, after trial and error, the object is eaten. Gradually, as sensory-motor associations are built up, the chick's accuracy should improve.

If, on the other hand, the chick is born with an innate ability to locate objects visually, the first pecks which such a chick directs toward objects seen through the displacement lenses should be about seven degrees to the right. Since the young chick starts its peck with its eyes about 25 to 30 millimeters away from the object, the actual displacement should be about 3 or 4 mm. With time and practice the chick might learn to correct for the displacement so that it would strike at objects seven degrees to the left of where they appeared to be. This, in fact, was the author's expectation.

In the actual experiment 28 Leghorn chicks were hatched in complete darkness and were immediately fitted with thin rubber hoods into which transparent plastic goggles had been inserted. The hoods were placed over their heads quickly in such a subdued light that the animals had essentially no normal light experience. The goggles in the hoods of 10 of the chicks were flat pieces of plastic which produced no image displacement. These 10 were the control animals. Twelve of the chicks had hoods which were fitted with plastic prisms which displaced the whole visual field seven

degrees to the right. Six of the animals wore lenses which caused a similar displacement of the visual field to the left.

All of the animals were returned to darkness for a period of about six hours so that they could become accustomed to the hoods. Then, when they were about one day old, all of the animals were tested for pecking accuracy. They were allowed to strike at small objects embedded in modeling clay. The targets were small brass nails, embedded so that they could not be dislodged by pecking. The modeling clay provided a simple means of recording the accuracy with which the chicks pecked at the nails. By photographing the dented clay after such a pecking session and then tracing the actual dispersion of pecks from a projected image of the negative, it was possible to get a clear picture of the accuracy or inaccuracy of the chicks as they were tested.

The pecks made by all of the chicks were scattered. There was, however, one fundamental difference in the performance of the control and experimental animals. In the control group the pecks were scattered about the target so that the target itself formed the center of the distribution. For those chicks wearing lenses which displaced the visual field to the right, the pecks were similarly scattered, but they were centered about a point seven degrees to the right of the target. Similarly, the group whose lenses displaced their visual images to the left showed a scattering of pecks to the left of the target. Some pecks of chicks in all groups actually hit the target.

Half of the control group and half of each of the two experimental groups were now placed in an enclosure in which grain had been loosely scattered on the floor. The other half of the three groups were placed in a box in which they had access to bowls of mash; accuracy in pecking was therefore not required. In the latter situation a chick which missed the grain at which it aimed would nevertheless hit other grains in the bowl almost every time it pecked. This was not true, of course, of those chicks which were pecking at individual grains scattered on the floor.

When the chicks were between three and four days old, they were tested again. The results showed a great increase in accuracy on the part of the control chicks: now their pecks clustered quite closely about the target. There was no detectable difference between the two subgroups of the control animals—those fed on scattered food and those fed on mash in bowls.

Among the animals wearing displacement prisms, improvement of a kind had also occurred. The pecks were clustered just as tightly as those of the controls, showing that increased accuracy had certainly been achieved. The centers of these clusters, however, were approximately 4 mm. to the right or to the left of the target, depending on which displacement glasses were worn by the experimental animal. Again there was very little difference in accuracy among the subgroups of experimental animals. But another difference was evident in the physical condition of the subgroups. Where the animals which had access to bowls of mash were as healthy as the control animals, the animals in the scattered grain situation were in poor physical condition and apparently would have died if they had been kept in the same situation. Two animals maintained in this situation died the following day.

We must conclude that the chick's visual apparatus for locating objects in space is innate and not learned. This conclusion is based on the fact that the chick wearing displacement prisms clustered its pecks about the spot where the

VARIOUS HOODS used by the author in his experiments in the department of psychology at the University of Chicago are mounted in the laboratory. The hoods are made of rubber.

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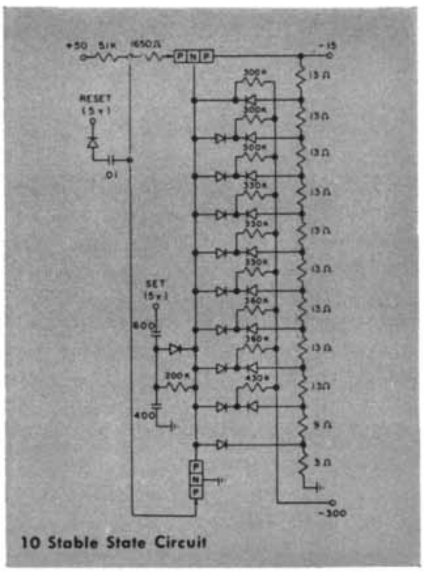
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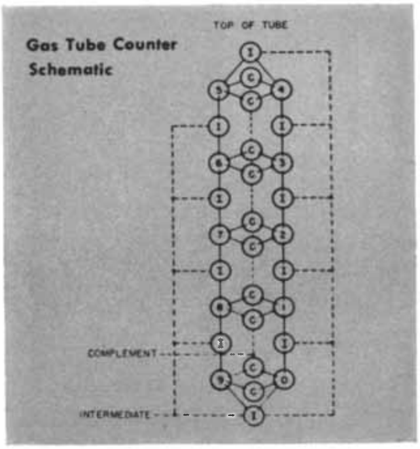

Gas Tube Counter Schematic

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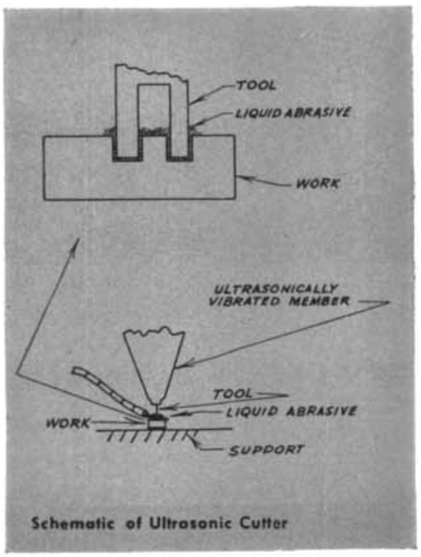

Schematic of Ultrasonic Cutter

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object was seen. It did not simply peck at random until it struck the target.

Furthermore, the chick whose visual field was displaced appeared unable to learn through experience to correct its aim. Its only improvement was to increase the consistency of the distance by which it missed the target. Apparently the innate picture which the chick has of the location of objects in its visual world cannot be modified through learning if what is required is that the chick learn to perform a response which is antagonistic to its instinctive one.

The technique developed for the foregoing experiment seemed to offer an admirable opportunity for studying another aspect of bird vision—stereopsis, or binocular depth perception. The question to be answered was whether the bird possesses this capacity.

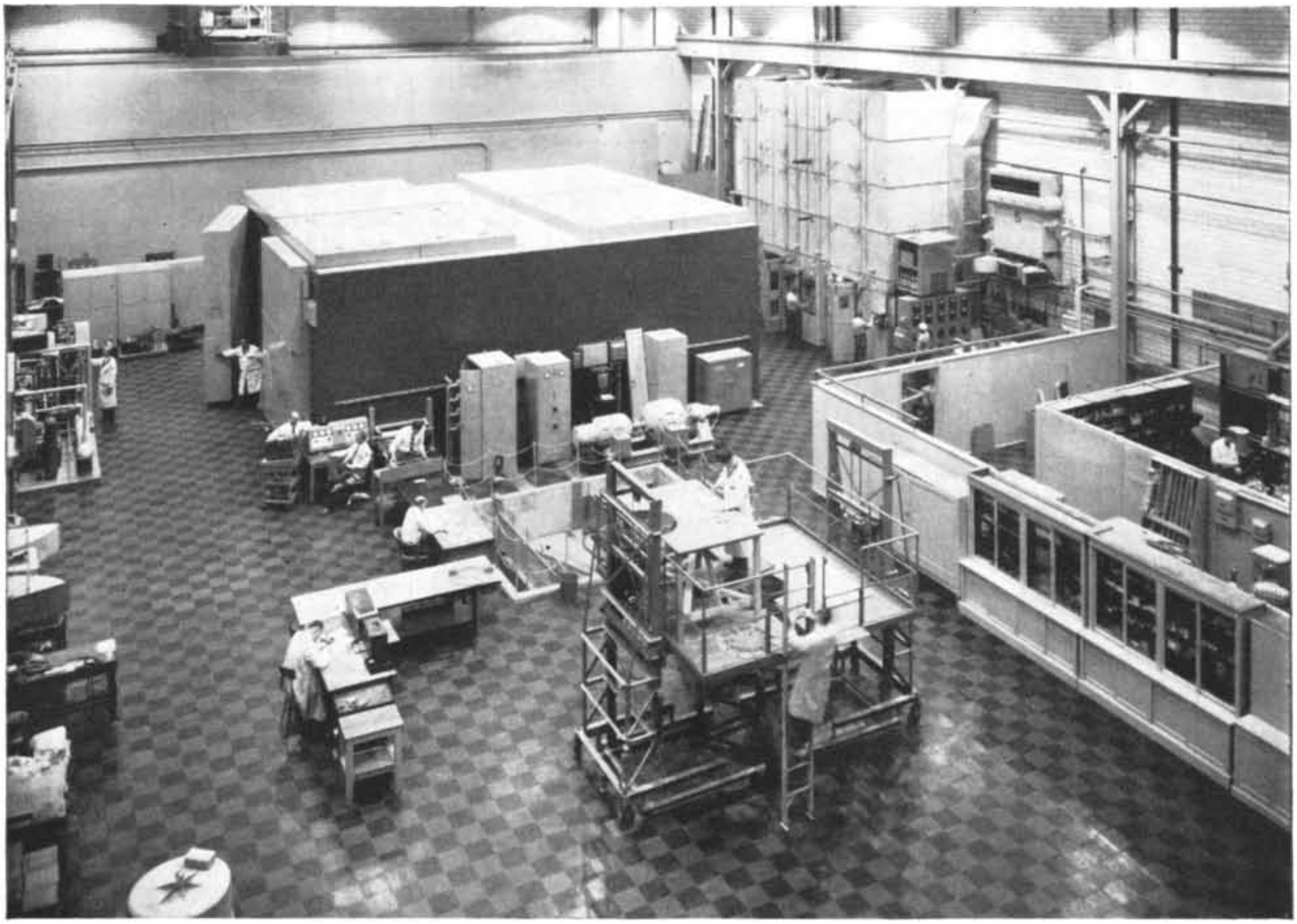
In man there is considerable overlap of the areas viewed by the two eyes. Since the pupils of the eyes are about two and a half inches apart, however, each eye gets a slightly different picture of the commonly shared view. In some way these two pictures are integrated in the brain so that objects viewed appear three-dimensional rather than flat.

In the chick, on the other hand, the eyes are at the sides of the head rather than at the front. Consequently, except for a relatively small area directly in front of the bird, the two eyes receive visual stimulation from different parts of the surroundings.

In man, optic fibers from each eye travel to both sides of the brain. In the bird this is not the case. The optic fibers from the chick's left eye presumably cross over completely to the right side of the brain and those from the right eye to the left side of the brain.

Essentially on the basis of these facts alone it was believed by some that the bird lacks binocular depth perception. In other words, it was thought that the bird's brain could not combine the two small overlapping images to produce an impression of depth or three-dimensionality. The bird's perception of depth and distance was believed to be entirely dependent upon monocular cues, *i.e.*, cues which can be utilized by one eye alone. One important monocular cue is received through the successive impressions of an object obtained by moving the head and viewing the object from various angles. Other monocular cues are the diminution of size with increased distance, the overlapping by nearer objects of more distant ones, and accommodation, or focus.

The author undertook the following



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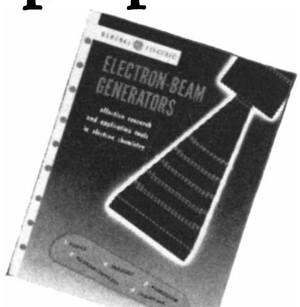

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experiment to determine whether the normal adult chicken uses binocular cues to localize objects in space. Rubber hoods were slipped over the heads of chickens six to eight weeks old. These hoods were fitted with prismatic lenses having their broad bases outward. If a man were to look through a similar, but larger, set of lenses, using binocular vision, objects would appear closer to him than they actually were. If he used his right eye alone, the object would appear to the left of its actual position. Similar results should be expected of chickens.

Of the six animals used, all pecked short at grains of mash placed before them. None struck the surface on which the grains rested. When the experimenter covered the right or the left eye of the chicken with masking tape, the bird struck the surface on which the grain rested but missed to the side away from the exposed eye. The conclusion to be drawn is that the normal adult chicken uses binocular cues to localize objects in space.

Later nine newly hatched chicks were outfitted with the same kind of prismatic lenses and were similarly tested. As with the adult chickens, the chicks struck in the direction of the grains but always short of them, thereby demonstrating that in the absence of any visual experience, binocular depth cues are still employed.

In the last of the three experiments on stereoscopic vision, nine chickens were raised to an age of two to three months with the opportunity of using only monocular vision. From the day of hatching they wore hoods, changed each day, which had openings for only one eye. In other words, on the first day they would wear a hood which would allow the use of only the right eye, on the second day a hood which exposed only the left eye, and so on. These hoods contained no lenses or prisms. The purpose of this procedure was simply to prevent experience with binocular vision, but at the same time to allow extensive use of both eyes. When these chickens were tested at the end of two or three months with binocular prisms having their broad bases outward, all nine animals pecked short of the grain. Apparently the lack of binocular experience did not prevent the appearance of binocular vision.

Summing up our results, we conclude that the naive chick as well as the experienced one possesses binocular depth perception. This innate organization for the perception of depth requires neither learning nor continued use for its presence in the adult animal.

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PALEOBIOCHEMISTRY

Until recently it was believed that ancient bones and shells contained none of their original organic substance. Now amino acids have been found in fossils as old as 300 million years

by Philip H. Abelson

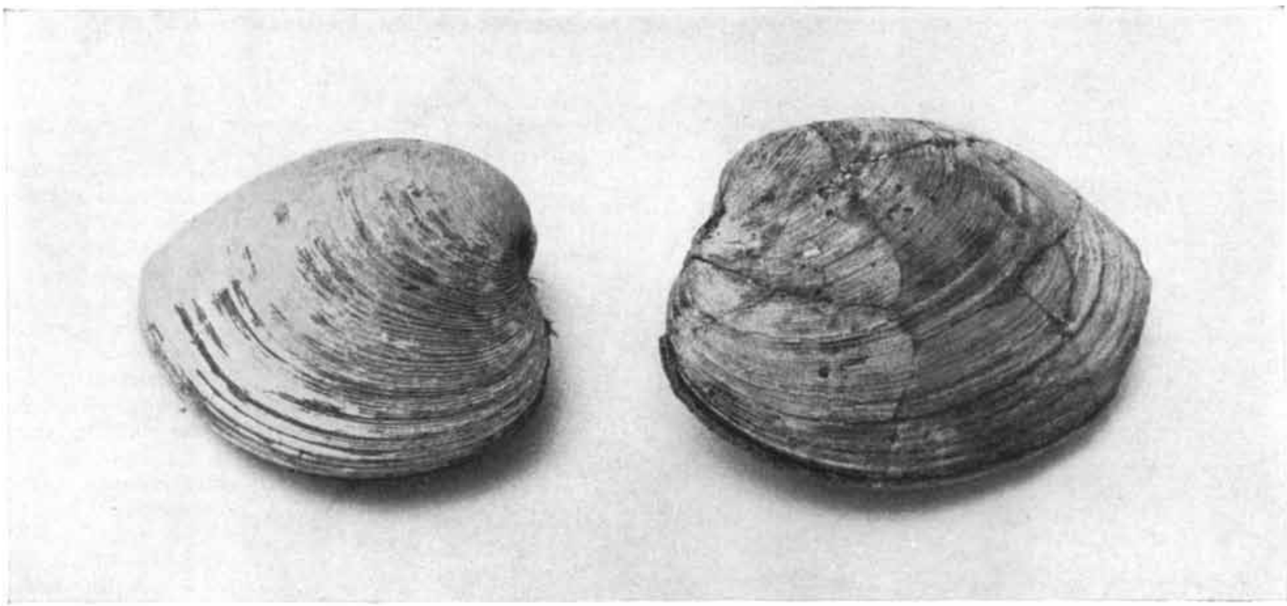
Man has speculated on the origin of life at least since the Book of Genesis was first written. Today we can clearly trace the evolution of life back to the beginning of the Cambrian Period some 500 million years ago. In the Cambrian Period animals began to make hard inorganic substances such as shell and bone. From these hard parts we can reconstruct the outlines of soft parts—the flesh of the animals.

Until recently it was thought that the hard parts could tell us little or nothing about the chemistry of extinct organisms. The biochemical approach was largely limited to the study of living organisms, especially those which appear to differ little from their fossil ancestors. (One such organism is *Limulus*, the horseshoe crab.) Now, however, it has been shown that the hard parts of many ancient creatures contain appreciable amounts of their original organic substance!

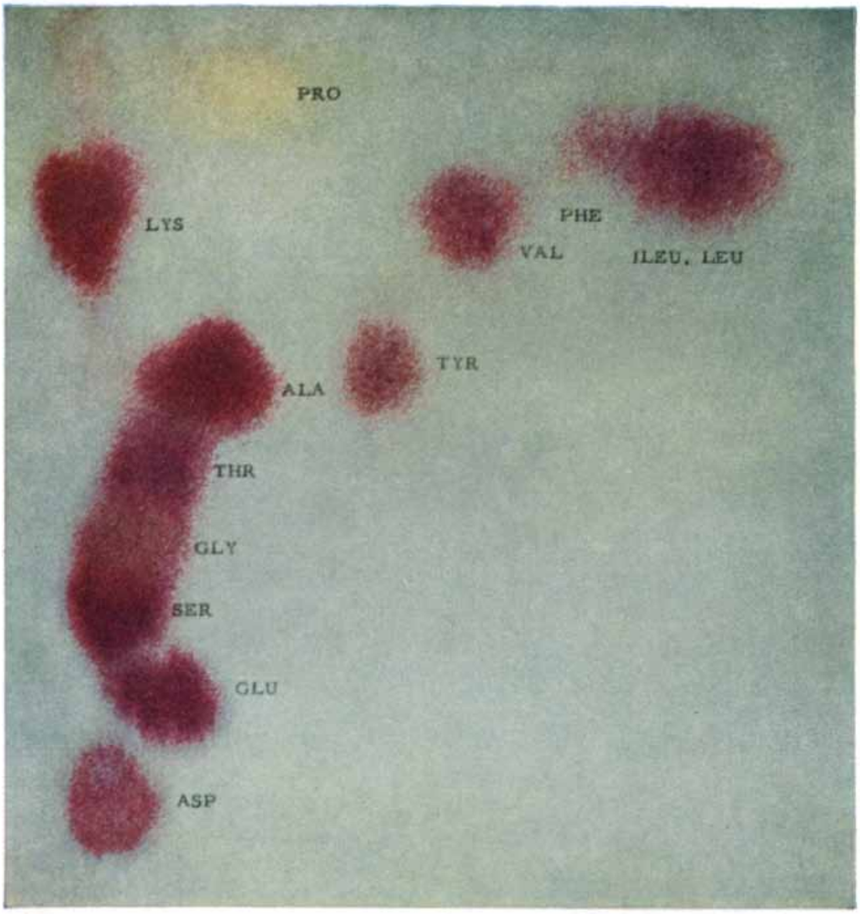
In the Geophysical Laboratory of the Carnegie Institution of Washington we have recently discovered organic material in fossils as old as 300 million years. Consider, for example, a vertebra of *Stegosaurus stenops*, a dinosaur which lived 150 million years ago. Suppose we take a bit of this bony material and dissolve it in hydrochloric acid. In the resulting solution we will find small amounts of various amino acids—the "building blocks" of living protein. The principal amino acids present are alanine, glutamic acid and glycine. We will also find lesser amounts of aspartic acid, isoleucine, proline and valine.

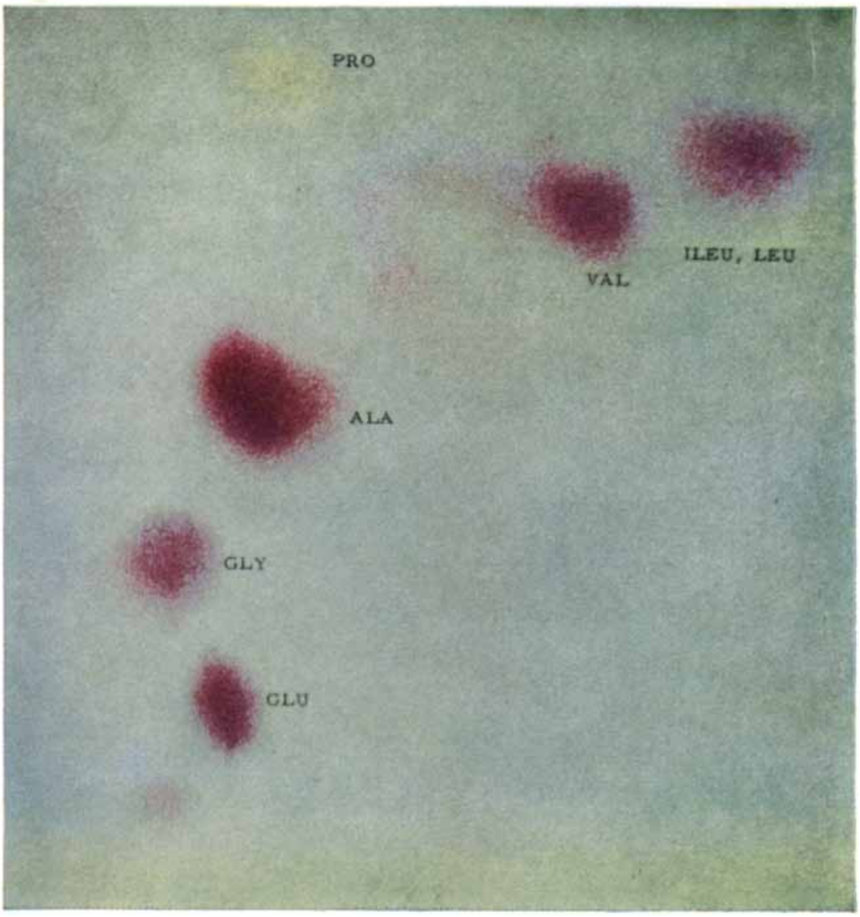
We have found a similar assortment of amino acids in fossils from many geological formations [*see table on page 90*]. We have also examined fossils which turned out to contain no amino acids at all. Some of these were collected from formations which at some point in their history had been buried at great depth and subjected to high temperatures, which would cause amino acids to break down. The crystal structure of others had been replaced by new structures. For example, shells which had originally contained the fine-grained mineral aragonite were found to consist of coarse-grained calcite. Thus we concentrated on those specimens which had probably never been subjected to high temperatures, and whose hard substance had not been replaced or altered.

There is not much to be gained from a



FOSSIL CLAM SHELL at the right is 25 million years old. At the left is the shell of a modern clam of the same species: *Mercenaria mercenaria*. The detection and analysis of amino acids in both of the shells is depicted in the photographs on the following pages.



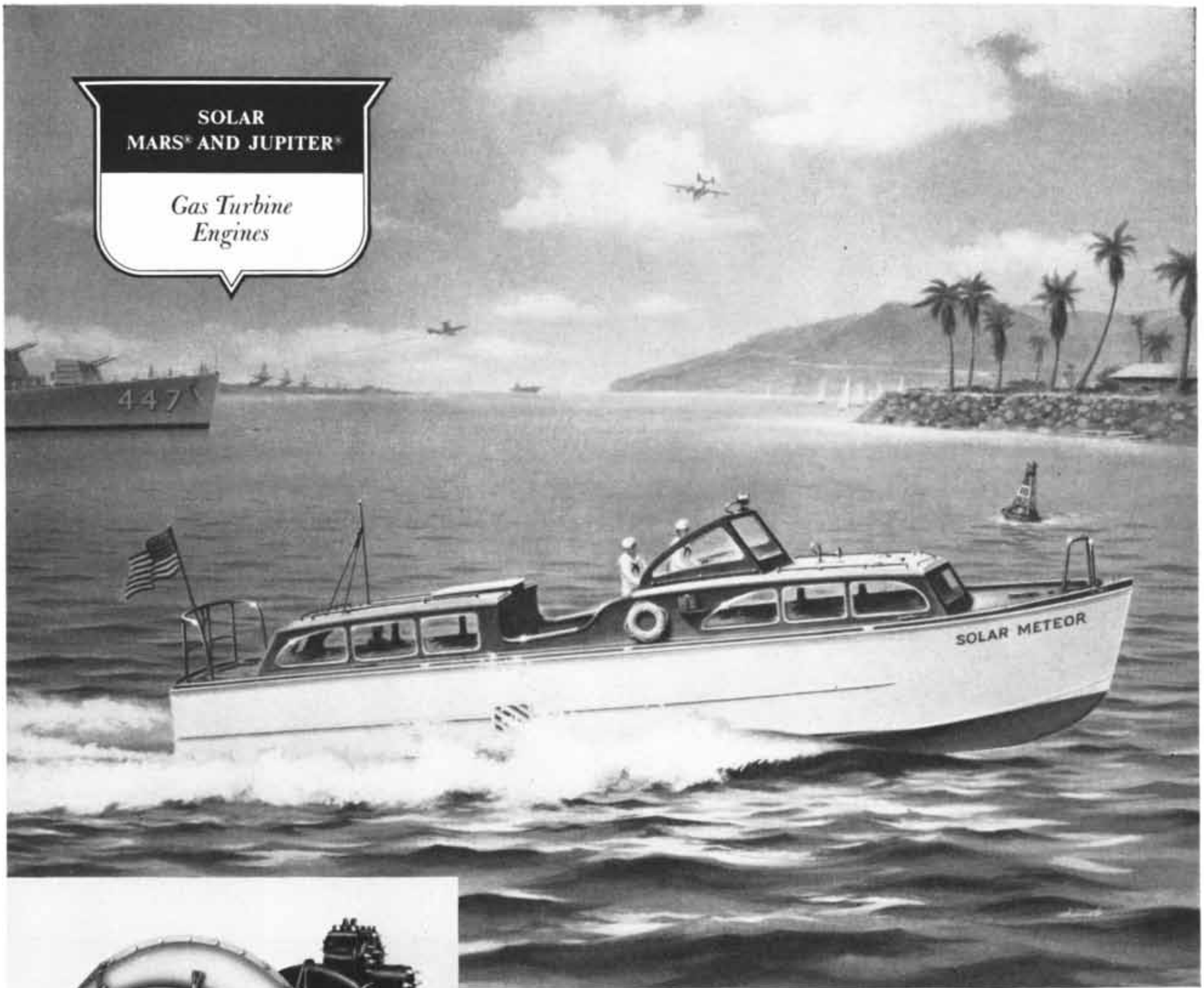


comparison of the amount of amino acids found in various fossils; the conditions under which they were preserved vary too widely. It is of considerable interest, however, that a plate from the armor of the Devonian fish *Dinichthys terelli* is particularly rich in amino acids. This specimen was found in the Black Shale of Ohio, which contains very little oxygen. Thus its amino acids were shielded against oxidation.

In order to understand the origin of the fossil amino acids, we reviewed the protein content of shells and bones from living animals. It is well known that bone contains considerable protein; in some cases protein accounts for half the weight of bone. It is less widely known that protein is also found in shells. We have investigated a wide variety of shells, and have found that they always contain protein. The shells of mollusks—clams, oysters and snails—have a protein content of .1 per cent to .5 per cent or more. In our experience only one of the hard substances made by living things does not contain protein. This is the silica skeleton of diatoms.

Although living shells contain much less protein than living bones do, fossil shells and fossil bones yield about the same amount of amino acid. This is because the protein of shells often occurs in laminated sheets, so that the inner laminations are protected from attack by bacteria. Bones are not so well protected against bacterial attack. Under special conditions, however, a substantial fraction of the original organic substance in bone may be preserved. Bones taken from the famous La Brea tar pit in Los

PAPER CHROMATOGRAMS demonstrate the difference between the amino acid content of a modern clam shell (*top*) and that of a fossil clam shell (*bottom*). The method by which the chromatograms were made is depicted on page 88. The modern shell was about .2 per cent protein. When the protein was broken down, the resulting solution contained 13 amino acids: alanine (ALA), aspartic acid (ASP), glutamic acid (GLU), glycine (GLY), isoleucine (ILEU), leucine (LEU), lysine (LYS), phenylalanine (PHE), proline (PRO), serine (SER), threonine (THR), tyrosine (TYR) and valine (VAL). The fossil shell contained seven amino acids comprising .01 per cent of it. The amino acids are colorless but are made visible by spraying them with reagents. All of them except proline leave purple spots. Proline makes a yellow spot.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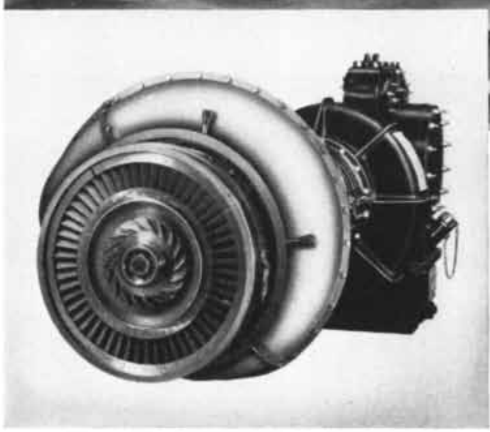
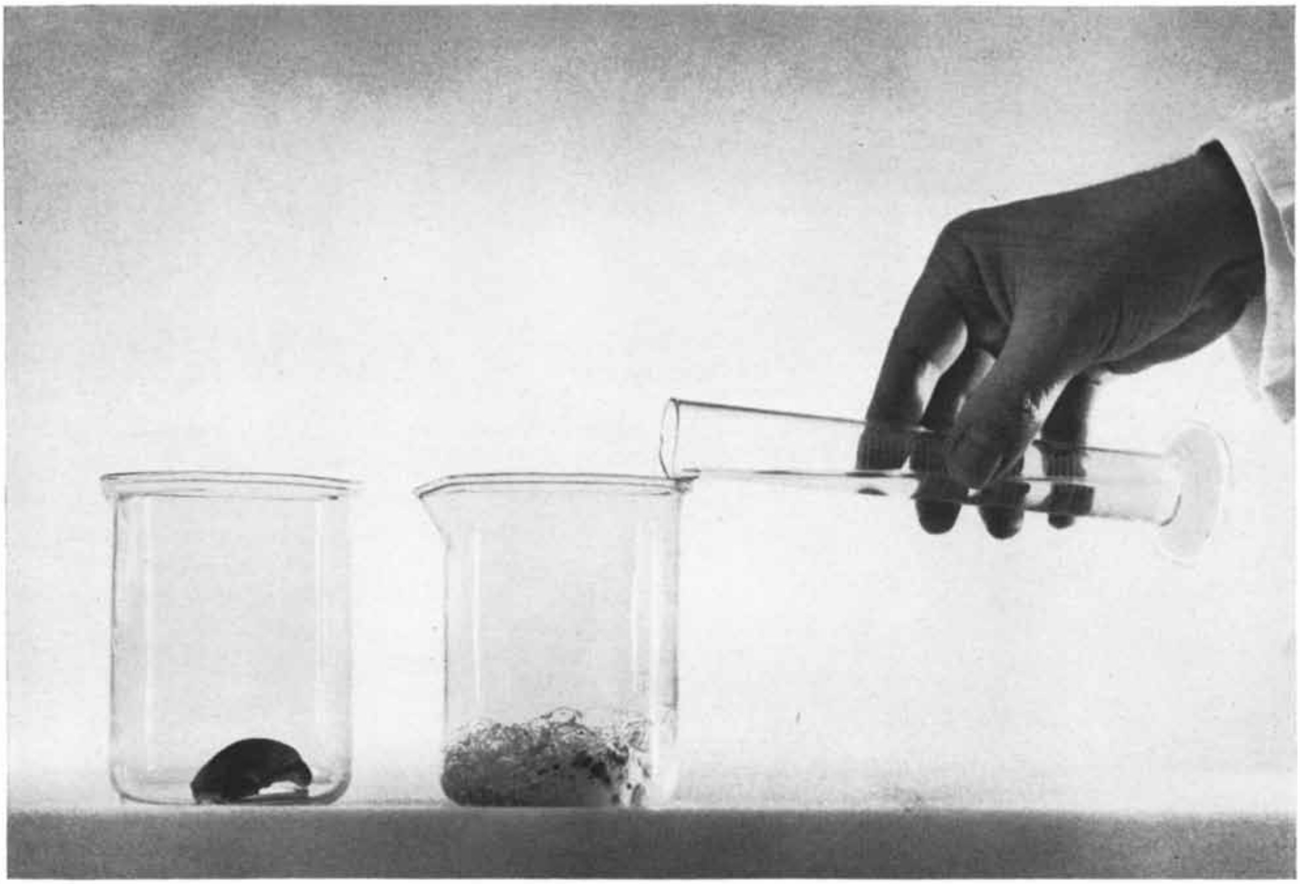
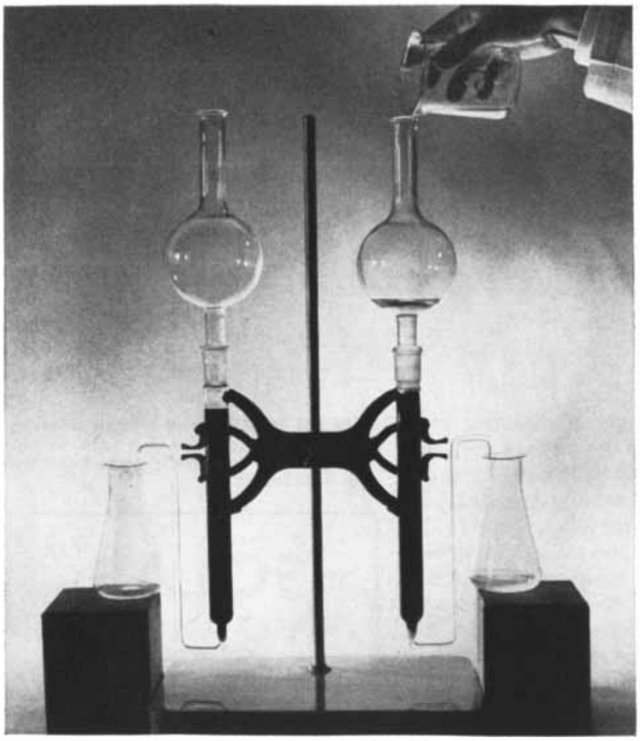
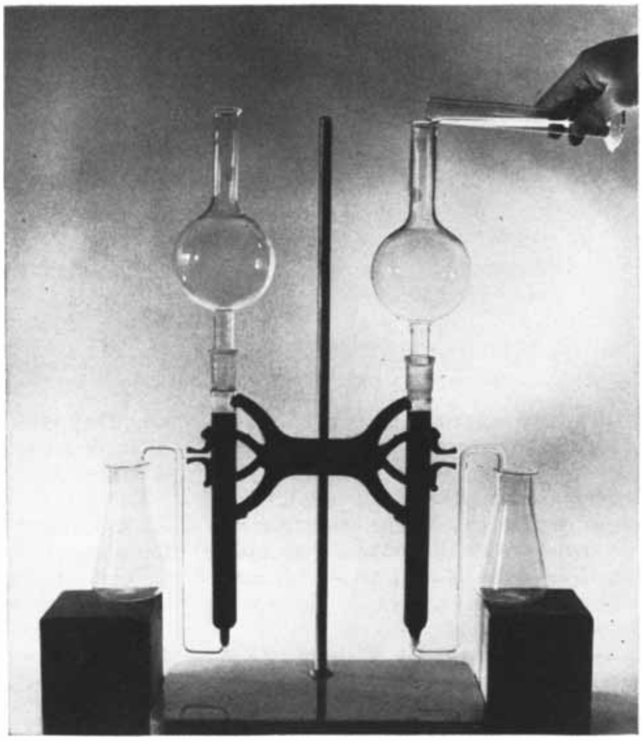




SHELLS ARE DISSOLVED with hydrochloric acid for their analysis in the Geophysical Laboratory of the Carnegie Institution of Washington. The beaker at the left contains a sample of the modern shell; the beaker at the right, a sample of the fossil shell.



DISSOLVED SHELL IS POURED into a glass column containing an ion-exchange resin (*opaque material at bottom of column*). The calcium and amino acids of the shell are adsorbed on the resin.



AMMONIA SOLUTION IS ADDED to the column. This removes the amino acids from the resin and deposits them in the beaker at the bottom. The amino acids are now concentrated for separation.

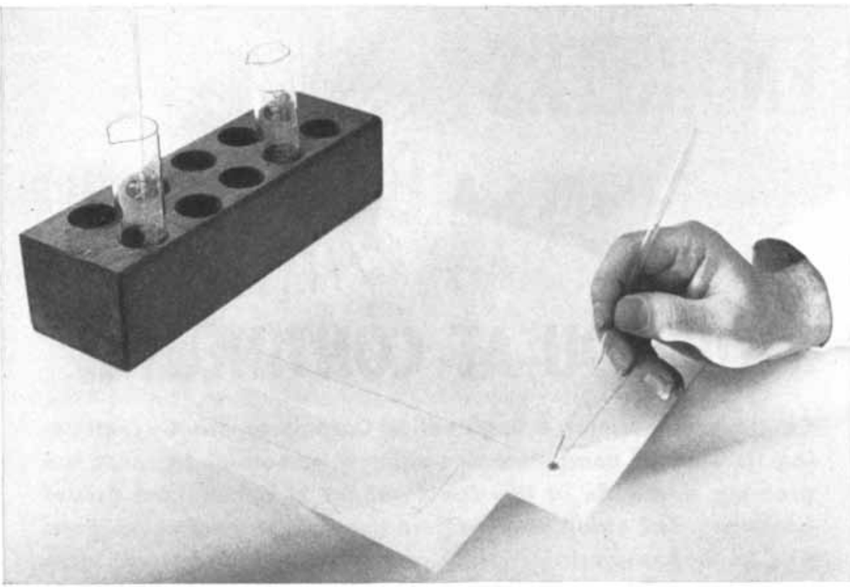
Angeles are more than 10 per cent amino acid. What is more, the amino acids are still linked in long peptide chains. Here the bones were encased in asphalt, and probably not exposed to bacteria, oxygen or water.

We were able to make a more detailed study of how amino acids are preserved in the edible clam, or quahog, of the Atlantic coast. This species (*Mercenaria mercenaria*) has been common for more than 25 million years, and its fossil shells appear identical with their modern counterparts. It was possible to study the content of protein and amino acids in the shells of clams now living and clams 1,000, 500,000 and 25 million years old.

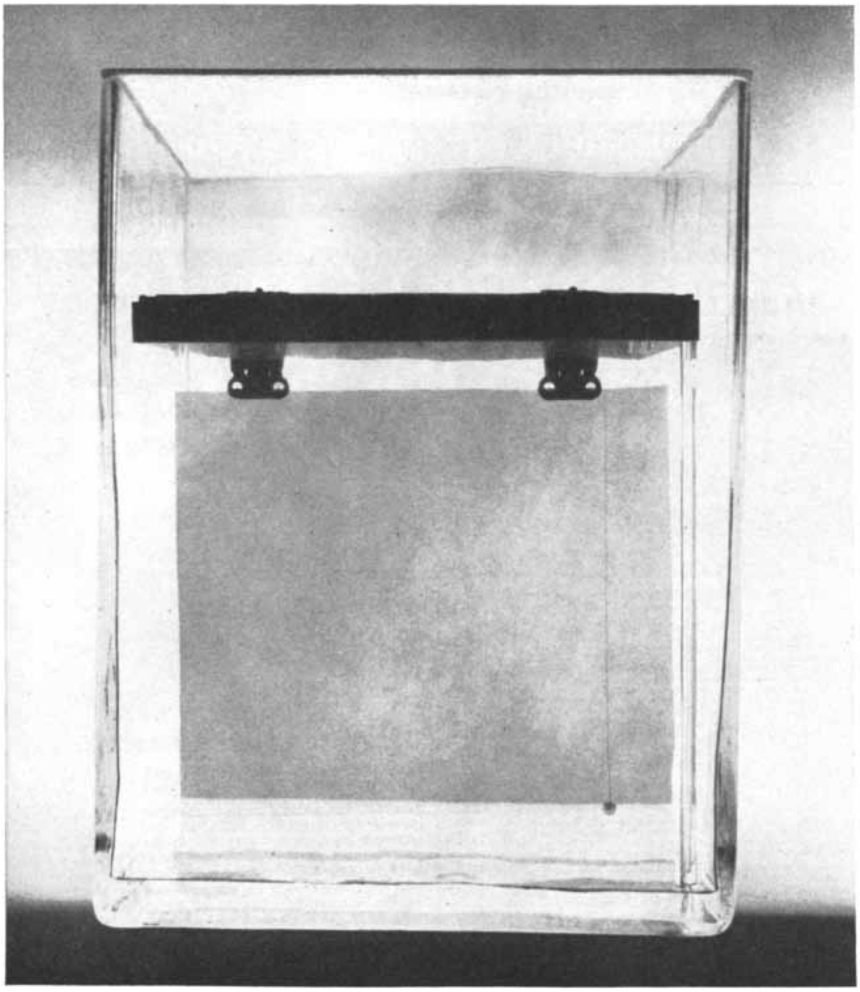
The laminated sheets of protein in modern clam shells are colorless and have some mechanical strength. The amino acids found in the protein are typical of amino acids found in other animals; some 15 were actually identified. The shell 1,000 years old, the age of which was determined by the carbon 14 method, had been buried in moist soil. There it had been exposed to such agents of destruction as bacteria. Its protein content was undiminished, and its amino acids were identical with those of the modern specimen. However, the sheets of protein had turned brown and had lost all mechanical strength. The shell estimated to be 500,000 years old, which because of the uncertainty of the dating method may actually be as young as 100,000 years or as old as a million, contained no protein at all. In place of the protein was a black, tarlike substance. The amino-acid content of the shell had diminished to about a tenth of that in the modern shell. About half of the amino acid was in the form of peptide chains consisting of two or more amino acids.

Only individual amino acids remained in the shell 25 million years old. The amino acids found in this shell and in the modern one are compared in the color photographs on page 84. Where the modern shell contains the usual protein building blocks, the ancient specimen consists predominantly of alanine, glutamic acid, glycine, isoleucine, proline and valine.

The sequence of steps in the decay of the protein seems clear. First water penetrates the shell and reacts with the protein so that it breaks down into peptide chains and individual amino acids. Because these smaller molecules are more soluble in water, some of them may drain out of the shell. Of the amino acids that remain in the shell, some (such as serine, threonine and tyrosine) are unstable and tend to break down more



DROP OF SOLUTION containing amino acids is placed on the corner of a sheet of absorbent paper. Two sheets are shown, one for the amino acids found in each of the two samples.



SHEET IS SUSPENDED in a vessel so that the spot containing the amino acids is at the lower right. At the bottom of the vessel is a solvent which travels up the paper by capillary attraction. As it does so, it carries the amino acids with it. Because each amino acid travels at a characteristic rate, this process separates the constituents of the mixture. The sheet is then turned so that the spot is at the lower left. This further separates the amino acids in the pattern shown on page 84. The spots are now treated with reagent to make them visible.

rapidly than the others. After a few million years they will vanish altogether. This explains why various older fossils contain the same unusual assortment of amino acids. Originally they all contained proteins composed of the same amino acids we find in proteins today, but only the stable amino acids have survived.

What about the possibility that the amino acids we extract from fossils do not originate with the original protein of the material, but with modern sources? Are our specimens, in short, merely contaminated? It would be difficult to eliminate this possibility if we considered only one fossil. The fact that we find similar amino acids in fossils of the same species collected from many different formations strongly supports the assumption that the amino acids in the fossils were there during the life of the animal.

Another indication that we are dealing with the original material has to do with the way in which certain amino acids are adsorbed on calcium carbonate precipitating in the laboratory. Aspartic acid and glutamic acid tend to be adsorbed on such a precipitate; other amino acids are not. The fossil material is largely composed of calcium carbonate; thus if the amino acids in it had been adsorbed from water in the ground, we would expect to find an abundance of aspartic acid and glutamic acid. Such is not the case.

We must also consider another point. Are amino acids sufficiently stable to last for long periods of geologic time? Faced with such a question, the average chemist would probably say no. Fortunately the question may be answered by resorting to an approach used in industry to test products. In this approach tests are designed to subject the product to the equivalent of many years of service within a few hours or days.

In the case of amino acids the test consists of heating these compounds to high temperatures and observing their rate of breakdown. In this way we were able to study the breakdown of alanine in some detail. The kind of reaction in which alanine breaks down proceeds at a rate which is described by a well-known law of physical chemistry: the Arrhenius equation, named for the famous Swedish chemist Svante Arrhenius. By observing the behavior of alanine at various high temperatures, it is possible to draw a curve which can be extended to predict its behavior at relatively low temperatures. We found that at 450 degrees centigrade it took about a second for a given

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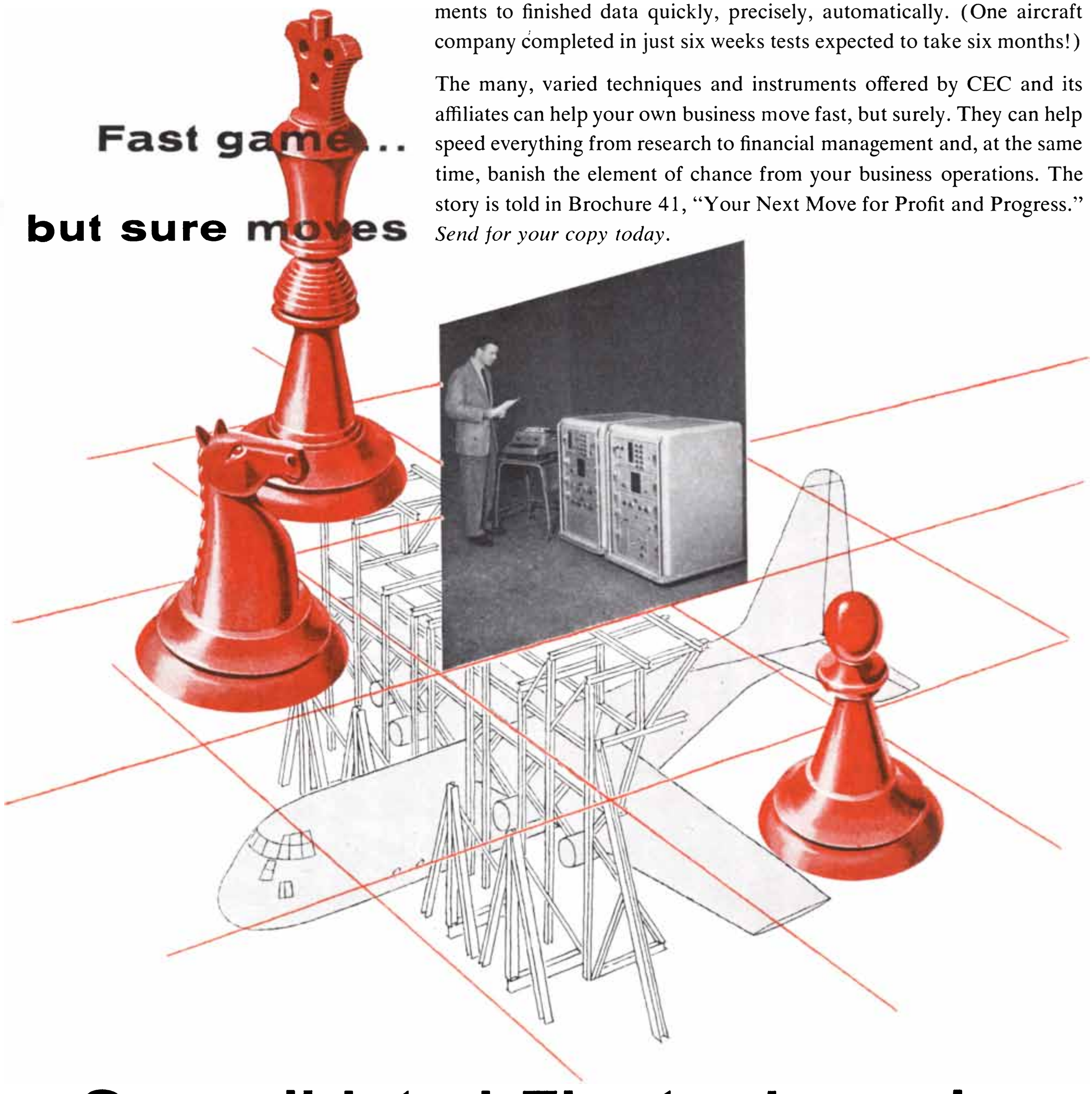

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We have similarly accelerated the aging of other amino acids, though not in so much detail. These studies have shown that the most stable amino acids are alanine, glutamic acid, glycine, isoleucine, proline and valine. The less stable amino acids are arginine, aspartic acid, lysine, phenylalanine, serine, threonine and tyrosine. Thus our laboratory studies correlate perfectly with our findings in fossils.

When we investigated the breakdown of phenylalanine, we uncovered an interesting possibility. Phenylalanine decomposes into carbon dioxide and phenylethyl amine, which is much more stable than the compound from which it is derived. Phenylethyl amine does not normally occur in living organisms. If we were able to isolate it from a fossil, we would have good ground for the assumption that the fossil had once contained phenylalanine. When we learn more about the decomposition of other amino acids, it may be possible to infer the existence of unstable amino acids that have broken down.

Amino acids are of course only one of many families of chemical compounds synthesized by living things. There is much evidence to indicate that compounds in other groups can also survive for millions of years. One such group is the porphyrins. An iron porphyrin is present in the blood pigment hemoglobin; indeed, all organisms that require free oxygen contain some kind of porphyrin. Large quantities of vanadium porphyrins have been found in petroleum. In one case it was apparent that the oil had been exposed to a temperature of 150 degrees C. for tens of millions of years. This survival indicates that porphyrins are far more stable than amino acids. If porphyrins were manufactured by the earliest forms of life, some of these substances should still be in existence.

Other constituents of petroleum provide evidence on the life of the past. Frederick D. Rossini at the Carnegie Institute of Technology has identified some 140 organic compounds in crude oil from the mid-continental deposits of the U. S. This oil, like many others, is rich in hydrocarbon molecules which have the shape of a single chain. Now all modern organisms contain fatty acids. When fatty acids are broken down by bacteria or heat, they yield single-chain hydrocarbons. Laboratory experiments indicate that only moderate heat is required to encourage this reaction. The very existence of petroleum in formations where it has been exposed to temperatures above 200 degrees C. is a testimonial to the durability of some organic matter.

It has long been known that coal is rich in organic compounds. By means of mild chemical treatment that does not alter the original molecules, a host of such compounds has been isolated. Among them are porphyrins, carotenoids, alcohols and fatty acids. The kind and amount of organic substance found in coal depends on its thermal history. Lignite and brown coal are richer in these compounds than bituminous coal or anthracite.

Perhaps the most exciting prospect for the study of fossil organic compounds lies in the vast stretch of time before the Cambrian Period. Although estimates of the age of the earth vary and are subject to change, the earth is at least 3.5 billion years old. A wide variety of living organisms existed at the beginning of the Cambrian Period some 500 million years ago. What forms of life existed during

NAME	PLESIPPUS (HORSE)	PLESIPPUS (HORSE)	LYROPECTEN (SCALLOP)	ECPHORA (SNAIL)	MESOHIPPUS (HORSE)	MOSASAURUS (DINOSAUR)	ANATOSAURUS (DINOSAUR)	DINICHTHYS (FISH)
GEOLOGICAL PERIOD	LATE PLIOCENE	LATE PLIOCENE	MIOCENE	MIOCENE	OLIGOCENE	CRETACEOUS	CRETACEOUS	DEVONIAN
APPROXIMATE AGE (YEARS)	5×10^6	5×10^6	25×10^6	25×10^6	40×10^6	100×10^6	100×10^6	300×10^6
FORMATION	HAGERMAN LAKE BEDS, IDAHO	HAGERMAN LAKE BEDS, IDAHO	CALVERT FORMATION, MARYLAND	CALVERT FORMATION, MARYLAND	WHITE RIVER, NEBRASKA	PIERRE SHALE, SOUTH DAKOTA	LANCE, LANCE CREEK, WYOMING	OHIO BLACK SHALE
AMINO ACID CONTENT (PER CENT)	.06	.15	.11	.12	.031	.18	.28	.30
PRINCIPAL CONSTITUENTS	ALANINE GLYCINE	GLYCINE ALANINE LEUCINE VALINE GLUTAMIC ACID	ALANINE GLUTAMIC ACID GLYCINE PROLINE VALINE ISOLEUCINE ASPARTIC ACID LYSINE	ALANINE GLUTAMIC ACID GLYCINE VALINE ISOLEUCINE PROLINE ASPARTIC ACID LYSINE	ALANINE GLYCINE	ALANINE GLYCINE GLUTAMIC ACID LEUCINE VALINE	ALANINE GLYCINE GLUTAMIC ACID PROLINE ISOLEUCINE VALINE ASPARTIC ACID	GLYCINE ALANINE GLUTAMIC ACID PROLINE ISOLEUCINE VALINE ASPARTIC ACID

AMINO-ACID CONTENT of various fossils examined in the Geophysical Laboratory is tabulated. The samples for Mesohippus and the second specimen of Plesippus were teeth. The amino acids are listed at the bottom in the order of their apparent abundance.

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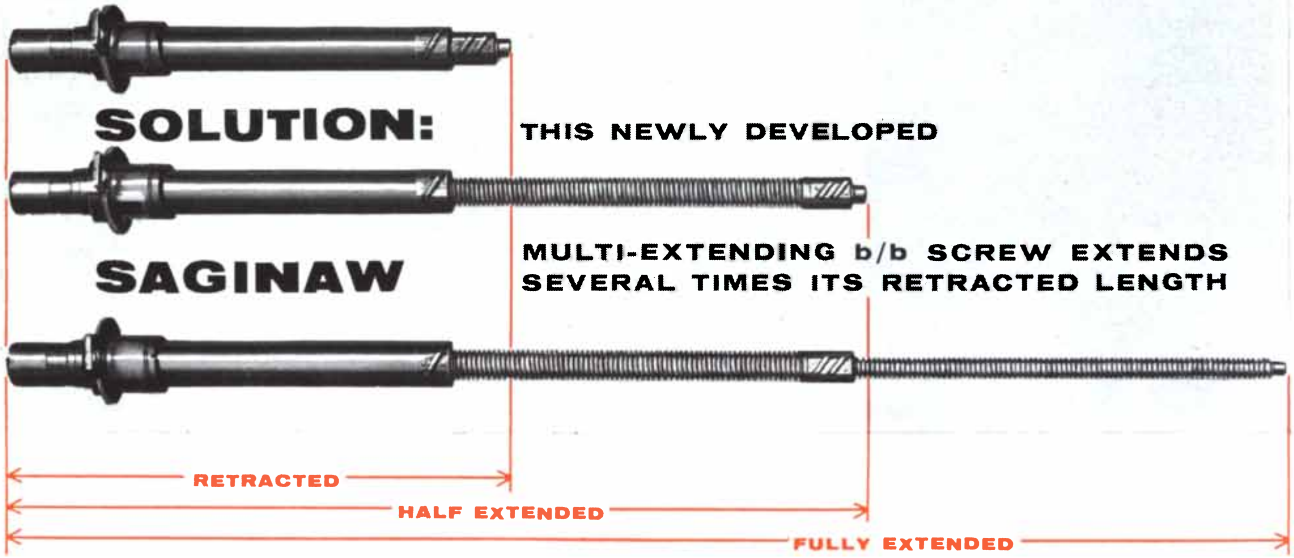

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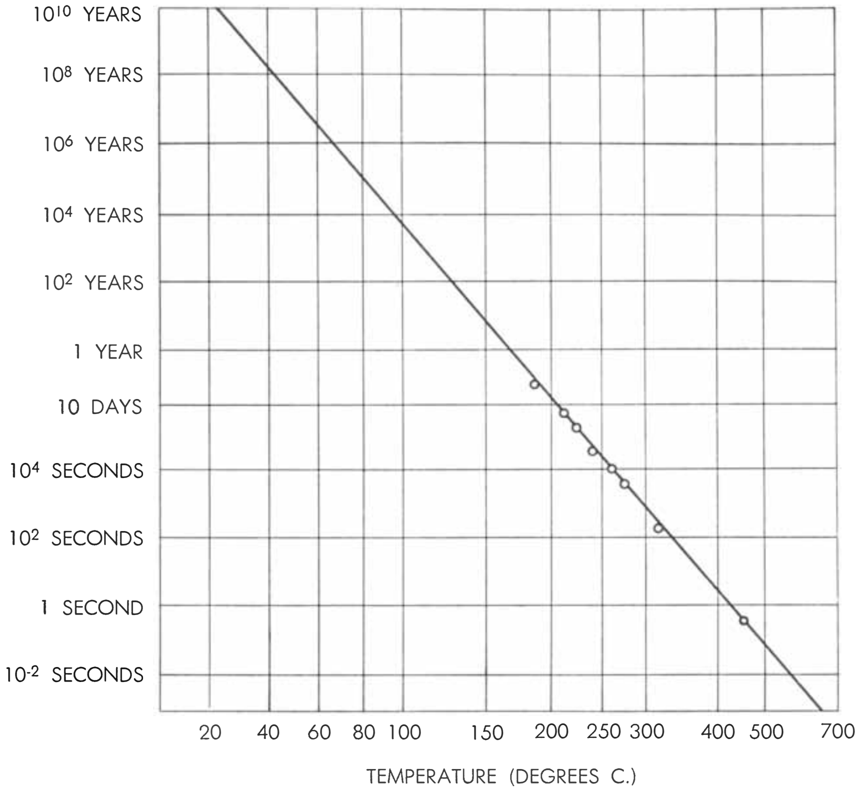


ALANINE WAS HEATED to various temperatures to determine whether it could persist for long periods. The horizontal coordinate of the small circles indicates the temperature to which each sample of alanine was heated. The vertical coordinate indicates the length of time it took for 63 per cent of the alanine in each sample to break down. If a straight line is drawn through the circles, it is apparent that at a temperature of 20 degrees centigrade nearly half of a given amount of alanine would remain after three billion years.

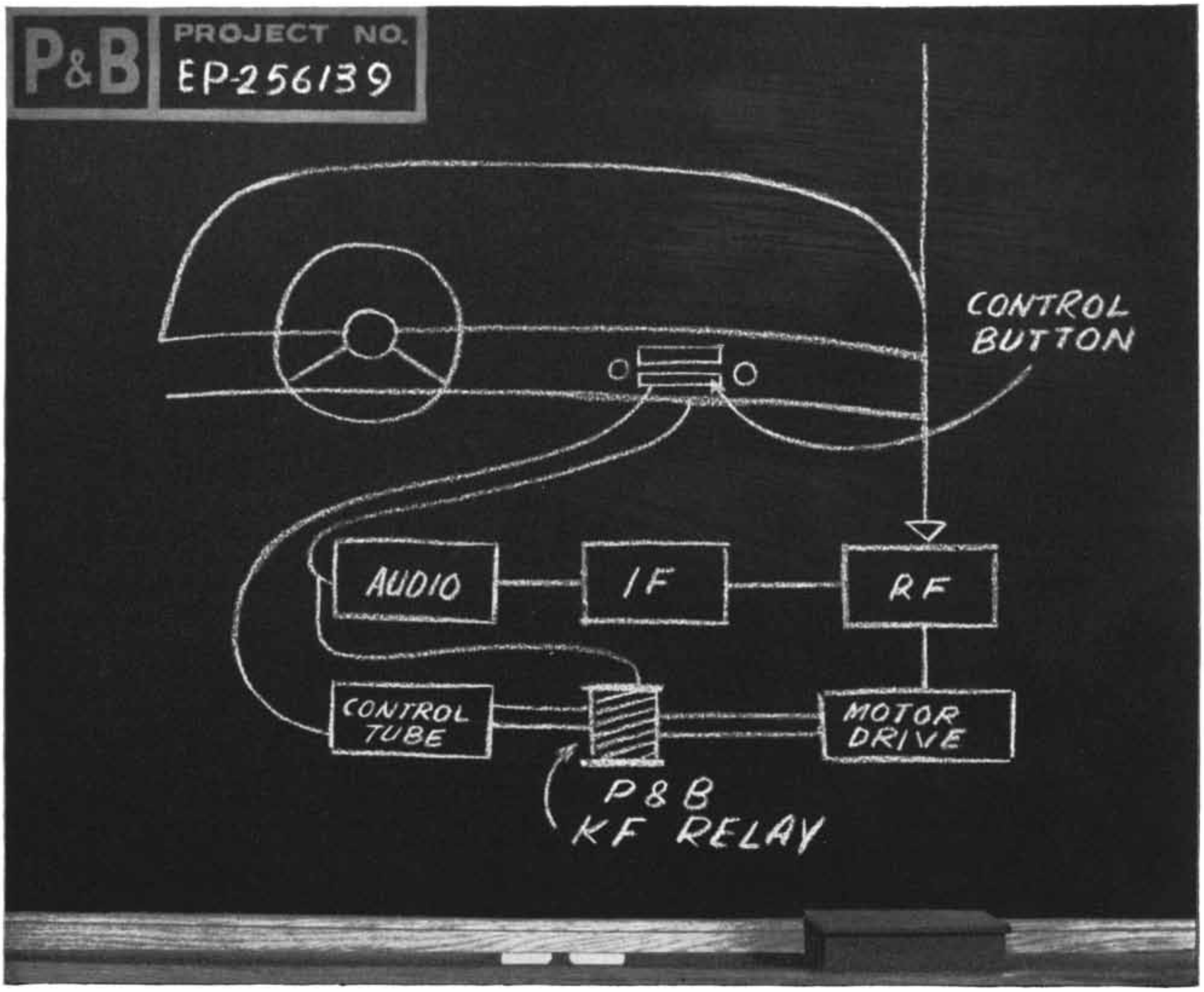
the preceding period? What was the chemistry of these organisms? When, indeed, did life originate?

These questions are difficult to answer because of vast changes that have occurred in the earth's crust since Pre-Cambrian time. The sediments that settled in Pre-Cambrian seas have been deeply buried and often folded. The high temperatures associated with these processes militate against the survival of organic substances. The absence of fossil hard parts further narrows the range of material that may be studied.

There are nonetheless good opportunities in the Pre-Cambrian black shale, which contains a certain amount of hydrocarbon. Small quantities of a petroleum-like substance have been observed oozing from such shales in Michigan. Pre-Cambrian shales in Sweden and Finland are relatively rich in organic matter. Elso S. Barghoorn of Harvard University has recently extracted an organic pigment from a black shale with an estimated age of 1.4 billion years. Similar studies will doubtless reveal a large number of organic compounds in Pre-Cambrian rocks.

It is not impossible that the soft parts of Pre-Cambrian organisms have been preserved. One possible mechanism of preservation may be observed today near hot springs. As the water flows away from the orifice of the spring, it cools and makes an excellent culture medium for algae. These waters are saturated with silica, which precipitates and traps the algae. Thus the organisms are sealed in rock, an ideal medium for the preservation of organic matter. Barghoorn and Stanley A. Tyler of the University of Wisconsin have reported the discovery of algal structures embedded in almost pure Pre-Cambrian silica.

In seeking traces of the earliest forms of life we suffer the handicap of not being certain of what it is we are trying to find. It is simple enough to look for the same organic substances that occur in living creatures. Of course it would be interesting to find the same substances in rocks two billion years old. But it is entirely possible that the chemistry of the earliest living things differed substantially from that of modern organisms. Finding evidence to support such a conjecture would be exciting indeed.



P&B relay "controls" signal-seeking radio

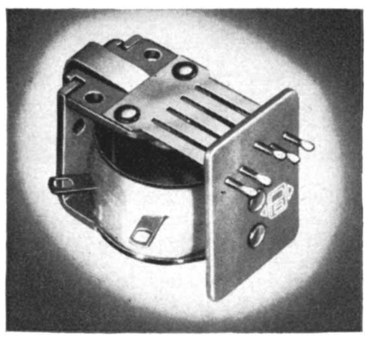
One of the latest and finest car radios actually tunes *itself, automatically.* The user simply presses a special button and the radio "finds" the first signal in the area strong enough for good reception. Another push, the next "listenable" station, wherever the car may be.

The principle of operation is simple. A P&B relay automatically interrupts the current to a tuning motor the moment the incoming signal reaches a usable level.

But the *practice* required a relay that would outlast the busiest station-changer. It had to withstand the vibration of the car, yet work on extremely low and critical drop-out current. It had to be highly compact and *low* in cost. The P&B engineered relay—one of more than 20,000 P&B design variations—was all of these.

Whether your product or problem requires the intelligent application of a standard relay, or the engineering of a special electro-mechanical device, you can be sure P&B will find the answer.

P&B series KF relay with common movable arm, available in Forms 5A, B or C. Unique combination contact and terminal mounted in relay front. Contacts rated 2 amperes. Coil resistance maximum 16,500 ohms. Voltage 6-115 VAC or 6-110 VDC.



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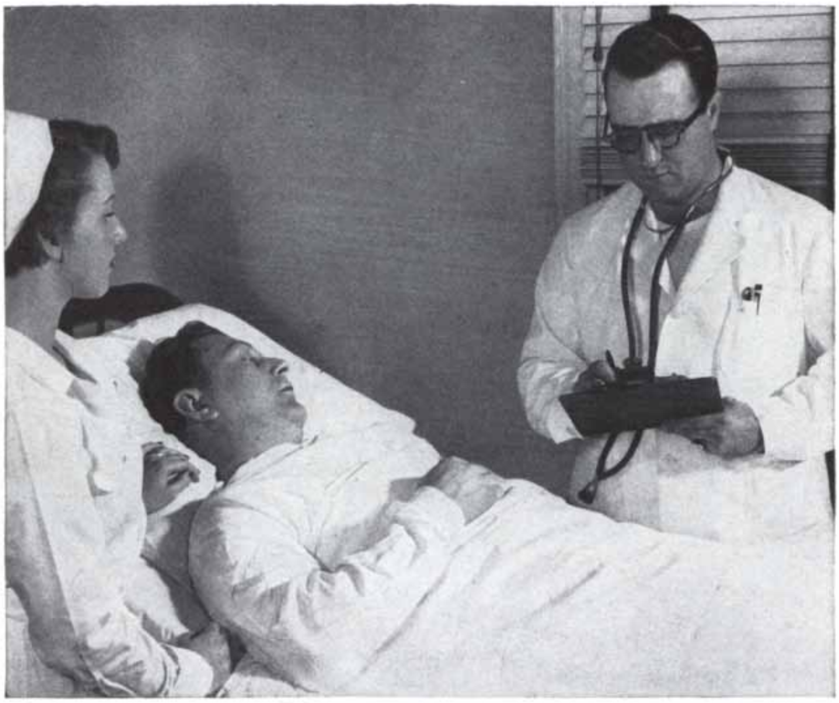
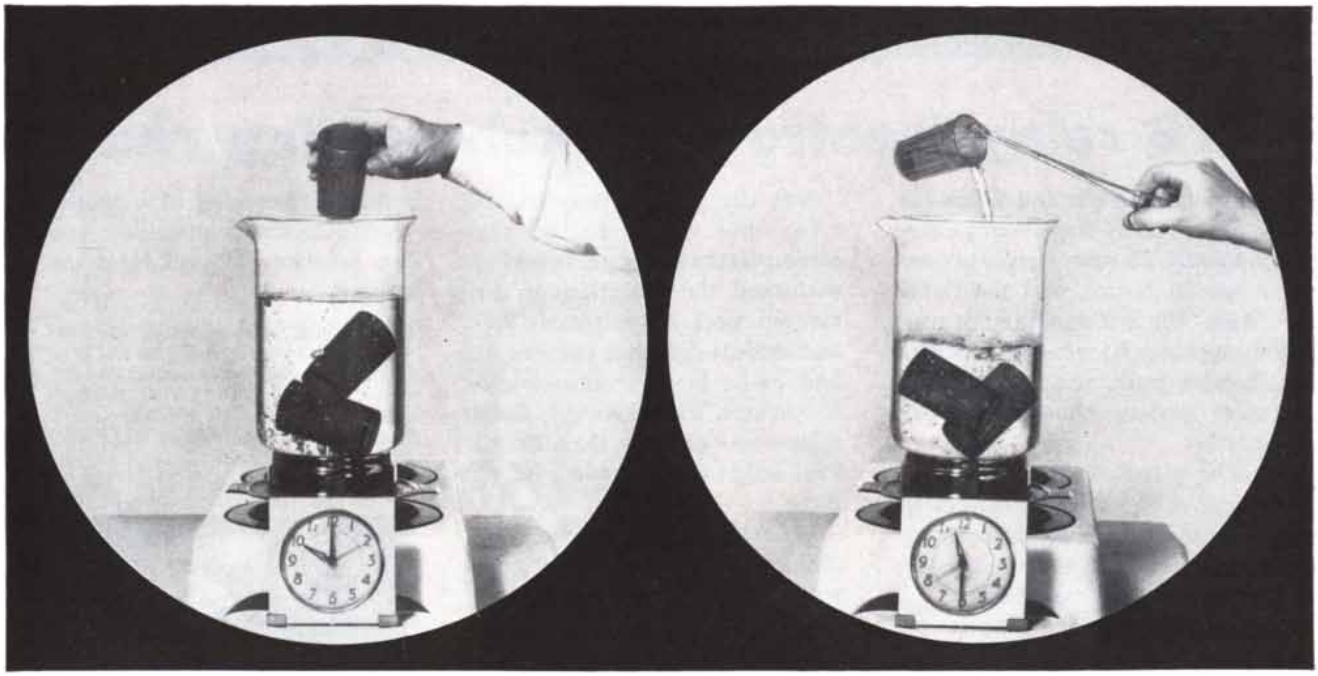
Life on the Chemical Newsfront



DISCOVERY OF TRANQUILIZING EFFECTS of thiazine derivatives has stimulated great interest in new starting materials for their synthesis. A possible source now undergoing research is 2-aminobenzenethiol, a new Cyanamid chemical. A highly reactive, bifunctional compound, it undergoes reactions typical of amino and mercapto groups and where possible, reaction occurs at both groups forming benzothiazole and benzothiazine derivatives. Other reactions are of interest in pharmaceutical, rubber, dye, petroleum and insecticide research. Its amphoteric character leads to salt formation by reaction with bases and acids. Oxidation leads to bis(2-aminophenyl)-disulfide (also available from Cyanamid), long known as a pharmaceutical. 2-Aminobenzenethiol is now offered in pilot-plant quantities. **(New Product Development Department)**



PROLONGED IMMERSION IN BOILING WATER causes no distortion of two new heat-resistant thermoplastic molding compounds demonstrated by Cyanamid at the 7th National Plastics Exposition in June. CYMAC* 400 Polymethylstyrene offers this unusual heat resistance together with the mechanical and electrical properties, clarity, luster, unlimited range of transparent and opaque colors and other desirable properties of polystyrene. CYMAC 201 Methylstyrene-acrylonitrile copolymer offers greater toughness, chemical and craze resistance than CYMAC 400, with high heat resistance, clarity and color range. Both new molding compounds offer the added value of heat resistance at costs no greater than competitive materials. **(Plastics and Resins Division)**

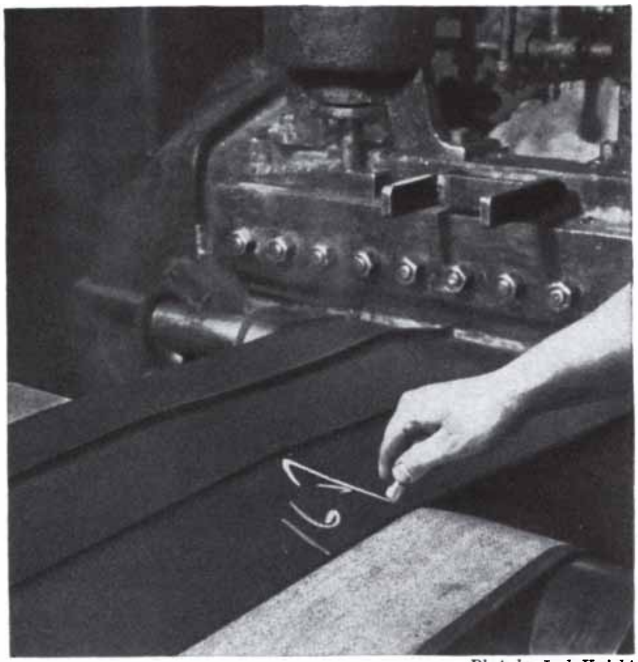


Photo by Jack Knight

HOT, BUT NOT SCORCHED! Higher rubber processing temperatures than ever before are encountered in the use of new, small particle size reinforcing furnace blacks. To prevent scorching in operations such as the extruding process above, a chemical was needed that would delay action beyond anything heretofore developed. Now the maximum in delayed action is offered in Cyanamid's new DIBS* Accelerator (N,N-diisopropyl benzothiazole-2-sulfenamide), available in semi-commercial quantities. With a melting point in the range of 55-59° C, DIBS is easily blended into furnace black stocks. It has good storage stability under normal temperatures. A special report on the behavior of DIBS in furnace black stocks is available on request. **(Organic Chemicals Division)**

UTILITY CAN BE EYE-APPEALING, TOO. Now tough, unbleached kraft corrugated cartons are coated with pigmented overlay coatings. In such applications, Parez® Resin 613 is used to help insolubilize the coating to give improved wet-rub resistance. With this protection, bright, even, solid color printing is possible which weathers scuffing in shipment, rough handling, even soaking rain, and still comes out bright with the manufacturer's label or message intact. **(Industrial Chemicals Division, Dept. A)**

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PRELIMINARY STUDIES OF FUNGICIDES made up of *s*-triazine derivatives of cyanuric chloride indicate the great versatility and potential of this chemical. 2,4-Dichloro-6-(*o*-chloroanilino)-*s*-triazine† has been shown to be extremely effective against tomato blight fungus and other leaf and turf diseases. Many other derivatives made possible by the high selective reactivity of the chlorine substituents of cyanuric chloride and the extreme stability of the triazine ring are leading to new developments in insecticides, plastics and resins, pharmaceuticals, dyestuffs, surfactants, rubber chemicals and other fields. For a comprehensive roundup of recent work, send for "Cyanuric Chloride Derivatives." **(Industrial Chemicals Division, Dept. A)**

†*U. S. Pat. No. 2,720,480*

Additional information may be obtained by writing on your letterhead to the Division of American Cyanamid Company indicated in the captions.

Building for the Future Through Chemistry

Progress in Solar Power

Although there are many ways to convert the energy of the sun into useful forms, most of them are uneconomic. The emphasis is now on devices simple and cheap enough to repay their cost

by Harry Tabor

Our period of history is sometimes called the atomic age, but scientists and engineers continue to investigate other novel sources of energy. During the past few years, as several articles in this magazine have indicated, there has been much interest in the possibility of converting the energy of the sun into useful power. This article will concern recent developments in the harnessing of sunshine.

We cannot continue to consume fossil fuels—coal, oil and natural gas—at the present rate without seriously depleting their readily available sources and raising the cost of winning them from the earth. This is without doubt the largest incentive for the drive to harness atomic energy on a large scale. But even atomic energy does not constitute a real solution, for our supplies of uranium and thorium are also limited.

It is true that if the nuclear fusion process of the hydrogen bomb can be tamed, the situation would be radically altered. The supply of fuel for this process—hydrogen—is virtually limitless. But although the fusion process occurs in the sun, no scientist is prepared to state that such controllable man-made suns are feasible.

Actually the fusion process of the sun is the source of all our conventional forms of energy: coal, oil, natural gas, wind, water—not to mention food. The sun showers on the earth 30,000 times as much energy as we presently use for all purposes. Why, we may ask, is it so difficult to utilize this boundless source of energy more directly? The answer is that in most cases it is not difficult but simply uneconomic. The patent offices of the nations are full of descriptions of devices to harness sunshine. Many of these could produce useful power, but their output would be so small that it would not amortize the cost of the devices.

Although the amount of sunshine that falls on the earth is very large, it is spread very thin. Thus any attempt to produce solar power means collecting the energy falling on a large area. This is the main reason for the high cost of solar energy. As an example, let us consider a few figures.

In a sunny area such as El Paso, Tex., the solar energy falling on one acre amounts to about 9.4 million kilowatt hours per year. If all this energy were collected and converted to power at an efficiency of 5 per cent (we will shortly explain why the efficiency is so low), the annual yield would be 470,000 kilowatt hours per acre of collectors. This would be 54 kilowatt hours of continuous power. To generate the same amount of power with a modern steam turbine would require about 120 tons of fuel oil, worth about $1,600. This, then, is the annual value of the sunshine collected by one acre of collectors. There are 43,560 square feet to an acre, so every square foot of collector would save 3.7 cents worth of fuel per year. This assumes, however, that we can store solar energy so that we can use it whenever we choose.

Now it is hard to imagine a collecting device of glass and metal that would cost less than a dollar per square foot. No bank in the world would provide funds for building a plant that would yield only 3.7 per cent interest per year. And we have not taken into account the fact that the plant would not last forever.

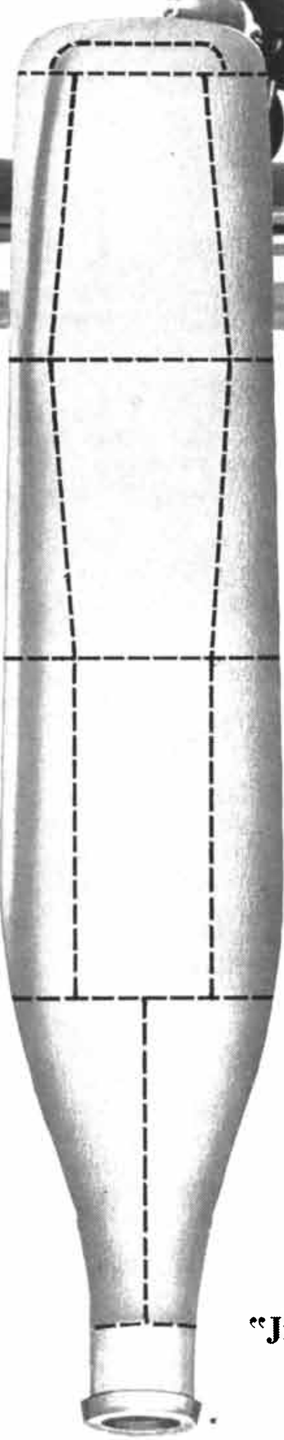
This is the principal reason why no one has yet built a large solar power station in the desert, where land is cheap and sunshine plentiful. There are, of course, other reasons. The demand for power in desert regions may be small; there may not be adequate water to cool large turbine generators; the problem of storing the energy has not yet been solved.

But the example given above shows that the situation is not hopeless, for a change in conversion efficiency or in fuel costs or in collector costs of a factor of two or three may be sufficient to make the solar power plant economically sound. This has given scientists and engineers two points of attack and economists a third.

To take the economic aspect first, it is clear that in those areas of the world where fuel is expensive because it must be brought great distances solar power units may be economic. An enterprising Italian company is actually marketing a small solar engine for such locations. Thus in central Australia, where sunshine is plentiful and fuel must be brought by truck some 1,000 miles from the coast, the use of solar engines for pumping water and for similar purposes is close to being economically sound. Furthermore, to pump water it is not necessary to store energy; the pumping occurs when the sun shines.

The two aspects which have fascinated scientists and engineers are (1) raising the efficiency of conversion and (2) making collectors with cheap "unfabricated" materials such as water or living organisms.

When most materials absorb a photon of light, they are unchanged except for being heated by an amount equal to the energy of the photon prior to absorption. This is known as thermal conversion; it is what happens when sunlight falls on any dark surface. "Dark" simply means that the surface reflects very little of the incoming light; the best solar absorbers are therefore dull black surfaces. Such surfaces may absorb over 95 per cent of the sunlight that falls on them, converting it into heat. This is



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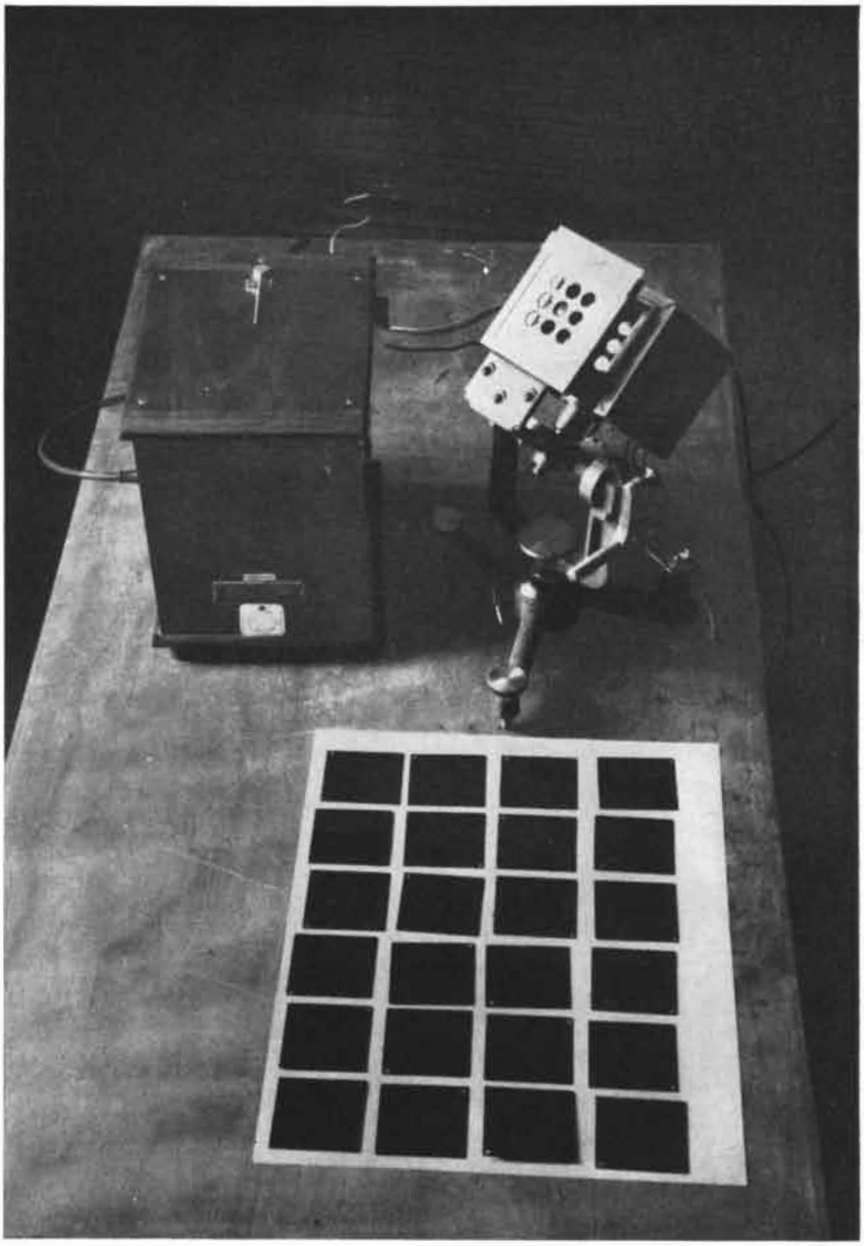
11 plants in New York, New Jersey, Pennsylvania, Ohio, Wisconsin, Illinois, Texas and California.

International Division: Milwaukee 1, Wisconsin clearly a very efficient way of collecting energy from the sun, provided that the heat so generated is not allowed to escape. Yet in practice even the best black surface has a much lower efficiency as a collector of *usable* heat, because when the surface becomes hot it loses heat to its environment. While it is possible to insulate the surface on its rear side, it cannot be covered on the side facing the sun except by transparent substances such as glass or air.

In thin sheets glass is not a very good insulator of heat. A layer of air about an inch thick, however, provides a fair degree of thermal insulation. Heat still passes across the air layer by convection and by radiation of heat from the hot surface to the colder glass. If several sheets of glass with intervening air spaces are used, the insulation of the heated surface is improved. Unfortunately every extra sheet of glass cuts down the amount of sunshine reaching the black absorbing surface. The solar water-heaters that have been used for many years in Florida and California consist of blackened metal plates insulated on the rear and covered on the upper side with two sheets of glass separated by one-inch air spaces. The whole collector is tilted in a southerly direction to "see" as much of the sunshine as possible. These are called flat-plate collectors. They are simple and reliable and do not have to be turned to follow the sun. But they are not very efficient at higher working temperatures. As the temperature of the collector plate rises above the temperature of its surroundings, the heat losses increase and the net useful heat collection diminishes. Thus, when used to heat water for domestic purposes in summertime, such collectors may have an efficiency of about 50 per cent, but in winter the collection efficiency, even on a sunny day, may be under 40 per cent. In cloudy weather it may fall to a very low value. If the water were heated until it boiled—which it would do only during the middle hours of a very sunny day—the efficiency would be so low that such collectors are not considered satisfactory for the production of steam.

So long as we are able to utilize our collected solar energy in the form of low-temperature heat, we can over the year convert 40 to 50 per cent of the photons to useful heat. About the best

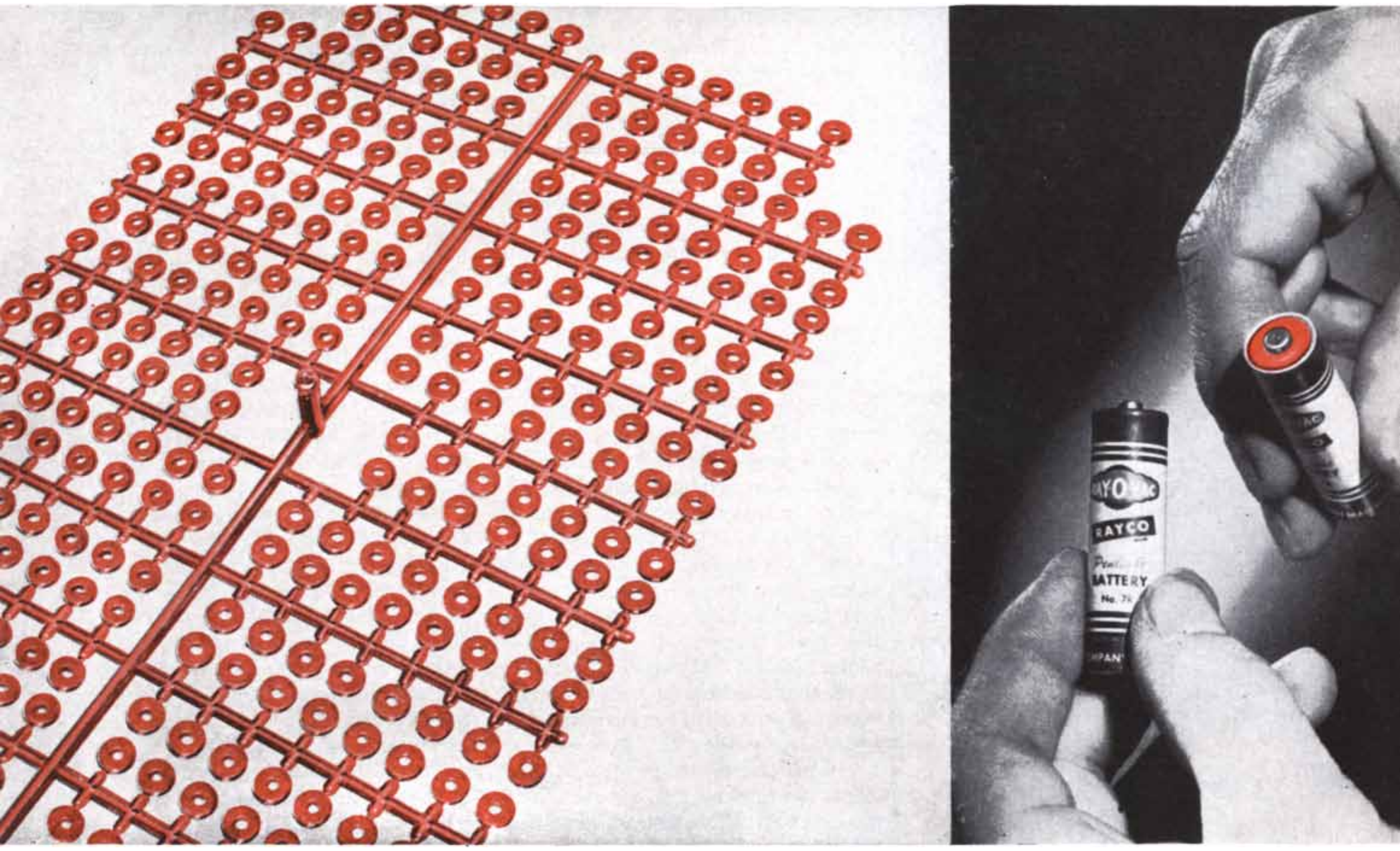
EXPERIMENTAL FLAT-PLATE COLLECTOR at the National Physical Laboratory of Israel traps solar energy between a reflector and transparent plastic. At right is a light meter.



VARIOUS BLACK SURFACES are tested for their effectiveness in absorbing light while not radiating heat. Each sample is inserted in the light absorption meter at upper right.

example of such an application is the heating of houses by solar energy. Here a collection temperature of about 150 degrees Fahrenheit is usually high enough to heat the house by means of circulating hot water. Of course this house heating is required only in winter, when the collector efficiency is generally lower than average. As a very rough guide, about a fifth of the annual sunshine falling on a collector might be usefully employed for house heating in regions with clear winters. In regions with cloudy winters about a 10th of the annual sunshine would be utilized. The fuel saved annually by such a collector might amount to between 10 and 20 cents per square foot of collector. If such a collector can be built and installed for, say, a dollar per square foot, it may be considered economic. When we realize that nearly a third of all fuel consumed in the U. S. is for space heating, we can see that the possibility of domestic heating by solar energy may not only be of interest to the individual householder but of national importance. Several sun-heated houses have already been built, mostly based on research conducted for the past 15 years under Hoyt C. Hottel at the Massachusetts Institute of Technology. Recent improvements in collector construction and their incorporation into architectural design promise that

With **TENITE POLYETHYLENE** 300 seals for dry cells can be made in one shot



Washers of Tenite Polyethylene molded for Ray-O-Vac Company by Evans-Zeier Plastic Company, both of Madison, Wisconsin

Every day sees new uses develop for Tenite Polyethylene. Here's one that's cutting costs and simplifying assembly procedures for a leading manufacturer of dry cell batteries.

Formerly, dry cells were finished by pouring molten pitch around the carbon anode to seal the open end. But look how Ray-O-Vac speeds this operation. A molded Tenite Polyethylene washer is force-fitted over the carbon rod and the metal edges of the cell are then crimped into the washer. Result: a water-tight seal, no electrical leakage, and faster production.

Design of the individual washers was no problem. But the design of the mold itself was. For collectively, 300 washers in one shot represented quite an intricate molding. Needed was a plastic that flowed easily at normal molding temperatures to completely fill every one of the 300 tiny mold cavities. Small wonder, then, that Tenite Polyethylene was the plastic chosen by the molder of these washers.

This Eastman plastic has exceptionally good molding properties. Its fast, even flow permits use of more complicated molds than were ever before practicable with Polyethylene. Investigate for yourself the production economies that may result through use of easy-to-mold Tenite Polyethylene. Investigate, too, the ability of this plastic to add longer life, better performance or greater sales appeal to some product you make. For more information about this versatile plastic, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

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an Eastman plastic

many more solar houses will be built in the future.

Thus far we have considered only the conversion of the photons of sunshine to low-temperature heat. What happens when we wish to secure mechanical or electrical power? To obtain this kind of power from heat it is necessary to use some kind of heat engine. Herein lies the real difficulty.

It is a fundamental law of physics that the conversion of heat into power is always an inefficient process. But as the temperature of the heat source rises, so does the efficiency of conversion. The large power stations of today convert only about 30 per cent of the heat content of their fuel into electricity, the other 70 per cent being carried away by the cooling water and wasted. These stations use steam at 900 degrees F. or higher. At lower temperatures in, say, a steam locomotive, as little as 8 per cent of the heat of the fuel is converted into power. All this means that if we wish to convert our solar heat into power, we must collect the heat at as high a temperature as possible. But we have noted that the efficiency of collectors decreases as their temperature of collection increases. So in coupling a solar heat collector to a heat engine, we must choose a temperature of operation which gives us the best compromise on combined efficiency. For flat-plate collectors of the type presently being used to heat water the "best" temperature (probably between 100 and 150 degrees F.) results in an engine which theoretically might convert 5 per cent of the incoming solar energy into power. This figure falls to 2 or 3 per cent in a real system. Clearly this is not good enough, for even the 5 per cent conversion efficiency of our initial example was not sufficient to pay for the cost of the collectors.

The need for higher working temperatures has tempted engineers to use mirrors or lenses to concentrate sunshine on a small receiver. Here the heat losses will be proportionately smaller than those of a system with a large exposed absorbing surface. In this way high-pressure steam can be produced, and with accurate paraboloidal mirrors such as those used in searchlights, temperatures up to 6,000 degrees F. have been obtained and used for research purposes. However, such mirrors are prohibitively expensive, and even if they could drive an efficient steam turbine they would be entirely uneconomic as sources of power.

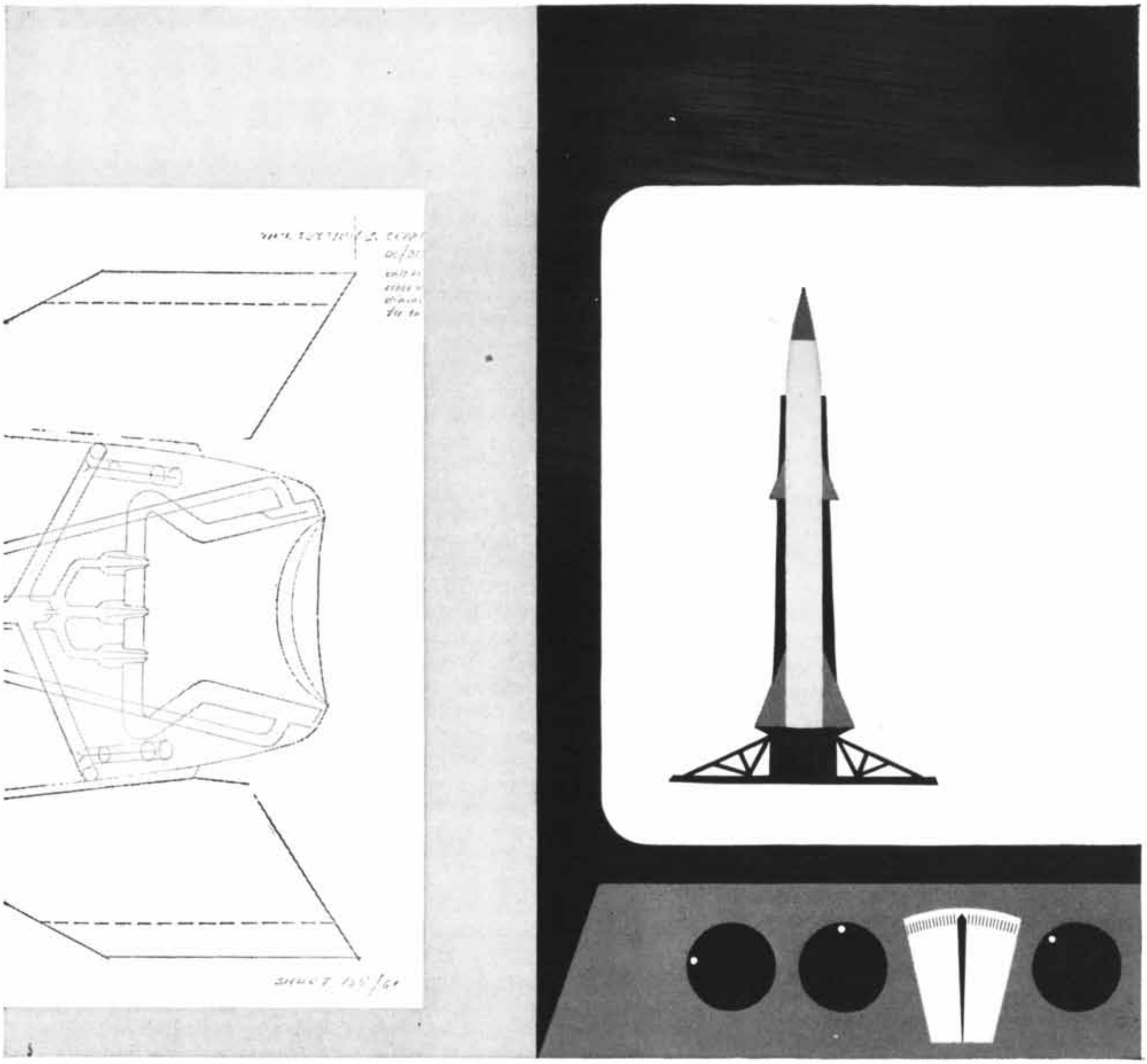
At the National Physical Laboratory of Israel in Jerusalem another and more direct approach to the problem of reducing heat loss from collectors has recently been made. One discouraging fact about black surfaces is that while they are good absorbers they are also strong radiators of heat. Indeed, the physicist describes a good radiator as a "black body." This rough generalization of a more precise and limited physical law seems to have led solar engineers to accept, almost philosophically, the notion that because solar absorbers must be black to absorb sunshine they must also lose much of the energy they absorb.

Now the more precise physical law states that a strong radiator of heat is "black" only for the radiation wavelengths that it *emits*, the word "black" meaning that it is an absorber for these same wavelengths. But it need not absorb other wavelengths. A weak radiator is a poor absorber of heat waves, but might conceivably be a good absorber of other wavelengths. Now it happens that moderately hot bodies radiate only energy of long wavelength, whereas solar radiation is all of short wavelength. Thus what we want is a surface that is "black" for sunlight but is not "black" for the wavelengths of radiant heat. The problem is rather like that of making optical color filters.

The solution is a polished metal surface coated with a rather special thin black layer. These surfaces appear black, and they absorb more than 90 per cent of sunlight. Yet the polished metal underneath radiates very little of the heat it receives from the surface coating. We call such surfaces "selective black" surfaces because they can distinguish between solar and heat radiation.

Trials in Jerusalem of the new surfaces show that in normal use they can reduce radiant heat loss by a factor of eight and in special applications by a factor of 14. One immediate result of this work is that it is now possible to build a simple flat-plate collector which in sunny weather will boil water and produce low-temperature steam at about 35 per cent collection efficiency without any concentrating mirrors. An application that immediately comes to mind, particularly for those living in hot, sunny climates, is the use of a solar energy collector to operate an absorption-type cooling unit for air conditioning. Such units, which have been built in the U. S. for many years, operate from steam at atmospheric pressure. It is thus now perfectly practical to couple a solar energy collector to such an air conditioner. The hotter the sunshine, the better the cooler works.

So far we have confined ourselves to collectors that are unchanged, except for



being heated, by the radiation they absorb. In some materials the absorption of a photon causes a chemical reaction, and newly formed compounds carry in them the energy given up by the absorbed photon. A notable example is a growing plant, which stores energy from the sun by photosynthesis and releases this energy when we eat the plant or burn it. The photochemical conversion of sunlight is remarkably inefficient. A growing plant, for example, collects and stores only .1 to .5 per cent of the sunlight it receives. No one has any real idea how to increase this efficiency greatly.

Another possible type of collector converts solar energy directly into electric current. Until very recently this method of collection was not significantly more efficient than photosynthesis. The best photoelectric cells could convert only about .5 per cent of sunlight into useful electrical energy. In the past few years the investigation of semiconductor materials has produced a solar battery that converts 10 per cent of sunlight into electricity [see "The Solar Battery," by Gordon Raisbeck; SCIENTIFIC AMERICAN, December, 1955]. Although it is efficient, the solar battery costs so much (about $3,000 per square foot) that it can be used only for very special applications where a small amount of power is essential and no other source is available. Of course research and development will undoubtedly reduce the cost of this device, but whether it can do so by a factor of 1,000 is unpredictable.

Up to this point we have discussed the possibilities of improving the efficiencies of various fabricated heat collectors. Another approach is to find or create a collector that costs almost nothing. Even if it were very inefficient, such a collector might prove economically sound in an area where land is not expensive.

The cheapest large collector we know is an ocean or a lake. The surface waters of a large body of water are heated by the sun; thus they are hotter than the waters at the bottom. It is therefore not surprising that attempts have been made to drive a heat engine using the surface waters as the heat source and the deeper waters for condensation. This system, first proposed by the Frenchman Georges Claude and later taken up by his countrymen under the leadership of the late André Nizery, has the important advantage that it can be used to desalt sea water. The relatively hot surface water enters a low-pressure vessel, where part of it flashes into vapor. This drives an extremely low-pressure turbine and is then condensed (by cold ocean water) to yield sweet water.

The over-all energy conversion of such systems is inefficient, but the "collector" costs nothing. However, the low efficiency means that tremendous quantities of sea water must be handled in order to produce a reasonable quantity of power. The present efforts of French engineers working in the African port of Dakar on this temperature-difference plant are almost entirely devoted to solving the purely mechanical but difficult problem of pumping huge quantities of water from the depths of the ocean.

At Dakar the temperatures used are about 82 degrees F. for the "hot" water and 46 degrees for the "cold," a range that would be extremely discouraging to the designer of a heat engine. Nizery realized this and inaugurated a series of experiments to try to raise the temperature of the surface water by passing it into shallow pans where it would be further heated by sunshine. The temperature of the water rose very little, because the water surface rapidly lost heat by radiation, conduction, convection and evaporation. Attempts were therefore made to reduce the evaporation losses by floating a thin film of oil on the surface of the water. This procedure increased the temperature of the water but not enough to change the over-all picture. Furthermore, oil tends to be blown to one side of the pan. If a metal cover or glass window is used we are of course getting back to a fabricated collector. The engineering aspects of a temperature-difference plant are now being studied at the University of California by a group under Everett D. Howe, but the method of getting the water initially hot has not been determined.

A most interesting possibility in utilizing sunshine for this purpose has been proposed by Rudolph Bloch of the Dead Sea Works in Israel. Bloch has suggested that if a shallow pond is arranged so that the water at the bottom is very salty and the water at the top is comparatively fresh, the heavier salt water heated by sunlight striking the bottom will stay at the bottom instead of rising to the top by convection. The cold water at the top would then act as an insulating blanket for the hotter water below. This heated water would be carefully decanted to provide the source for a temperature-difference plant.

Water can also be used as an energy collector for photosynthesis. It has been found that certain types of algae such as Chlorella can, when placed in a tank of water six inches deep, convert about 2 per cent of the solar energy falling on

DELAY LINES

by Admiral

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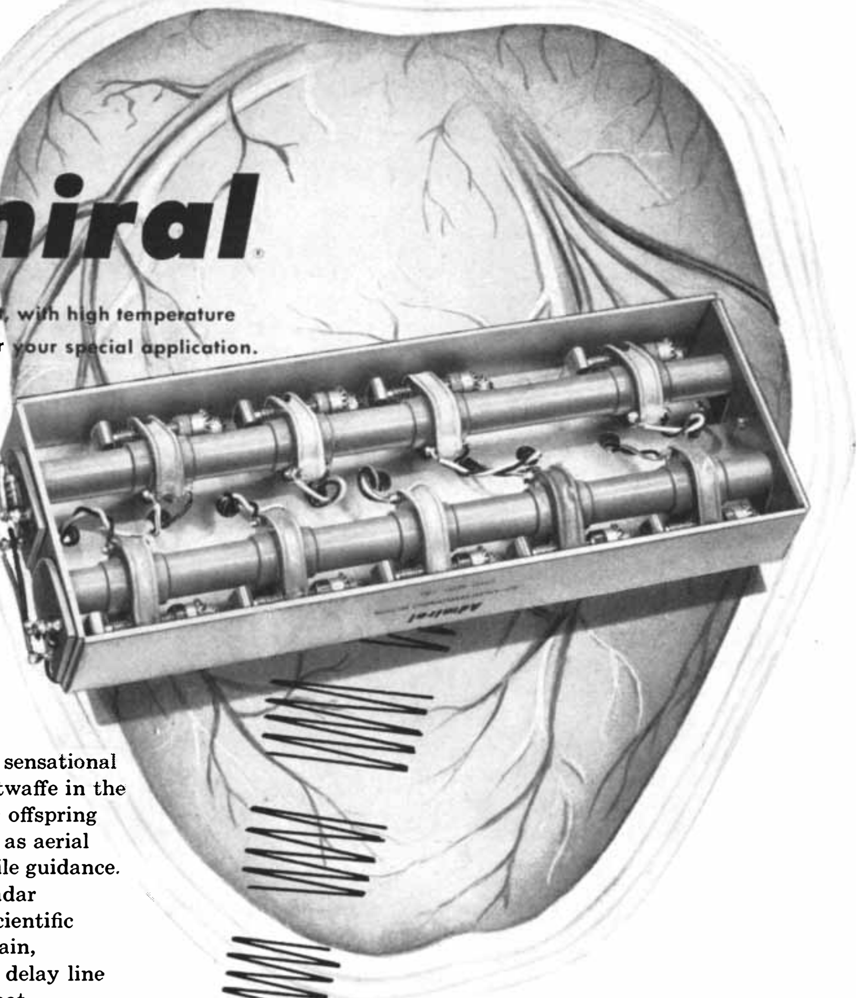

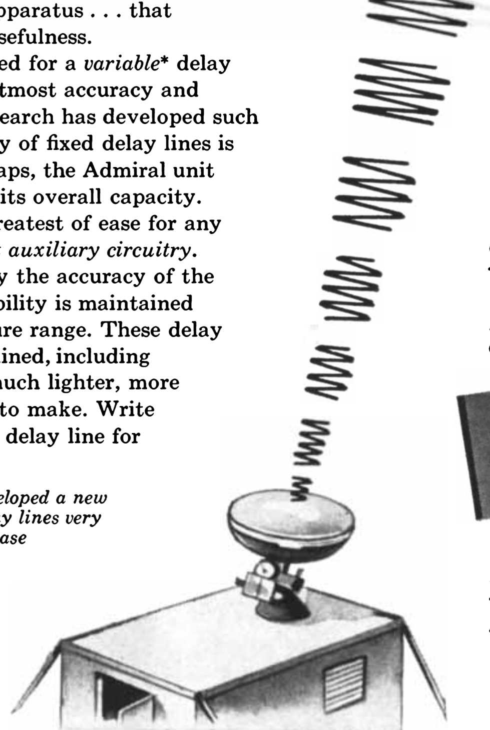

Micro-second Control for an Electronic Pulse

Scarcely fifteen years ago radar made its sensational debut when it helped defeat Hitler's Luftwaffe in the Battle of Britain. Since then its scientific offspring have become commonplace in such fields as aerial navigation, interrogation (IFF) and missile guidance.

All these elaborations of the basic radar principle, and many others now on the scientific horizon, depend on an electronic pulse train, established and controlled by means of a delay line . . . the very *heart* of the apparatus . . . that determines its scope and usefulness.

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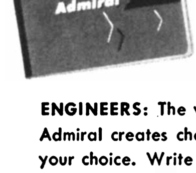

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the tank. Normal vegetation might utilize only .1 per cent. Yields of 15 dry tons per year per acre have been obtained from Chlorella, and some workers believe that much higher yields are possible. If the Chlorella is burned as a fuel, the system cannot compete with the thermal systems previously described. But if it is used as protein or converted to alcohol by fermentation, as suggested by R. L. Meier of the University of Chicago, the process looks more promising. Algae ponds are much cheaper than glass and metal flat-plate collectors, but they are not as cheap as would appear. The water must be mechanically stirred to expose all the algae to the sunshine, and carbon dioxide must be added to speed photosynthesis.

A good deal of thought has been given of late to making cheaper collectors of glass, metal and mirrors. Farrington Daniels and his colleagues at the University of Wisconsin are searching for ways to make very cheap mirrors of aluminized plastics, metal foil on cement, and other such combinations. Silvered glass and metal mirrors are too expensive, but it is just possible that these new techniques might produce crude mirrors (with rather low concentrating power) at a fraction of the present price. Because of the higher conversion efficiency of a concentrating system, these might then compete with the flat-plate systems now being used.

There are a few other methods of harnessing sunshine, such as solar ovens and solar stills. A great deal of work has been done on these methods in various parts of the world, including the U. S. The present picture is that they are still too expensive and limited in usefulness.

To summarize, we may say that using solar energy to supply low-temperature heat is economic in many circumstances, and a large increase in the number of houses heated and cooled by solar energy can be expected in the next few years. The production of power from the sun by means of a heat engine is still uneconomic in most areas, but advances in methods of collection and collector design show promise of improving the economics to a point at which it is worth while in many areas where cheap conventional fuels are not available. Even today it is economic in a few extreme cases. Among the nonthermal processes photosynthesis may one day offer a reasonable method of harnessing sunshine. The photoelectric process will be significant only if completely new methods are conceived which will reduce the cost of the apparatus by a factor of 1,000.

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

Industry's First Private Research Reactor Now in Operation

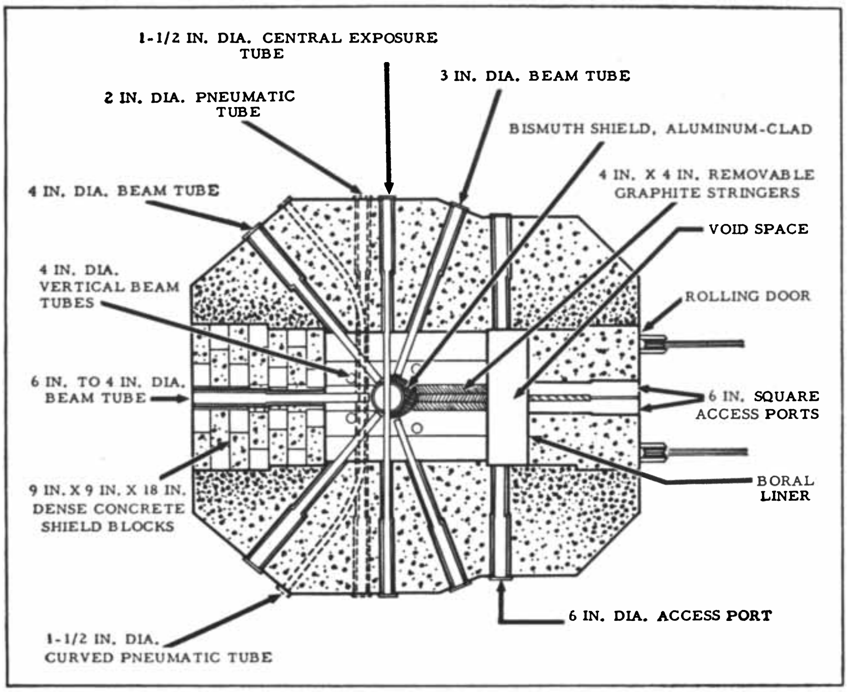
The Armour Research Foundation's nuclear reactor, located on the Illinois Institute of Technology Campus on State Street near Chicago's Loop, began operating early this spring. This marked the first time that private industry has had at its disposal a nuclear reactor expressly designed for industrial research.

Already under way at Armour are programs by participating companies, taking advantage of the revolutionary research techniques made possible by the new facility. The schedule includes allocation of reactor "time" for private studies, free of security restrictions. Areas of study include: food and drug processing; materials research – glass, ceramics, plastics, rubber, textiles, etc; petroleum, chemicals and other industrial materials and processes.

The Model L8 Armour reactor is of the homogeneous solution type, designed to operate at 50 KW and to produce a maximum thermal neutron flux of about 1.7×10^{12} neutrons/cm^2-sec at the center of the reactor core. Exposure facilities are provided through which the neutron flux is available in varying intensities for experimental purposes. Power level is controlled either manually or automatically by a vertical control-rod system. The reactor is safeguarded by a unique control system which "scrams," or automatically shuts down the reactor, if necessary.

One of several reactors produced by Atomics International, a Division of North American Aviation, Inc., the design and construction of the L8 Model is based on the company's 10 years' experience in the development of peaceful applications of nuclear energy. Other applications include a reactor designed for a prominent southern California university, specially adapted for cancer and other medical research; the important Sodium Reactor Experiment in the Santa Susana Mountains near Los Angeles, part of the AEC program to develop economical power from nuclear energy; plus development and design of a 75,000 KW sodium-graphite nuclear power plant.

Atomics International is a major reactor builder—experienced in the design, construction and operation of nuclear reactors for research and the production of power.



Reactor Plan View

ARMOUR RESEARCH REACTOR MODEL L8

Characteristics

Design Power	50 kw
Zero Power Critical Mass*	850 gm U^{235}
Maximum Thermal Neutron Flux	1.7×10^{12}n/cm^2-sec
Mass Coefficient of Reactivity*	0.03%/gm
Temperature Coefficient of Reactivity*	–0.029%/°C
Fuel Solution Temperature at 50 kw*	80° C
Excess Reactivity at 20° C, Zero Power*	3%
Reactivity Held in Control and Safety Rods*	8% (2% each rod)
H : U^{235} Atomic Ratio*	350
U^{235} Concentration*	75gm/liter
Power Density, Maximum	5.5 watt/cm^3
Power Density, Average	3.85 watt/cm^3

**Approximate Value*

Brief General Description—The reactor fuel is a light water solution of UO_2SO_4, enriched in U^{235}. This fuel is contained in a spherical stainless steel core tank, which is surrounded by a graphite reflector. The reactor is shielded with high density concrete (density 3.5 gm/cm^3) plus other selected materials. Fuel-handling, gas-handling and cooling systems are provided; also complete instrumentation and equipment are installed for remote operation and to provide automatic safety action.

Experimental Facilities—The experimental facilities include nine assorted beam tubes, 3" to 6" ID; straight and curved pneumatic tubes, 1½" and 2" ID; central exposure tube; horizontal thermal column 5′ square, with four 6" access ports. In addition there are special exposure facilities which make use of the gamma activities in the reactor atmosphere.

If you are interested in any phase of our activities, Atomics International is staffed and equipped to help you. Please write: Applications Engineering Service, Dept. SA-N3, Atomics International, P. O. Box 309, Canoga Park, California. Cable address: Atomics.

ATOMICS INTERNATIONAL

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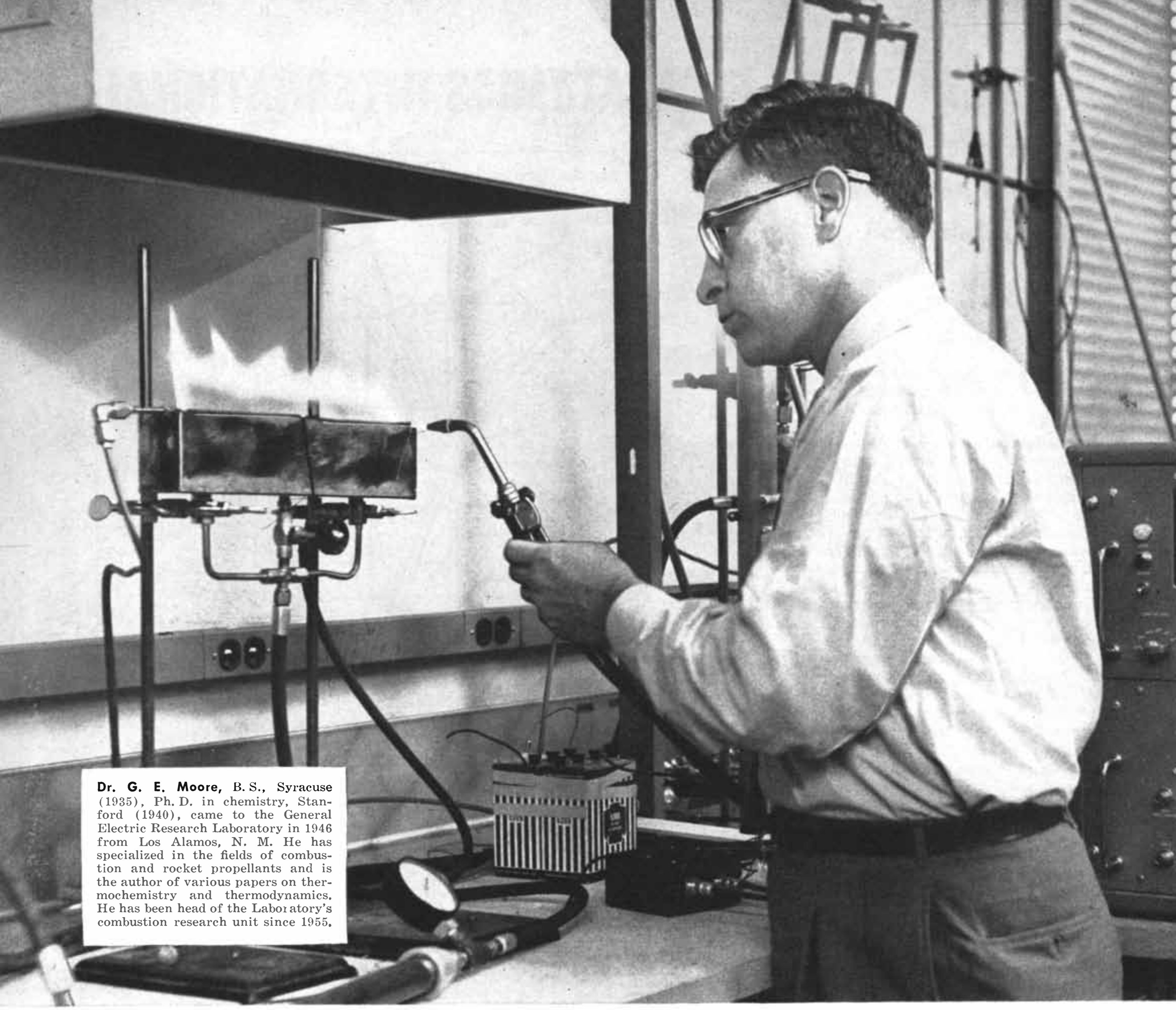
PIONEERS IN THE CREATIVE USE OF THE ATOM



Dr. G. E. Moore, B.S., Syracuse (1935), Ph.D. in chemistry, Stanford (1940), came to the General Electric Research Laboratory in 1946 from Los Alamos, N. M. He has specialized in the fields of combustion and rocket propellants and is the author of various papers on thermochemistry and thermodynamics. He has been head of the Laboratory's combustion research unit since 1955.

Research for better rockets

General Electric's Dr. George E. Moore applies basic studies of combustion to development of propellants

Behind the use of rocket motors in such devices as guided missiles and earth satellites is a history of painstaking research into the fundamentals of *combustion.* Dr. George E. Moore's contributions to this comparatively new science have included calculations of the effect of combustion-chamber size and shape on rocket efficiency, innovations in the use of fuels, and new understanding of the general chemistry of rockets. He and a group of General Electric associates have devised a new type of "hybrid" motor—using both liquid and solid fuels—that is a model of simplicity and efficiency in rocket propulsion and promises to play a significant role in what is certain to be a big future for rockets.

As General Electric sees it, providing individual scientists with freedom and incentive to solve the problems of research is part of solving the larger problem of how we can all live better, with better materials and better products with which to work, better jobs, and extra human satisfactions in terms of what people expect and want in life.

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SEXUALITY IN BACTERIA

It has only recently been shown that bacteria have chromosomes and genes. Now it has been found that one bacterium can inject its genes into another by conjugation, giving rise to a hybrid

by Elie L. Wollman and François Jacob

Sexual reproduction is common among living things. The mating process, however, varies widely among forms of life as different as men and algae. Among highly evolved organisms such as man, mating is the obligatory method of multiplication. On the other hand, sexual reproduction seems to be rare among simpler, one-celled organisms.

Bacteria are a case in point. At one time it was thought that bacteria had no sex. Though some observers claimed they had beheld the tiny creatures in the act of conjugation, the prevailing view denied them a nucleus, chromosomes or genes. If they were thus lacking in equipment for carrying on genetic processes, sexuality could have no meaning in the life of bacteria.

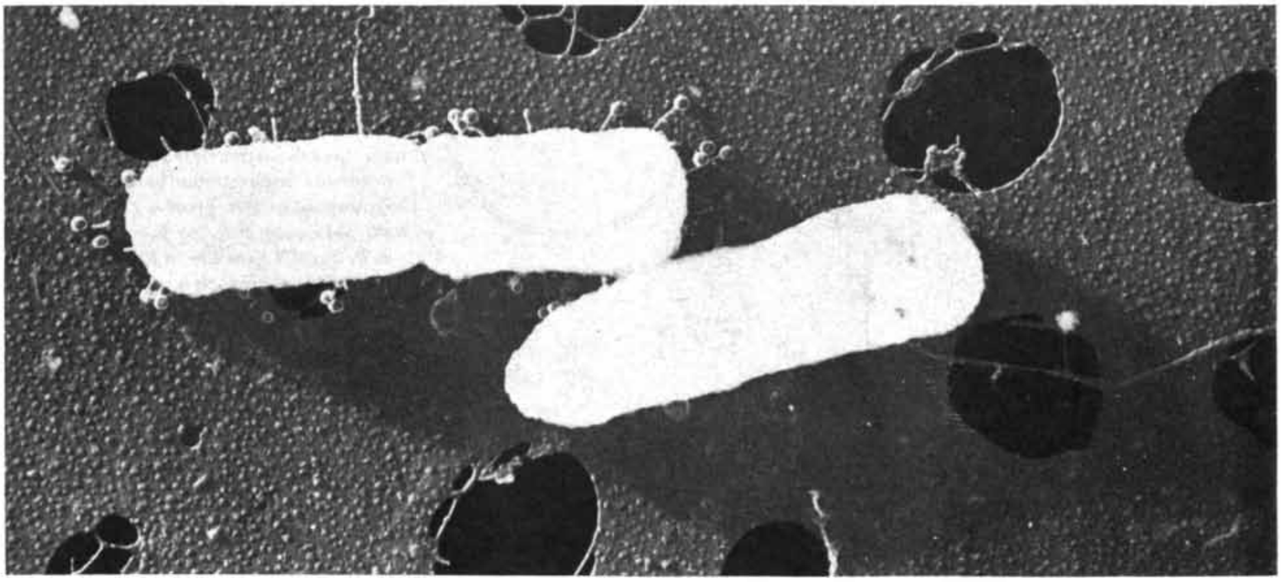
Recent work, however, shows us that we must be as broad in our approach to this question as Paul Verlaine on the topic of love:

Ces passions qu'eux seuls nomment encore amours
Sont des amours aussi, tendres et furieuses
Avec des particularités curieuses
Que n'ont pas les amours certes de tous les jours.

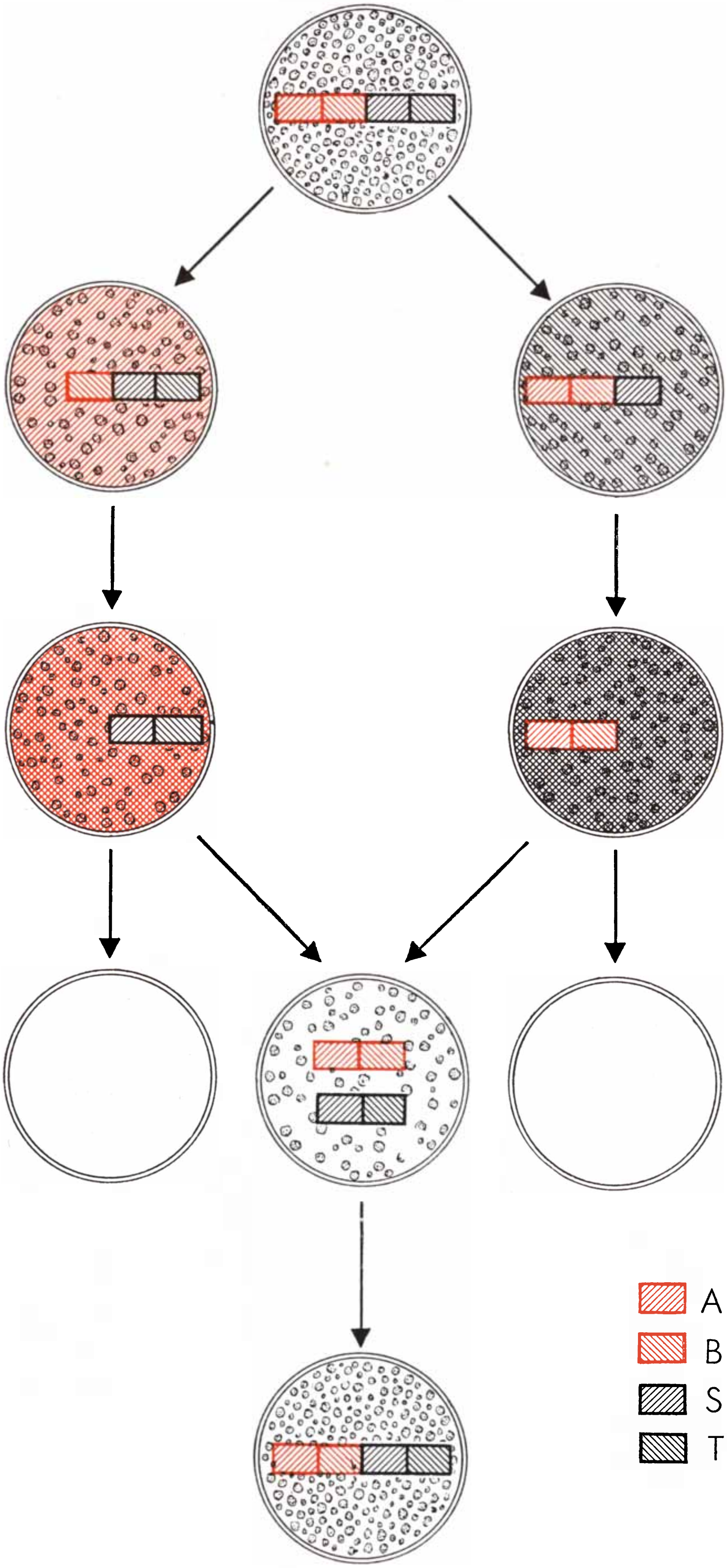
[*These passions which only they in their sport*
Call love: they too are love, tender and furious
And with particularities curious
Not love of the everyday sort.]

The question of sex in bacterial reproduction is important not only for its relevance to our understanding of the genetics of bacteria but also to the things we may learn from bacteria about genetic processes in general. Genetics has made its principal progress as the science of breeding. It is through the mating of individuals that differ from one another by recognizable characteristics that the concept of the gene as the unit of heredity has emerged. These same experiments, plus the study of the anatomy and physiology of cells, give us our picture of the organization of the genes in the structure of the chromosome. Through the exchange and recombination of genes in sexual reproduction we comprehend the spread of change and the stabilization of characteristics in a species. Since bacteria could not be mated, they have not been of much use to geneticists working along these lines.

The presumably sexless bacteria have been fruitful, nonetheless, in another major line of research in genetics. This



CONJUGATING BACTERIA are shown in this electron micrograph. The bacterium at upper left is labeled with killed bacterial viruses, the tadpole-shaped objects around it. This technique is used when experiments call for observation of individual bacteria.

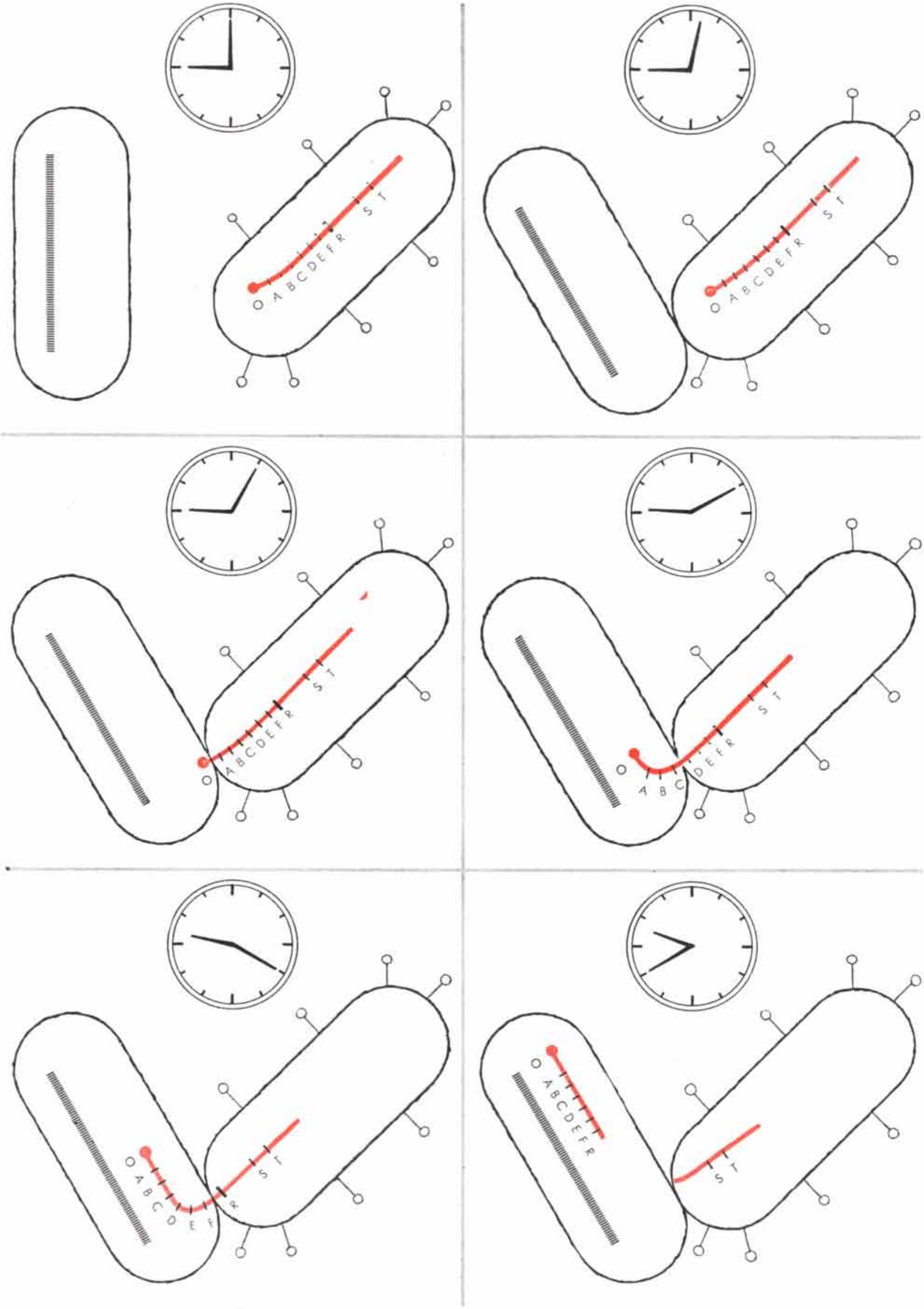


is the study of mutation, the sudden change in a hereditary characteristic of a species. Mutations are rare events. To study them requires large homogeneous populations and a rapid cycle of reproduction—specifications not easily met even by the fruit fly and maize, the two beloved subjects of the geneticist. Given a suitable culture medium, however, some bacteria will produce a new generation every 20 minutes. Bacteria are easy to handle and available in very large populations: a quarter-teaspoon of a broth culture of *Escherichia coli*, the colon bacillus, contains more than a billion bacterial cells.

Bacteriologists noticed long ago that when bacteria were cultured in a medium that was made deliberately unfavorable to their growth, they often acquired, sooner or later, the ability to grow in this medium. This acquired characteristic of the bacterial population was thereafter inheritable. In this manner, it was found, bacteria could "adapt" to innumerable changes in the physical or chemical constitution of the medium and to the presence of drugs or bacterial viruses. At first bacteriologists thought that the environment acted in some way upon the bacteria to change their properties.

As the result of a summer's collaboration at Cold Spring Harbor, N. Y., Salvador E. Luria and Max Delbrück were able to show in 1943 that this "adaptation" is effected by the same process of mutation and selection observed in the evolution of other organisms. They found that it is, in most cases, the outcome of change in a discrete and heritable characteristic in a single bacterium —a mutation in a gene—followed by selection of the mutant offspring. Such

RECOMBINATION of genetic traits in bacteria through mating of two different mutant strains was demonstrated in the experiment diagrammed at left. From a culture of bacteria able to synthesize four amino acids (*A, B, S and T; see key at lower right*) and hence able to grow in a minimal medium (*white culture dish at top*) two strains were first isolated, one unable to synthesize A (*upper left*) and the other unable to synthesize T (*upper right*). To make them grow, the corresponding amino acids, indicated by crosshatch, had to be supplied to the culture medium. From these two strains mutants unable to synthesize B and S, respectively, were isolated in turn. When the two strains were sown alone in minimal media (*blank culture dishes at lower left and right*) no colonies were formed. When they were sown together (*center*) on minimal media, the colonies proliferated and could be transplanted on minimal media (*bottom*).


O A B C D E F R S T

mutations can affect all known characteristics of bacteria, including the morphology of their colonies, their virulence and their nutritional requirements. Further investigation showed that radiations and certain chemicals increase the frequency of mutation in bacterial populations, just as they do in higher organisms, thus confirming that bacteria, as well as fruit flies, must have genes.

The next question was whether bacterial genes are organized and disposed on some kind of structure like a chromosome. The evidence strongly suggested that this was the case. Biochemists had found that bacteria contain desoxyribonucleic acid, or DNA, the helical molecule which is found in chromosomes. Cytologists, in turn, had shown that the DNA in bacteria is concentrated in bodies as it is in the nuclei of other cells.

That DNA is indeed the bearer of hereditary characteristics in bacteria was proved in 1944 by O. T. Avery, Colin M. MacLeod and Maclyn McCarty at the Rockefeller Institute for Medical Research. They were able to transfer a purified extract of DNA from one strain of pneumococcus to another. This artificial injection of a gene into a cell was followed by the appearance of its associated characteristic, the ability to synthesize a certain complex sugar, in the descendants of the cell.

The success of this experiment suggested that there must be some natural mode for the exchange and recombination of hereditary characteristics in bacteria. Since no one had ever observed such a process, it was clear that recombinant individuals must be extremely rare in bacterial cultures, if they existed at all. Joshua Lederberg and Edward L. Tatum attacked this question at Yale University just 10 years ago. They set a brilliantly devised experimental trap for the rare recombinant.

In designing their experiment, they took advantage of an important finding established in the investigation of the bread mold *Neurospora* by George W. Beadle and Tatum at the California Institute of Technology. This mold is sexually differentiated. By mating nutritional mutants, that is, strains which lacked the capacity to synthesize different nutritional factors, Beadle had shown that such synthesis is under genetic control [see "The Genes of Men and Molds," by George W. Beadle; SCIENTIFIC AMERICAN, September, 1948]. With the knowledge that nutritional capacity is a hereditary characteristic, Lederberg and Tatum set out to determine whether bacteria can exchange this characteristic.

As the subject of their experiment they adopted the ubiquitous *Escherichia coli*. This bacterium grows perfectly on a minimal medium containing only minerals and sugar as a source of energy and carbon. In other words, from such simple materials it is able to manufacture all the complex elements of its protoplasm. Nutritional mutants can be induced in *E. coli* by treatment of the culture with ultraviolet radiation, X-rays or mustard gas, and isolated by suitable screening procedures. Such mutants will not grow on the minimal medium even if billions of cells are seeded.

From a common strain Lederberg and Tatum isolated two different lines of nutritional mutants. As indicated in the diagram on page 110, one mutant lacked the ability to manufacture two particular amino acids; it could grow on a minimal medium only if these two acids were supplied. The second mutant was similarly unable to manufacture two other amino acids. When the two strains were mixed, however, and seeded together on minimal medium, numerous colonies were formed that could be indefinitely replanted on minimal medium.

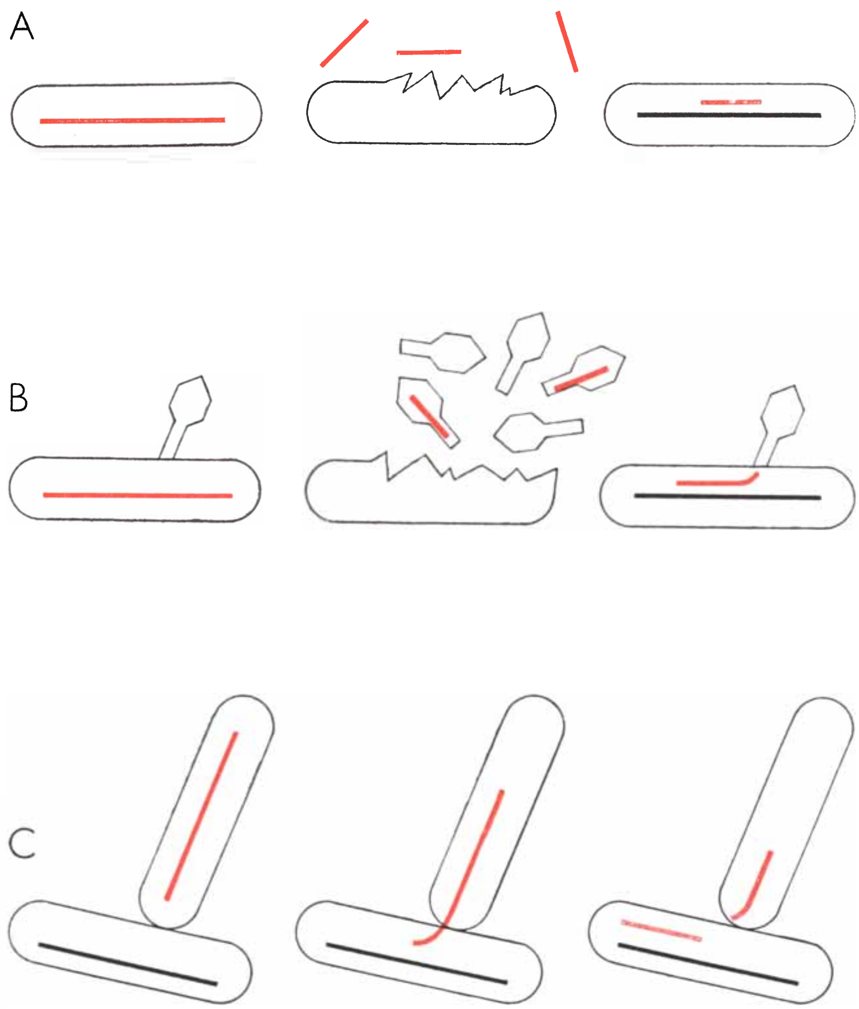
It was clear that something had happened on the agar plates between the two strains. New individuals, able to synthesize all four amino acids, and hence bearing characteristics inherited from each "parent" strain, had appeared. Further experiment showed that this process must involve some curious particularity of contact between the parental cells. Contrary to what had been found in the artificial transformation of the pneumococcus, the inhibition of di-

BACTERIAL GENES are transferred from one bacterium to another in the linear order demonstrated in the experiment diagrammed on the opposite page, suggesting that the genes are organized on a chromosome-like structure. The "male" in these diagrams is tagged with virus as in the electron micrograph on page 109. Conjugation begins a few minutes (*at upper right*) after the two strains are mixed. The transfer of genetic material (*at left center*) begins a few minutes later. The letters represent the location along the chromosome of genes for specific, identifiable traits. Experimental interruption of conjugation process at successive stages shows that genes of a given strain always penetrate the "female" cell in the same order. How section of chromosome transferred combines with female chromosome to form the recombinant hybrid is unknown.

rect contact between the *E. coli* strains prevented the production of hybrids.

This ingenious experiment, performed on purely theoretical grounds, clearly demonstrated that genetic recombination does exist among bacteria. The study of bacterial genetics, however, presents some very special problems. Geneticists ordinarily try to examine all the progeny of individual matings, or at least to take random samples of the progeny of a series of like matings. With *E. coli* the procedure is quite different. The rate of recombination in a cross such as Tatum and Lederberg effected is about one recombinant per million bacteria of each parental type. This precludes any possibility of examining the offspring of a single mating event. It also makes it necessary to choose in advance, as they did, the type of hybrid offspring one hopes to find. Despite these difficulties, variations on the first successful laboratory mating of *E. coli* have since told us much more about bacterial genetics.

Lederberg himself, continuing his work at the University of Wisconsin, laid the experimental foundation for the important conclusion that the genes of *E. coli* are organized on a chromosome structure. He isolated strains of nutritional mutants distinguished by a variety of other characteristics having nothing to do with the nutritional defect for which they were selected. When he crossed two such strains he found that their recombinants inherited some of these characteristics from each parent. The characteristics were not randomly transmitted to the recombinant but turned up in fixed patterns of association. Bacterial genes must thus be arranged on linear structures analogous to the chromosomes in the nuclei of animals



GENETIC EXCHANGE in bacteria occurs in the three ways shown here. "Transformation" (A) involves experimental or accidental transfer of genetic material from one bacterium to another. "Transduction" (B) is accomplished by viruses which carry genetic material from one strain of bacteria to another. "Conjugation" (C) requires direct contact of bacteria.

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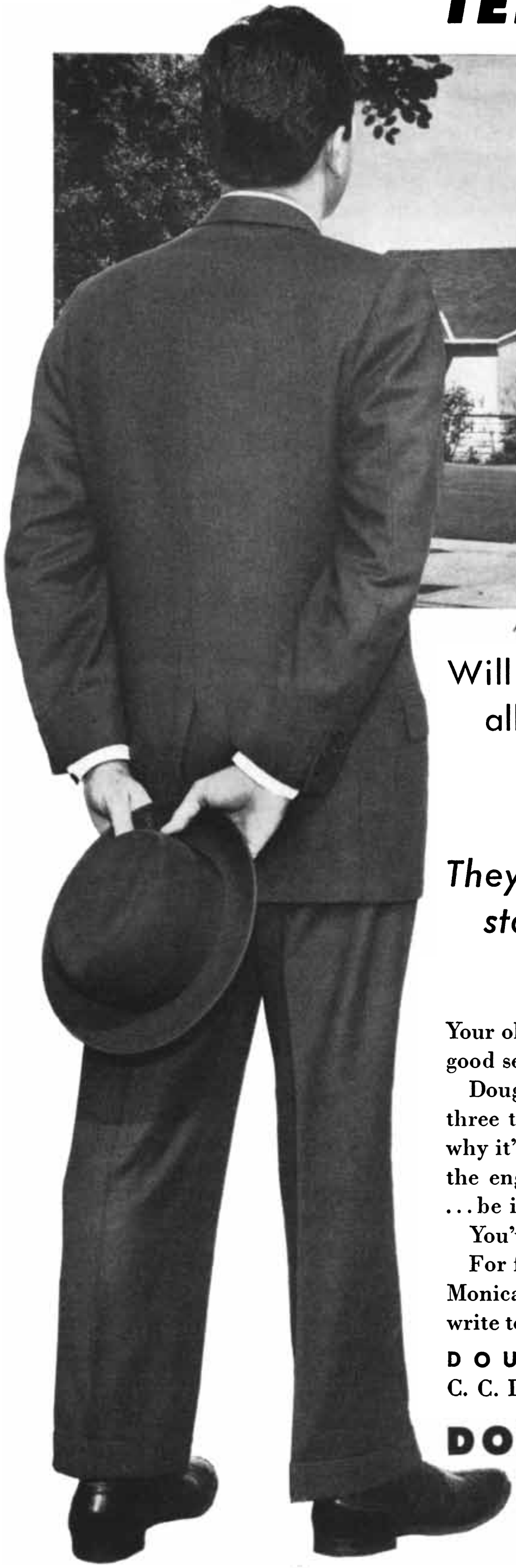

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and plants. It was not yet possible, however, to establish the location of each gene on the chromosome or to determine whether bacteria have more than one chromosome.

An important step toward the answer to these questions was taken in 1952 when William Hayes at the University of London demonstrated that the mating of bacteria involves a kind of sexual differentiation. Hayes made this discovery by an experiment in which he treated one or the other partner in a mating with streptomycin, thereby rendering it incapable of division. In one case there would be no recombination. When the other partner was treated, recombination would occur. This differential result indicated that the two parental types play different roles in mating. One behaves like a male whose transitory role is to fertilize the other. Evidently this capacity is not impaired by streptomycin. In order to get recombinants, however, it is essential that the capacity to divide should remain unimpaired in the other, or female, partner. Genetic recombination in bacteria can thus be visualized as a one-way transfer of genetic material from a male type to a female.

This sexual differentiation was confirmed by Joshua and Esther Lederberg at Wisconsin and by L. L. Cavalli in Italy. They showed that the two types may be distinguished by a sex determinant which is possessed by the male and is lacking in the female. The sex determinant has a surprising potency; when males and females are mixed together, it is transferred with high efficiency to the females and transforms them into males.

The special nature of sex in bacteria was further underscored by a discovery of Hayes that the male transfers only a part of its genetic material to the female. The recombinants always inherit a larger fraction of their genetic characteristics from their mother than from their father. The male can therefore be viewed as a gene donor, whereas the female is a gene acceptor.

Investigators succeeded in amassing all of this lore about the sex life of *E. coli* despite the one-in-a-million rarity of its manifestation in the reproduction of the species. Experimental procedures were very much simplified when Hayes and Cavalli independently discovered strains of supermales 100 and 1,000 times more potent than ordinary males. The very process of conjugation in bacteria was now opened to detailed investigation.

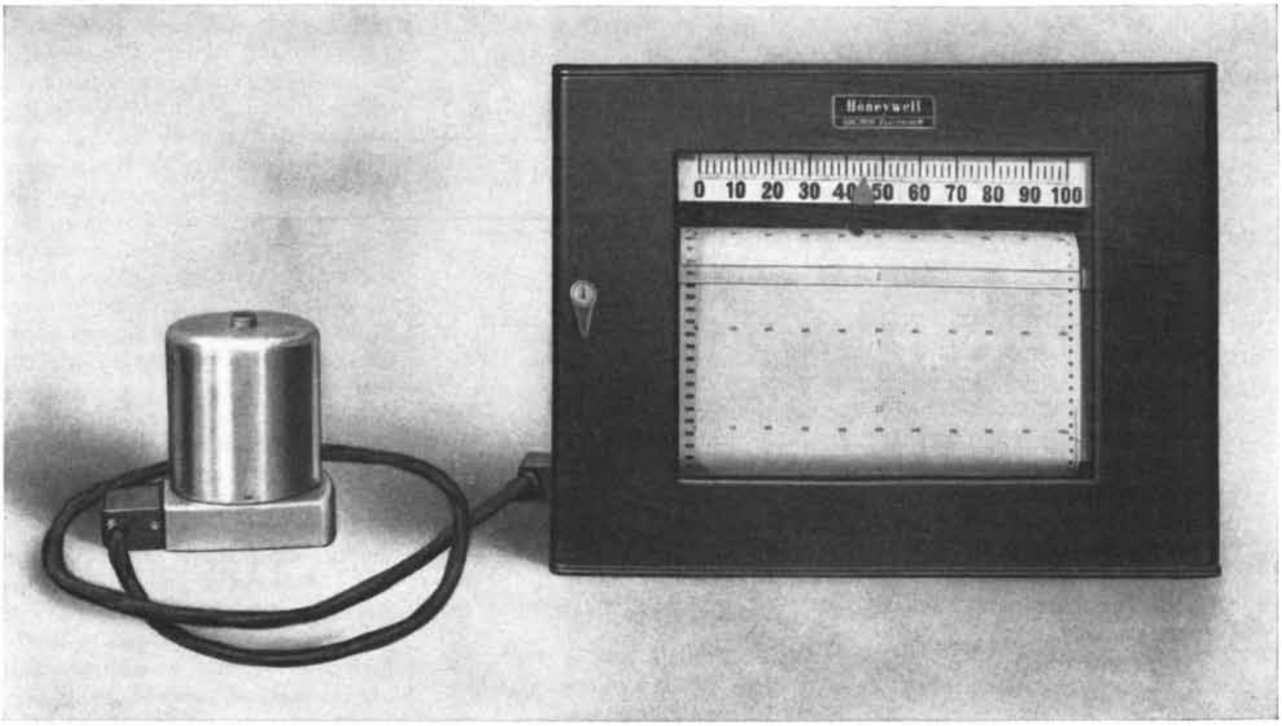
Several steps can be identified and described. First of all, when supermales and females are mixed together, they rapidly come into contact. Under optimal conditions each supermale begins conjugation with a female within a few minutes. This can easily be observed under the microscope, especially when the two types of cells exhibit differences in shape or motility or when one is tagged with killed bacterial virus, as in the electron micrograph on page 109.

The two bacteria lie side by side in conjugation for as much as half an hour. During this period a portion of genetic material is slowly passed from the supermale to the female. This was discovered in our laboratory when we subjected mating suspensions to vigorous beating in a Waring blendor. Beating the suspensions at different times during conjugation developed the quite unexpected evidence that the male genes enter the female cell in a definite order, peculiar to each strain.

The results of a series of such experiments on one strain are shown in the diagram on page 112. It is seen that the gene for the first demonstrable characteristic, one that controls the synthesis of the amino acid threonine, starts penetrating at about seven minutes. This is followed at nine minutes by B, a gene which controls the synthesis of another amino acid, leucine. At 10 minutes comes C, a gene for sensitivity to the drug sodium azide; at 11 minutes, D, a gene for sensitivity to the bacterial virus strain known as T1; at 18 minutes, E, a gene for lactose fermentation; and finally, at about 25 minutes, gene F, which controls galactose fermentation.

The process of conjugation thus lends the strongest support to the notion that bacterial genes are organized on a linear structure; that is, on a chromosome. The chromosome always enters the female with the same extremity first and carries the genes into the female in the same sequence. When everything proceeds normally, about one third of the total length of the male chromosome penetrates the female cell. Beating in the blendor not only separates the mating cells but chops the chromosome off at the point to which it has penetrated. Of course even under natural conditions spontaneous breakages may occur. Inside the female, the chromosome segment is still functional and, longer or shorter, takes its part in the formation of genetic recombinants.

This detailed picture of the mating process prompted a re-examination of the difference in fertility between the supermales and ordinary males. Was this a difference in the ability to make close contact with the female? Or was it a dif-



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ference in ability to inject genetic material? Recent experiments show that all types of males are able to conjugate in an equally high percentage of cases. But ordinary males are then able to inject only a very small piece of chromosome which does not carry any known characteristic except the sex determinant itself. The otherwise recognizable recombinants are formed by the rare supermale mutants that turn up in a population of normal males. The supermales can be distinguished from one another according to the characteristics they inject into females.

Now that we know bacteria are equipped with genes and chromosomes and the capacity for sexual reproduction, our attention turns to the question of what happens inside the female cell to the genetic material injected by the male. We want to know how a given piece of material is integrated into the genetic setup of a cell, making more of itself and imposing its features on the biochemical machinery of the offspring. This problem is not peculiar to bacteria; it is the general problem of how the recombinant chromosomes of the offspring are assembled from the chromosomes of the parents. Because it is possible to control the transfer of their male chromosomes, bacteria may help us to develop important information on this question.

Sexual reproduction in bacteria thus holds high interest for the geneticist. It is perhaps more important to his work than it is to the survival of the bacteria. We must recall that for the most part they reproduce by simple division and very rapidly. Enormous populations can be built whose capacity for adaptation to environmental changes is insured by the random appearance of a great variety of spontaneous mutants. Recombination by sexual exchange seems merely incidental to the survival and evolution of bacterial populations. Yet we find among bacteria the range of processes we have discussed here for the exchange of genetic material between individuals. These fill in gaps in the evolutionary scale of sexual reproduction, and they open up new approaches to the study of genetics.

There is little doubt that the basic features of genetic recombination must be similar whether they occur in bacteria or in man. It would be rather surprising if the study of sexual reproduction in bacteria did not lead to deeper understanding of the process of genetic recombination, which is so vital to the survival and evolution of higher organisms.

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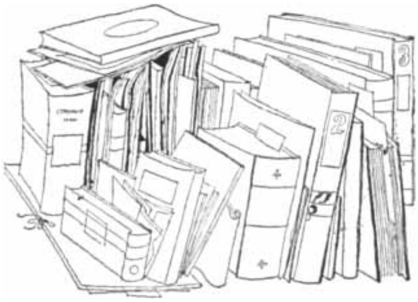

BOOKS

Two social scientists reflect on secrecy, loyalty and disloyalty

by Harry L. Shapiro

THE TORMENT OF SECRECY, by Edward A. Shils. The Free Press ($3.50) THE LOYAL AND THE DISLOYAL, by Morton Grodzins. University of Chicago Press ($4).

For the past decade we have undergone in this country an experience that has no precise counterpart in our history. The trust of the average American in the loyalty of other Americans, and particularly of those connected with government, was profoundly shaken by a series of widely publicized charges and exposures. We have seen Federal, state and community investigations into the loyalty of individual citizens. Accusations of treason have been freely leveled at a variety of people, some in rather exalted positions. Charges of espionage have been brought against fellow Americans, with a conviction handed down in at least one case. In addition to this, thousands of employees of the government have been screened as security risks, and virtually everyone planning to leave the country or to enter it on a visit has had to be cleared whether he knew it or not.

We have had in the past episodes of recrimination following periods of crisis. After the Civil War and World War I charges of bad management, of profiteering and of other delinquencies were common. Some of them were perhaps justified; others were ways of letting off steam—a kind of catharsis for the tensions that preceded them. But never before have so many citizens been scrutinized with suspicion.

Under such circumstances the fever of distrust tends to become uncontrollable, with the result that no group is exempt from attack. Even the clergy, normally a respected and trusted segment of the population, found itself touched by the infection. Scientists in particular have had to endure suspicions and to work under conditions that to many of them were personally intolerable or restrictive and eventually damaging to their work.

Obviously this is an abnormal condition in the sense that it is one that has never existed before in this form in our society. It of course raises many questions. In the first place, is it or was it necessary? Is it symptomatic of latent forces in our democracy? Is it an expression of cultural conditions that were aggravated by the tensions of war? Above all, what *are* loyalty and disloyalty?

It is natural that the tensions created by the atmosphere of suspicion and investigation, by the demands for loyalty oaths and by the rediscovery of the Fifth Amendment, should have stimulated some basic reflection on the problems of loyalty and security. In the two books reviewed here some of these questions have been thoughtfully analyzed.

In *The Torment of Secrecy* Edward A. Shils, professor of social sciences at the University of Chicago, has undertaken the formidable task of identifying the basic principles and traditions of a free society and, in particular, of the U. S. "After nearly a decade," he writes, "of degrading agitation and numerous unnecessary and unworthy actions, the disturbance aroused in the United States by the preoccupation with secrecy and subversion has begun to abate. All is not yet entirely serene. Many of the injustices committed have not yet been righted—if they can ever be righted—and security policies are not yet sufficiently realistic, but the abatement is substantial and genuine."

But, he goes on, "a great society should not allow its partial recovery from a humiliating and unjustifiable lapse from decent conduct to diminish the necessity for the conscientious scrutiny of the lapse. It must try to understand in the most detached and unimpassioned way what that lapse signifies in terms of its own history and general principles. It must reaffirm and clarify its standards and turn a cold eye on its weaknesses."

It is Shils's thesis that a free society can exist only when public spirit is balanced by an inclination to mind one's own business. There is a necessary balance between publicity, privacy and secrecy. Often the balance is an uncertain one, fluctuating in one direction or another, but always righting itself in a sound democratic community. This maintenance of equilibrium is inherent in a pluralistic society such as ours, where men may join together in a variety of ways and where the excesses of one element may be restrained by the interests of another.

Secrecy for reasons of state has always been a barrier to publicity, and attains its maximum and necessary effectiveness in the field of foreign and military policy. Information about military resources, intentions, strategy and tactics are considered legitimate matters for secrecy. Traditionally the major threat to this secrecy was the spy working for the enemy and the major protection the use of counterintelligence.

In the past, because of our traditions and our cultural conditioning, this kind of secrecy was relatively rare. It was, however, generally respected by the institutions of publicity. How was the balance upset?

Shils sees one factor in the existence of another kind of secrecy which before World War II never played an important role in our national life. This is the secrecy of revolutionary activity. It is the fear of such activities that generates an invasion of privacy and demands a heightened uniformity and solidarity. It ignores the legitimate privacy of the individual or corporate body. It calls for publicity and creates a disequilibrium. Inevitably, under these pressures, a greater secrecy is demanded.

Shils considers these tendencies to be peculiarly characteristic of a populistic society such as ours under strain. Publicity in this country, compared for example with that in Great Britain, has always tended to claim prerogatives; thus its encroachment on privacy is more likely to occur. Even our highest officials use the "leak" for political purposes, and our legislators find their careers dependent upon the uses of publicity.

The disequilibrium between publicity

and privacy was brought about, Shils believes, by a number of overt factors. These were the world situation, involving Communism as a threat to our institutions, the atomic bomb and the evidences of conspiracy. But these factors operate because of deeper characteristics of our culture and institutions. In a country of such diverse and recent origins as the U. S., the "Americanism" of various groups comes under suspicion very readily in times of crisis. The older groups question the commitment of the newer ones. Hyperpatriotism becomes a reaction of the insecure. Xenophobia, which goes back to our earliest days and has served to speed the assimilation of immigrants, can become a fundamental cause for uncertainty and doubt in their fellow Americans. Isolationism is another deep-seated determinant that encourages the overt factors of disequilibrium.

Shils sees a reinforcement of these trends in the American practice of politics. U. S. politics makes a heavy demand on the individual performance of the candidate for office. Support from the party organization is relatively unimportant. Thus the candidate is highly sensitive to the voters. He responds to their deep-seated attitudes and to the vocal and vigorous minorities of his district. Face to face with the bureaucrats, he finds himself in competition with them and often at a disadvantage because of their specialized knowledge and competence.

For a long time the intellectual in American politics was an outcast, but in recent years intellectuals began to enter public service. As bureaucrats they inherited the distrust in which the politician has always held them. The situation was aggravated by a number of irritants, among others the feeling on the part of the legislators that the intellectuals considered themselves superior. It is the intellectual who is the hero of Shils's book, and to whose defense he has come. He sets out to explain how it came about that the intelligentsia became allied with the bureaucracy of the U. S., and why leftist attitudes appealed to some of them. Their basic attitudes, he asserts, were in the American tradition. He enters an apologia for the involvement of the intelligentsia with Communist ideas. His case is a cogent one and undoubtedly contributes much to our understanding of the situation that developed in the 1930s. His book might have been more effective if in several instances he had not strained his evidence to the point of absurdity. For example, he argues that *New Masses* appealed to intellectuals because it respected serious books, while *Collier's* and *The Saturday Evening Post* did not. This loaded comparison strikes a rather sour note.

Shils's argument rests fundamentally on the fact that in a pluralistic society citizens must respect one another and accept the role of law. He admits the need for security and a limited secrecy for reasons of state. But security, he feels, must be attained without violence to the essential balance of publicity and privacy; exaggerated fears injure security itself. The outlawing of the Communist Party, for example, he considers to be a hindrance to the surveillance of the Party. The Congressional investigations yielded little, for all the damage they inflicted. The existing mechanisms for security purposes work well and should be allowed to do the job without interference.

The Torment of Secrecy affirms a faith in the self-regulating processes of our democracy, but it does so without minimizing the dangers that beset them. It is an impressive job, and one badly needed in a time like this. Shils ends his book with a plea for a moderation and order that allow for both conservation and change. The enemy is extremism—revolutionary or reactionary.

Morton Grodzins, another University of Chicago professor and chairman of the University's department of political science, has explored in *The Loyal and the Disloyal* another phase of the same problem that concerns Shils. In this book, with a brilliance that shades into facility and overgeneralization, Grodzins has essayed the difficult business of analyzing what makes for disloyalty.

Loyalty, according to Grodzins, is a relative thing; it has many facets and its expression as national loyalty is an outgrowth of a complex series of group commitments and identifications. Even the concept of loyalty to the nation, which we hold as the highest loyalty, is a recent development in Western society; in an earlier time, for example, loyalty to the Church transcended all others. Grodzins' analysis draws from cultural and political data and seeks to give the concept of loyalty, with all its conflicts and contradictions, a dynamic and living reality.

In the sense that loyalty can be equated with behavioral or cultural patterns, all men have loyalties. Generally speaking they have a variety of them. They have loyalties to family; to the group with which they work; perhaps to their union, club or lodge; to their occupation or profession, and ultimately to the nation. This follows from the or-

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ganization of society in which the component elements can be tolerated only as they reinforce the larger body. These loyalties can exist because they serve the basic satisfactions and status that an individual derives from the various groupings of which he is a part.

Besides these indirect connections that foster loyalty, there are also the direct connections that the nation makes with the individual. One example is the actual services rendered to the individual by the nation, although this may be overemphasized and is contradicted to some extent by other sections of Grodzins' argument. Identification of the individual with the nation is reinforced by familiarity, ethnocentrism and, of course, by language and traditions. "Life," says Grodzins, "may be hell. But disloyalty is the last way out. By inclination or by default, most men are patriots."

All men find themselves in a network of loyalties, some of which may be in competition or conflict: the claims of the family as against those of the occupational group, those of the profession as against those of the church, and so on. In this connection Grodzins seems to define conflict as disloyalty and ultimately treason. But conflict need not mean disloyalty. After all, disagreement with the government is still permissible in a democracy. To bolster his argument on the strength of primary group loyalty Grodzins cites the data of the French psychologist Jean Piaget on the strength of face-to-face relationships among children. These are often more powerful than parental or other controls. It is risky, it strikes me, to draw an analogy between adult behavior and that of children still in play groups. The patterns of behavior go through developmental stages; the compulsions for the six-year-old are not necessarily the same as those for the 16-year-old or the adult.

Some men resolve conflicts between national and non-national loyalty by occasional choices against the nation; others drift aimlessly into national disloyalty. But for most men the national loyalty is ambiguous enough to contain the various conflicts. Thus the Poles of Chicago can urge an anti-Soviet policy on the U. S., fulfilling a loyalty to Poland and acting as Americans at the same time.

In contrast with the dynamics of loyalty in a democracy, totalitarian regimes deliberately foster direct ties. The primary groups are controlled; in a sense all life becomes political. Terror, although often overestimated as an effective political force, goes a long way in reinforcing loyalty to the nation.

Grodzins illustrates the origin of disloyalty by the case of the Japanese-Americans who during World War II were evacuated from their homes in California and held in concentration camps. The example is used to demonstrate how devotion to family and to American ideals of justice (which the Japanese felt had been betrayed) could result in disloyalty.

The road to treason itself grows out of disloyalty and discontent. As Grodzins points out, the paths are numerous and devious, but alienation starts the journey. The mechanism he suggests is that since loyalty is an essential feature of human life, the individual whose loyalty is destroyed for one reason or another must seek a new loyalty. Adrift and lonely, he may join a deviant group. Friendship, living up to the demands of the group, dedication and integration lead him on and eventually make any break with the group extremely difficult. Grodzins indicates that these conditions only rarely make for disloyalty. Most people, "despite disenchantment," do not go the whole road. Does Grodzins mean to suggest that disloyalty is largely due to accident? If so, why are there so few?

The ambiguity of the terms used by the author unfortunately make the reader a bit uncomfortable. For example, we are offered as an instance of disloyalty the butchers who flouted price regulations during the war. "Such violations clearly define the stuff out of which disloyalty is made." This goes far beyond the legal and customary definition of disloyalty and ends by becoming a *reductio ad absurdum*. Since everyone breaks or flouts some regulation or other —traffic, tax and so on—we are all disloyal and on the road to treason.

Grodzins describes the Duke of Windsor as an alienated person—the inference being that he chose love instead of country. I must confess that it is hard to accept the former Edward VIII as an alienated Briton bereft, according to Grodzins' definition, of the satisfactions of play groups and of national identification.

Where are the disloyal to be found? Grodzins suggests: Wherever there are dissatisfactions and alienation. Although they are not to be found in any one group, conditions favorable for their emergence are probably more frequent in some. College students, because they are generally in a stage of social transition and have not yet established themselves in the social milieu, are particularly susceptible. Moreover, the idealism of college students makes them readier for discontent.

To illustrate the fine line that divides the loyal from the disloyal, Grodzins has coined the word "traitriot." A traitriot may be one who puts certain values, like the welfare of all mankind, first and that of the nation second. He may be an American-born Japanese who has become pro-Japanese because he has cherished values of American democracy which, in his experience, have been violated. Traitriotism may also be found in shifting loyalties to a social class or group. An example is the man who rises in the social scale and abandons his old loyalties and friends. Here we have an illustration, it seems to me, of a defect in Grodzins' exposition: he freely equates social and political loyalty. This undoubtedly enlarges the scope of his analysis, but it also makes it less convincing.

In the concluding section of his book Grodzins discusses the problem of security in the light of his previous analysis of the dynamics of loyalty and disloyalty. Here he is in essential agreement with Shils. The necessity for security is a very real one, he indicates, but he finds that current methods of assuring it are not well suited to the task. Reputations have been ruthlessly destroyed; frustration and discontent generated. Scientists essential to the national welfare have been unnecessarily alienated. More desirable methods of administration and more exact knowledge of the ingredients of loyalty would, Grodzins claims, more adequately protect the nation.

It is, I suppose, inevitable for a book on such a controversial and difficult subject to leave the reader with a sheaf of queries and rejoinders. But one cannot but admire the many insights that Grodzins brings to the problem, and his bold application of cultural studies to the phenomena of loyalty and disloyalty. Grodzins recognizes that he must generalize rather too freely on his data. This may leave the reader who is unfamiliar with this information occasionally gasping for air. But like *The Torment of Secrecy*, *The Loyal and Disloyal* serves to define a problem of the first importance.

Short Reviews

DWELLERS IN DARKNESS: AN INTRODUCTION TO THE STUDY OF TERMITES, by S. H. Skaife. Longmans Green and Company ($5). There are 1,929 known species of termites (1,861 living and 68 fossil), the oldest of the social insects, with an established lineage of some 200 million years. Dr. Skaife's engrossing monograph gives a detailed account of the strange ways of the black-mound termite, common to the mountain

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slopes near Cape Town, South Africa—a species never studied before. Termites, South African or other, are the "most difficult of all insects to study in a living state in the laboratory" and little is known about them. They live in "fortress homes"—assuming they are not at this very moment crunching through beams under your living room—where the rays of the sun never reach them. Skaife's species makes black mounds which rise to about two feet and contain thousands of cells used as living quarters. The cells are connected by circular openings about a sixteenth of an inch in diameter. The building materials of the mounds are particles of soil and termite excrement, a quick-hardening substance which acts as a weatherproof cement; the excrement thus combines the functions of sanitation and construction. In the heaviest winter rains the mounds stay dry; they stand for decades, and a man jumping on a mound does not damage it. The inhabitants themselves are less durable. The majority of the adults are workers, male and female, about a fifth of an inch long, sterile, quite blind, slow-moving, soft-bodied, with white heads and gray or black abdomens. They are defenseless creatures, entirely at the mercy of their age-long foes—agile, aggressive ants that would wipe them out if they could get at them. Part of their protection comes from soldier termites—5 per cent of the population—which are also sterile males and females, the same size as the workers but with large yellow heads and powerful curved jaws. But the soldiers cannot stand off the ants for more than a few seconds. The main protection of the community is the mound itself, which is constantly being enlarged by marvelous engineering operations conducted entirely from the inside. Only in the event of an accidental break are the soldiers called upon to fight. The blind workers fill the hole with grains of sand and cement them together—usually a matter of seconds—and the soldiers on the outside who have been keeping off the ants are left to die. The safety of the community is paramount. Reproduction is the function of a king and queen, who live in plain quarters like their subjects. The king is dark brown, a quarter of an inch long, and timid. When there is an alarm—or, at any rate, when *he* is alarmed—he hides under his wife's huge abdomen which is bloated with eggs and fat. She is one half to three quarters of an inch long, depending on her age, and changes color over the years, from white to reddish brown, as a result of the constant licking of her abdomen by her sons and daughters. She has wing stumps, as does the king. These are the remnants of the wings the pair used on their brief nuptial flight, their one excursion into the outside world, when they departed as prince and princess from the mounds of their respective parents, met, mated, and founded their own community. Both the king and the queen are exalted over all their subjects in having eyes. However, when one lives in perpetual darkness, it is perhaps worse to have eyes than to have been born blind. Skaife's remarkable account, based on years of personal observation, describes the life and order of the community, population control, rearing the young, the succession to the throne, the protozoan parasitic partners of the termite, their enemies, their caste problems. A chapter is devoted to other species of termites, among them the Australian *Amitermes meridionalis* Froggatt which builds the most extraordinary insect structures in the world, the famous Port Darwin wedge-shaped compass mounds. These reach a height of 12 feet and a length of 10 feet and are always placed so that they point north and south; thus they obtain protection from the fierce heat of the midday sun which strikes only the narrow edge of the wedge. An outstanding example of popular natural history. Illustrations.

REALMS OF WATER, by P. H. Kuenen. John Wiley & Sons, Inc. ($6.50). If one were to name the inorganic substance which is the greatest repository of diverse qualities, the most typical embodiment of the laws and forces of nature, the ubiquitous and indispensable servant and supporter of life—the substance would be water. It is the only kind of matter to be found on earth as a solid, a liquid and a vapor. It is responsible for nearly all visible movements in inanimate nature. In the outermost three miles of the earth there is three times as much water as all other substances together. It is an almost universal solvent. It has the highest surface tension of all fluids. It possesses extraordinary properties when subjected to freezing, the greatest thermal conductivity of all liquids except mercury, the highest dielectric constant of all fluids, the greatest heat of vaporization, the greatest thermal capacity and heat of fusion (after ammonia). These are but a few of the facts set forth in this fascinating book by Dr. Kuenen, a noted geologist of the University of Groningen. Rich though it is in scientific details, Kuenen's work is so wide in its scope, so clearly written (and so ably translated by May Hollander), so vivid in its presentation, that the ordinary reader will find it as enlightening and enjoyable as the student does. Dr. Kuenen discusses the cycle of water, the configuration of the ocean floor, tides, the great ocean circulations and currents, the interaction between the atmosphere and the ocean, the effect of water waves upon the earth's crust. His account of wave formation and behavior is a model of lucidity, as is the story of the calculations underlying the damming of the Zuider Zee, a brilliant example of applied research carried out by a committee under the chairmanship of the eminent physicist H. A. Lorentz. We are told that if all the salt dissolved in the oceans of the world were collected and spread upon the continents, they would be covered with a layer 500 feet thick; the total amount of the water in the atmosphere, if condensed, would form a layer no more than one inch thick. Winds, storms, clouds, heating and evaporation at the earth's surface are fully dealt with, as is water in the solid state, including snow, avalanches and glaciers. A chapter is devoted to ground water—from springs, geysers and underground streams to karst landscapes and stalactites. In a section on surface water, apart from the usual topics, one finds delightful out-of-the-way information on potholes, turbulent flow, meanders, fans of debris, and "piracy or beheading"—when one river captures a portion of a neighboring river's territory and so weakens its victim that "it stands no chance of ever recovering its lost domain," and simply gets thinner and thinner in ensuing battles. Many maps, drawings, diagrams and plates, all of which contribute substantially to the exposition.

RUTHERFORD, BY THOSE WHO KNEW HIM. Physical Society (eight shillings sixpence). A collection of the first five Rutherford lectures of the Physical Society of London. The lecturers, H. R. Robinson, J. D. Cockroft, M. L. E. Oliphant, E. Marsden and A. S. Russell, knew Rutherford and worked with him so that, besides describing his scientific discoveries, they are able to add their personal reminiscences. An interesting picture emerges of Rutherford's youth, his education in New Zealand and Cambridge, his career at McGill, Manchester and the Cavendish Laboratory. There is a good deal of overlapping and repetition in the various accounts, and the memories and anecdotes, while mildly diverting, are in the main small beer. Rutherford was of course one of the eminences of modern science and it is understandable that his former pupils

and associates delight in honoring his memory. It remains, however, that his witticisms were not exceptionally witty nor his epigrams memorably epigrammatic, and that the recital of his foibles is of general interest only on the theory that it was gracious of the great man to behave, at times, as foolishly as any other mortal.

Research Reactors ($6.50); Reactor Handbook: Physics ($12); Reactor Handbook: Engineering ($15); Reactor Handbook: Materials ($10.50); Neutron Cross Sections ($12); Chemical Processing and Equipment ($6). McGraw-Hill Book Company, Inc. The purpose of these volumes, most of which were commissioned by the Atomic Energy Commission four or five years ago, is to make available to persons engaged in the reactor field a wide variety of scientific and technical data accumulated in AEC laboratories or by other groups under AEC contract or sponsorship. Issued initially as classified documents, the handbooks have now been revised and released for general distribution, with what is still regarded as "secret" information having been deleted. Since there are frequent innovations in this fledgling sphere of technology, the editors advise the practitioner "to survey the literature from August, 1952, in order to bring himself up to date." But since the later literature may not have been declassified, this procedure may involve difficulties and somewhat limit the usefulness of the series, especially for the scientists and engineers of foreign countries to whose representatives sets of the complete work were presented at the Geneva Conference in 1955.

Calculus: A Modern Approach, by Karl Menger. Ginn and Company ($5). It is unusual for this department to review textbooks, but this is an unusual textbook. Dr. Menger has long been interested in developing improved methods for teaching the calculus. During the war, while directing mathematical courses in the large Navy training center at the University of Notre Dame, he began "serious study of how some of the stultifying routine drill in mathematics might be replaced by instruction that would lead to better understanding." After testing various innovations on his many students, including "slightly tired" engineers, he achieved this new approach. Fundamental concepts are clearly explained at the outset; symbols are unambiguously defined and the rules of operation are precisely formulated. In the first two pages of the book, integration and differentiation are made plain, no less for young beginners than for mature general readers; and by page 13 the vital relation between slope and area—the very core of the calculus—is lucidly exposed. Menger's pedagogic technique embraces several novelties—among them new symbols and the elimination from all consideration of the hallowed y-axis, which plays no role in his conception of the calculus (all curves are oriented only with respect to a basic horizontal line, or x-axis). These features may cause orthodox teachers considerable suffering, and students who already know the calculus—or think they do—will find it a lot harder to get used to Menger's accent than those who are first tasting the language. Still the renovations are likely to benefit all concerned, sophisticates as well as innocents, for it is doubtful that a sounder and more sensible entry into the subject has appeared in many years.

The Veteran Motor-Car, by David Scott-Moncrieff; The Vintage Motor-Car, by Cecil Clutton and John Stanford. Charles Scribner's Sons ($5 each). These indispensable shelf items for boys and girls of every age present a delightful sampling of facts about automobiles made between 1905 and 1914 and 1919 and 1930. Among the subjects of loving attention are the leading racing drivers (gentlemen and professionals), classic endurance and reliability tests, races and hill climbs, great builders and designers, the evolution of engines and body styles, fashions in motoring clothing, relevant statistics. Noteworthy items: In the pre-windshield period the standard cold-weather driving uniform in France was a goatskin coat with the fur outside; in the U. S., a raccoon coat; in England, a "dark-blue melton cloth lined with fur" topped—so as not to be conspicuous—by a bowler hat. Lady drivers were not required to wear corsets; lady passengers regarded as a sports car "any car which you cannot walk through with your hat on." The 1907 Peking to Paris race was won by the Prince Borghese in an Itala. In 1904 a secondhand 60-horsepower Fiat (four speeds ahead, magneto ignition, red upholstery) was advertised for sale at 1,500 pounds. The 1917, seven-h.p. Bébé Peugeot, designed by the immortal Ettore Bugatti, is the most marvelously edible-looking car ever built. The 1908 four-cylinder Cadillac was so beautifully engineered that three separate specimens had their parts "scrambled" and reassembled under the observation of Royal Automobile Club judges—a feat

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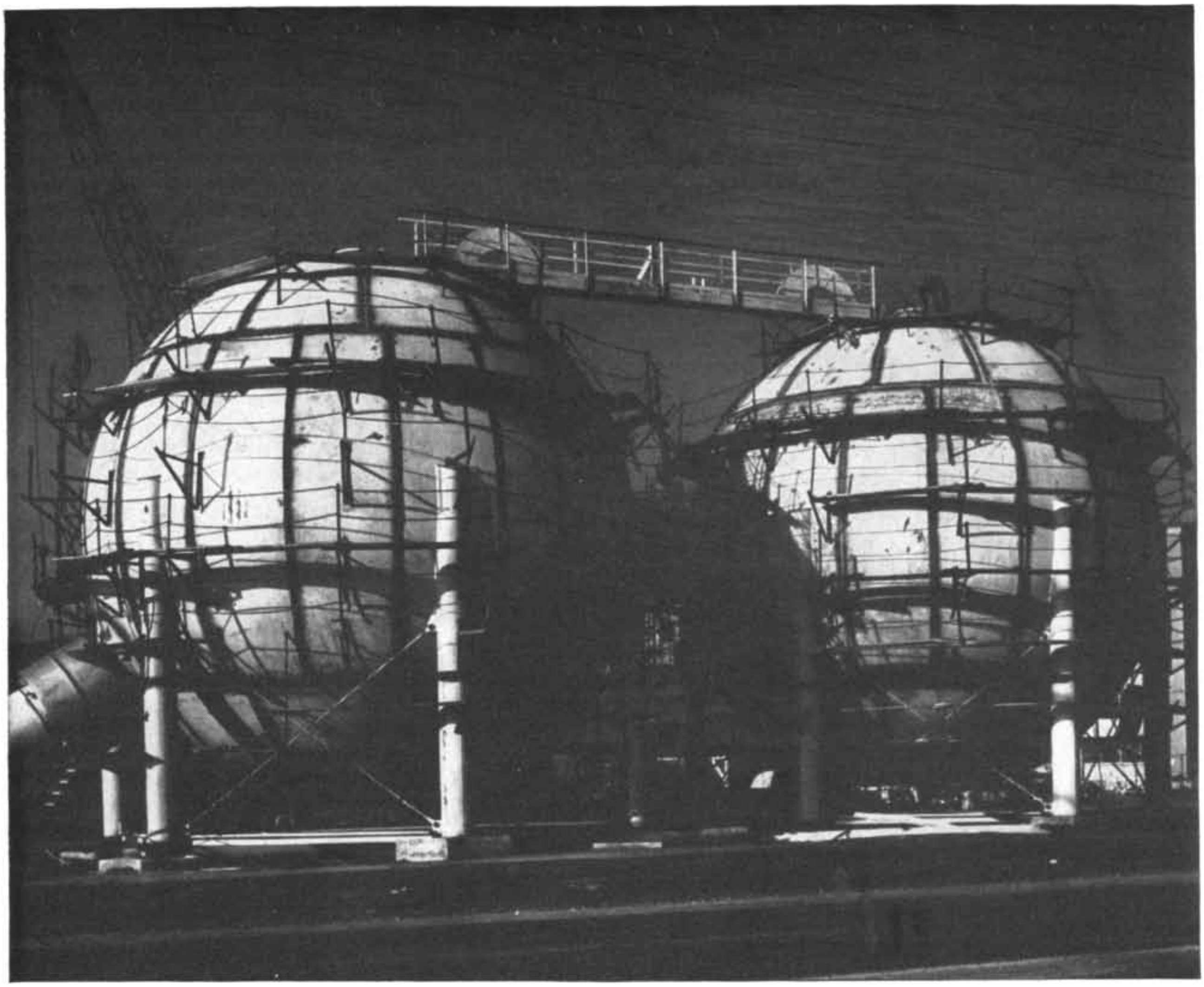
"never seen before or since." The net profit to the makers on each Cadillac was $20. Fine photographs.

Studies in Ancient Technology, by R. J. Forbes. W. S. Heinman (three volumes, $5.50 each). These attractive, admirably illustrated volumes contain a collection of essays on ancient technology by a University of Amsterdam scholar well known in the field. Among the subjects surveyed by Dr. Forbes are the uses of bitumen and petroleum in antiquity, water supply, irrigation and drainage, land transport and road building, cosmetics and perfumes, foods and alcoholic beverages. His studies, rich in detail, give vivid pictures of the arts and crafts of Egypt, India, China, Mesopotamia, Rome, Greece and other ancient lands. One reads, for example, of the widespread uses of bitumen as a bonding and mending material, for lighting and heating, for waterproofing, in magic and medicine (just the thing, according to Pliny, for a chronic cough or shortness of breath), as a fumigant in agriculture, for mummification and embalming. Bituminous materials, including petroleum, were also much used in warfare to set fire to ships and the walls and buildings of enemy cities, either by direct application or by coated arrows; and as "Greek Fire" (a mixture of petroleum and quicklime) in hand grenades, syringes and various missiles "for the burning of armies." A most interesting essay describes ancient recipes for eye paints, rouges and powders, the manufacture of cosmetics, and classical make-up secrets. To free the face from wrinkles Egyptian ladies used a mixture of gum of frankincense, wax, fresh balanites oil, and rush nuts ("Make it and thou shalt see," says the recipe). "Interior of the fruit of the kesbet tree is mixed with red ochre and applied to the face very often" to "expel spots in the face." Powder puffs and long, elegant lipsticks were widely used. The great Roman baths had special anointing rooms with heated floors and pictures on the wall; each part of the body had its own perfume, and at fashionable dinners precious unguents were "sprayed on the guests from pipes installed for the purpose." Pastilles were sold for bad breath. Henna was used as a nail paint and both manicure and pedicure were considered essential. In Greece a wealthy lady disposed an army of beauty specialists; it consisted of "tractatores" to give her an after-bath massage, "unctoristes" to rub her with cosmetics, "depilaristes," "pictrices" to brush her hair, "ciniflones" who "combed, lustered (sometimes with gold dust!) and undulated her hair with irons," "phialiges" who painted her brows and hair, "psecacies" who perfumed and "ponceuses" who powdered her face, "catoptrices" who held her mirror, "flambaries" who held her fan, "appraciatrices" who directed the operations, and "cosmetes" in charge of the dresses.

Information Theory in Psychology, edited by Henry Quastler. The Free Press ($6). The rather severely technical papers collected in this volume, most of them drawn from a 1954 conference arranged by investigators at the University of Illinois, deal with the applications of information theory to experimental psychology. As the editor points out in an interesting essay, the theory which has grown from the writings of Claude Shannon and other pioneers appears to provide useful tools in making models of "human information processing." Between the stimulus, which is the observation of a physical fact, and the response, also a physical fact, there is a mediating apparatus—the nervous system. If this is treated as a "black box," one may learn a good deal about input-output probabilities, and in time certain plausible models emerge as to the internal structure and function of the black box itself. Neurophysiological data can then be fruitfully combined with the more formal system to achieve a better understanding of how living beings select, arrange and act upon the information provided by various stimuli. Lest psychologists be carried away by some of the exciting possibilities of this new approach, one of the contributors, Alfred Leonard, warns that a good many researches in which the techniques of information theory are used might be carried out more effectively using older methods or concepts. "It may well be," he says, "that in so doing we would do less violence to . . . the problems we are investigating as well as to information theory."

Galen of Pergamon, by George Sarton. University of Kansas Press ($2.50). This little book, presenting the third of the Logan Clendening Lectures on the History and Philosophy of Medicine, exhibits the late George Sarton's ample erudition, sympathy and ability spiritedly to portray the leading figures of science in the intellectual, social and political setting of their time. The range of Galen's interests and skills was astounding. He was an anatomist and physiologist; a physician, surgeon and pharmacist; a philosopher, historian and philologist. The famous Kühn Greek-



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Latin edition of his works consists of 22 thick volumes, and is probably not complete. Dr. Sarton sketches Galen's life and background, his thought, his treatises, his character and style and his influence—which deserved to be great but was even greater than it deserved. As in all of Sarton's writings, the extensive scholarly footnotes, while somewhat profuse and adorned, are full of engaging historical trinkets.

Notes

THE ANNUAL SURVEY OF PSYCHOANALYSIS, VOLUME III, edited by John Frosch, Nathaniel Ross, Sidney Tarachow and Jacob A. Arlow. International Universities Press ($10). The third volume of this useful, comprehensive annual which presents skillful condensations of the current journal literature of psychoanalytic theory and practice.

ADVANCES IN APPLIED MECHANICS, VOLUME IV, edited by H. L. Dryden and Th. von Kármán. Academic Press, Inc. ($10). Eight survey articles appear in the fourth volume of this series, discussing such topics as the turbulent boundary layer, nonlinear elasticity, physical and statistical aspects of fatigue, dislocation theory of plasticity of metals, elastic stability.

SURVEYS IN MECHANICS, edited by G. K. Batchelor and R. M. Davies. Cambridge University Press ($9.50). A collection of surveys of research in mechanics written in commemoration of the 70th birthday of the noted British physicist Sir Geoffrey Taylor. The range of Sir Geoffrey's work is evidenced by the fact that each of the 10 articles is in a field in which he has been active.

LAND, AIR & OCEAN, by R. P. Beckinsale. Essential Books, Inc. ($4). An ably written and dependable introduction to physical geography. The general reader as well as the student will find in these pages a sound and succinct presentation of basic information on the earth.

THE NEZ PERCÉS, by Francis Haines. University of Oklahoma Press ($5). A history of a famous tribe who once ruled the Pacific Northwest, were "renowned fighters, yet eager for peace." Dr. Haines tells the story of these attractive people from the days of their glory as horsemen and hunters on the Plains to their present status as small farmers and ordinary members of the community in central Idaho, whose customs and traditions are gradually fading.

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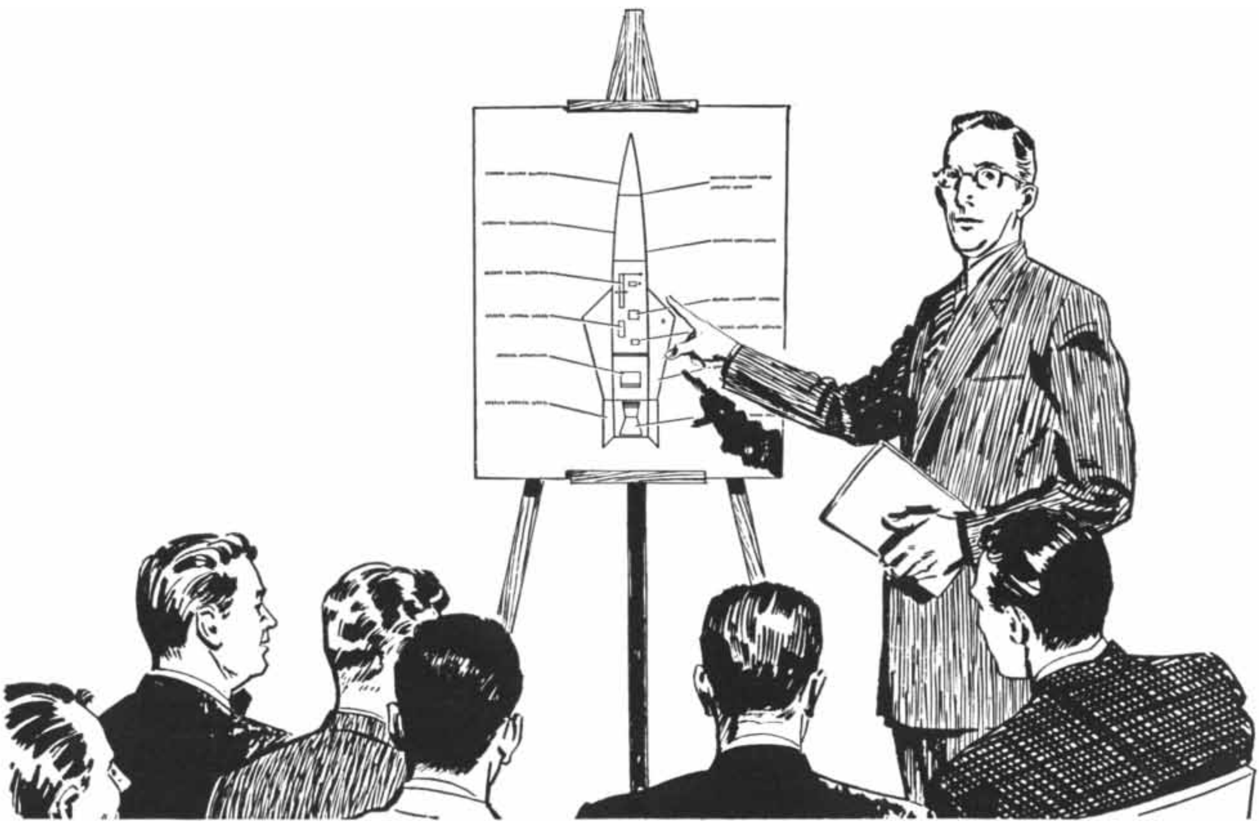


THE AMATEUR SCIENTIST

Concerning an inexpensive and safe method for the generation of X-rays

Harry Simons of Kearny, N. J., is a lonely amateur scientist. "For 23 years," he writes, "I have been dabbling in the X-ray portion of the electromagnetic spectrum without once coming across a fellow amateur. Thousands of enthusiasts can be found in the region of radio waves, of light and of gamma rays. But none of them come to play in my back yard. If the prospect of exploring fresh electromagnetic territory sounds interesting to any of these amateurs, I can promise good hunting in the 10^{-8}-centimeter region—and for a total investment of less than $20."

As a lure Simons offers the collection of radiographs reproduced on the next page. He takes special pride in the picture at the top, which shows screws embedded in an inch-thick block of wood. This shot resulted from his first experiment with X-rays and illustrates what can happen when a fellow with a sharp eye follows a happy hunch.

During a rainy weekend back in 1933 Simons was fiddling with an Oudin coil. This almost-forgotten gadget, a close relative of the Tesla coil, can step up low voltages 1,000 times or more. High voltage generated in this way has an advantage for the amateur experimenter in that it is relatively harmless. In the course of stepping up the voltage the Oudin coil also increases the frequency of the current, so that it tends to flow through the skin and away from vital organs such as the heart.

"My original Oudin coil," Simons writes, "was part of an ultraviolet lamp with which I tested mineral specimens for fluorescence. For no particular reason I decided to replace the evacuated quartz bulb, which produced the ultraviolet rays, with an old radio tube of the 01 type. The glass envelope of these tubes is coated inside with a silvery film of evaporated magnesium—the so-called 'getter' which helps clear the tube of stray gas during the evacuation process and absorbs any that may be liberated by the glass walls or metal parts after the seal-off. I simply held the 01 in my hand and touched its prongs to the high-voltage terminal of the coil.

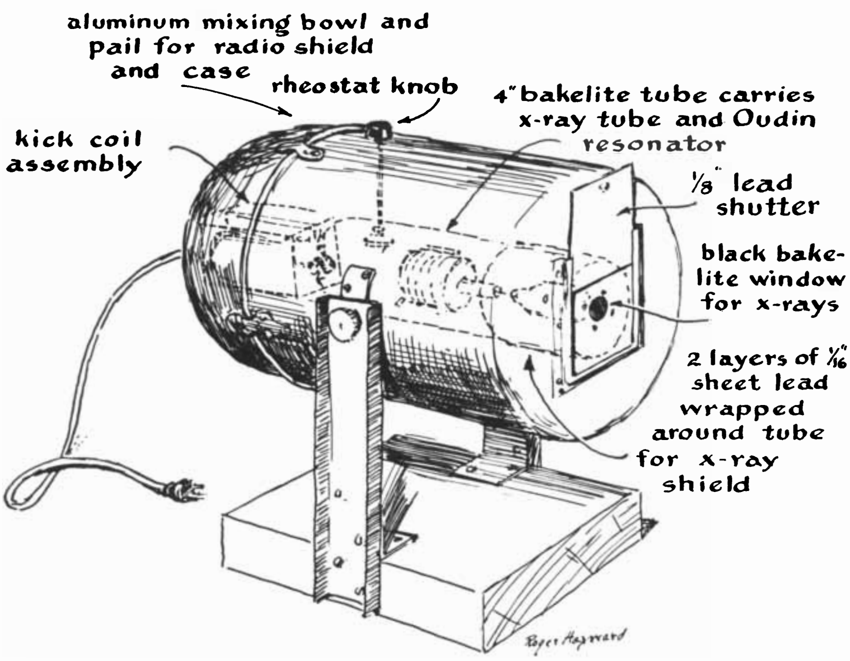
"Instead of filling with a lavender glow, like the quartz bulb, the inside of the tube remained dark but the glass in contact with the magnesium lighted with a pale greenish fluorescence that reminded me of the glow emitted by old style X-ray tubes of the gas type. Was the radio tube producing X-rays?

"To obtain the answer to these questions I put a narrow band of tinfoil around the top of the tube and grounded it—as a substitute for the electrode previously represented by my hand. I then fished a small block of wood, which happened to have two screws in it, from the trash box and placed it on a sheet of photographic film wrapped in black paper. The combination was exposed to the energized tube for 15 seconds at a distance of seven inches. When I had developed the film, I discovered a wonderful radiograph of the screws—plus a lifetime hobby that should appeal to anyone interested in physics."

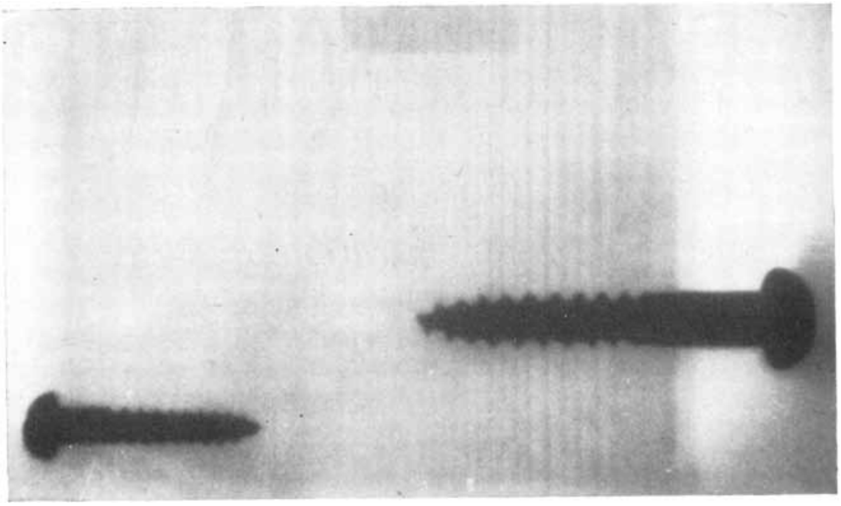
Why has Simons's hobby failed to catch on? One reason is that commercial X-ray equipment is costly. Even tubes of relatively low power are priced at $100 and up. Many other commercial X-ray parts are also expensive and difficult to procure. The apparatus supplying high voltage to conventional tubes, while no more complex than the power supply of a husky radio transmitter, calls for special rectifying devices, transformers and other components not regularly stocked by dealers in electrical supplies.

Moreover, X-rays have earned a bad reputation as playthings. No distinction can be drawn between the danger of exposure to a high-powered X-ray machine and the fallout of an H-bomb. It is a danger that extends not only to the experimenter but to his potential progeny. Human evolution is the result of mutations caused by, among other agents, cosmic rays and the radiations of radioactive elements in the earth's crust. Any radiation added by man alters the rate of mutation, and is rightly a cause of deep concern.

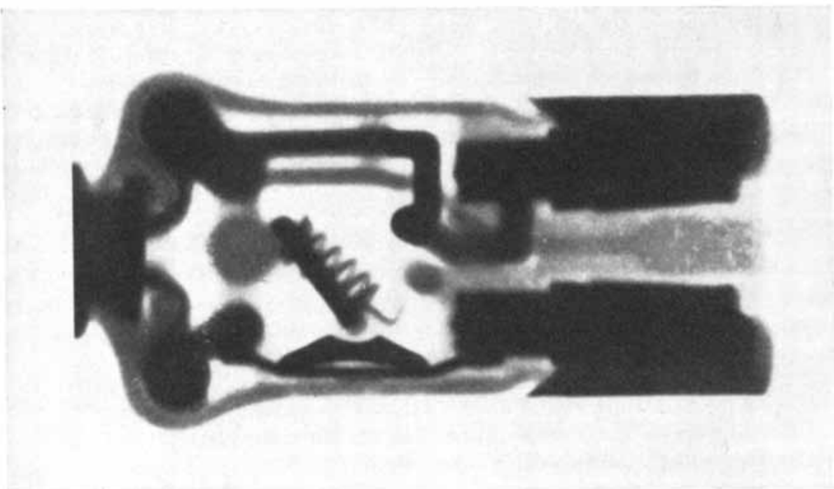
Simons has solved the problem of



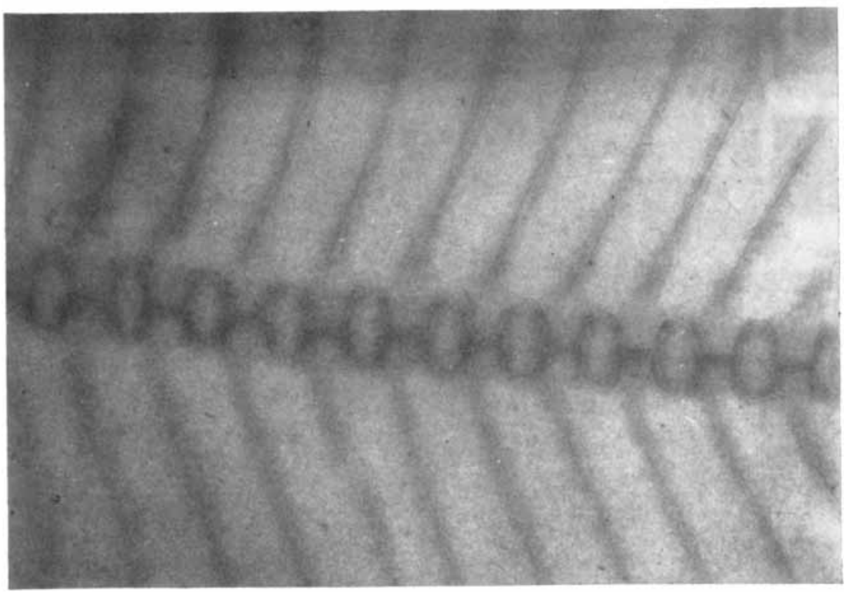
X-ray apparatus built by Harry Simons of Kearny, N. J.



Simons's radiograph of two screws in a block of wood



Radiograph of the plug from an electric flatiron



Radiograph of bones in a fish

equipment cost. Protection against exposure to the rays is not difficult to arrange. With these two considerations out of the way, X-rays open a range of experiments equaled by few other phenomena of physics. In addition to providing a source of X-rays for radiographs, a generator of X-rays in combination with accessories enables you to measure the charge of the electron, to study the structure of crystals, to observe the wave-particle duality of matter and radiation, and to probe other microcosmic corners.

Like visible light, X-rays are a form of radiant energy. Their ability to penetrate substances opaque to visible light, however, is neither unique nor particularly unusual. Many substances opaque to light are transparent to other electromagnetic waves. For example, long electrical waves, as well as the shorter ones of radio, pass freely through dry wood, plaster and other substances that do not conduct electricity and are opaque to light. If this were not so, all radio and television receivers would need outdoor antennas. On the other hand, a thick sheet of flint glass, which transmits radio waves and light with no appreciable loss, stops X-rays. The ability of X-rays to penetrate substances like flesh and bone is merely their most publicized property. However, this property provides a striking case of the immediate application of a scientific discovery. Within weeks of the description of X-rays by Wilhelm Konrad Röntgen in 1895, surgeons heralded them as a tool of the first importance.

They are characterized chiefly by extremely short wavelength—about one ten-thousandth the length of visible light waves. Like light waves, X-rays can be reflected, refracted, diffracted and polarized. The techniques by which they are manipulated differ from those employed with light, just as light techniques differ from those of radio. The longest X-rays are indistinguishable from ultraviolet rays; the shortest are identical with gamma rays. The distinction between the two is largely a matter of definition. When the emission accompanies the disintegration of a radioactive substance such as radium, it is called gamma radiation. Identical waves generated by electronic means are called X-rays.

All radiant energy, including X-rays, has its origin in a disturbance of electrical charge. Consider a point charge—an electron—surrounded by a symmetrical electromagnetic field and moving through space at constant velocity. What happens to the motion of the field if the central charge is speeded up or slowed down? Experiments indicate that the

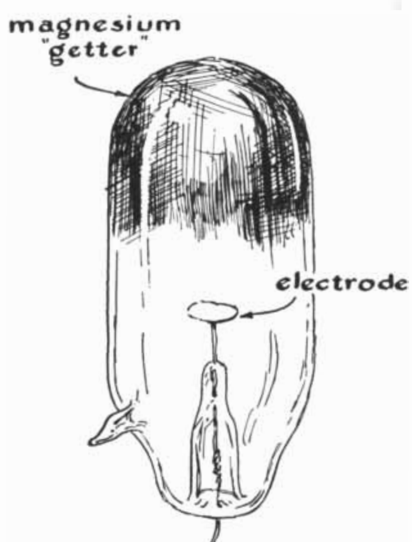
field reacts much like a mass of jelly. When the central charge is accelerated, the disturbance is communicated radially through the field as a wave motion—the outside parts of the field requiring an appreciable time interval to catch up with the center. Work expended in accelerating the central charge is carried away by the wave as radiant energy, at a velocity which depends on the nature of the "jelly." In a vacuum the wave attains a maximum velocity of slightly more than 186,000 miles per second. The length of the wave depends upon the abruptness with which the central charge is either disturbed or made to change direction. Violent disturbances require the investment of more work than gentle ones, and result in proportionately shorter and more energetic waves. The waves radiated by electrical power lines, in which a stream of electrons changes direction only 60 times a second, measure about 3,200 miles from crest to crest.

It is possible to subject electrons to much faster oscillations. Military radars, for example, are constructed around magnetron oscillators, small copper chambers that have been called electrical counterparts of the familiar police whistle. The cavities are electrically tuned to frequencies on the order of four billion cycles per second, and streams of electrons forced into the cavities vibrate at this rate. The resulting electromagnetic waves measure some three inches from crest to crest. As the cavities are made progressively smaller, the pitch goes up and the wavelength goes down in obedience to the principle that the smaller the whistle, the shriller its note. Where, then, can a "whistle" be found that will accelerate charges rapidly or abruptly enough to create electromagnetic waves a mere 25 thousandths of an inch long—the wavelength of visible light? Nature provides such systems in the form of molecules and atoms.

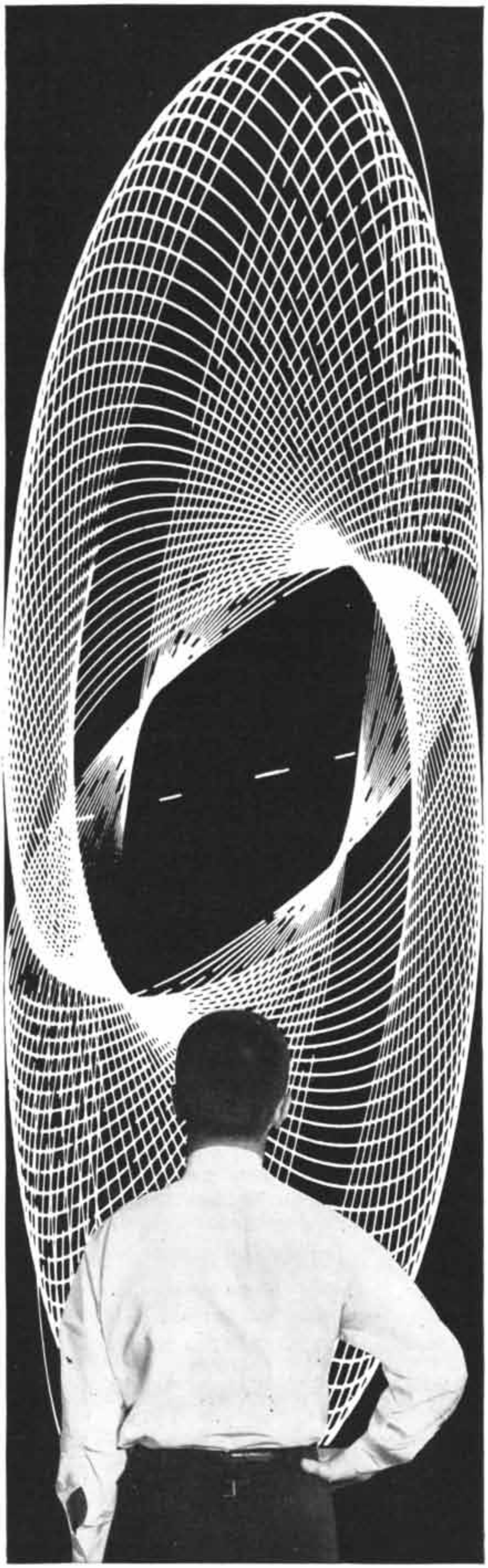
The normal, stable atom emits no radiation unless it is acted upon by an external source of energy. If a fast-moving electron encounters an atom in its normal state, the interloper may collide with one of the planetary electrons in the outer orbital shell of the atom. The impact may cause the electron in the atom to jump to an orbit still more remote from the center of the atom. A sufficiently energetic electromagnetic wave impinging on the atom can accomplish the same end, the requirement being that the frequency of the wave coincide with the period of the outer electron's orbital motion. In either case the atom gains energy from the encounter and thus becomes unstable. The normal state is soon restored when the electron hops back into its "home" orbit. This represents the shifting of a center of charge, and the excess energy is radiated into space by the accompanying electromagnetic wave. The abruptness of the jump, and hence the length of the wave, depends upon the attraction of the positive nucleus for the planetary electron. When loosely bound electrons occupying an orbit remote from the nucleus make such jumps, the length of the radiated wave measures on the order of 25 thousandths of an inch—the wavelength of light.

This same mechanism accounts for the origin of one kind of X-ray. When a free electron, accelerated to a velocity of some 18,000 miles per second, collides with an electron occupying an inner shell of the atom, both the interloper and the inner-shell electron may carom into space. The vacancy thus created is immediately filled by an electron from a shell more remote from the nucleus. The attraction of the nucleus for this electron is immense and the jump accordingly violent. The resulting wave measures on the order of 250 millionths of an inch—an X-ray.

This initial jump does not end the display. A vacancy has been created in the adjacent orbit by the electron that moved inward. Hence a series of jumps follow as electrons from orbits still more remote from the nucleus move in to fill the succession of gaps. In the end the atom must capture a new electron to complete its outermost orbit. In the meantime the atom has emitted a whole set of waves at progressively lower frequencies, beginning with X-rays and ex-



One of Simons's X-ray tubes



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AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE tending through ultraviolet radiation and visible light to heat.

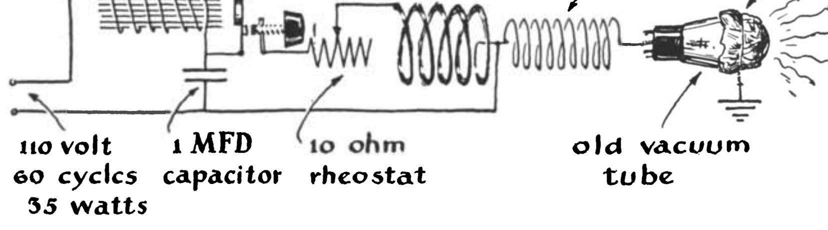
The pattern of forces acting between the nucleus and orbital electrons responsible for the radiation is unique for each kind of atom. Measure the radiation emitted at each frequency and you have an identifying tag for the atom. This is the basis of spectroscopy. The fundamental particles of the atom move in their orbits at rates fixed by these same forces. In effect the atom is "tuned," much as a group of radio receiving sets might be pretuned for a group of broadcasting stations.

Atoms low on the periodic table, such as carbon, hydrogen, oxygen and nitrogen—the stuff of living matter—are far out of tune with X-rays of extremely high frequency. When such waves impinge on protoplasm, they ignore the barrier and sail right through.

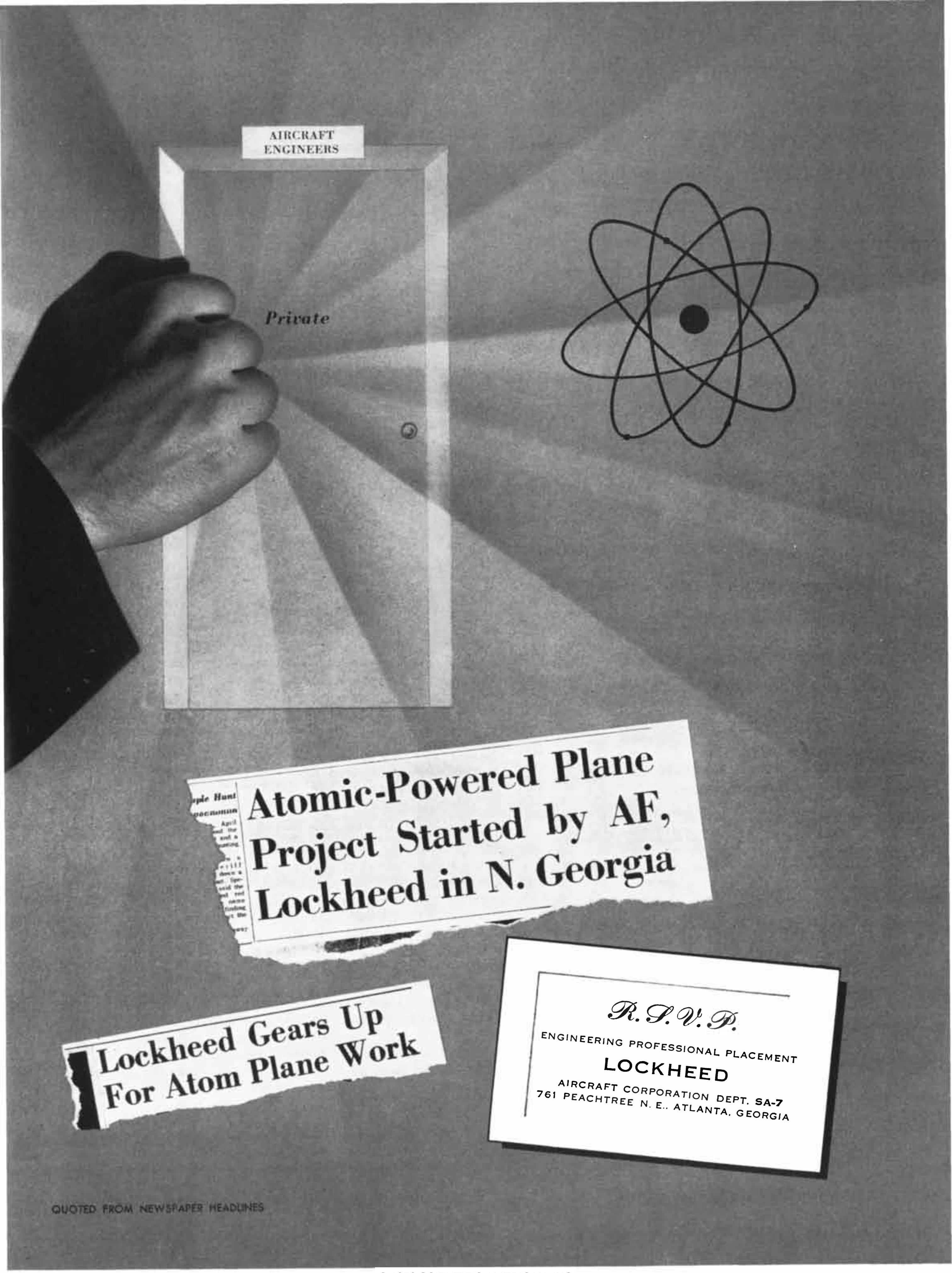
X-rays of the highest frequency, those used for making most radiographs and for the treatment of disease, are liberated when the bombarding electron crashes into the massive nucleus of a target atom. The precise nature of such encounters is not fully understood, but it appears that when the bombarding electron collides with the nucleus head-on, and is stopped dead in its tracks, the onrushing field consumes the entire mass of the arrested particle and, in effect, transforms the electron into an X-ray of very high energy and frequency. Other electrons strike the nucleus glancing blows, and are thus decelerated. The deceleration is accompanied by the emission of an X-ray of proportionate wavelength and energy. Hence when a stream of bombarding electrons plays on a target composed of massive atoms, the emission of radiant energy includes: (1) X-rays liberated by the acceleration of planetary electrons, characteristic of the kind of atoms comprising the target, and (2) X-rays that span a continuous band of frequencies from the ultraviolet range to those of almost infinitesimal wavelength.

It was this continuous or "white" X-radiation, arising from the bombardment of silicon nuclei in the glass of a Crookes tube, that led Röntgen to his discovery. While studying the green fluorescence that appears at one stage in the evacuation of the energized tube, Röntgen observed a bright fluorescence among some nearby crystals of platinocyanide. The crystals continued to glow even after he covered the energized tube with black paper. He concluded that the tube was emitting a previously unobserved form of radiation. The Crookes tube consists of a pear-shaped glass bulb that is partially evacuated and fitted with a cathode at the small end and an anode at the large end. When a direct-current potential of about 20,000 volts is connected across the electrodes, positive ions, accelerated by the electric field, bombard the cathode and dislodge electrons from the metal. Most of these are attracted to the anode, but some overshoot the mark. The latter electrons continue to the end of the tube, where they collide with the glass target.

Soon after Röntgen's discovery, the mechanism of white X-ray production was explained by a number of investigations. These paved the way for improvements in the tube. By shaping the cathode in the form of a paraboloid, for example, the electron stream could be focused sharply on a metallic target composed of atoms more massive than silicon. X-rays liberated at the spot were more energetic and cast sharper shadows than those from the broad expanse of glass. Electrostatic machines for the production of accelerating voltages grew in size until some featured a spinning disk of plate glass seven feet across, capable of generating 200,000 volts and currents up to five milliamperes. All the early tubes contained some gas, the atoms of which were needed as a source of electrons. The gas imposed an upper limit on the accelerating voltage. The limitation was impressively removed in 1913 when W. D. Coolidge of the General Electric Company succeeded in making ductile filaments of tungsten, which he substituted for the cold cathode of the gas



Circuit diagram for Simons's X-ray apparatus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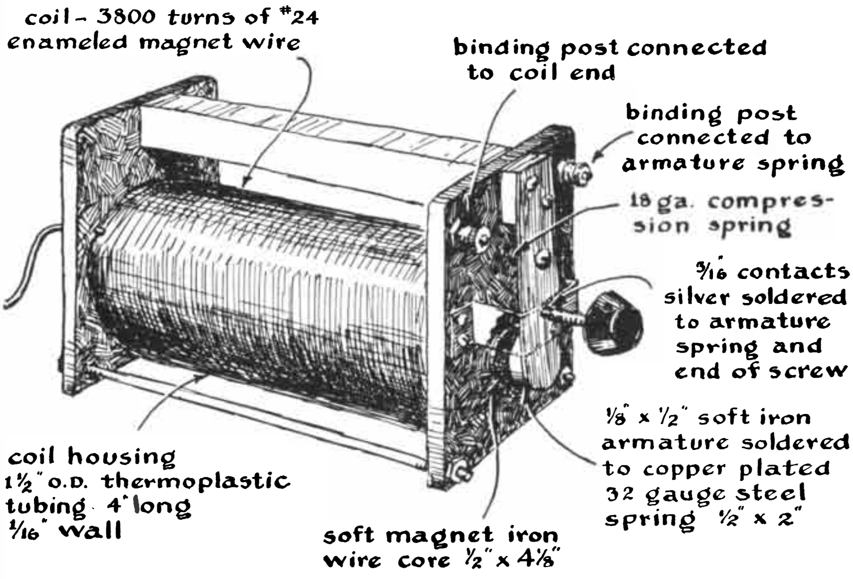

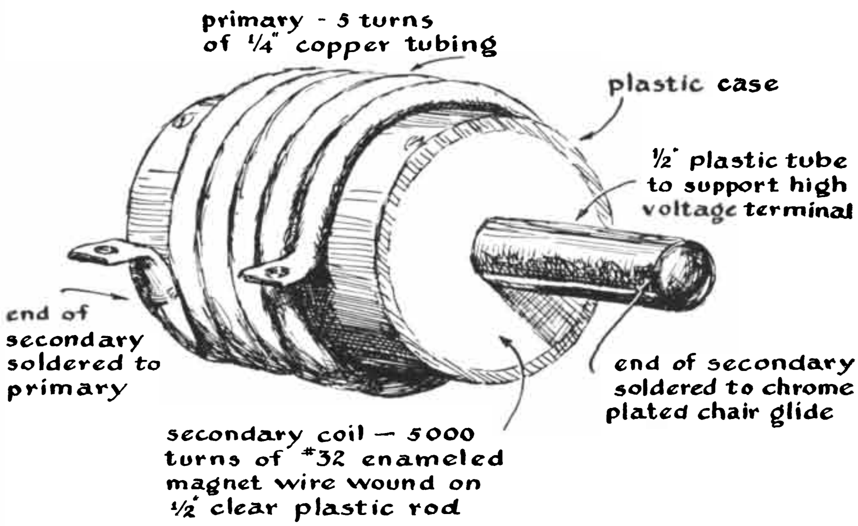

A source of high-voltage for Simons's apparatus

tubes. With this independent source of electrons, tubes could be evacuated to the limit of pumping techniques. Accelerating potentials of 300,000 volts and more became practical. Such power levels aggravated another problem; the heating of the anode or target. This problem was first tackled by using tungsten, with its high melting temperature, at both ends of the tube, then by cooling the target with water, and finally by focusing the bombarding electrons in a small spot near the edge of a motor-driven disk made of tungsten.

Although Simons's tube is a far cry from large X-ray tubes of the modern Coolidge type, it performs astonishingly well. A number of years ago Simons shipped his first machine to George L. Clark at the University of Illinois who, after testing it, reported in the journal *Radiology:* "Simons's apparatus proves that X-rays can be produced for experimental purposes by a unit which can be built for a very small fraction of the cost of an installation of standard commercial equipment. The machine, when in operation, will produce a beam of X-rays easily detected for a distance of several feet in all directions. With 'r' meter measurements we determined the intensity of the rays to be three fourths of a Röntgen unit per minute at a distance of three feet."

The explanation of this copious radiation, compared with that of a Crookes tube, appears to lie in the magnesium coating of Simons's generator.

Unfortunately the old 01 and tubes of similar construction are currently in

THE UNIVERSE

Cluster of distant galaxies photographed by 200-inch Palomar Mountain telescope. The galaxies are the blurry or fuzzy, noncircular objects. The picture takes in less than one-fifth of a degree of sky.

short supply because magnesium is no longer favored as a material to remove gases, except in certain types of mercury-vapor rectifying tubes which are unsuitable for X-ray production. For this reason (plus the fact that he is an inveterate experimenter) Simons now designs his own tubes and has them manufactured by a local glass blower. They cost about $15 each. He rarely makes two alike, for the same reason that amateur telescope makers seldom build two identical instruments. Each design is a new and exciting experience. One of Simons's latest designs is illustrated on page 138. This tube is equipped with a disk-shaped cathode of molybdenum and a magnesium target. It is evacuated to a barometric pressure of .0001 millimeters of mercury. The over-all length of the tube is about seven inches. Its emission is substantially greater than that of the 01 tube. The radiographs on page 136, with the exception of the one showing the screws in a block of wood, were made with it. Such tubes can be made with a wide variety of target materials and cathode shapes.

Almost any source of high voltage can be used for energizing X-ray tubes, including Van de Graaff electrostatic generators of the type described in this department [SCIENTIFIC AMERICAN, April, 1955]. Simons prefers to stick with the Oudin coil. It is easily constructed with hand tools. The job is simplified if you can lay hands on a vibrator of the type used in the spark coil of a Model-T Ford. As shown by Roger Hayward's diagram on page 140 and the general view on page 142, the vibrator consists of a core of soft magnetic iron equipped with an armature of soft magnetic iron and a set of breaker points. The core of the vibrator is wound with 3,800 turns of No. 24 magnet wire and connected in series with the breaker points as shown. When bridged with the one-microfarad capacitor and connected to the power line, the self-inductance of the coil is sufficient to charge the capacitor to a potential of several hundred volts when the breaker points are adjusted to open at the peak of the current cycle. The capacitor discharges through the five-turn primary winding of the Oudin coil. The primary is wound with five turns of ¼-inch copper tubing on a 2¼-inch plastic form three inches in diameter. The secondary winding consists of 5,000 turns of No. 32 enameled magnet wire wound on a ½-inch rod of clear plastic. Each layer of wire must be carefully insulated with a layer of varnished cambric that extends well beyond the end of the coil. When the winding is completed, the secondary

coil must be thoroughly doped with high-grade insulating varnish. Both ends of the coil are insulated with a tube of varnished cambric. The assembly is then slipped inside the plastic form on which the primary was wound. The outside end of the secondary is brought out through a small hole in the form and soldered to one end of the primary winding. The inner end of the secondary is threaded through a four-inch length of ½-inch plastic tubing and soldered to the inner face of a chromium-plated chair glide, which serves as the high-voltage terminal. The ends of the primary form are then closed with disks of ¼-inch plastic and secured in place with screws at the edge. A ½-inch hole in the center of one disk admits the tube support for the high-voltage terminal. The chair glide is lifted temporarily and enough transformer oil or potting compound poured through the ½-inch tube to fill the interior. When wired according to the diagram on page 140 and connected to the power line, the coil will produce some 50,000 to 75,000 volts continuously. The power consumption at 110 volts and 60 cycles is 35 watts.

As shown in the drawing on page 135, all this apparatus must be housed in a well-grounded metal container. The X-ray tube must be enclosed in an inner compartment of lead sheet at least ⅛-inch thick. An opening in the end of the double housings opposite the tube provides a window for the X-rays.

Two precautions are of utmost importance. First, Oudin coils are notorious emitters of radio waves that take the form of ragged noise. They can black out radio and television reception for miles around. Federal regulations prohibit the operation of such devices unless they are thoroughly shielded. If any stray radiation can be detected on a nearby radio or TV receiver after the apparatus is assembled as described, it will be necessary to insert a low-pass filter at the point where the power cord enters the housing. The design of such filters is available in standard radio reference texts. Whenever the machine is in operation, the experimenter should wear a lead apron and stand well behind the orifice through which the rays are emitted. It is also advisable to place a few exploratory samples of film around the room while the apparatus is in operation. When developed, these will show the pattern of radiation and protective lead shielding can be installed accordingly. Finally, resist the temptation to make X-ray examinations of the bones in your hands or other body parts. A frozen fish makes a much safer test object.

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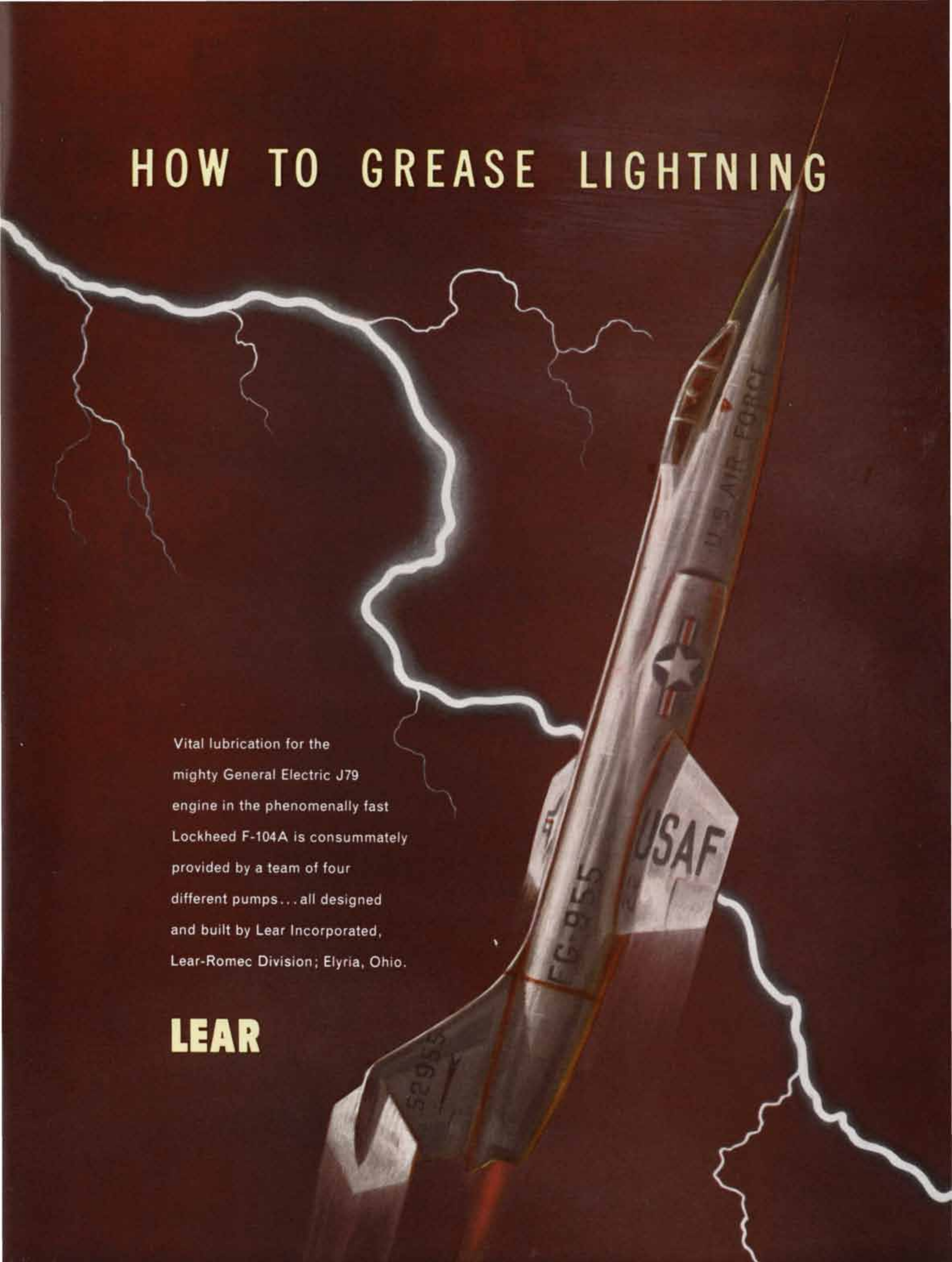
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