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March 1957

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"Hemo the Magnificent"

The fascinating story of blood and circulation

Dr. Frank Baxter and Richard Carlson in a scene from "Hemo the Magnificent"

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Following its presentation last fall, "Our Mr. Sun" was acclaimed by people associated with the sciences as an imaginative and informative TV science drama.

On March 20 you will see the second program in this educational and entertaining series—"Hemo the Magnificent."

Combining actual photo-micrography with ingenious animation, "Hemo the Magnificent" dramatizes the vital roles of blood and circulation in the life process. Scientific accuracy is assured by a distinguished Scientific Advisory Board and four eminent medical scientists who acted as special advisors. The program was produced and directed by Frank Capra, winner of three Academy Awards.

Everyone associated with the sciences will find "Hemo the Magnificent" of unusual interest. Don't miss it—and remind your colleagues to see it on Wednesday, March 20.

Tune in this special science telecast on the **CBS-TV** *network,* **9-10 P.M., E.S.T.,** *Wednesday,* **March 20.** *Check local listings for time and station.*

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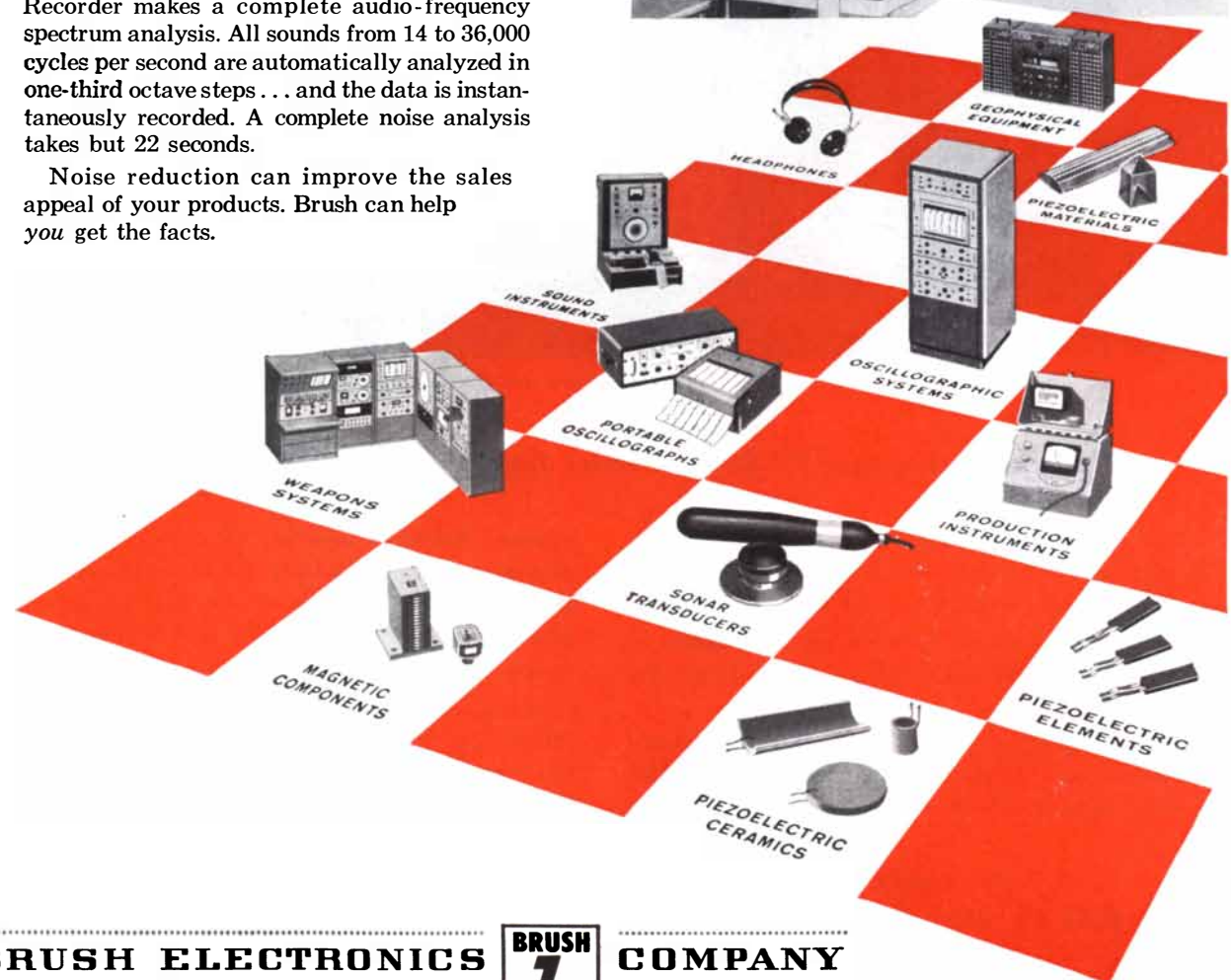

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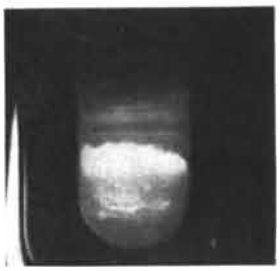
ARTICLES

DEPARTMENTS

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



THE COVER

The photograph on the cover shows the glow of free nitrogen atoms which have been frozen out of an electric discharge. The nitrogen is deposited in a thin layer on the inside of a glass tube which is bathed in liquid helium (*page 90*). The photograph was made in the laboratories of the Free Radicals Section of the National Bureau of Standards.

THE ILLUSTRATIONS

Cover photograph
by Paul Weller

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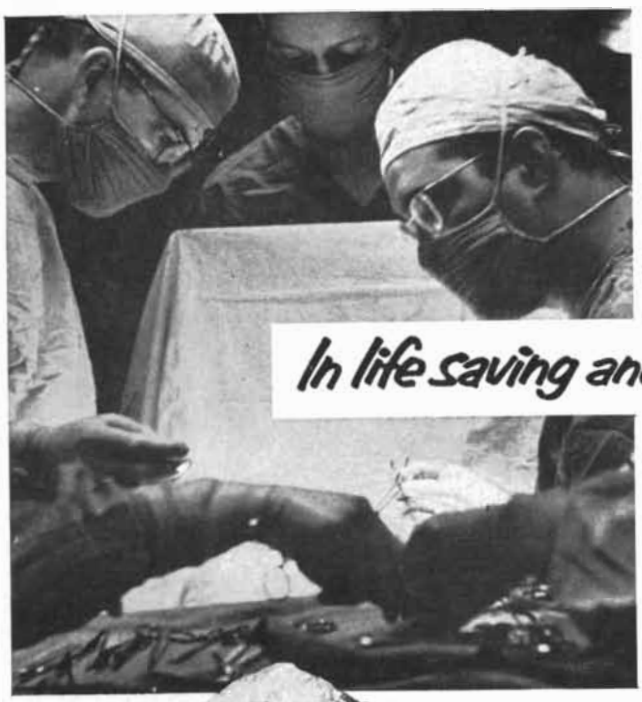

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These fibres also improve asphalt compounds, auto underbody coatings, moulded plastics, gypsum joint sealers, welding rod coatings, caulking compounds, paints, adhesives and other products.

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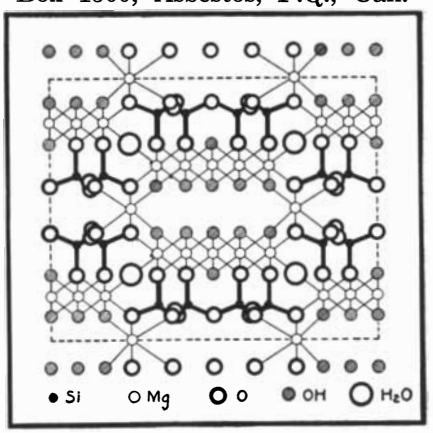

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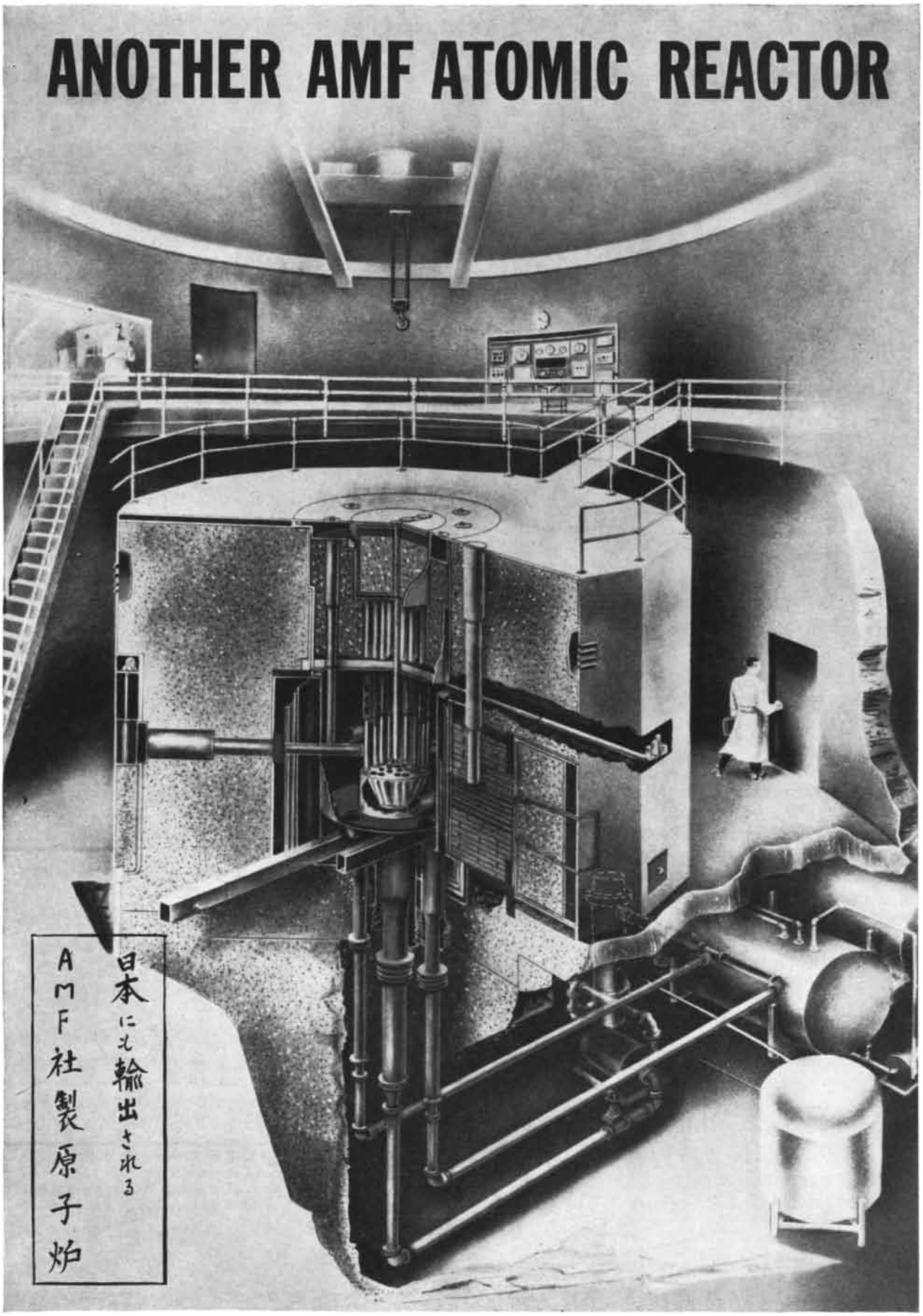
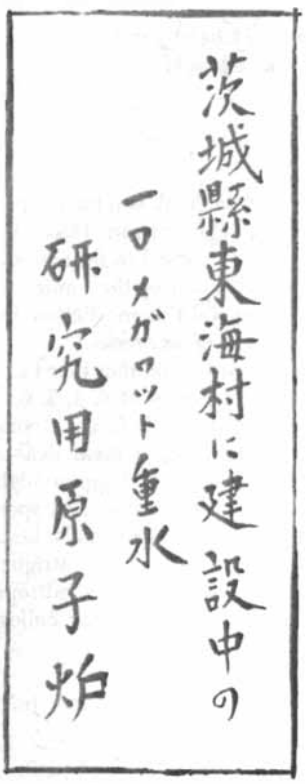


10 megawatt heavy-water research reactor under construction at Tokai-Mura, Japan



The AMF reactor being built for the Japanese Atomic Energy Research Institute is another example of the important role AMF is playing in the development of the peaceful uses of atomic energy throughout the world.

From initial facility planning to final start-up, AMF is assisting research organizations everywhere to build reactor centers that will support both extensive experimental programs and personnel training.

The recognized leader in the design and construction of research reactors, AMF is able to draw upon its extensive experience to provide "Custom Designs", such as the JAERI reactor at Tokai-Mura, at a minimum of cost and delivery time. Many tested design features have been incorporated in the AMF heavy-water system—engineering improvements that have further advanced the safety, versatility, and efficiency of this reactor type. The AMF "Unitized" design approach results in minimum initial costs, greater safety, and simplified maintenance.

Design Features—AMF Heavy-Water Reactor

Power—The AMF heavy-water reactor employs heavy water as coolant, moderator, and reflector. The usual graphite reflector has been eliminated, and a special thermal shield consisting of alternate layers of steel and light water has been incorporated, permitting higher power levels than would otherwise be possible. The higher neutron flux densities are often required for radiation damage studies, isotope manufacture, many in-pile experiments, and solid-state physics work. The AMF heavy-water reactor offers standard power levels of 1, 2, 5, and 10 megawatts, with still higher power levels possible. Flux densities range from approximately 1.4×10^{13} at 1 mw. to 1.2×10^{14} at 10 mw. with 20% enriched uranium. With fully enriched fuel operating at 10 mw., flux densities of 2×10^{14} can be achieved.

Control—Control rods are of the vertical rather than the semaphore type. They are thus not only easily removed for servicing, but provide an even control effect that is directly proportional to control rod movement. Both the mechanical and electronic portions of the system are of the same AMF design that has proved safe and reliable in research reactors now in actual operation both here and abroad.

Safety—All elements of the design have been pointed toward providing the greatest safety possible. Among the numerous safety features included are a dump valve for automatic or manual lowering of the heavy water, which eliminates the vertical reflector. In the event of pump failure, a natural convection path is automatically opened to provide emergency cooling.

A rotary top plug and semi-automatic refueling cask have also been incorporated to provide for safe, easy refueling, eliminating the need for an individual opening and seal for each fuel element.

Facilities—A total of 30 individual experimental facilities are included in the AMF heavy-water reactor. 11 beam tubes, 2 horizontal through-tubes, 2 isotope trains, 4 pneumatic tubes, 10 vertical thimbles, and a thermal column permit an exceedingly wide range of experimental activities. Motor-driven vertical shutters provide convenient access to the horizontal beam tubes. And with AMF's unitized design, these reactor facilities can easily be modified to meet specific research requirements.

For a complete reactor facility, from first plans to final start-up, or merely for reactor components, contact AMF. You'll find AMF Atomics has both the *experience* and the *fully proven technical ability* to assist you in all phases of atomic energy involving research or power reactors and facilities.

See booths 117–21, 3rd ATOMIC EXPOSITION, March 11–15, Convention Hall, Philadelphia

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LETTERS

Sirs:

Congratulations on the very beautiful cover photograph of your January issue. I did not need to open the magazine to know that the picture was of Peru, and was not very surprised to find that the scene was the Callejón de Huaylas, where I spent a very happy summer mountaineering in 1955. This is wonderfully beautiful and fascinating country, and I am surprised that so few North Americans know it. Despite the poverty, one feels there is hope; Peru has the resources to feed her people and give them a decent standard of living, and also, I believe, has the enterprise to do something about it.

One of John and Mary Collier's photographs disturbs me a little. It shows two handfuls of potatoes, the little ones "before," the much larger ones "after" selection of seed and improved culture. The best potatoes I have ever tasted were those the Indians used to bring to our base camp over in the Jancapampa valley, the other side of the mountains, in exchange for medicines and empty tin cans (which were highly prized). While these potatoes were not as tiny as those in your photograph, they certainly were not large. The high Andes is the home of the potato, and all kinds of strains grow together in the same steep fields. I hope our Indian friends will not fall for the cult of bigness where potatoes are concerned.

HAROLD F. WALTON

Department of Chemistry
University of Colorado
Boulder, Col.

Sirs:

I am writing to thank you for the presentation of flexagons in your December issue. I was first exposed to flexagons at Purdue University during the summer of 1955 at the General Electric Fellowship summer program of six weeks.

It might interest the author that I successfully made flexagons of 3, 4, 5, 6, 9, 12, 18, 24 and even 48 faces. It took some doing, but I felt a great deal of satisfaction in doing it. I am a high-school mathematics teacher, and spent one day having my students make hexahexaflexagons in class, and it intrigued the majority of them. It is a good topic to be given in high school or college mathematics clubs.

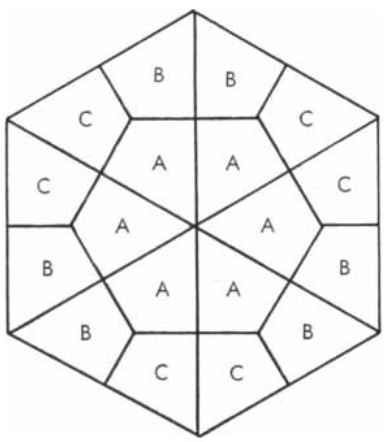
PRYOR T. SMITH, JR.

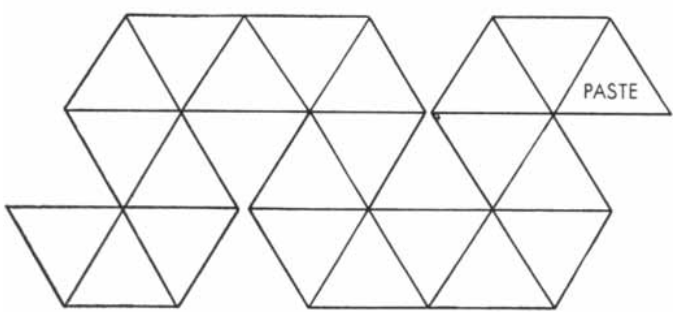
Winterset, Iowa

Sirs:

Apparently many initiates into the art of flexigation succeed, like Mr. Smith, in constructing flexagons up to six faces, but are unable to find the elusive seven-faced heptahexaflexagon. It can be folded from any one of three "crooked" strips, one of which is pictured below.

One strip folds into a heptahexa in two different ways, making four dis-

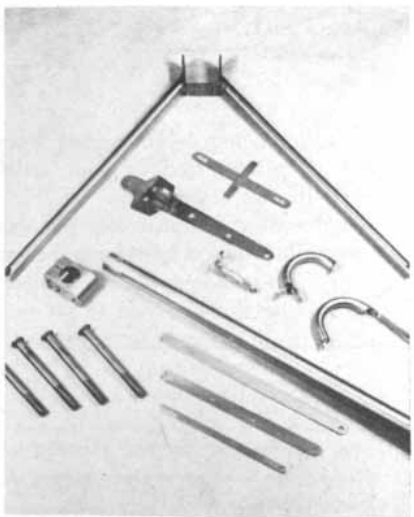




The hexahexafrustragon (top) *and a strip that may be folded into a heptahexaflexagon*

Progress with **TITANIUM**

Over 1,000 years of salt water would whittle only 1/1000 of an inch off titanium



Marine fittings fabricated from Mallory-Sharon unalloyed titanium are immune to salt water corrosion, also offer substantial weight savings.

Salt water and marine atmospheres are traditional enemies of most metals. But not titanium. Its resistance to such corrosive attack is unchallenged. Tests show a corrosion rate so infinitesimal that it would actually take over a thousand years of salt water exposure to reduce the thickness of a titanium sheet by one-thousandth of an inch.

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tinct species in all (not counting mirror-image forms; all flexagons obey the law of parity!). The octahexa has 12 species; the enneahexa, 27. In searching for these forms, a useful rule to bear in mind is that the sum of the "leaves" (thicknesses of paper) in any two adjacent sections of a flexagon always equals the number of faces that can be achieved.

Both *Scientific American* and William Kelley of New Haven, Mo., independently decided to send hexahexas as Christmas cards. I would have supposed these to be the first printed flexagons, but was surprised to learn that printed trihexas were used in October, 1955, to advertise the service award banquet of the Rust Engineering Company in Pittsburgh.

A Chicago correspondent, who desires to remain nameless, created a hexahexafrustragon. He divided each face of a hexahexa as shown [*upper left on page 8*], pasting parts of three different pictures on the spaces marked A, B and C.

As shown, only parts of picture A form a complete picture, but, by flexing, the same face can be found in two other forms, one bringing together the parts of picture B; the other, parts of picture C. Since each of the six faces accommodates three pictures, there are spaces for 18 pictures in all. Unfortunately, three of the 18 will never come together on a hexahexa formed from a straight chain of triangles. It was on these three areas that the Chicago correspondent pasted full-figure portraits of rather handsome young ladies.

MARTIN GARDNER

New York, N.Y.

Sirs:

I was quite taken with the article entitled "Flexagons" in your December issue. It took us only six or seven hours to paste the hexahexaflexagon together in the proper configuration. Since then it has been a source of continuing wonder.

But we have a problem. This morning one of our fellows was sitting flexing the hexahexaflexagon idly when the tip of his necktie became caught in one of the folds. With each successive flex, more of his tie vanished into the flexagon. With the sixth flexing he disappeared entirely.

We have been flexing the thing madly, and can find no trace of him, but we have located a sixteenth configuration of the hexahexaflexagon.

Here is our question: Does his widow draw workmen's compensation for the duration of his absence, or can we have him declared legally dead immediately? We await your advice.

NEIL UPTEGROVE

Allen B. Du Mont Laboratories, Inc.
Clifton, N.J.

Sirs:

I have a thought about an article in your January issue which may be of interest to you. Regarding Woodburn Heron's article "The Pathology of Boredom," I wonder if the position in which the subjects were kept might not, in some instances, have influenced their thinking, particularly in regard to the hallucinations reported. I have found, personally, that *sleeping* on my back results in the most unbearable nightmares, and doctors whom I have talked to about this say that it is not unusual. If there is anything, in any percentage of normal subjects, which causes hallucinations when on the back, sleeping or daydreaming, the position in which the subjects of these experiments were placed would certainly bring it out, and the experiments would show the result of the position as well as of boredom.

WATSON PARKER

Hill City, S.D.

Sirs:

As a practicing psychoanalyst I was particularly interested in your article "The Pathology of Boredom."

The so-called hallucinatory phenomena described therein have been the sub-

Scientific American, March, 1957; Vol. 196, No. 3. Published monthly by Scientific American, Inc., 415 Madison Avenue, New York 17, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer.

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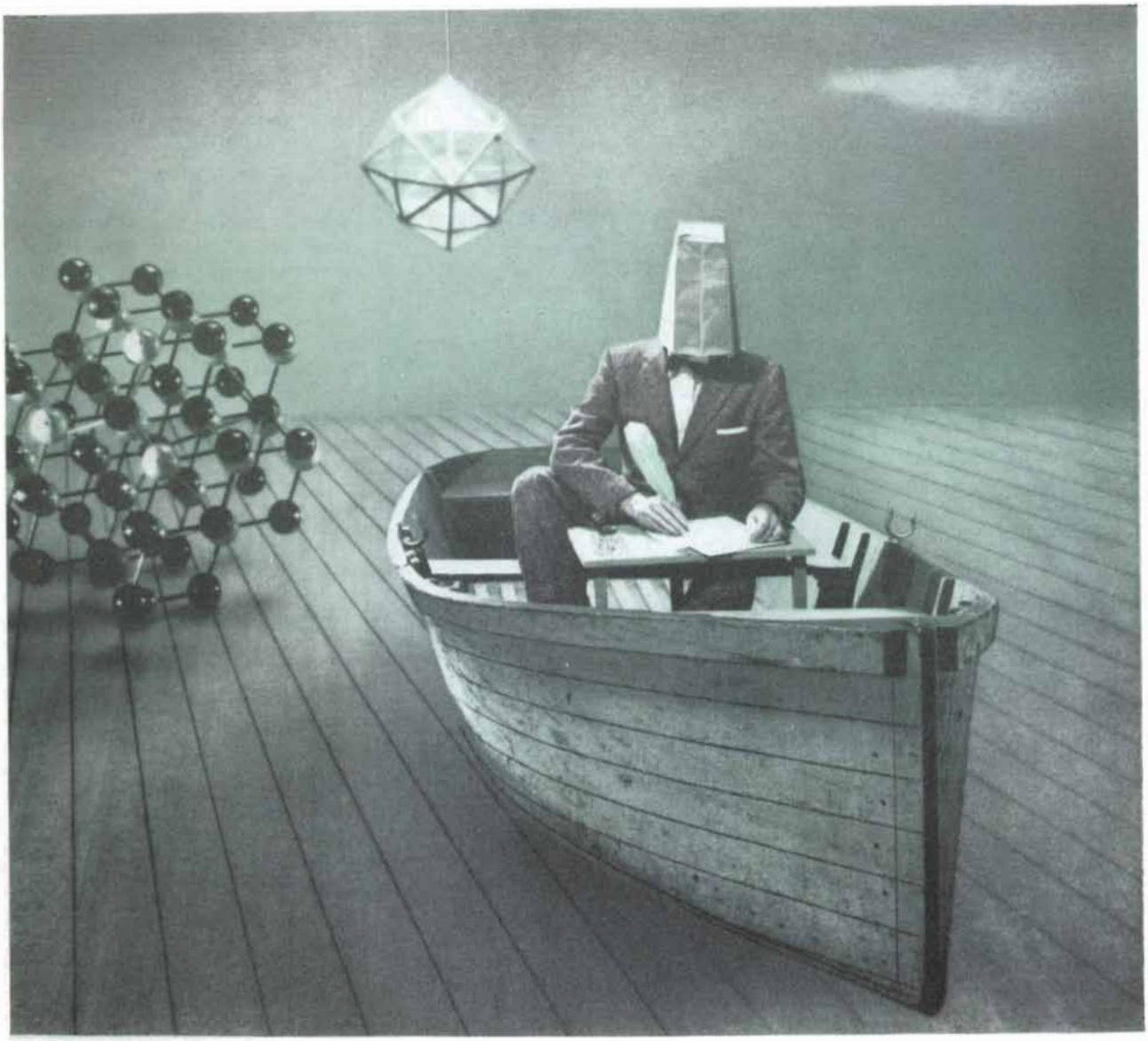

A Man Nobody Wants

This man's motto is "Don't rock the boat!" Now that he has reached his present high post in the Company, his life is dedicated to proving that once you get a good thing, you don't have to change. In fact, if things get too new, you can always search the past for something really safe to use.

He, naturally, has no interest in the new things coming out of Rogers.

Rogers is not looking for him, either. Rogers serves engineers – those men who sail the seven seas in search of an eighth. And they, in turn, find Rogers an interesting port of call – a cove of research and development brains eager to meet the challenge of their ideas with new materials.

Our business is to create – if we don't already have them – the materials that engineers are seeking to convert today's dreams into actual products. Please write for samples of recent developments.

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ject of observation by psychiatrists in their daily office practice, and psychodynamic explanations have been offered by many men; the best is still Freud's work *The Interpretation of Dreams*, especially chapter seven, "The Psychology of the Dream-Processes."

Visualization of ideas known as the "Silberer effect" is a regular psychic phenomenon and is an expression of regression to more primitive modes of psychic functioning. It occurs during dreams, during transitory toxic states such as poisoning or intoxication or severe illness, during extreme physical fatigue and any state of emotional conflict which restricts the functioning of the ego; in other words, during the regression of the ego.

Standard psychoanalytic technique repeats many of the experimental factors set up as described in your article, with emphasis on the absence of all external stimuli and absolute regularity of those stimuli which cannot be eliminated. The consequence is that many patients report phenomena described in your article. The simplest psychodynamic explanation should be understood stepwise:

1. The individual's attention and interest is withdrawn from the external world and focused on the internal world (of internal ideas and wishes).

2. These internal ideas which seek expression sometimes cannot be expressed directly—because motor expression is denied to the individual, or because the acts themselves are repugnant to the individual, or perhaps because the ideas are repugnant to the individual.

3. In other words, a conflict is present between ideas and wishes which one tries to express, and counterforces which try to repress these ideas. The result is a compromise and a regression, where the ideas are expressed in a disguised manner, in the form of visual and auditory hallucinations, as in a dream.

4. To some degree, the mind always functions this way; that is, the idea of the *thing* or the representation of the *thing* is substituted for the very abstract idea of the *word*.

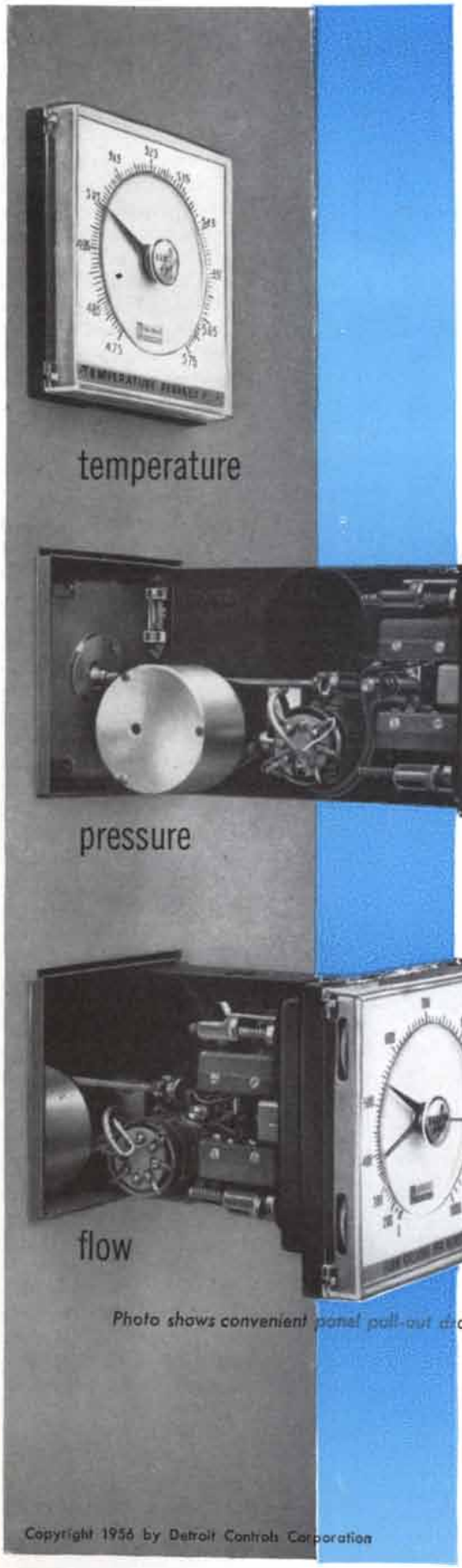
I enjoyed reading about the systematic approach to this problem, but I feel some theoretical framework should have been offered.

ROBERT H. KOFF, M.D.

Chicago, Ill.

Sirs:

Mr. Parker's suggestion that the effects of isolation are confounded with



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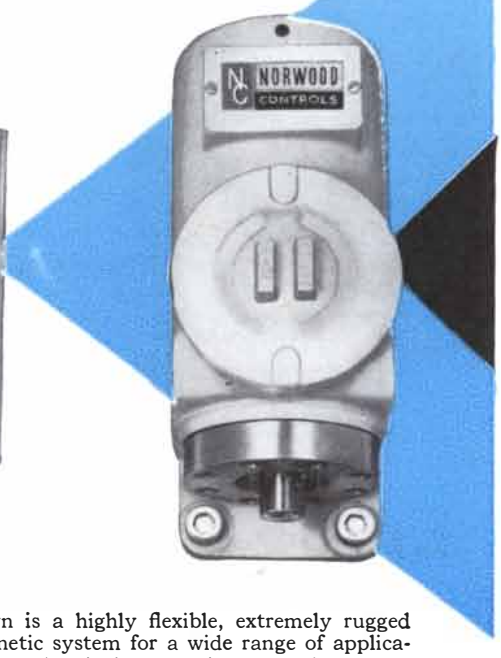

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the effects of lying on the back cannot be ruled out entirely. However, there is some evidence not brought out in the article which makes it seem unlikely: (1) the phenomena occurred even when the subjects were sitting up for meals; (2) the subjects were able to lie on their sides; (3) similar effects have been reported in recent experiments by Dr. John Lilly, in which the subjects were floated in a liquid medium.

From my very limited reading of the psychoanalytic literature I had not realized that patients experienced vivid hallucinatory activity during their sessions. I was therefore very interested by Dr. Koff's observations, but I feel unqualified to comment on them.

As far as the question of interpretation is concerned, we made some crude attempt to work out what could be going on in the brain; and it has occurred to us, as it did to Dr. Koff, that the same kind of mechanisms that are involved in dreams, hypnagogic hallucinations, etc., may be at work.

However, so little is known at the moment that all interpretations, psychoanalytic or otherwise, must of necessity be highly speculative. While such speculations are essential for guiding research, they should be recognized for what they are. The only conclusion we can draw with any degree of certainty is that perceptual isolation has disruptive effects on some aspects of organized behavior.

WOODBURN HERON

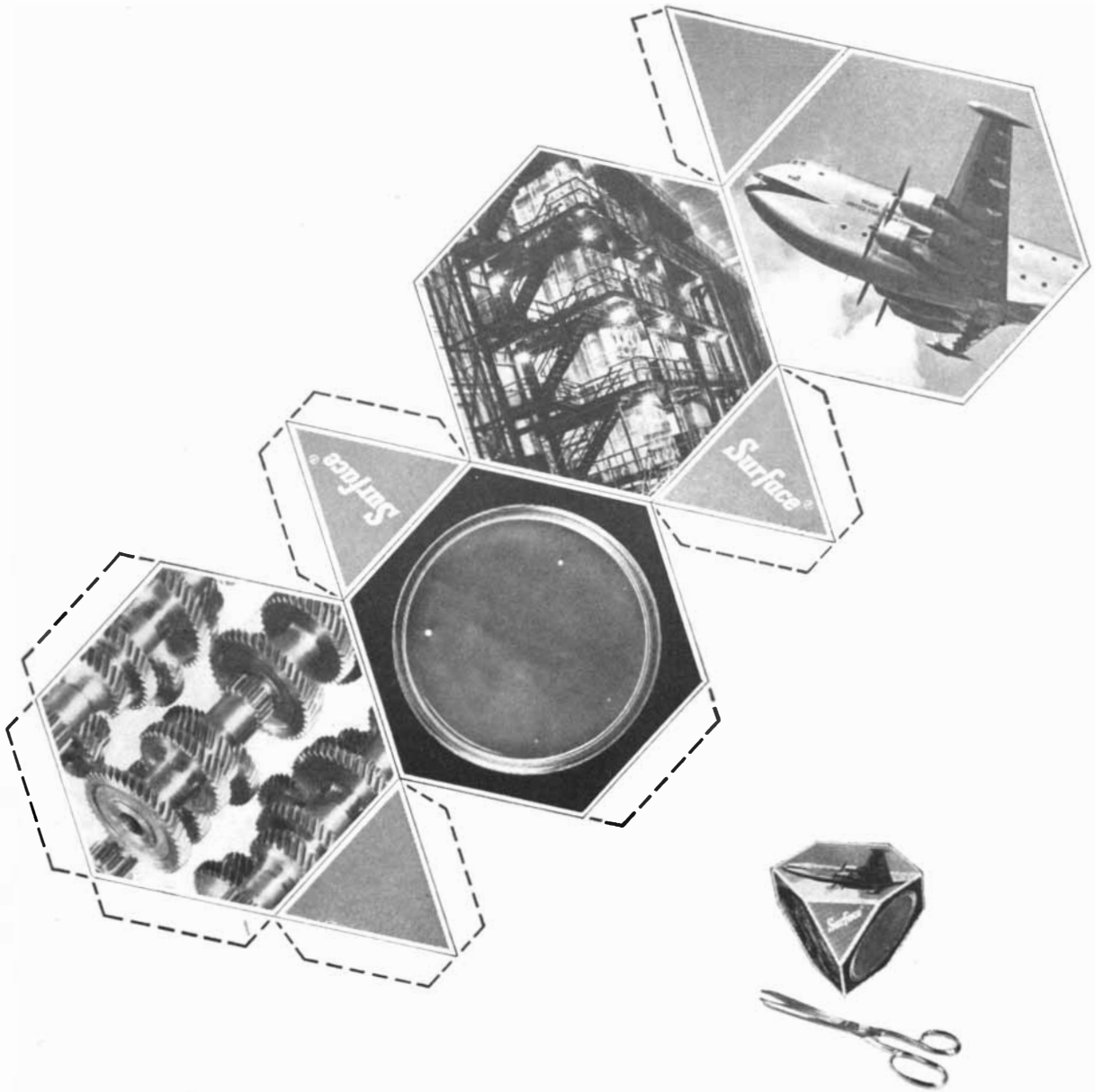
McGill University
Montreal, Quebec, Canada

Sirs:

Your article "The Pathology of Boredom" struck a responsive chord. Perhaps you might be interested in an involuntary experiment in the subject that I underwent.

A year ago last July I was hospitalized for eye surgery to correct a detached retina. Before and after surgery I was completely immobilized, forbidden to raise my head even for feeding, and with my vision in both eyes blocked out with heavy bandages. Moreover, I am deaf in one ear, and therefore was not able to hear with any accuracy. I did not have to wear gloves, though, so I could mitigate the boredom by feeling how my whiskers were coming along.

At first I passed the time by solving a rather simple problem in mathematics that I had heard just before going into the hospital. I solved it over and over. By about the second day (I was in the



Consider all the angles of this Surface

This is Archimedes' truncated tetrahedron, opened out to show just a few of the many angles of Surface Combustion Corporation which you should consider.

Here's a towering annealing furnace which processes steel strip at the speed of a thousand feet a minute. There are automotive gears with extremely tight metallurgical specifications, made faster and cheaper in an automatic carburizing line. Wing pod heaters provide 1,200,000 btu/hr of anti-icing protection for the Antarctic Expedition's Douglas C-124's. And in that petri dish is proof (by the Toledo University Research Foundation) that Kathabar air conditioning equipment kills 97% of airborne bacteria.

From any angle, this represents a tremendous range of skills and services, many of which can contribute to the success of your project.

Write for further information. Surface Combustion Corporation, 2391 Dorr St., Toledo 1, Ohio.

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blackness for exactly three weeks) I began to see visions.

They were of remarkable clarity—extremely sharply defined and in vivid and beautiful colors. I had no control over them. Two examples: A giraffe standing in a stream, up to his shoulders in water, with a number of frightened monkeys clinging to his neck. A horizontal window in the wall above my bed, through which I could see people passing back and forth in the hall outside.

Looking back, I have no feeling of having been blind. I could describe in some detail the smooth, white covering on my bed as it was immediately after I returned to it from my operation, and I can almost see now the rather pretty, washed-out-blonde nurse who tended me that day, and the sunshine falling across the bed. As a matter of fact, the bed had a pastel-colored cover, the room was darkened, and the nurse was very likely a brunette.

I also had a nonvisual hallucination. As I lay on my back, I could feel on my chest the pressure of a tray laden with brimming coffee cups. It was hot coffee, the cups were fragile, and there would be disaster if I moved a muscle. This hallucination persisted for some weeks after I came home in my pinhole goggles; sitting in a chair, I would hesitate to stir until I had slowly lowered my head and peered at my lap through the goggles.

The hallucinations were rather more interesting than frightening or boring. I knew they were fakes, and speculated on where they came from, and why. I speculated also on what the nurses and orderlies looked like, and formed very clear (and entirely wrong) mental pictures of them. I remember watching, via hallucination, the arrival of my roommate. He was a small Italian, accompanied by three even smaller Italian doctors who chattered incessantly while they wrapped him in corn husks as some sort of therapy. This is probably not a genuine hallucination; rather, it is the product of my defective hearing—but the picture, false as it was, was clear and bright.

I don't think the visions came from drugs. I had sedation at night, and slept dreamlessly. During the days, I occasionally had codeine, or a similar painkiller, but the visions came no clearer or oftener because of the painkiller. Apart from the codeine and the barbiturate sedatives, my medication consisted of antihistamine and an occasional mild antacid for indigestion.

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B&W Nuclear Facilities Plant in Lynchburg, Virginia, showing new expansion program under construction.

Behind B&W Atomic Energy

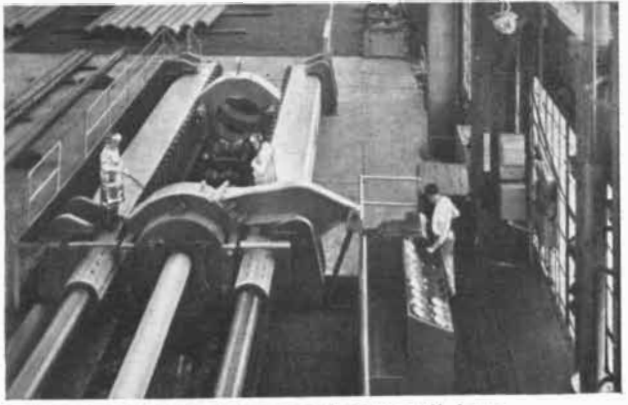
INDEPENDENT NUCLEAR RESEARCH • 90 YEARS OF STEAM POWER

Many of the components in nuclear steam generating systems are remarkably like those in use in modern conventionally-fueled power plants. And in the design and fabrication of reactors and fuel elements, many of the solutions to problems—in metallurgy, metal working techniques, heat transfer and fluid flow, and welding—are being found through extensions of past B&W experience and research.

In this very real sense B&W offers you the benefits of 90 years of experience in design, fabrication, testing and erection . . . the skills and techniques acquired and developed through the creation of thousands of conventional-fuel, high pressure boilers. You get the advantages of direct atomic energy experience accumulated since the days of the Manhattan Project through active participation in many AEC-sponsored projects... the practical results of B&W's own continuing program of independent nuclear research and development.

These, together with specialized facilities, form the unique background B&W brings to single compo-

B&W Critical Experiment Laboratory, Lynchburg, Virginia.

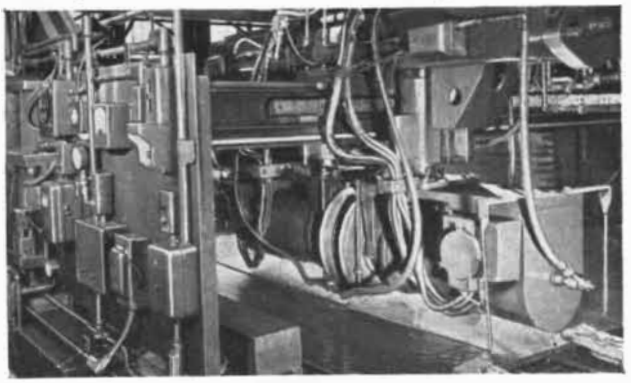


Massive draw bench produces heavy-wall, large-diameter hollow forgings.

8500-ton hydraulic press bends and forms heavy plate, pierces ingots.

This high-speed digital computer helps speed computational work in reactor core design.

A continuing program of independent nuclear research is carried on at B&W's Research Center at Alliance, Ohio.



B&W-designed electrical-resistance welding process clads base plate with alloy sheet.

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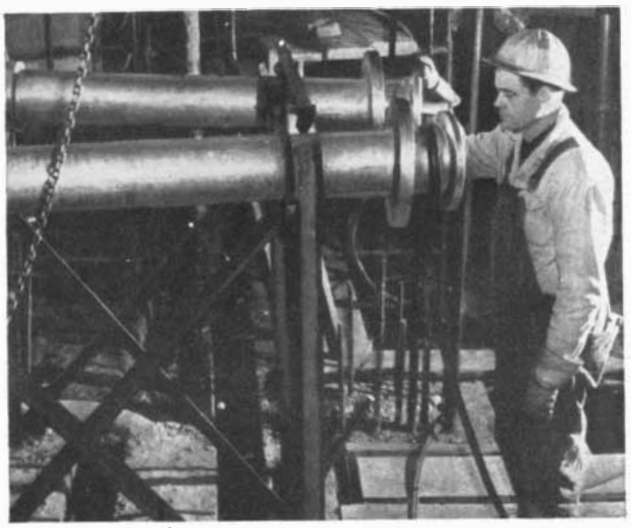
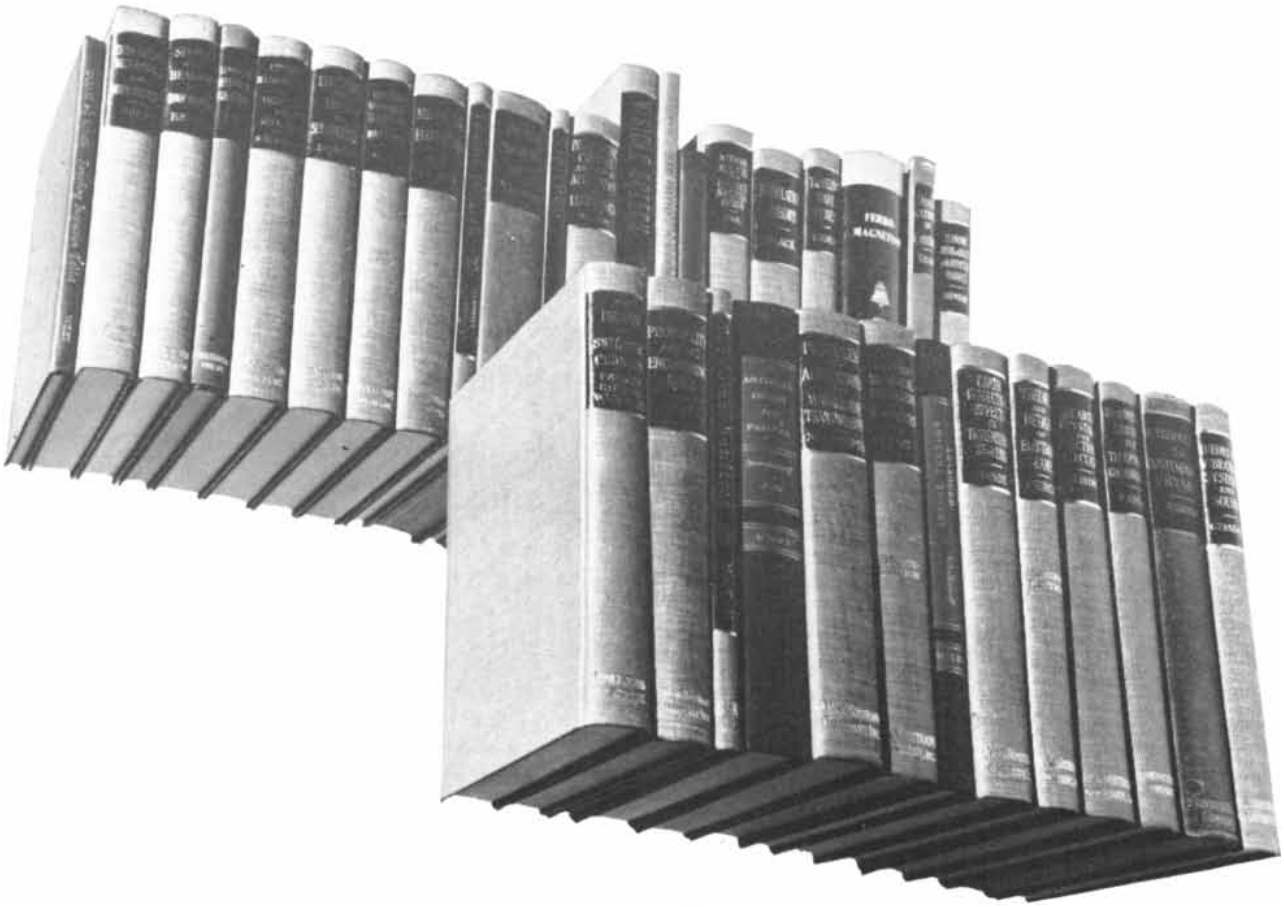


Experience, skills and tools developed over 90 years are applied to design, fabrication and erection of nuclear steam generators.

The books...



How the scientific world shares in fruits of the telephone art

In their work to improve telephony the scientists and engineers of Bell Telephone Laboratories make important findings in many sciences. They thoroughly report these findings in professional journals and magazines. But sometimes, as knowledge accumulates in a vital field, a "treatment in depth" is prepared in book form.

Bell Laboratories authors have written 36 books to date and others are in preparation. Many have become classics in the Laboratories' primary field of communications. Many have become standard works of wide application because they provide a fundamental guide for technologies in other fields. For example, the design of automatic switching systems is of primary importance in computers; statistical quality control provides the indispensable basis for economical manufacture. Through their books these scientists and engineers and the Laboratories attempt to repay benefits they receive from the published works of others.

The pictures on the opposite page show some Bell Laboratories authors of technical books. A complete listing of titles may be obtained by sending in this coupon.

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Harold S. Black, B.S. in E.E., Worcester Polytechnic Inst., author of "Modulation Theory."

John R. Pierce, Ph.D., California Inst. of Tech., author of "Traveling-Wave Tubes."

Richard M. Bozorth, Ph.D., California Inst. of Tech., author of "Ferromagnetism."

W. Thornton Read, M.S., Brown University, author of "Dislocations in Crystals."

Hendrik W. Bode, Ph.D., Columbia University, author of "Network Analysis and Feedback Amplifier Design."

Walter A. Shewhart, Ph.D., University of California, author of "Economic Control of Quality of Manufactured Product."

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MARCH, 1907: "The death of Mr. Orson Desaix Munn brings to a close a period of 62 years in the history of this journal. In 1846 young Munn was induced by his former schoolmate, Alfred Ely Beach, to join him in the purchase of SCIENTIFIC AMERICAN from its founder, the restless inventor and editor Rufus Porter. A partnership was formed, and the firm of Munn & Co. established. An office was taken in the old *Sun* building at the corner of Fulton and Nassau Streets in New York City, and the knowledge and advice secured by such close association with the great daily proved invaluable to the young editors and publishers. The first issue under the new firm appeared on July 23, 1846. In a period when SCIENTIFIC AMERICAN was the only journal in the United States devoted purely to science and mechanics, it was inevitable that its editors should be brought into touch with the inventors of the day, and one of the most frequent callers was Elias Howe of sewing machine fame. This intercourse naturally led to the establishment of the patent department. The announcement of this policy, coming at a time when the profession of the patent lawyer was practically unknown, met with immediate response, and marked the auspicious beginning of a practice which speedily necessitated the opening of a Washington office, and ultimately grew to be the largest of the kind in existence. The offices of the journal soon became the center for the gathering of the most noted inventors of the day, and here the editors were in constant intercourse with such men as Capt. John Ericsson, Commodore Edwin A. Stevens, Capt. James B. Eads, and Samuel F. B. Morse. The next important step in the history of the firm was the publication of the *Scientific American Supplement*, whose *raison d'être* was found in the wish to describe and illustrate the mass of interesting exhibits at the Centennial Exposition of 1876. The success of the venture led to the decision to continue the publication as a weekly review of the scientific literature of the day, in which might be included articles too long or strictly technical for the more popular tastes of the readers of the parent paper. This was followed by the publication of *La America Científica*, designed to place the various Spanish-speaking peoples of South America in touch with the progress of science and the arts in the sister northern republic. In 1885 the firm decided that, in view of the large number of requests for information on the subject of house building and furnishing and kindred subjects, the time was ripe for launching a monthly journal covering this field, and the first issue of the Building Edition of SCIENTIFIC AMERICAN made its appearance. The success of this venture justified the enlargement of the scope of the publication, and in 1905 it was remodeled and published in a new form under its present name of *American Homes and Gardens*."

"That the American square-rigged sailing vessel is being gradually forced from the ocean highways, where it was long an important factor in the world's carrying trade, has been apparent for some time to those well versed in maritime affairs. Yet few have realized that the outlook for vessels of this type is as serious as has been set forth by the Commissioner of Navigation in his last annual report, lately from the press. The Commissioner states that the existence of our square-rigged fleet cannot under present conditions extend beyond the period of 20 years. A second consecutive year has passed without the building of even one square-rigged vessel in the United States, something never heard of before. As the Commissioner tersely expresses it, 'the construction of square-rigged vessels has probably not entirely ceased in the United States, but the future output will not equal the loss through wreck. abandonment, and cutting down into barges.' The history of the square-rigger is inseparably interwoven with that of our country, and those who are conversant with the career of this type of vessel will view the retirement with feelings of genuine regret."

"Within the past few months we have illustrated on the front page of this journal two office buildings, both in course of erection, which are considerably to exceed half a thousand feet in height. Both of these structures are built as additions to existing office buildings, and the predisposing motive in carrying them up to such unprecedented heights is the desire to obtain a maximum amount of office space on a given amount of ground area. There can be no question that the

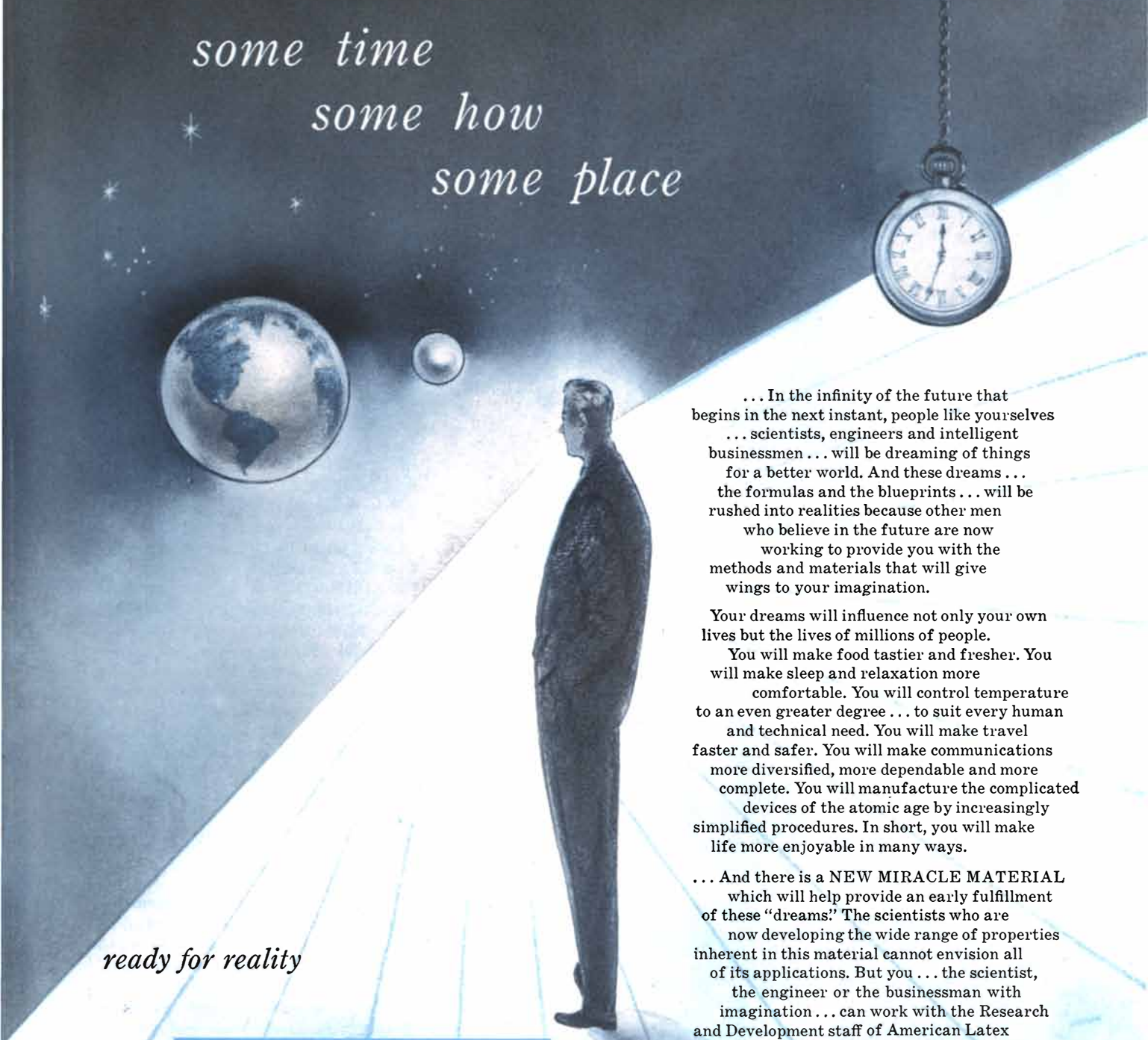
skyward race having begun with such daring aspiration, other builders will be seized with the vertical 'speed madness.' And so we may look to see a repetition of the tower-building craze of medieval times, which led the wealthy men of Siena and Bologna to build those curious and not unsightly shafts which form one of the historical and architectural attractions of those cities."

"A recent and novel use of the telephone has been the reporting of the Michigan–Ohio State football game. Two bare wires were stretched across the field, and a small trolley arranged to run on them. To this trolley was attached a portable telephone set, which was used by the reporter, who followed the progress of the ball along the field. This circuit was connected with the Ann Arbor, Mich., exchange, and through it to the University of Michigan. In this way the progress of the game was followed at Ann Arbor almost as closely as it was on the field where it was played."

"Through the death of Prof. Berthelot, the world has lost a man eminent not only as a philosopher and a scientist, but also a figure prominent in the national politics of France and in the affairs of the world in general. Aside from Berthelot's chemical researches, his labors in behalf of the beleaguered French in Paris during the 'Terrible Year' of the Franco-Prussian war, and his political activity, brought him to the notice of the world. As the head of the Scientific Committee of Defense of Paris in 1871, he undertook the investigations which practically led to the invention of smokeless explosives. In his researches and discoveries in the synthesis of fats, glycerines, carbohydrates and alcohol, in coal-tar dyes, in thermo-chemistry and in explosives, he added enormously to the scientific knowledge of mankind."

SCIENTIFIC AMERICAN

MARCH, 1857: "In view of the tremendous obstacles facing construction of a bridge between Manhattan and the city of Brooklyn, Joseph de Sendzimir has proposed an entirely radical and most ingenious solution. He suggests that an iron tube be sunk in the East River. As in this project neither pier buildings nor excavations would be necessary, all or rather nearly all outlay



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. . . And there is a NEW MIRACLE MATERIAL which will help provide an early fulfillment of these "dreams." The scientists who are now developing the wide range of properties inherent in this material cannot envision all of its applications. But you . . . the scientist, the engineer or the businessman with imagination . . . can work with the Research and Development staff of American Latex Products Corporation toward applications only *you* can dream of . . .

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would be comprised in the construction of the iron tubes, which, to use the language of the inventor, may be built at any convenient point on boats, and, when nearly the whole length is completed, may be made to float by closing the extremities watertight and then floated to the place appointed for the thoroughfare; and, ultimately, that portion of the tube sunk which is destined to remain under water, by introducing the proper ballast into the interior and on the platforms outside, would make a submarine tubular thoroughfare."

"Professor Thompson has recently put forward the hypothesis that meteors falling into the sun give rise to the heat which he emits. All the theories that have yet been proposed to account for the heat of the sun, he remarks, as well as every conceivable theory, must be one or another, or a combination, of the following three· 1st, that the sun is a heat ing body, losing heat; 2d, that the heat emitted from the sun is due to chemical action among materials originally belonging to his mass, or that the sun is a great fire, 3d, that meteors falling into the sun give rise to the heat which he emits. It is demonstrable that unless the sun be of matter inconceivably more conductive of heat, and less volatile, than any terrestrial meteoric matter we know, he would become dark in two or three minutes, or days, or years, at his present rate of emission if he had no source of energy to draw from but primitive heat."

"The peace of the great European nations does not appear to be followed by an increase of prosperity in the industrial interests, but rather the reverse Much of the work on arms and equipment was, of course, immediately suspended on the confirmation of the peace, and we have already alluded to the fact that the war vessels under construction are temporarily abandoned, and the small vessels afloat are being hauled up to diminish the expense of sustaining them. Many men are necessarily thrown out of employ, and a meeting of between five and ten thousand of the laboring classes of London was lately held to consider their distressed condition. It was stated that 25,000 persons engaged in the building trade alone in that city are out of work, and that the total number of unemployed persons in that great metropolis would probably reach a quarter of a million."

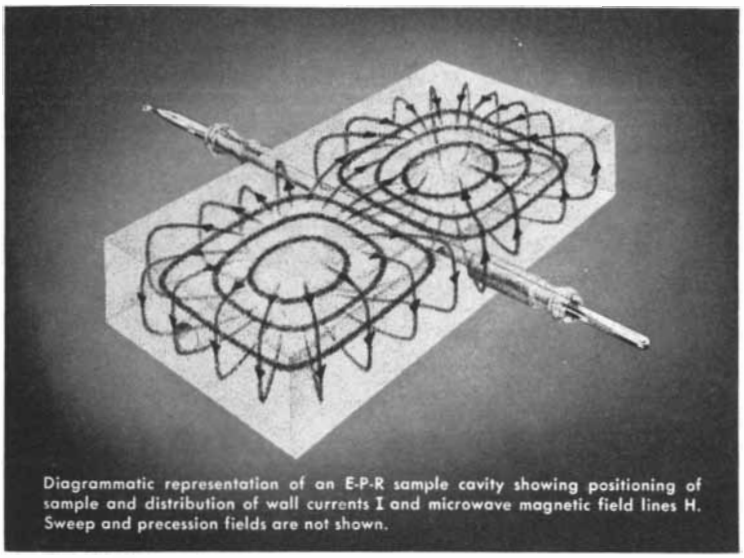
"The ship *Supply* has landed another lot of camels in Texas."

E-P-R SPECTROSCOPY AT WORK

(Electron Paramagnetic Resonance)

1

Beginning . . . an informative application series from Varian on an important new laboratory tool for the physicist, chemist and biologist



Diagrammatic representation of an E-P-R sample cavity showing positioning of sample and distribution of wall currents I and microwave magnetic field lines H. Sweep and precession fields are not shown.

The Varian E-P-R Spectrometer accelerates the accumulation of knowledge on molecular structure, kinetics of chemical reactions and the solid state. It indicates the interaction of unpaired electrons with their chemical environments by inducing and recording E-P-R signals from substances possessing a resultant electronic magnetic moment.

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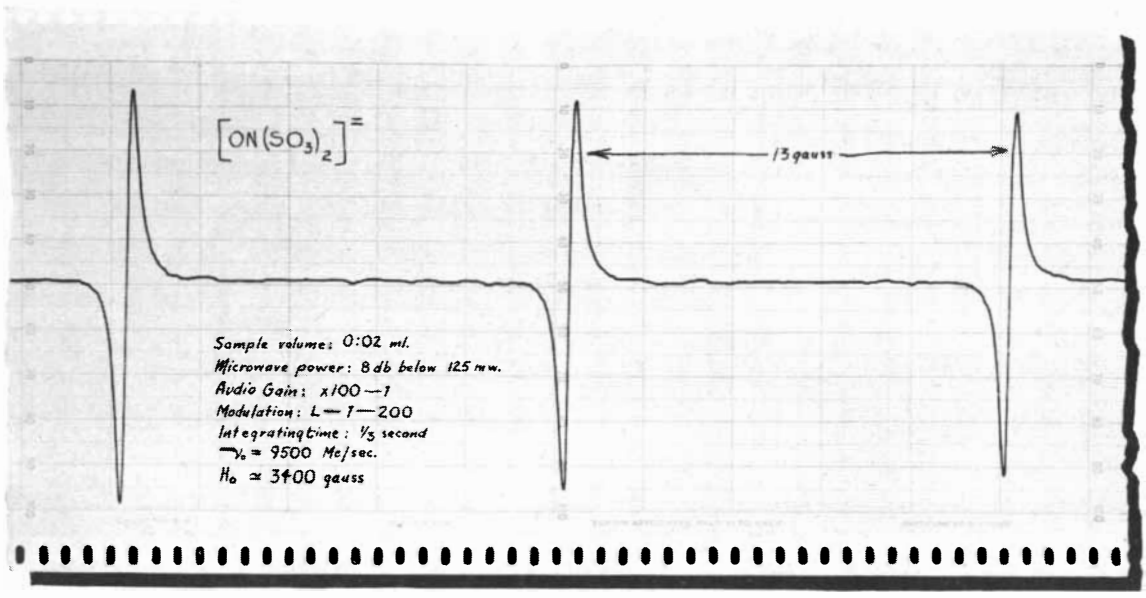
This continuing series of examples will show clearly how E-P-R study is applied to both organic and inorganic substances. Unpaired electrons from various sources will be identified and from them determinations will be made.

Number 1 of a series **HYPERFINE STRUCTURE IN FREE RADICALS**

INTERPRETATION: One of the first characteristic hyperfine structures to be observed by paramagnetic resonance was the simple one shown below. This arises from the nitrosodisulphonate (peroxylamine disulphonate) ion $(ON(SO_3)_2)^=$ and is due to the I·S coupling of the nitrogen nuclear spin with the spin of the unpaired electron on the ion. Since the nitrogen is the only non-zero spin nucleus in the ion, the spectrum consists of three lines of equal intensities produced by the three $(2I+1)$ equally probable magnetic orientations of the nitrogen $(I = 1)$ nuclei. From the magnitude of the splitting one may also ascertain the fractional s-state character of the odd electron around the nitrogen atom.



For full technical details on E-P-R and N-M-R Spectroscopy and Spectrometers, write to the Varian Associates Instrument Division.

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Argonne National Laboratory Experimental Boiling

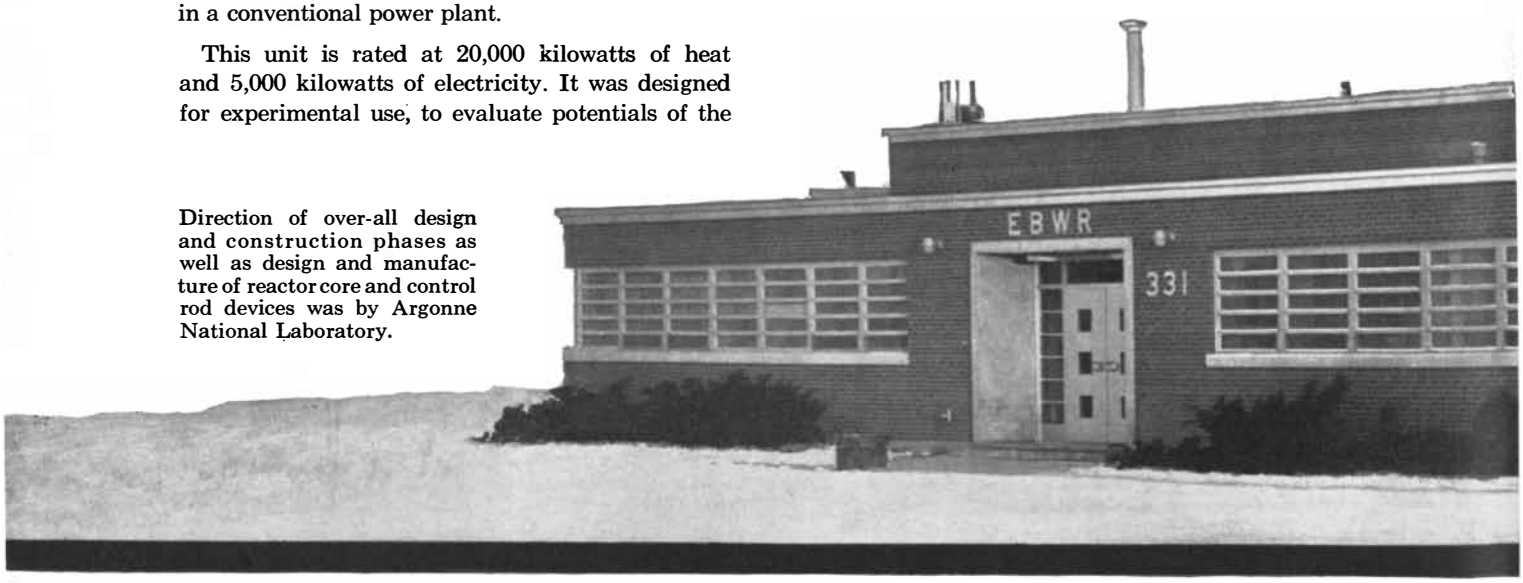
Electricity from NUCLEAR POWER TODAY!

NOW in operation at Lemont, Illinois, this is the first commercial-type power plant in the United States to generate usable quantities of electric power from nuclear fuels.

The unique feature of this boiling water reactor is that live steam is actually generated in the uranium core by nuclear heat and piped directly to the turbine without need for intermediate heat exchangers as required by other types of reactors. In effect, it operates very much like the coal-fired boiler in a conventional power plant.

This unit is rated at 20,000 kilowatts of heat and 5,000 kilowatts of electricity. It was designed for experimental use, to evaluate potentials of the boiling water reactor for large-scale commercial applications. Power generated is used by the Laboratory to meet a portion of its own electric power requirements.

Allis-Chalmers is proud of its association with this significant project. It's another example of "Engineering in Action" to provide power for better living from any source, whether it be water, steam, oil, or the atom itself.



Direction of over-all design and construction phases as well as design and manufacture of reactor core and control rod devices was by Argonne National Laboratory.

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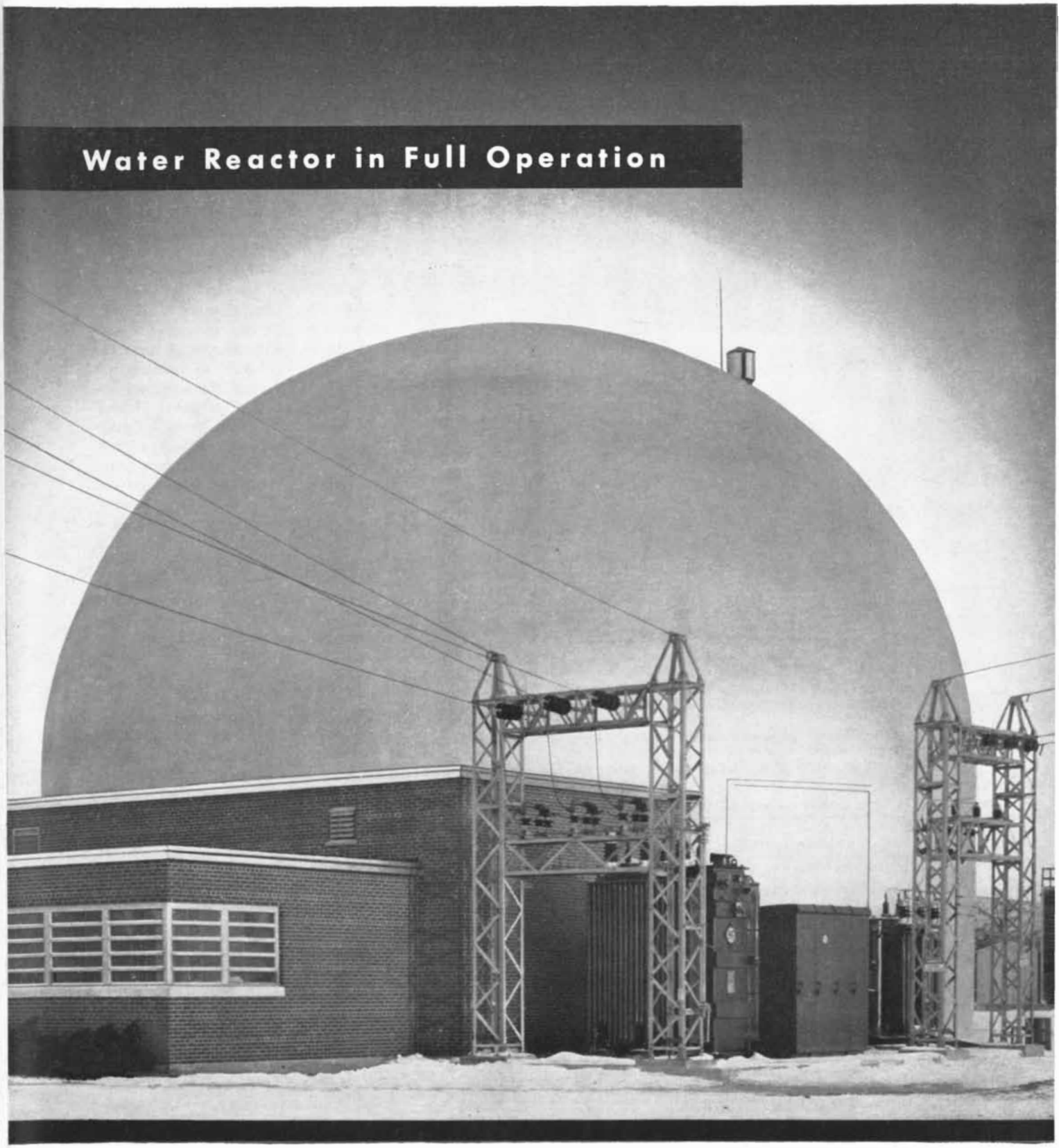
- Circulating water pumps
- Auxiliary cooling water pumps
- Motor control centers
- Main and reserve power transformers
- Indoor and outdoor switchgear
- Automatic voltage regulator
- Circulating water treatment system
- [illegible] ribution center
- Diesel-generator set



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THE AUTHORS

DAVID S. JENKINS ("Fresh Water from Salt") directs the Office of Saline Water of the U. S. Department of the Interior. Before World War II he served as a hydraulic engineer with the U. S. Geological Survey and the Soil Conservation Service. He investigated the problem of airport drainage for the Civil Aeronautics Administration from 1942 to 1946, then began a study of salt-water conversion for the Bureau of Reclamation. This study led him to conclude that much research would be necessary before the building of proposed Federal "demonstration" plants could be justified. The Government's present program of research and pilot plants, now being developed by both public and private agencies, is based largely on Jenkins' studies. Besides his work at the Department of the Interior, Jenkins has been a member of the working party on saline water conversion of the Organization for European Economic Cooperation. A native of Colorado, he graduated from George Washington University in 1935.

JEAN PIAGET ("The Child and Modern Physics") commutes between the universities of Paris and Geneva; he is professor of psychology in both institutions. Piaget started out in the natural sciences: his doctoral thesis at the University of Neuchâtel concerned the altitude distribution of mollusks in the canton of Valais. Later he studied psychology at Zurich and Paris and began his famous experiments on the mental growth of small children, which he has described in a series of 22 books, many of them translated into Czech, English, Polish, Spanish, Turkish and Swedish. Aside from psychology, Piaget's main concern is the philosophy of science. Both subjects converge in his research on how children form concepts of space, time, velocity, force and chance. This work is summed up in his three-volume *Introduction to Genetic Psychology*, which will soon appear in English. Piaget is codirector of the Institute of Educational Sciences at the University of Geneva, where with the help of the Rockefeller Foundation he has founded the International Center of Genetic Epistemology—a meeting-ground for psychologists and philosophers.

JAN H. OORT ("The Crab Nebula") is professor of astronomy and director of the observatory at the University of Lei-

Today, magnetic tape is an accepted tool for data acquisition, processing, and storage. It has proved its worth in laboratories, industrial plants, even missile test centers. But a decade ago magnetic tape data recording did not exist. And without the inspired cooperation of a government agency and a private enterprise, it might not exist yet.

Kennard and V. C. McIntosh of
WRIGHT AIR DEVELOPMENT CENTER
Install Magnetic Tape Recorder in F-101 Aircraft.

MAGNETIC TAPE data recording

born april 7, 1950

Dynamics Section, Engineering Support Branch at Wright Air Development Center's Equipment Laboratory is primarily responsible for evaluating aircraft equipment under conditions of actual use . . . particularly vibration, shock, and acceleration. Under Section Chief D. C. Kennard, it records these phenomena as they actually exist in aircraft and missiles under all conceivable service conditions.

Prior to 1952, 12-channel recording oscillographs were used. But weight and size limited their use, as did the need for an operator to set attenuators for optimum sensitivity on each channel. Furthermore, the Dynamics Section is particularly interested in the frequency content of vibration, and the relative amplitude of each component frequency. But getting this information from oscillograph traces proved something of a problem. Visual examination was neither accurate nor complete. The Section resigned itself to using the 24-point method of Fourier Analysis in conjunction with punched card equipment, but was far from satisfied.

Searching for an entirely new approach, the Dynamics Section settled on magnetic tape recording, despite the fact that no suitable equipment was in existence. On November 2, 1949, in Exhibit MCREXE84-2, The Air Force called for the development of airborne magnetic tape data recording, reproduction and analysis equipment.

Among the responses to the exhibit was a proposal from the Davies Laboratories, Inc. Though the company had no previous experience with tape or recording, the ideas which Gomer L. Davies set forth in that proposal were interesting enough to gain his company the contract. Let on April 7, 1950, it called for three 14-channel airborne recorders, a 14-channel ground playback unit, and a dual channel automatic wave analyzer.

The combined efforts of Davies and his staff, and the Dynamics Section overcome obstacles that for years had chained magnetic tape to the broadcasting studio. The first system delivered to the Dynamics Section included such refinements as servo speed control for correcting low-frequency tape speed variations and a unique, completely electronic compensation system for eliminating the effects of wow and flutter.

By 1952 magnetic tape data recording was a reality, with the delivery and acceptance of the first complete system for airborne use in November.

Substantially all the requirements set forth in the 1949 exhibit had been met. And several had been exceeded. The completely self-contained recorders were even smaller than specified. The three recorders so speeded up data acquisition that The Air Force immediately placed an order with Davies for four additional channels of analysis equipment.

With the introduction of magnetic tape data recording in November, 1952 as a full grown art, the technique was quickly adopted in laboratories, manufacturing plants, and government installations across the country . . . an amazing growth. But the record set by Davies equipment at Wright Air Development Center is impressive enough in itself. Davies recorders have been used there in testing every conceivable kind of aircraft, including:

F-86A F-86D B-36 B-45 B-47
B-50 B-52 B-57 B-66 C-47
C-54 C-123 C-124 C-130
H-19 KC-97 Q-2A RB-50

They have been used for ground testing at least ten different power plants. They have been taken to other military installations so that data recorded there could be analyzed on Davies equipment at the Dynamics Section. Most important, data made available by Davies equipment assisted in causing revisions in basic Air Force Specifications. It has been possible to prove, for example, the importance of high frequency vibration as a vital design consideration, and thereby eliminate an arbitrary upper limit of 55 cps on vibration testing.

Surely, magnetic tape data recording has been proved a development of vital importance. But it has even greater significance as an outstanding example of the benefits of a country in which government and industry can work hand-in-hand . . . cooperating on every level for the eventual betterment of all mankind.

den in the Netherlands. Notes on his career were published in the issue of September, 1956, to which he contributed the article entitled "The Evolution of Galaxies."

SIR SOLLY ZUCKERMAN ("Hormones") is Sands Cox Professor of Anatomy at the University of Birmingham. He was born in Cape Town, South Africa, and studied at the University of Cape Town and at University College in London. In 1928 he became research anatomist at the London Zoological Society. In Africa and at the Zoological Society Zuckerman studied baboon colonies, and in 1932 he published *The Social Life of Monkeys and Apes,* which is still the standard work in its field. Zuckerman found that the harem rank of female baboons depended on their sexual cycles; this led him into the study of endocrinology. He was a Rockefeller Fellow at Yale University in 1933-1934 and subsequently a university lecturer at the University of Oxford. During World War II he studied the biological effects of the London blitz. As a top scientific adviser to Air Marshal Lord Tedder and SHAEF, he defined the tactical and strategic purposes of aerial bombardment. He was awarded the Order of the Bath and the U. S. Medal of Freedom with Silver Palm.

CHARLES M. HERZFELD and ARNOLD M. BASS ("Frozen Free Radicals") collaborate on research at the National Bureau of Standards, where Herzfeld is acting assistant chief of the heat and power division. Herzfeld was born in Austria in 1925, came to the U. S. during the war, and in 1945 graduated *cum laude* from Catholic University. He then studied physical chemistry at the University of Chicago, where he obtained his Ph.D. with a thesis on the magnetic properties of uranium compounds. Bass is assistant chief of the free-radicals research section of the Bureau of Standards. A graduate of the College of the City of New York, Bass received his Ph.D. from Duke University in 1949 after World War II service as radar officer aboard a seaplane tender. His main interest has been spectroscopy, particularly in studying the energy states of free radicals in flames for the purpose of temperature measurement.

FREDERICK G. KILGOUR ("Galen") is librarian of the Yale Medical Library and a lecturer in the history of science at Yale University. He graduated from Harvard College in 1935 and stayed on at the Harvard College Libra-

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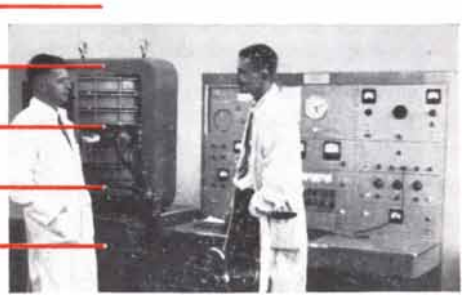

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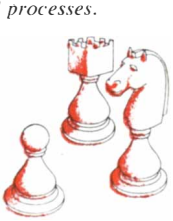

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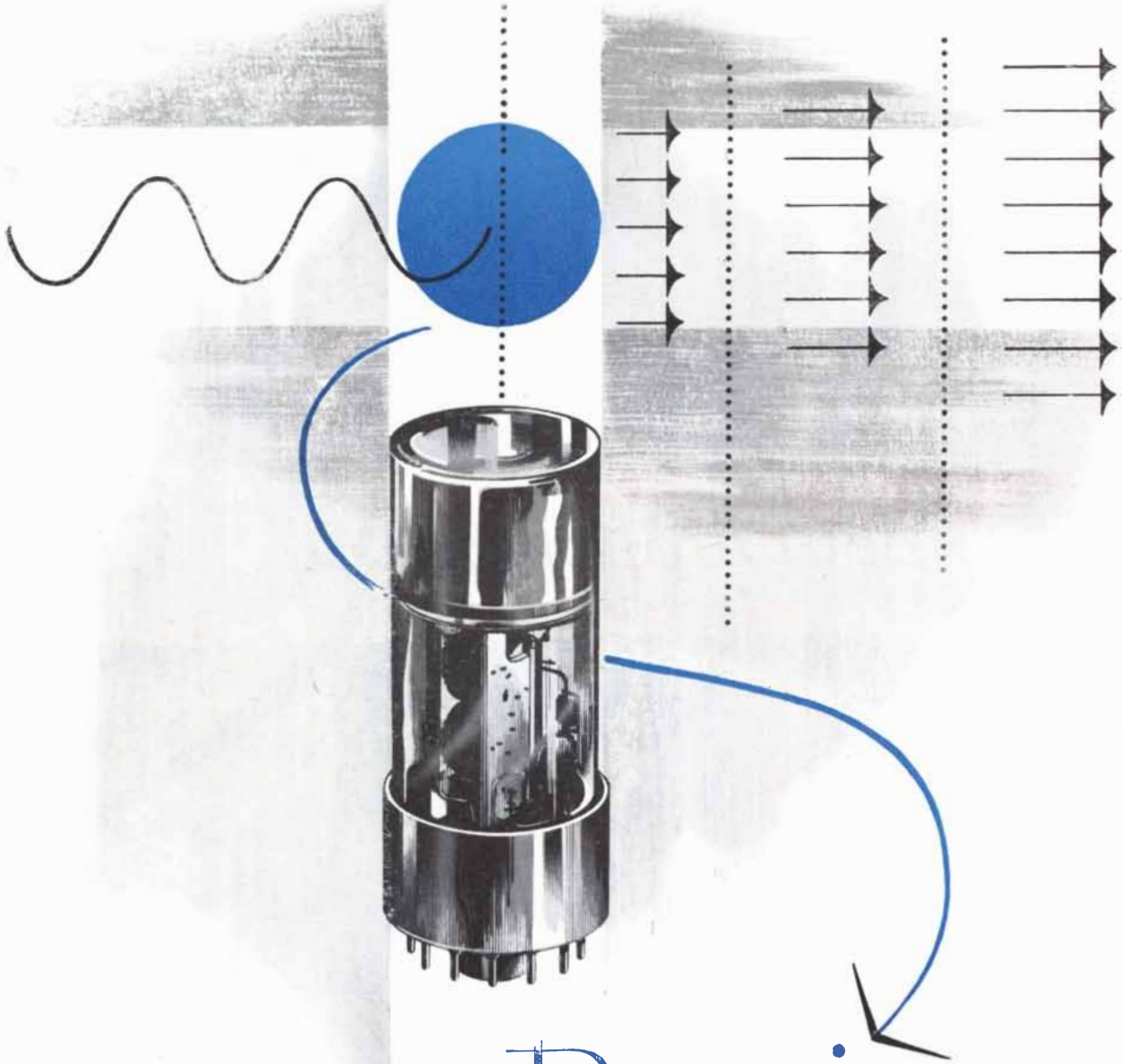
ry until the Second World War, when he joined the Office of Strategic Services and later saw active duty as a lieutenant in the Navy. After another two years in the U. S. Department of State as an intelligence officer, Kilgour came to Yale in 1948. Among other activities, he serves as managing editor of the *Yale Journal of Biology and Medicine*. He was the author of a biographical sketch of William Harvey, the discoverer of the circulation of the blood, in the June, 1952, issue of SCIENTIFIC AMERICAN.

LESLIE C. DUNN and STEPHEN P. DUNN ("The Jewish Community of Rome") are a father-and-son team combining the disciplines of genetics and anthropology. Abetted by Louise P. (Mrs. Leslie C.) Dunn, they spent a year in Rome's ancient ghetto district gathering material for the study reported here. Leslie C. Dunn, the senior partner in this operation, is professor of zoology and director of the Institute for the Study of Human Variation at Columbia University. He was born in Buffalo in 1893, graduated from Dartmouth College, taught at Harvard University and worked at the Connecticut Agricultural Experiment Station before becoming a full professor at Columbia in 1928. He is widely known for his book *Heredity, Race and Society*, written in collaboration with Theodosius Dobzhansky, and has contributed previously to SCIENTIFIC AMERICAN ("Genetic Monsters," June, 1950). The younger Dunn is also at Columbia University, where he is a doctoral candidate in anthropology. He has recently completed a dissertation on the historical influences that have shaped the Jewish community of Rome.

GEOFFREY DEAN ("Pursuit of a Disease") is senior physician at the Provincial Hospital in Port Elizabeth, South Africa, where he practices as a specialist in neurology. An Englishman, Dean enlisted in the Royal Air Force upon completing his internship in 1942. After World War II he became medical registrar and tutor at the Liverpool Royal Infirmary and entered the Royal College of Physicians and Surgeons in London. In 1947 he emigrated to South Africa, where his abilities as a medical detective were first applied in discovering the similarity of multiple sclerosis to the sway-back disease in sheep, which is attributable to a defect in metabolism of copper. Dean has visited the U. S. to confer with physicians interested in porphyria. His general research interest is the interaction of inheritance and environment in causing disease.



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How to cool a pilot in the Thermal

The Douglas X-3, used in heat dispersion studies.

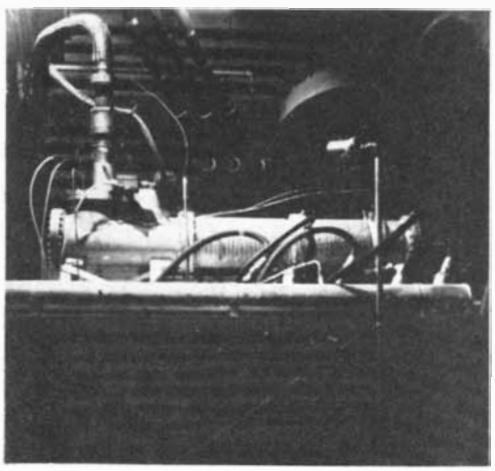
With aircraft that top 1000 mph now in military service, the problem of *heat dispersion* gets growing attention from Douglas engineers.

Once called the heat barrier, science now uses a more accurate term, *thermal thicket.* The faster you fly through the earth's atmospheric blanket, the further into the thicket you get . . .

At Mach 2, twice the speed of sound, a plane's skin temperature can reach 275°F. At Mach 3 it leaps to 650°F, and at Mach 5 hardened steel wilts like lettuce . . .

Douglas is attacking this heat problem on many fronts. Air conditioners powerful enough to cool a theater were tested in the famous X-3 research plane seen at left. In current Douglas missiles, amazing advancements are being made in the design of heat-resisting materials and structures. This knowledge will speed the solution of the thermal thicket problem for piloted aircraft.

Thicket



The Douglas Aero-rotor, an instrument that blasts out high velocity gas at temperatures upward of 3000 degrees Fahrenheit, helps in research for materials to withstand high temperatures and jet velocity erosion. Other work now on the boards at Douglas ranges from designs for the practical application of atomic power to the complete design and building of intercontinental missiles — and even includes the engineering for a space platform first considered as early as 1946.

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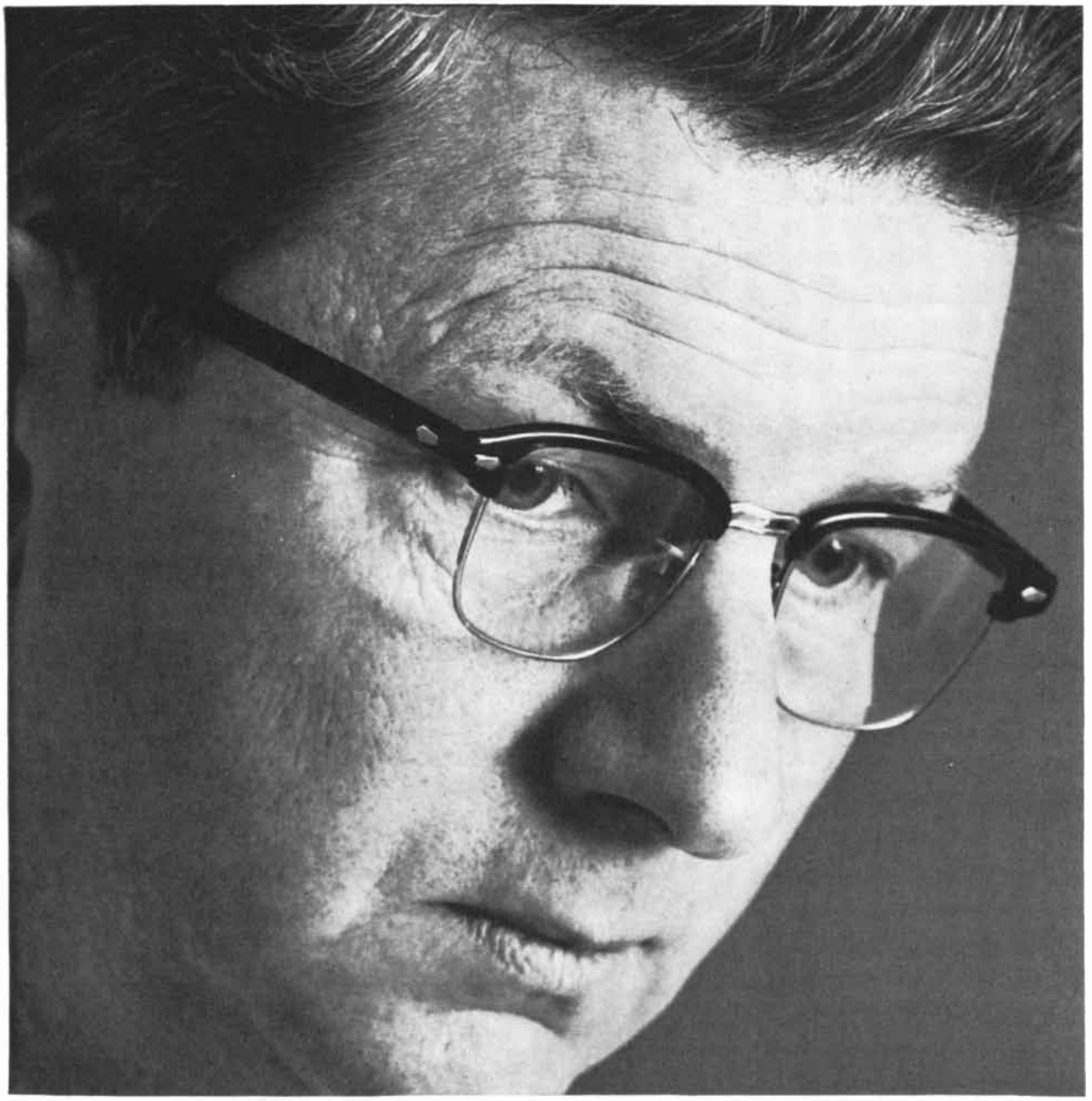

YAVNO

...on economy in national defense

"The widespread belief that there is an inherent conflict of interest between those who put national security first on the one hand and the taxpayer and his cost-conscious representatives on the other is simply erroneous—except when the level of the national security budget is at issue. Once the budget level has been fixed, the choice of weapons which maximizes our military capability is logically equivalent to the choice which minimizes the cost of attaining that capability. Moreover, the weapon characteristics so chosen are typically similar at different budget levels. In these circumstances economy and military effectiveness are not opposing objectives to be compromised; they are different but equivalent aspects of the same national objective."

—Charles Hitch, Head of the Economics Division

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

Established 1845 SCIENTIFIC AMERICAN March, 1957 Volume 196 Number 3

Fresh Water from Salt

The thirst of civilization now presses hard upon the naturally available supply of fresh water. It is easy enough to desalt sea water, but it must be done cheaply, abundantly and soon

by David S. Jenkins

In the face of our increasing control over nature, it is ironic that we have steadily been losing ground with regard to one of mankind's most vital needs—water. Over much of the civilized world, water shortage is a grave and growing problem.

To be sure, water has always been a major concern of man. The children of Israel recovered their faith in God only when Moses smote the rock and produced water. Egypt rose and fell with the flow of the Nile and even today is placing its hopes for the future on plans to develop the resources of that great river. Few things have more powerfully influenced the course of the human race than the perennial search for fresh water.

But in today's world the need for water has become acute in many areas. In some arid countries the per capita consumption of water, thanks to improved sanitation, has suddenly risen from two or three quarts per day to 20 or 30 or more. Underdeveloped countries seeking to raise their standard of living by industrialization and irrigation find themselves with huge new needs for water supplies. Even our own water-favored country is beginning to be concerned, with many communities already facing shortages. The problem is widespread, not confined to localities such as the drought-stricken Southwest. Since 1900 the U. S. has increased its consumption of water almost sevenfold. By 1975 our water requirement will have nearly doubled again. We shall then be using about 27 per cent of the total supply of natural fresh water in our rivers, lakes, springs and wells. Many areas will have reached the limit of their local resources. The remaining 73 per cent of the total supply, largely stream water, will probably be prohibitively expensive to collect, store and distribute to the places where it is needed.

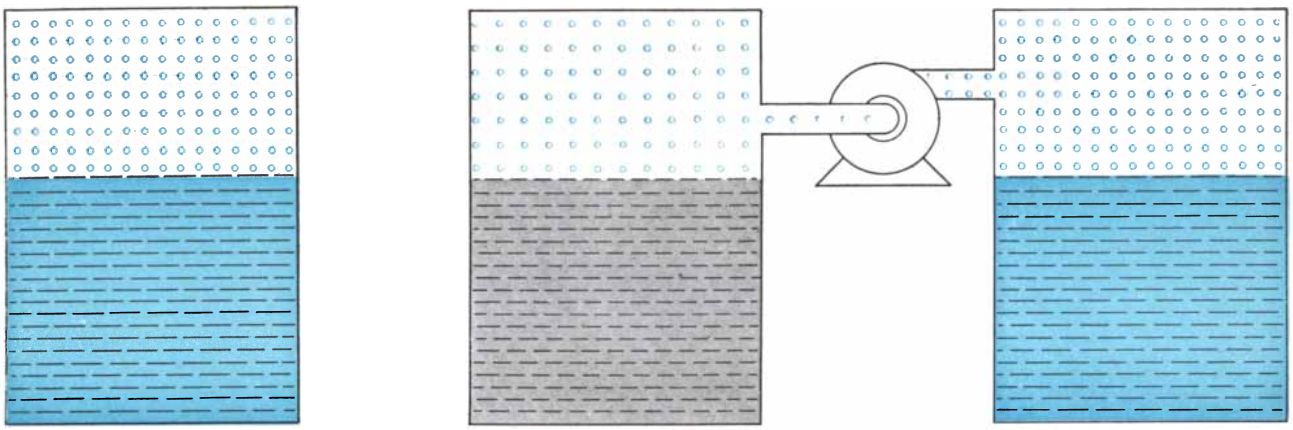
There are two major steps we can take. The first, and most important for the years immediately ahead, is to reduce our lavish waste of water. Among other things, we can reduce the pollution of our streams, recover used water by purification, capture floodwaters and manage the industrial use of water more carefully. Some industries have already shown what can be accomplished along this line. For instance, the Kaiser steel mill at Fontana, Calif., has reduced the consumption of water in manufacturing steel from the average of 65,000 gallons per ton to only 1,400 gallons per ton, by recirculating the water it uses.

But in the last analysis we must also increase the water supply itself. There is one way this can be achieved on a very large scale: by converting salt water. There is plenty of water in the oceans, and man's ingenuity is certainly equal to the task of converting sea water and other saline waters into fresh water at a reasonable cost.

Five years ago the U. S. Congress, recognizing the gravity of the situation, passed a Saline Water Conversion Act which authorized a program of research and development. Under the administration of the Department of the Interior a coordinated campaign of investigation is now under way in the U. S., with cooperation from abroad. Government agencies, private industries and other institutions are engaged in more than a score of laboratory investigations, a few of which have progressed to pilot-plant tests. The salt-water conversion methods under investigation include a number of well-known processes and several completely new ideas.

Fresh water is commonly defined as water containing less than 1,000 parts per million of dissolved salts. But how fresh the water needs to be depends on the use to be made of it. Drinking water, according to the U. S. Public Health Service standards, should have no more than 1,000 and preferably less than 500 parts per million. In general salinity of water for agricultural irrigation should be no more than 1,200 parts per million, the allowable concentration depending on the specific salts it contains. For some industrial purposes, such as cooling and flushing, unrefined sea water will do; on the other hand, in high-pressure boilers it may be necessary to have almost pure water containing not more than two or three parts per million of salt. Thus the economic feasibility of sea-water conversion depends on the use to which the water is to be put: for some purposes the cost may be reasonable, for others not. For the guidance of the research program a survey of the various industries' water requirements is urgently needed.

The salinity of the waters available for conversion varies greatly. The oceans are



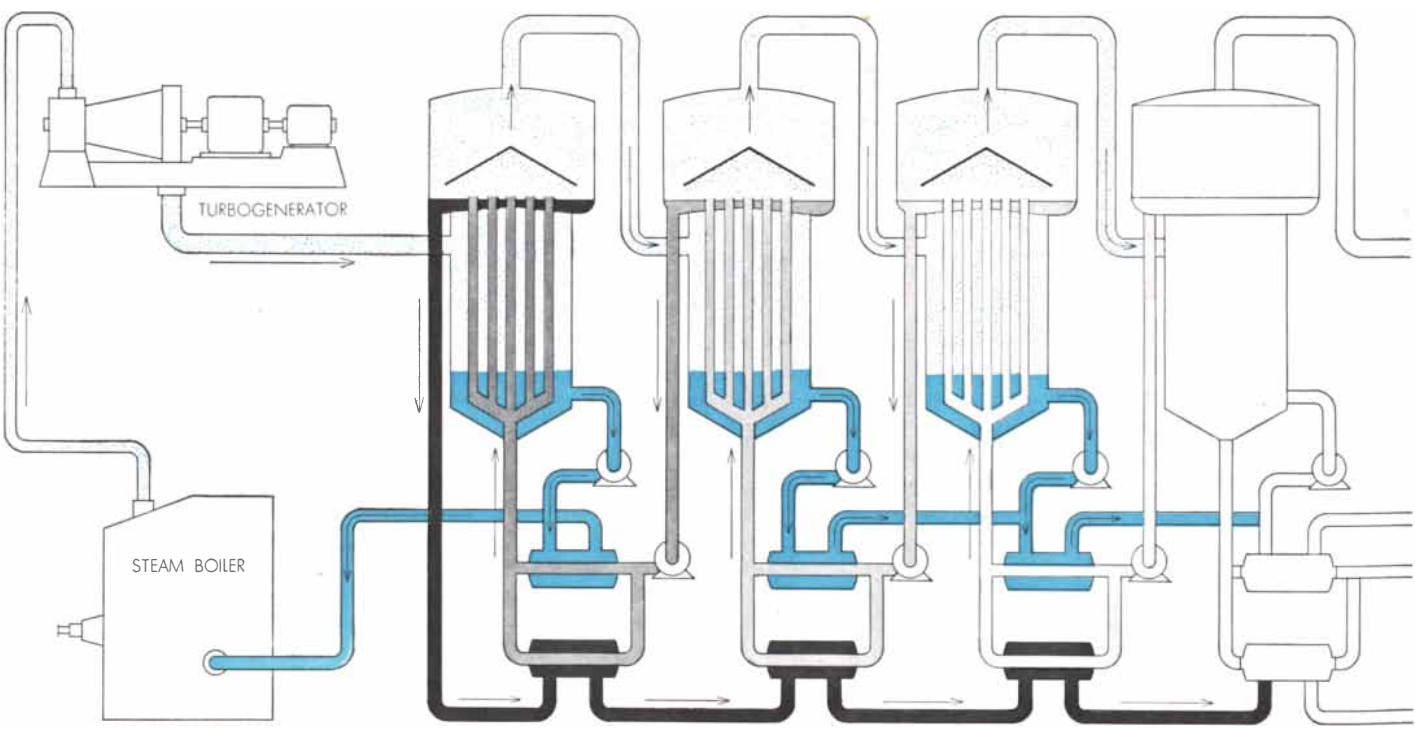
THEORETICAL ENERGY needed to separate water molecules from salt ions can be calculated from experiment shown here. At the same pressure and temperature, more water molecules will go into the vapor phase from fresh water (*left*) than from salt water (*center*). By compressing the vapor from the salt water to the same density or vapor pressure as that of the fresh water vapor, it can be just made to condense to fresh water (*right*). The energy needed is equal to the energy that binds the water molecules to salt ions.

fairly uniform, averaging about 35,000 parts per million of dissolved salt. But in the Persian Gulf it is nearly 40,000 parts per million; in Chesapeake Bay about 15,000; in the Baltic Sea only 7,000. Any water less salty than the oceans but with more than 1,000 parts per million is called brackish.

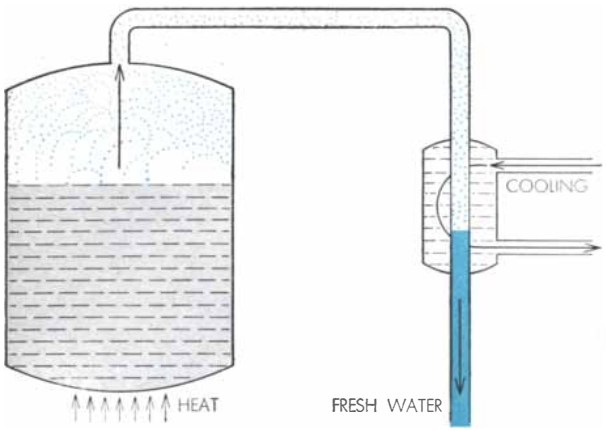
Common salt, sodium chloride, accounts for most of the saltiness of sea water. However, sea water contains small amounts of many other salts—some 44 dissolved elements in all [*see table on page 42*].

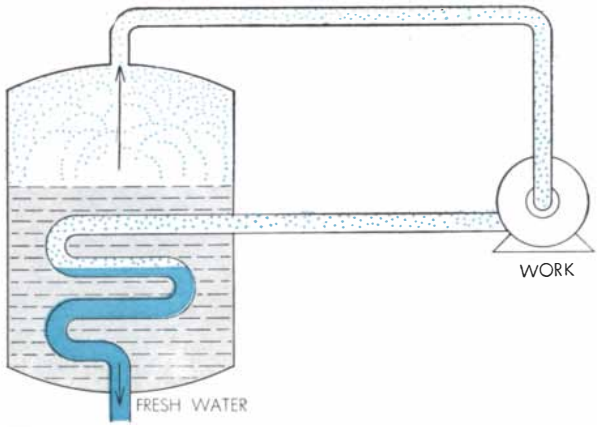
What is required to desalt water? The basic facts are simple enough. A salt dissolved in water is separated into ions —*e.g.*, in the case of sodium chloride: the positively charged sodium ion and the negatively charged chlorine ion. The ions are bound to water molecules by their electric charges. The problem, then, is to pull the water molecules and the ions apart.

We can make a calculation of how much energy this takes. Consider two sealed flasks, one partly filled with pure water, the other with sea water. At room temperature, say, a certain amount of the water in each flask evaporates into the unfilled part of the vessel, and this establishes a certain equilibrium vapor pressure. The vapor pressure in the container of sea water is lower than in the flask of pure water, because its water molecules, being bound to salt ions, do



MULTI-STAGE STILL uses the latent heat released by condensation of water vapor at each stage to evaporate the brine flowing in from the next stage. The first stage (*left*) provides a condenser for the steam from a turbogenerator. The steam (*colored dots*) is condensed to water by the cooler salt water (*gray*) flowing in through the evaporator tubes. The salt water, heated by the condensation of the steam, separates into water vapor (*colored dots*) and droplets of brine (*black dots*) in the steam chest above the evaporator.

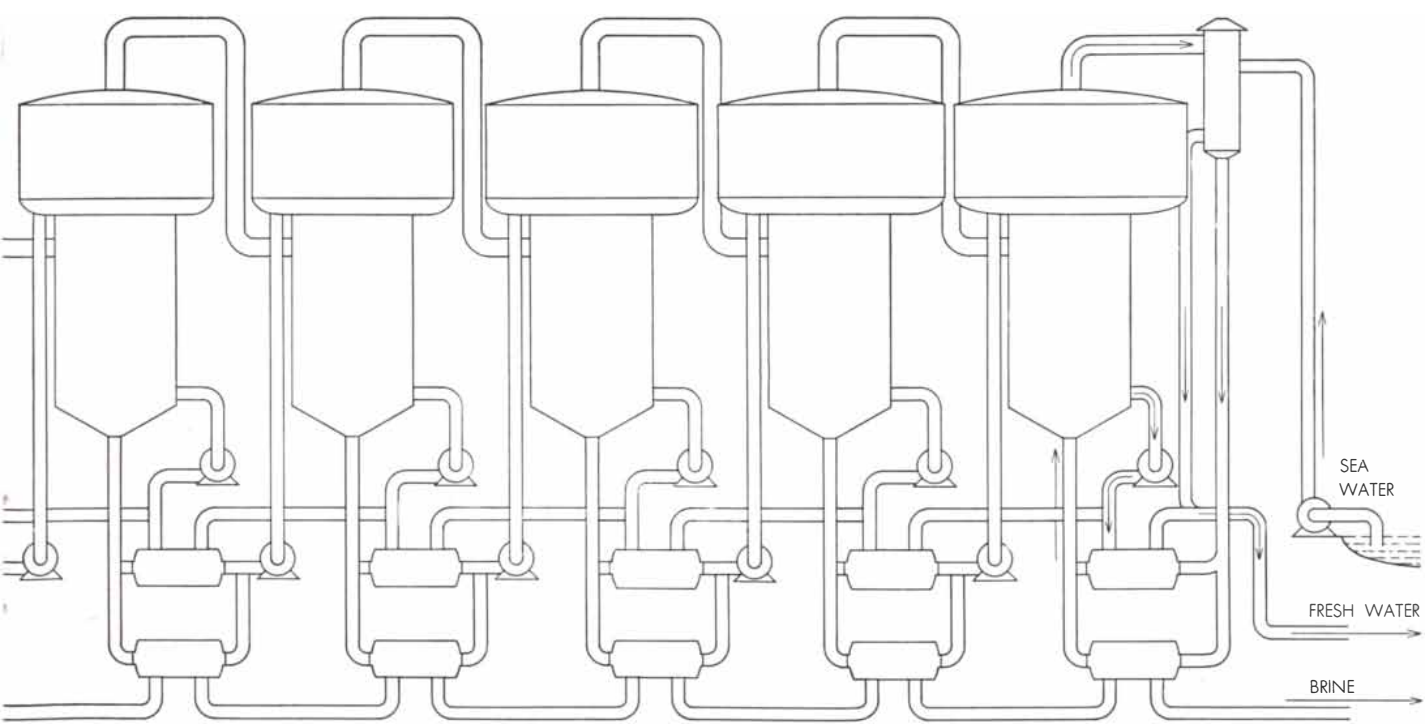




ACTUAL ENERGY needed to evaporate fresh water from salt water is necessarily much greater than the theoretical (*opposite page*) which assumes a barely perceptible rate of evaporation and 100 per cent efficiency in conversion of energy. Simple distillation (*left*) may require 1,000 times as much energy. Compression distillation (*right*) is more efficient. Compression of the vapor raises its temperature; the superheated vapor is piped through the boiler where it condenses, yielding its latent heat to evaporate more brine.

not evaporate as easily. Now the extra energy needed to separate water molecules from the ions can easily be measured: it is just equal to the energy we have to supply to compress the vapor from the sea-water bottle so that its pressure is the same as that of the vapor in the bottle of pure water [*see diagrams on opposite page*]. For sea water of average saltiness this energy amounts to 2.8 kilowatt hours per 1,000 gallons.

But this is merely the minimum amount needed to tip the scale of vapor-pressure equilibrium so that evaporation can proceed—at a barely perceptible rate. To raise the rate of evaporation to a useful level requires a great deal more energy. Furthermore, there are fundamental limitations on the efficiency of conversion of energy to useful work in any process or machine; consequently a considerable part of the energy we feed into the machine is unavoidably wasted. In practice, to separate water from salt by evaporation in a simple still takes 1,000 times the amount of energy given above as the theoretical thermodynamic requirement—that is, about 2,800 kilowatt hours of energy (in the form of heat) per 1,000 gallons of water. But there are, of course, much more efficient processes than simple, single-stage distillation. It is estimated that some of the processes now under study may reduce the energy requirement to about four or five times the thermodynamic minimum,



Here the brine droplets are stopped by the conical baffle plate and fall to the bottom of the steam chest, draining out at left. The water vapor rushes out at the top and to the right into the second stage. There it gives up its heat to evaporate the salt water flowing in from the third stage and condenses to fresh water. Because the temperature of the salt water at each stage is lower, the boiling point must be brought lower; this is accomplished by reducing the pressure at each stage, as indicated by increased size of steam chests from left to right.

EXPERIMENTAL SOLAR STILLS designed by Maria Telkes are shown on rooftop at New York University. In unit at left water vapor rising from shallow pool of sea water condenses on underside of inclined glass or plastic roof. Units at right are "sloping stills," in which sea water is flowed through a black wick tilted at right angles to sun's rays with considerable increase in output.

or about 10 to 15 kilowatt hours per 1,000 gallons.

Let us see what devices we can employ to enhance the efficiency of distillation. The simple still evaporates water to steam at atmospheric pressure. But now if we compress the steam to a few pounds per square inch above atmospheric pressure, the temperature of the steam will rise slightly, and we can use this added heat to evaporate more water. In other words, we have increased the yield of distilled water without feeding more heat to the system, merely spending a little energy to drive a mechanical compressor. This method, called "compression distillation," reduces the total energy requirement from 2,800 kilowatt hours to about 200 kilowatt hours per 1,000 gallons of water. The idea is more than 100 years old: it was first patented by a Frenchman, Pierre Pelletan, in 1840. The U. S. armed services used it extensively during World War II for supplying water to troops in areas lacking ready fresh water.

In the past three years interest in compression distillation has been heightened by an exciting new system. It was devised by Kenneth C. D. Hickman, a collaborator in the governmental research program. In essence what Hickman has added is a simple device for increasing phenomenally the rate of heat transfer to the water: namely, spreading it out in a thin film. The salient feature of his device is a rotating drum, shaped something like a child's musical top [*see diagram on page 44*]. Salt water at a temperature of 125 degrees Fahrenheit is sprayed on the inside surface of the drum. The centrifugal force of the drum's rotation spreads the water over this surface as a very thin, turbulent film. Some of the water evaporates (the unevaporated brine is constantly drawn off through a scoop). The water vapor leaves the drum via a pipe where a blower compresses it slightly, raising its temperature. The warmed vapor then circulates to the outside surface of the drum; there it condenses and gives up its latent heat; the drum shell transmits this heat to the film of water on its inside surface, speeding evaporation. The condensed vapor is collected as distilled water.

This system is recommended not only by its simplicity and low power requirement but also by another great advantage: the low operating temperatures (125 to 150 degrees F.). In distillation processes using much higher temperatures, the sea-water salts are deposited on metal surfaces as scale. Scale formation, which impedes the transfer of heat to the water, is the greatest single enemy of efforts to bring down the cost of distillation. In Hickman's apparatus little scale forms, because of the low operating temperatures. The main limitation of the rotary compression still is that such a still obviously must be limited in size.

There are other highly promising attacks on the problem of improving the efficiency of distillation. One of the most hopeful is the multi-stage still. In this system the latent heat released by

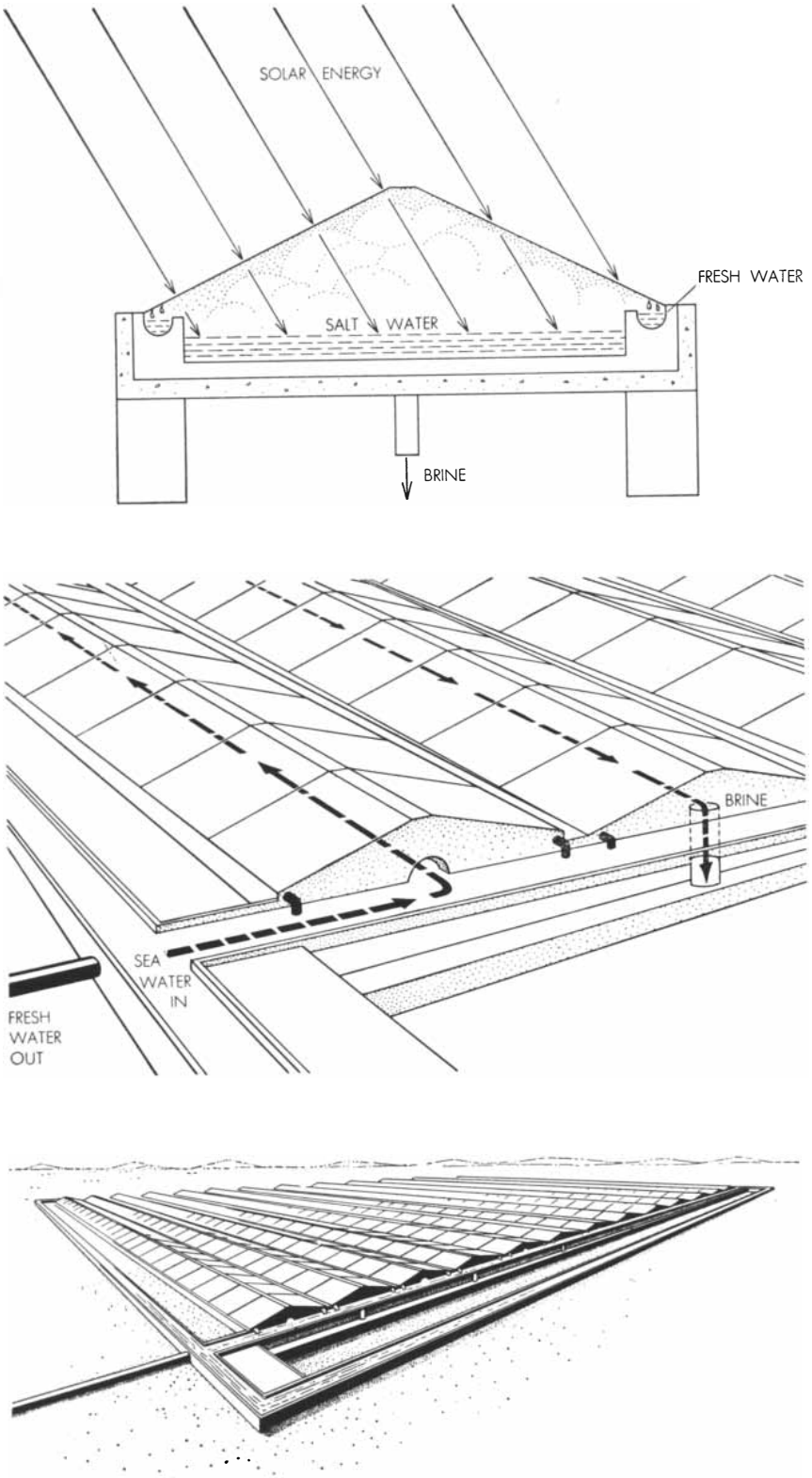
the condensation of the evaporated water at each stage is used for the next stage, providing a chain effect. For example, in the first stage sea water is evaporated to steam at atmospheric pressure or higher; the steam passes to coils in a second evaporator, condenses there and is collected as distilled water; in condensing it releases its latent heat to evaporate sea water in that container, and so on through a number of stages [*see diagram on pages 38 and 39*]. Vacuum pumps keep each successive evaporator under lower pressure, so that its water boils at a lower temperature. Such a system could operate on the exhaust (waste) steam from an electricity-generating plant. The main problem is to prevent the formation of scale, and the method is promising enough to justify the considerable research being conducted on that aspect. If scale can be eliminated, a 20-stage still may be feasible, and it might produce fresh water at between 30 and 40 cents per 1,000 gallons.

There is a comparatively new distillation method which uses a sudden reduction of pressure instead of heat to evaporate water. At a given temperature, the amount of water vapor that air can hold depends on the air pressure. If salt water is fed into a closed chamber in which the pressure is lower than outside, part of the water will "flash" to steam. This method is being used extensively in multi-stage systems. In French West Africa engineers are attempting to develop a flash evaporator which will operate on the temperature differences between upper and lower levels of the ocean, using the colder water to chill and condense the vapor from the flash chamber. The U. S. Department of the Interior and the University of California have been working on similar systems.

Various other distillation processes have been studied, including distillation at "supercritical" temperatures and pressures. It is not possible to discuss here all the distillation ideas that are under study. But even this brief description of the work in progress must make clear that the prospects for distilling salt water to fresh at a reduced cost are bright.

The sun, which showers us with a vast abundance of energy free of charge, is responsible for our natural supply of fresh water by its evaporation of the seas. Is there any way to harness solar energy to provide us with more? Some ingenious solar stills have been proposed.

The simplest form of solar still is a pan



SOLAR STILL of type under development by Department of the Interior is diagrammed. Water vapor evaporating from salt water condenses on underside of glass or plastic plates and drains into gutter on either side of unit (*top diagram*). Incoming sea water (*middle diagram*) flows into first unit and returns through second. Outlet pipes for fresh water and brine are immersed in incoming sea water in order to preheat it by heat-exchange effect. Drawing at bottom shows the plan of a large installation which might cover many acres.

containing a shallow layer of salt water (say about an inch) and covered with a sloping glass plate. The glass is transparent to the sun's radiation but holds in the heat reradiated within the pan. Water evaporated from the bottom condenses on the glass, trickles down its sloping surface and is collected in a trough. This type of still, using only about half of the incoming solar energy, can produce little more than a pint of fresh water per day per square foot of area, even in the hot, clear climate of Arizona.

Some economy can be achieved by reducing the cost of the equipment. Several manufacturers have recently produced transparent plastic films which can replace glass at much less expense. One of them is a fluorocarbon called Teflon, reported to resist all forms of weathering. E. I. du Pont de Nemours and Company has designed an arrangement in which the Teflon canopy is supported by inflating it to slightly higher than atmospheric pressure, eliminating the need for a supporting frame.

Several radically new designs for solar stills are now under serious study. In Denver George O. G. Lof, a consulting engineer, is investigating for the Department of the Interior a still in which the ground acts as a storage bank for the sun's heat. A basin containing a foot of water is placed directly on the ground, so that solar heat absorbed by the water is transmitted to the ground. This heat reservoir then continues to evaporate water when the sun is not shining. If the loss of heat by radiation at night is not too great, it has been estimated that this type of still may produce up to a fifth of a gallon of fresh water per day per square foot at something like 50 cents per thousand gallons.

Maria Telkes of New York University has designed an interesting 10-stage still. It operates without machinery or any energy requirement except solar heat (or comparatively low-temperature heat from some other source). The apparatus is a sandwich-like arrangement of alternate absorbing and condensing layers. A black wick in sheet form, soaked with salt water, absorbs the sun's heat. The evaporated water condenses in the next layer, gives up heat to warm the next wick, and so on. This arrangement produces five or six times as much water as a single-stage solar still per square foot of area exposed to the sun.

Solar stills of various types are being developed in the U. S., North Africa, Australia, Spain, Italy and elsewhere.

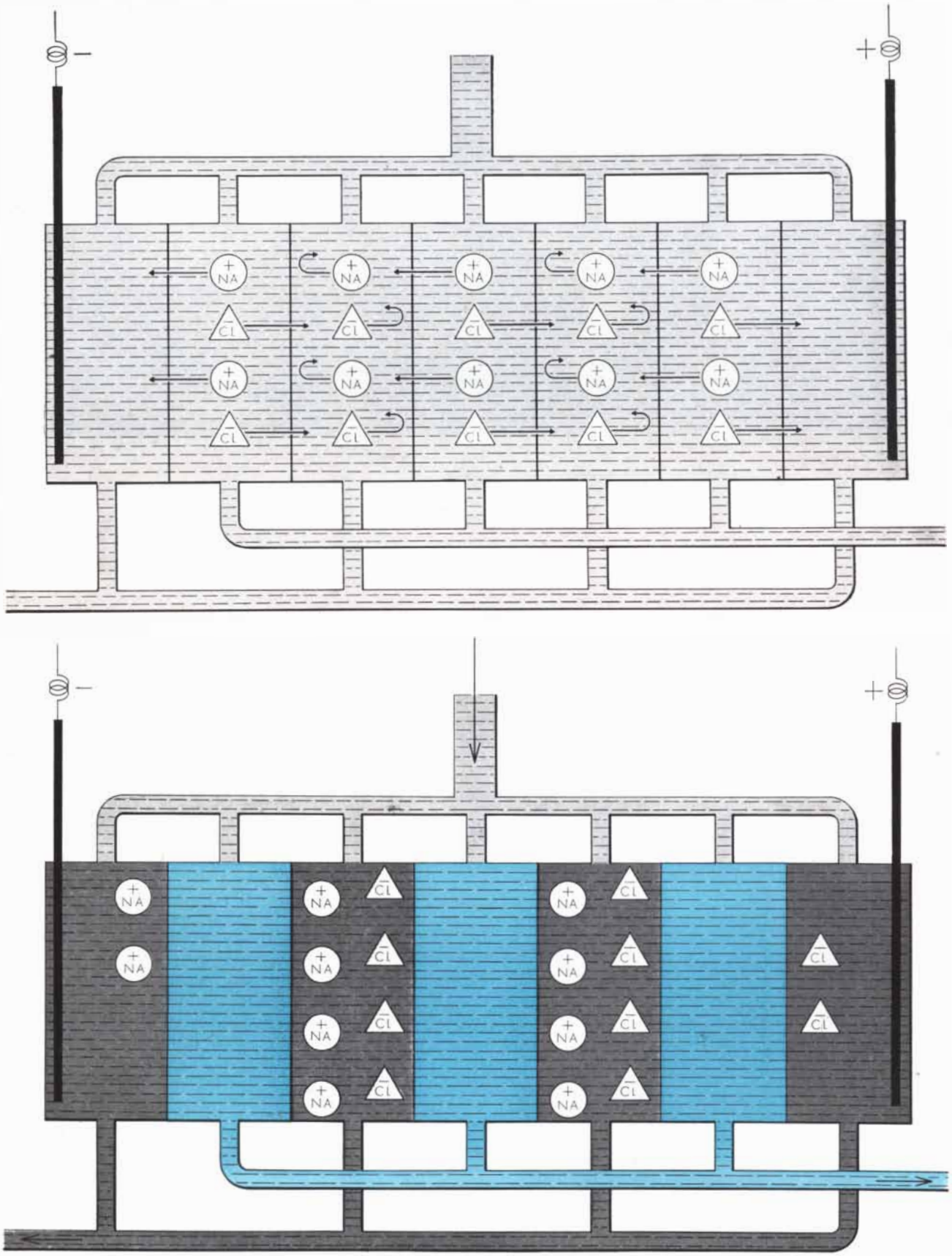
EXPRESSED AS SALTS	PARTS PER MILLION PARTS SEA WATER (APPROXIMATE)
SODIUM CHLORIDE ($NaCl$)	27,213
MAGNESIUM CHLORIDE ($MgCl_2$)	3,807
MAGNESIUM SULFATE ($MgSO_4$)	1,658
CALCIUM SULFATE ($CaSO_4$)	1,260
POTASSIUM SULFATE (K_2SO_4)	863
CALCIUM CARBONATE ($CaCO_3$)	123
MAGNESIUM BROMIDE ($MgBr_2$)	76
TOTAL	35,000
EXPRESSED AS IONS	
CATIONS	
SODIUM (Na^+)	10,722
MAGNESIUM (Mg^{++})	1,297
CALCIUM (Ca^{++})	417
POTASSIUM (K^+)	382
TOTAL	12,818
ANIONS	
CHLORIDE (Cl^-)	19,337
SULFATE (SO_4^{--})	2,705
BICARBONATE (HCO_3^-)	97
CARBONATE (CO_3^{--})	7
BROMIDE (Br^-)	66
TOTAL	22,212

SALTS IN SEA WATER are of many varieties, the principal being shown here. Sea water contains 44 principal elements, including gold in the amount of .000006 parts per million.

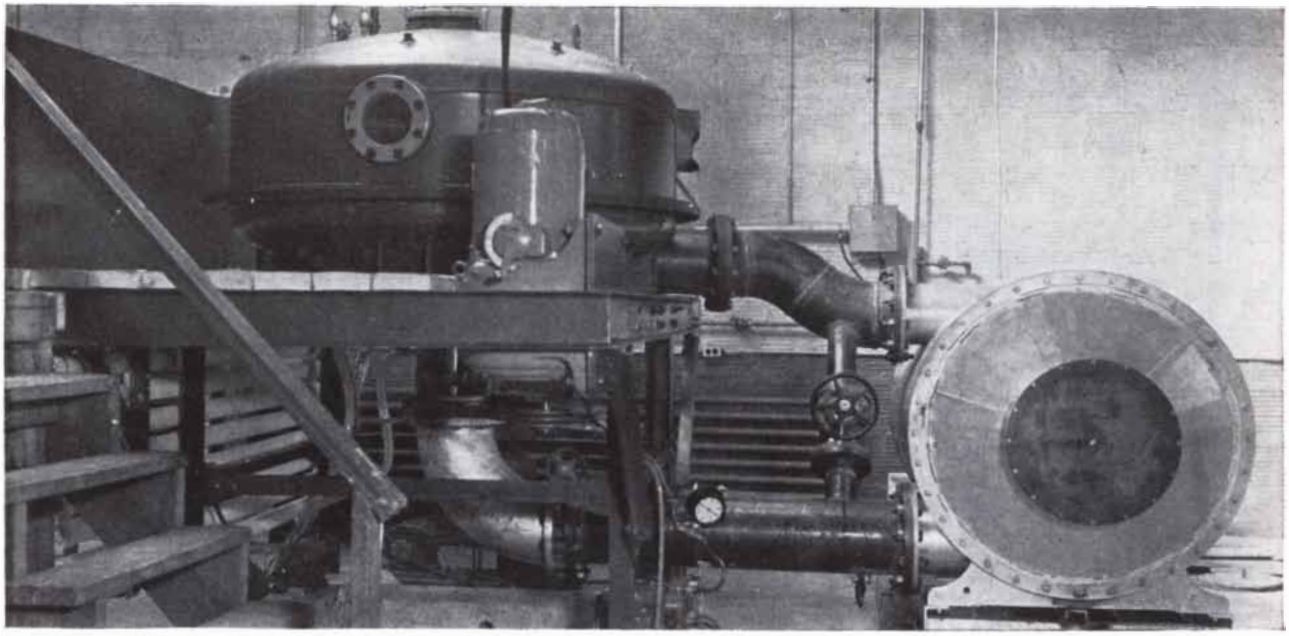
Now let us turn from distillation to other methods of separating salt from water. In recent years the ion-exchange method has been used by industry for special purposes, such as refining brackish water. But it appears that ion-exchange systems will not become sufficiently economical for large-scale desalting of sea water.

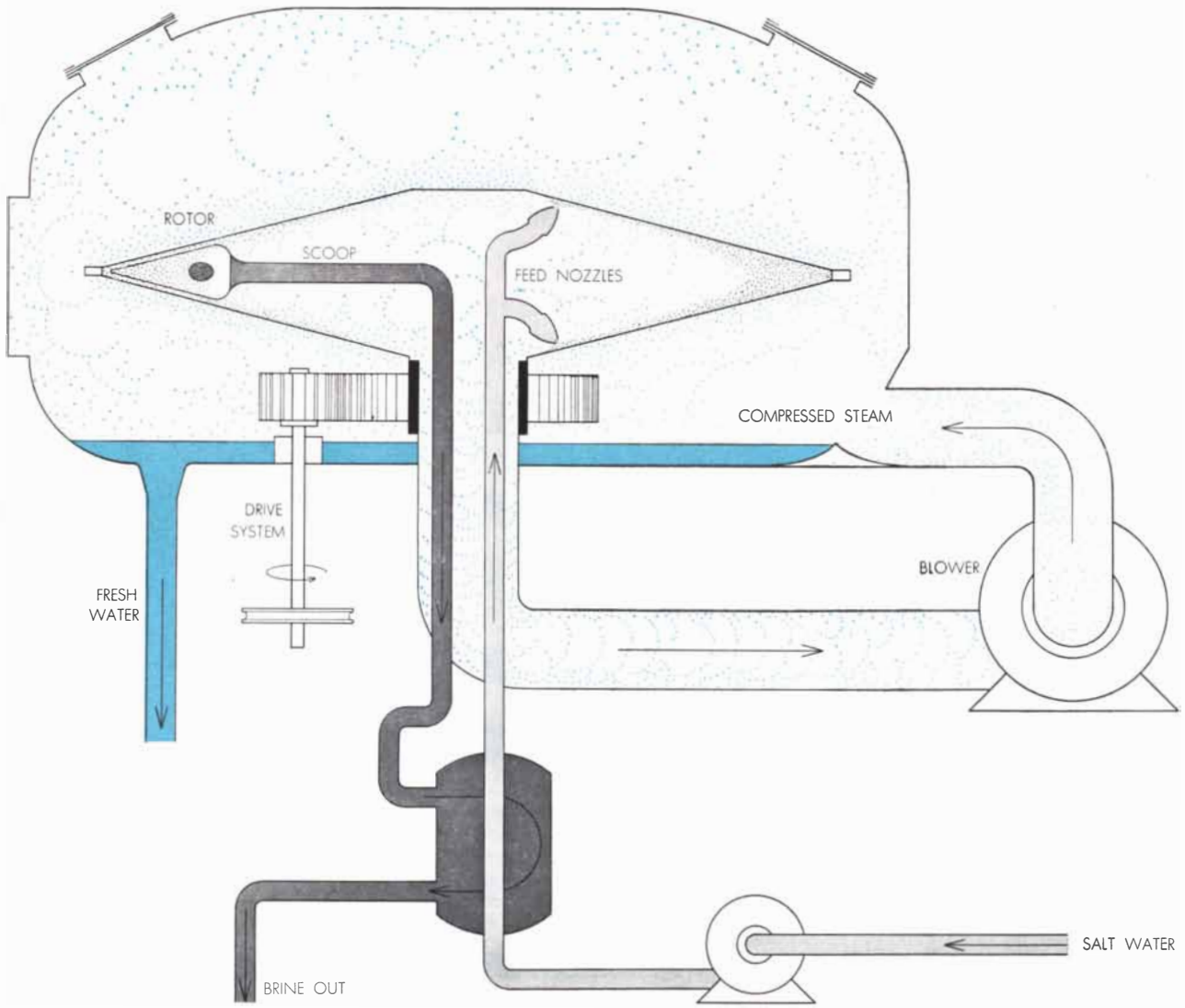
In the ion-exchange process for treating water, the salt water is washed through resins or other material where its salt ions are replaced by unobjectionable ions. Ion exchange has been employed for softening water, for purifying water for special industrial purposes and for desalting brackish well water in the Sahara Desert and elsewhere.

Now the ion-exchange principle has been applied to form selective membranes which can separate ions from water. Ion-exchanges within the membrane make it impermeable either to positive or to negative ions. In the case of a membrane impermeable to positive ions but not to negative ones, an electric current will drive the negative ions through the membrane while it repels the positive ones. If a current is applied in a tank of salt water divided into compartments by a series of membranes, alternately permeable to positive and to negative ions, the salt ions collect in alternate compartments and the water in



ION-EXCHANGE SEPARATION of fresh water from salt employs membranes which are alternately permeable to the sodium or chlorine ion and impermeable to the other. By applying an electric current across the system (*top diagram*), the sodium ions are attracted toward one end of the system and the chlorine ions toward the other. The ions are thus concentrated in alternate cells, leaving desalted water in the cells between (*bottom diagram*). The brine can then be drawn off via one pipe and desalted water via another.





ROTATING-DRUM STILL incorporates principle of compression distillation (*see diagram on page 39*). Salt water is jetted against the hot inner surface of the drum and spread out in thin film by centrifugal force. Water vapor (*colored dots*) is sucked out and compressed by blower at right and then condenses on outer surface of drum. Waste brine is scooped into drain at left inside drum.

the intervening ones is desalted [*see diagram on page 43*].

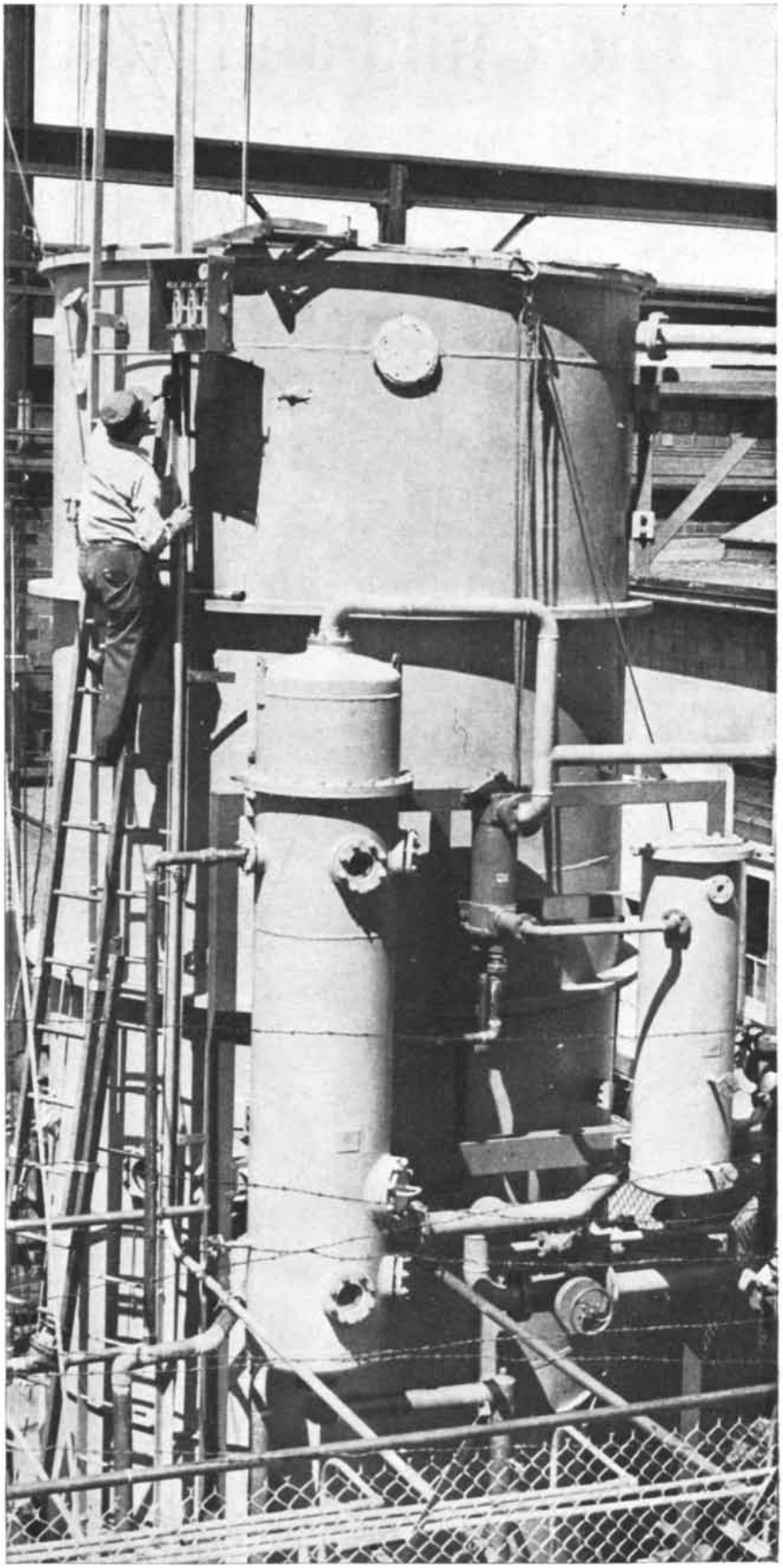
This process, called electrodialysis, is being developed by research groups in the U. S., the Netherlands, England and the Union of South Africa. Because of the electric power requirement, it does not look economically promising for converting sea water, but it offers good prospects for desalting brackish waters.

George W. Murphy, now at the University of Oklahoma, has proposed using the electrical charge of ions from a strong brine, instead of an electric current, as the driving power to push ions through the membrane. Research on this possibility is being done at the Southern Research Institute in Birmingham.

Another promising membrane method is based on the phenomenon of osmosis. As every student of chemistry knows, if a salty solution is divided from a less salty one by an osmotic membrane, which is impermeable to salt but not to water, water passes through the membrane into the more salty solution, tending to equalize the salinity on both sides of the membrane. But this process can be reversed by applying to the more concentrated solution a mechanical pressure greater than the osmotic pressure acting on the water (which amounts to 350 pounds per square inch between fresh water and sea water). That is to say, the "reverse osmosis" forces water through the membrane out of the salty solution, while the membrane holds back the salt ions. Charles E. Reid of the University of Florida has demonstrated that with membranes made of cellulose acetate, 90 to 95 per cent of the salt can be removed from sea water in one pass.

Two other processes which offer promise are being developed. One is separation of salts from water by freezing. The Carrier Corporation, under contract with the Department of the Interior, is conducting research on a very attractive combination of freezing and evaporation, and similar developments have been reported by Israel and Yugoslavia. The other promising process is separation of water by dissolving it in organic solvents which do not dissolve salts.

We are already converting salt water to fresh for some purposes. In five to 15 years we should be able to convert it at reasonable cost for a much larger number of uses, with industrial uses first. Undoubtedly man will find not one but many solutions of the problem, and will begin manufacturing water by a number of devices and on a scale ranging from small household stills to large municipal and industrial plants.



MULTI-ROTOR STILL made up of eight rotating drums of type shown on opposite page, each eight feet in diameter, is under development at Badger Manufacturing Company in Cambridge, Mass. Rotary drum achieves high rate of heat transfer and thus high efficiency.

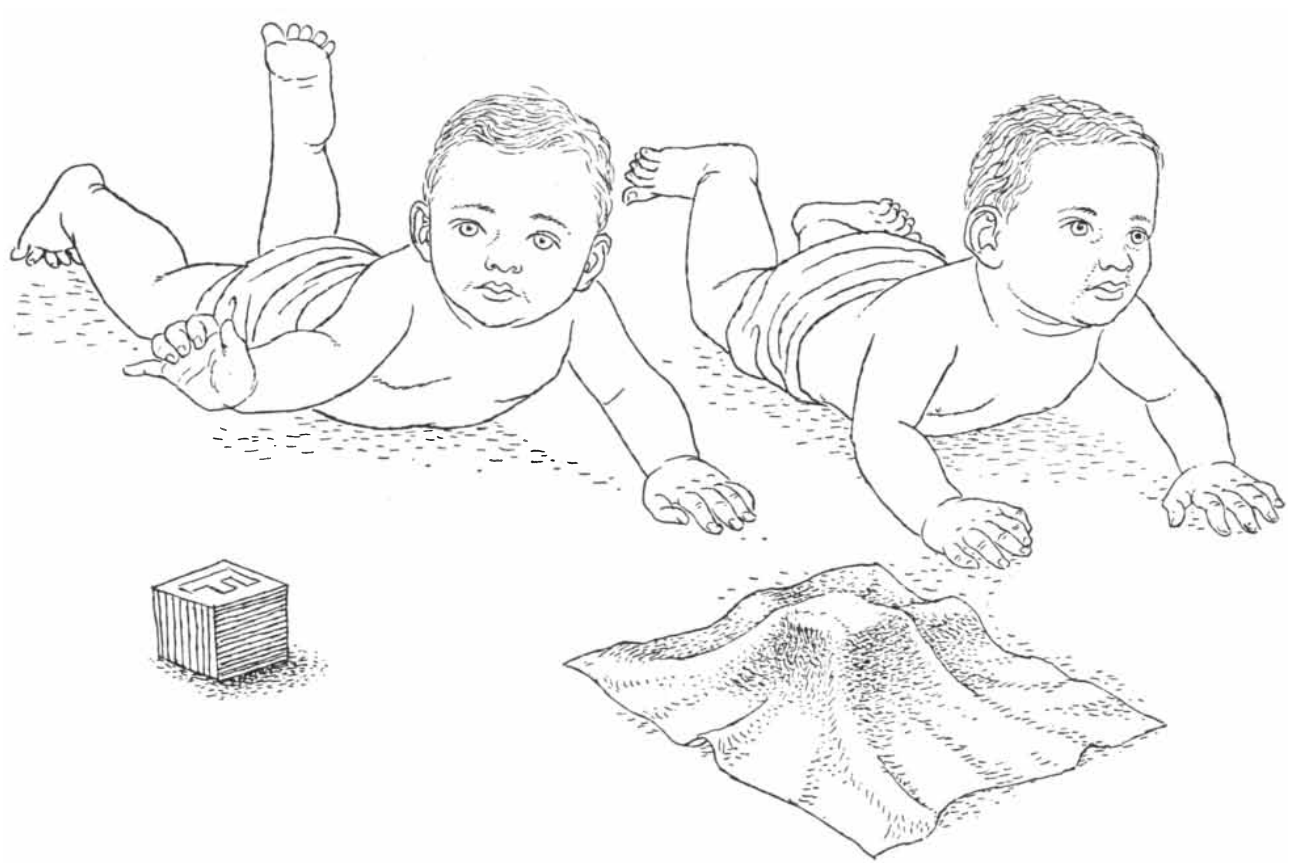
The Child and Modern Physics

A Swiss psychologist experiments with babies, including his own, and comes to the conclusion that their view of reality has much in common with that of the sophisticated physicist

by Jean Piaget

SCIENTIFIC AMERICAN has asked me to discuss some experiments described in my book *The Construction of Reality in the Child*, and I do so with pleasure. These observations, carried out on very young children during the first 18 or 24 months of life, clarify in the most striking manner how we form certain fundamental concepts of the physical world, such as the existence of objects, space and causality. Surprisingly, they also lead us directly into some basic philosophical and psychological questions of present-day thinking in physics.

Contemporary physicists have abandoned some old intuitions about the nature of the physical world. They have, for instance, renounced the concept of the permanence of objects in the submicroscopic realm: a particle does not exist unless it can be localized; if it cannot be located at a particular position, it loses its title as an object and must be described in other terms. Now by an extremely curious coincidence it is found that a very young baby acts with regard to objects rather like a physicist. The baby believes in an object as long as he can localize it, and ceases to believe in



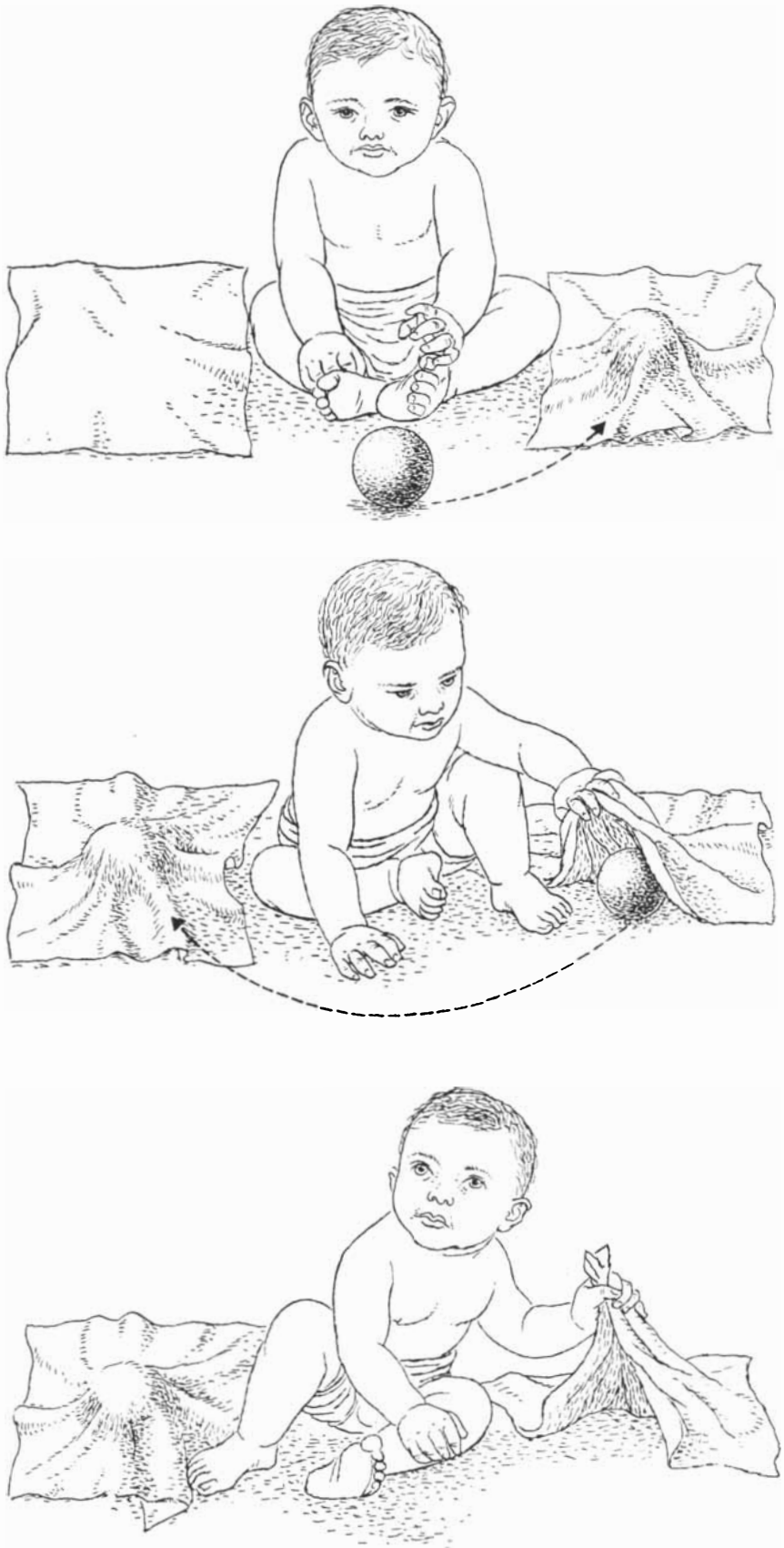
CHILD OF ABOUT SIX MONTHS will usually reach for an interesting object placed in front of it (*left*). In one experiment Piaget put a cloth over the object as the child reached for it; the child withdrew his hand as though the object had been removed (*right*).

it when he can no longer do so. The great difference between the baby and the physicist, of course, is that the baby's faculty of localization is less powerful.

Let us, for example, take the case of a baby of five or six months—that is to say, at an age when he has begun to coordinate vision with prehension and so can pick up an object he sees. We place before him an object which he will find of interest, such as a watch. He starts to pick it up. As his arm begins to reach for it, we cover the watch with a piece of cloth. A baby at this stage of development will withdraw his hand as though the object had become inaccessible. It is not that the child is deterred by the cloth as an obstacle, for if we place the cloth over his face he will remove it readily enough. Nor is it lack of interest in the object. I performed the same experiment with a milk bottle on my son at the age of seven months, when he was being bottle-fed. At his feeding time I offered the child his bottle filled with milk, but as he stretched out his hands I moved the bottle behind my upraised arm. If the bottle remained partly in sight, the baby would reach around my arm to seize it. But when my arm hid the bottle, the child would begin to cry as though it had vanished completely!

One might, then, form the hypothesis that for a child at this level of development objects are not yet endowed with substantial permanence. However. the preceding observations are open to many other possible interpretations. We must pursue the matter further and analyze behavior at the stage when a child begins to look for concealed objects. Sooner or later he will discover that when an object has disappeared under a piece of cloth he may still find and identify it by taking hold of the bump under the cloth, and so on. What occurs when a child begins to search systematically for concealed objects? Does he immediately grasp the concept that an object has been moved to a particular place by a sequence of displacements? If not, what sort of concept of the existence of objects does he have?

The experiments by which I explored this point were first suggested to me by a chance observation of a baby who was chasing a ball around a room. When the ball rolled under an armchair, he retrieved it without difficulty. But after it had rolled under a sofa where he could not see it, he soon stopped looking there and ran back to look for it under the armchair! We must conclude that he had

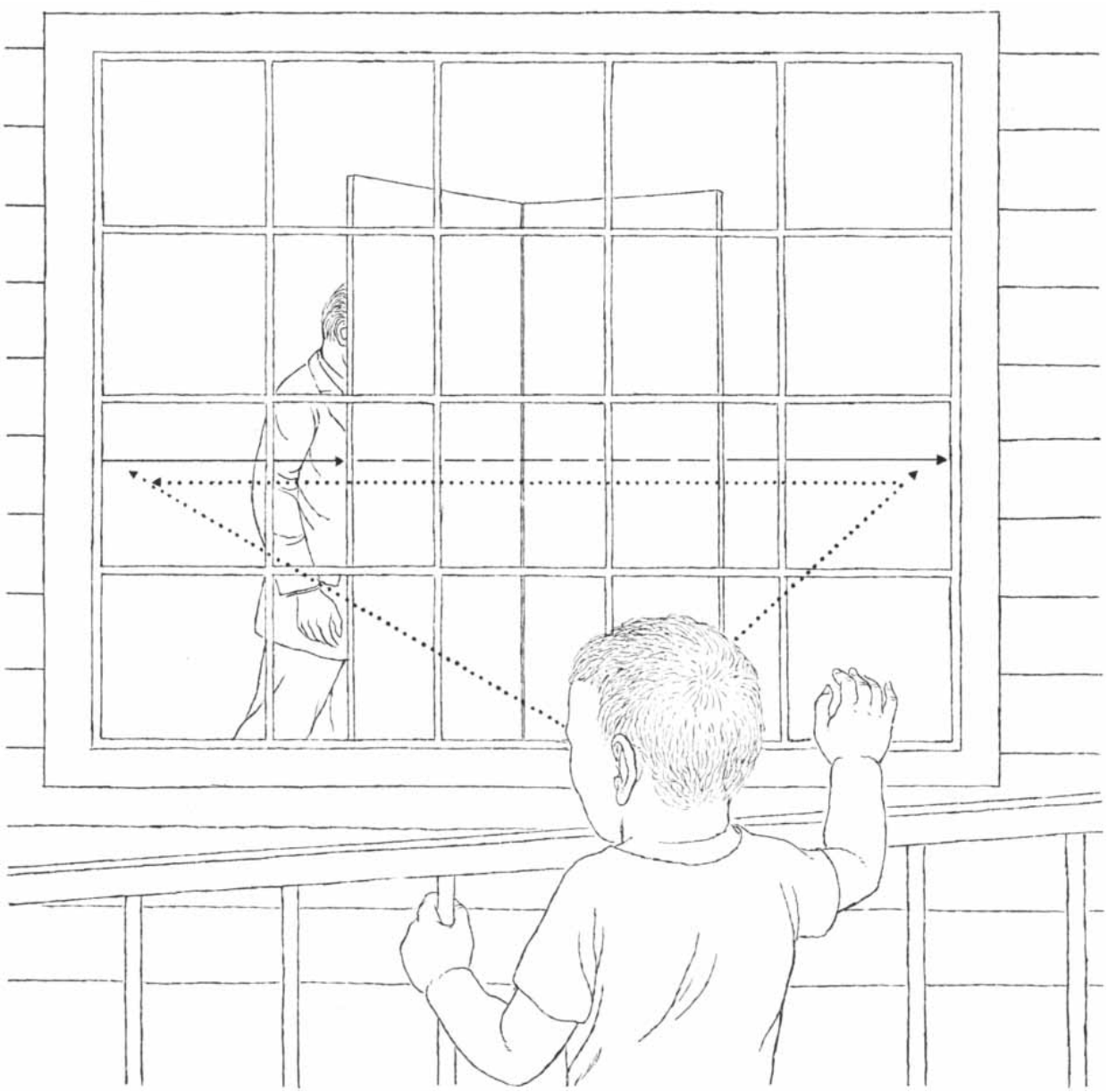


IN ANOTHER EXPERIMENT a child watched a toy placed beneath a cloth. The child then looked for the toy. When the toy was placed beneath a second cloth, he looked under the first.

not yet constructed the concept of a permanent object; the ball existed only as a sort of semi-object, midway between perceptual image and substance. There was a beginning of localization, necessary to give an object permanence, but the localization was linked to the place of the child's previously successful action, not yet to the object itself.

As my own children developed, I watched for the time when they began to look for concealed objects, and at the appropriate stage I made certain systematic experiments with each. The child would be seated between two pieces of cloth, two cushions or other covering objects. I would give him a toy, then take it back and place it under cover *A*. The child would follow it with his eyes and recover the toy. Then I would take it back, and, very slowly, place it under *B*. In no case did the child look immediately under *B*. On the contrary, all three of my children began by searching under *A*. One of them persisted in looking under *A* rather than *B* for the first three weeks of testing. Then he began to search under *B* first when I placed the toy there, but not finding the toy immediately, because it was far under, he would go back to *A*. Not until much later did he confine his search to *B*, ignoring the empty *A*. Another of my children followed the same evolution but took a shorter time; the third telescoped it into a few hours. My friend the late Kurt Lewin once told me that he obtained the same results in similar experiments with several subjects.

It would seem, from these results, that the child's formation of the concept of an object as a permanent thing is linked to his construction of space. In the process the child's mind passes from subjective localization, which is a function of previously successful actions, to objective localization, which is a function of the displacements of the object itself. The latter must be coordinated according to the structure of what geometers call a "group of displacements." In other



CHILD LOOKED TOWARD THE LEFT while the experimenter walked behind a screen. When the experimenter emerged from the right side of the screen, the child was astonished. When the experimenter walked out of sight to the right, the child looked back to left.

words, the idea of the permanence of the object is constructed at the same time as the "group of displacements," and the permanent object is none other than the "invariant" of the group.

During the first year of life, before he has begun to look for concealed objects, the child seems to be incapable of organizing displacements into a group structure. He is therefore unable to comprehend reversible or circuitous motions. The absence of the concept of reversibility of movement is illustrated by two experiments I performed. In one I walked past a large window while the child watched me from his crib on the balcony outside. I had covered the middle section of the window with a large screen. As I came into view of the child at the left, I would exchange signs and smiles with the baby and continue walking until I disappeared behind the screen in the middle. Through an arrangement of mirrors I could see that the child was still looking for me at the left side of the window. When I emerged from behind the screen on the right side, the baby was quite astonished. He followed me with his eyes until I passed out of sight beyond the right end of the window. Then he looked for me at the left!

In the other experiment I rotated the child's bottle before his eyes to see if he could restore it to its original position by reversing the rotation. First I held it upright and offered it to him; as he was about to take it, I began turning it over slowly. So long as the red rubber nipple was visible to him the baby would quickly right the bottle when he seized it. But if the bottle was turned over completely, he did not attempt to turn it upright but would begin to suck the glass bottom of the bottle.

These simple experiments (and many others) show that a very young baby has little or no organized conception of space or movements. When he does begin to form a concept of space, it is at first centered on his own body and on the location of successful actions. At this stage there is no such thing as a permanent object. The child begins to attribute permanence to objects only after he develops a sensory-motor realization of space in which objects are displaced with regard to one another according to certain laws, so that objects assume a definite location. His construction of the object and of space are one and the same construction. It involves, among other things, a process of decentralization from his original spatial egocentricity. As his spatial concept grows, his own body becomes only one object among others.

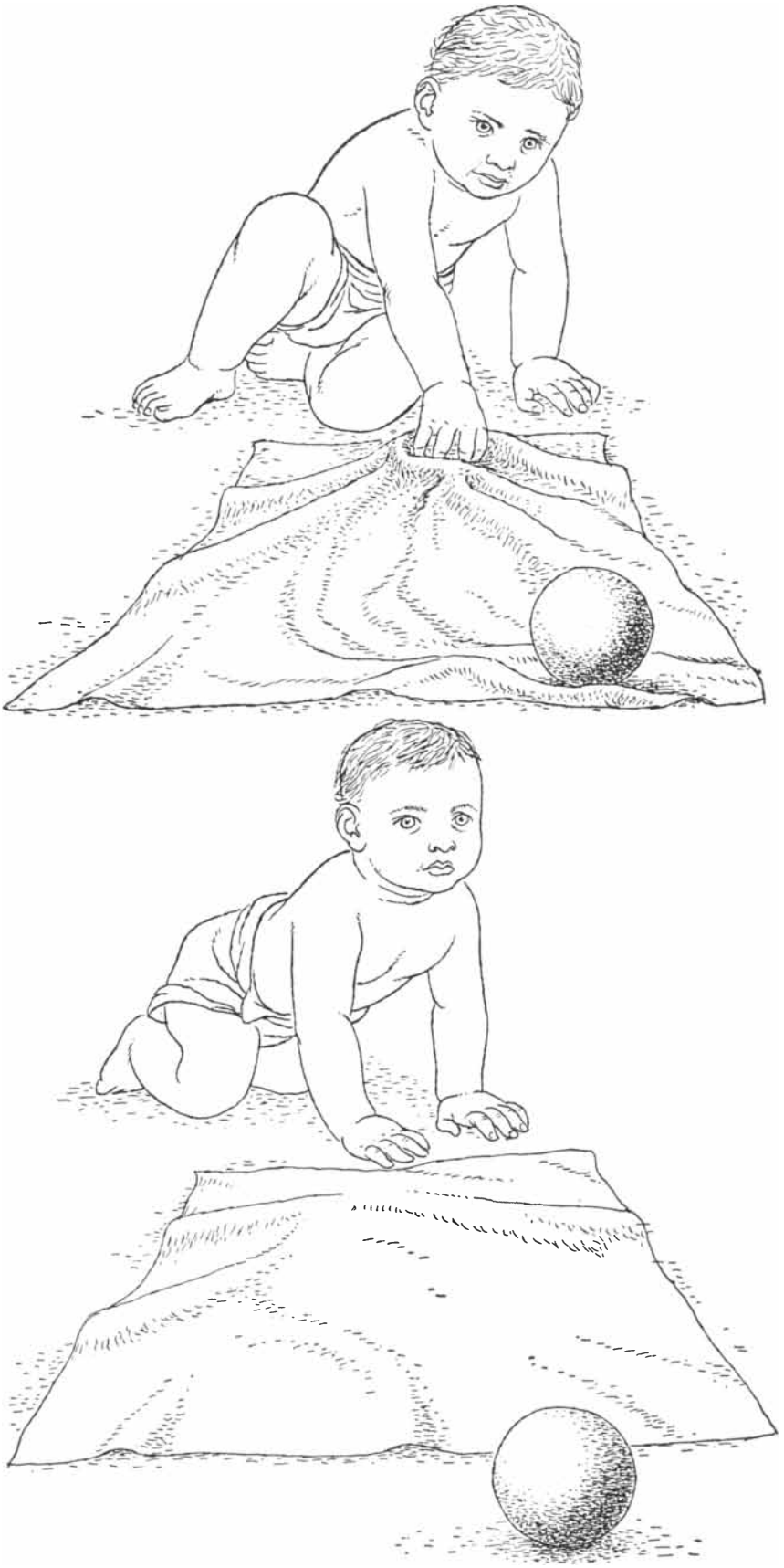
CHILD PULLED AT STRING attached to a semitransparent canopy, on top of which was a collection of rattles. When the child heard the sound of the rattles, he pulled the string again and again. Later the experimenter removed the rattles and interested the child in a series of pleasant whistles. When the whistles stopped, the child pulled the string again.

With equally simple experiments one can study the child's development of the concept of cause and effect. For example, I made the following experiment as soon as my children began to pick up objects they saw—which on the average starts at about the age of four and a half months. I would cover the baby's crib with a semitransparent canopy and lay several celluloid rattles on top of this covering. A cord was suspended from the cover, so that when it was pulled the cover and rattles would shake. Sooner or later the baby would happen by chance to grasp the cord and of course make the rattles bounce. At first the baby would be frightened by these unforeseen noises, but he would soon become enchanted and pull the cord harder and harder, watching the dance of the toys above him.

Did the child actually note a relation between the action of pulling the cord and the dance of the toys? I removed the rattles from the crib cover and brought a new toy. The baby stretched out his hands for it, but instead of giving it to him I put it on the crib cover. He reached for the cord, at the same time watching the toy. Clearly the infant did establish a causal relationship between the action of pulling the cord and the behavior of toys on the cover.

But what was the nature of this relation? Does an infant of this age perceive a physical connection between the cord and the covering of the crib and comprehend a physical cause and effect? Or does he merely make a more general and subjective connection, at once egocentric and phenomenalistic, between the "action of pulling the cord" and the interesting sensory results in the form of the sight and sound of the bouncing toys?

In order to decide this matter, we construct the following experiment. Leaving the transparent cover on the crib, I stand behind the crib where the baby cannot see me and gently swing above him a toy suspended from the end of a long stick. The baby watches it, smiles, coos and so on. Then I stop swinging the toy. The baby's response now answers our question with utter clarity. He immediately seizes the cord hanging from the canopy and pulls it! When his yanks fail to make the toy resume its swinging, he pulls harder, watching the motionless



CHILD OF ABOUT ONE YEAR will pull a blanket toward him to pick up an object lying on the blanket. If the object is lying on the floor, the child will not pull at the blanket.

toy all the while. It does not occur to him to follow down the stick with his eyes to see what might have caused its previous motion.

The baby may even respond in the same manner to a distant sound. Hiding myself behind a screen in a corner of the room, I whistle a certain number of times at regular intervals until the baby has acquired a sufficiently lively interest to stretch his head and look in the direction of my corner. Then I stop whistling. The baby's eyes explore the corner for a moment; then he pulls the cord hanging in his crib, looking back to the corner from which the whistles came!

In short, the action of pulling the cord has been generalized to represent a means of prolonging interesting experiences, without any thought being paid to distances or points of contact. This scheme of action even becomes a means of exploration. If the baby, handed an unfamiliar object, fails to get a sufficiently interesting result by shaking or banging it, he pulls the cord with the other hand, all the while regarding attentively the object he is holding.

A child's first sense of causal relation, then, is simply a diffuse connection between an action on the one hand and a result on the other, without comprehension of spatial relations or intermediary objects. This is perfectly consistent with what we have learned of the infant's initial inability to organize space and his consequent lack of the concept of permanent objects. Toward the end of the first year, as he begins to organize space and comprehend the existence of objects, he acquires an objective and spatial idea of causality. An experiment illustrates this point. We seat the child before a blanket with an object placed on it at the other end, beyond the child's immediate reach. He tries at first to seize the object directly. Failing to reach it, he may immediately comprehend that pulling on the blanket will bring the object closer; if not, he may discover this accidentally by random jerking of the blanket. In the latter case we can make a test which shows how much he comprehends of the significance of his discovery. We put the object not on top of the blanket but on the floor just off the end or the side. If the child still has only a generalized concept of causality, he will pull the blanket, watching the object as if he expects it to move toward him. But if the child has reached the stage where his sense of causality has become spatialized and objectivized, he will pull

the blanket only if the object is lying on top of it.

I could go on to describe analogous experiments which demonstrate how a child acquires his primary concepts of chronological order, of the relations between movements and time, and so on. But I think it will be most interesting to conclude with some studies which bear on certain basic questions in physics—namely, the concepts of velocity and relativity.

Does a child's first conception of velocity include comprehension of it as a function of distance and time, or is his notion more primitive and intuitive? Albert Einstein himself posed this question to me in 1928 when I was demonstrating some experiments on causality to him one day. I have since performed a very simple experiment which shows that a child does not think of velocity in terms of the distance-time relation. We place before the child two tunnels, one of which is obviously much longer than the other, and then we push a doll through each tunnel with a metal rod in such a way that the dolls arrive at the other end of both tunnels simultaneously. We ask the child:

"Is one tunnel longer than the other?"

"Yes, that one."

"Did both dolls go through the tunnels at the same speed, or did one go faster than the other?"

"The same speed."

"Why?"

"Because they arrived at the same time."

Now we take the tunnels away and push the dolls along the floor in full sight, over the respectively different distances, both arriving at their destinations simultaneously as before. This time the child recognizes that one doll traveled faster than the other.

"Why?"

"Because this doll passed the other."

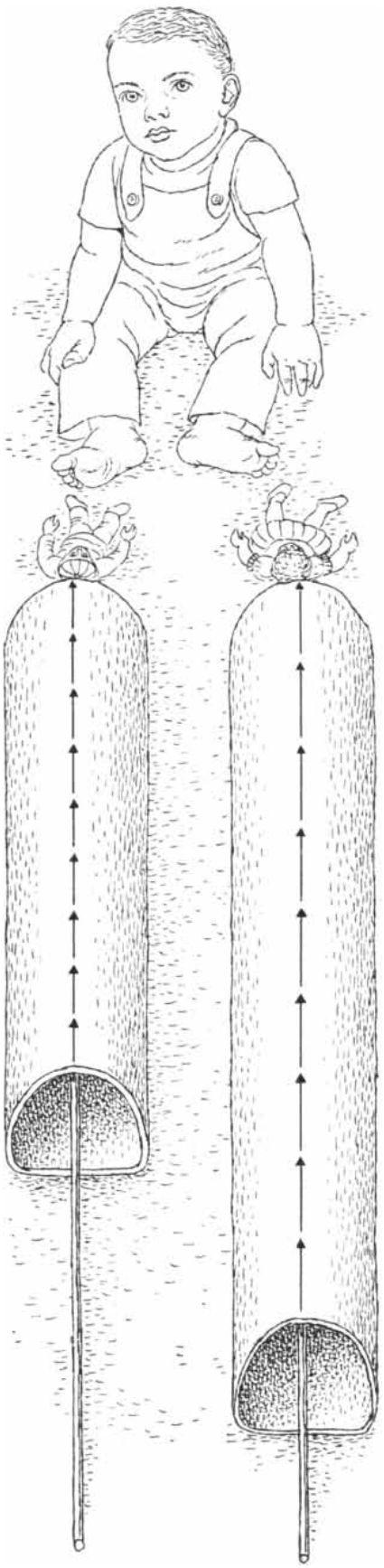
Incidentally, if anyone wishes to repeat these experiments, I must remark that I have not described them in full here; the details are given in my book *The Concepts of Movement and Velocity in the Child.* I mention this because a psychologist took issue with a previous article of mine in SCIENTIFIC AMERICAN ("How Children Form Mathematical Concepts"; November, 1953) on a basis of misunderstanding and lack of full knowledge of my experiments.

What the experiments I have just outlined, and others, demonstrate is that a child's first notion of velocity is based on the intuitive realization that, of two bodies in motion in the same direction, the one that passes the other is empowered with greater velocity. If this intuition is much simpler for the child to acquire than the distance-time relation, this is in part because the notion of order is easier to grasp than the concept of intervals or measurement. Passing is nothing but a change of order of two objects. The child will judge similarly on the basis of the order of arrival at a given point: if a rapidly moving body stops before overtaking a slower moving one, the child will often pronounce the one in the lead to have the greater velocity.

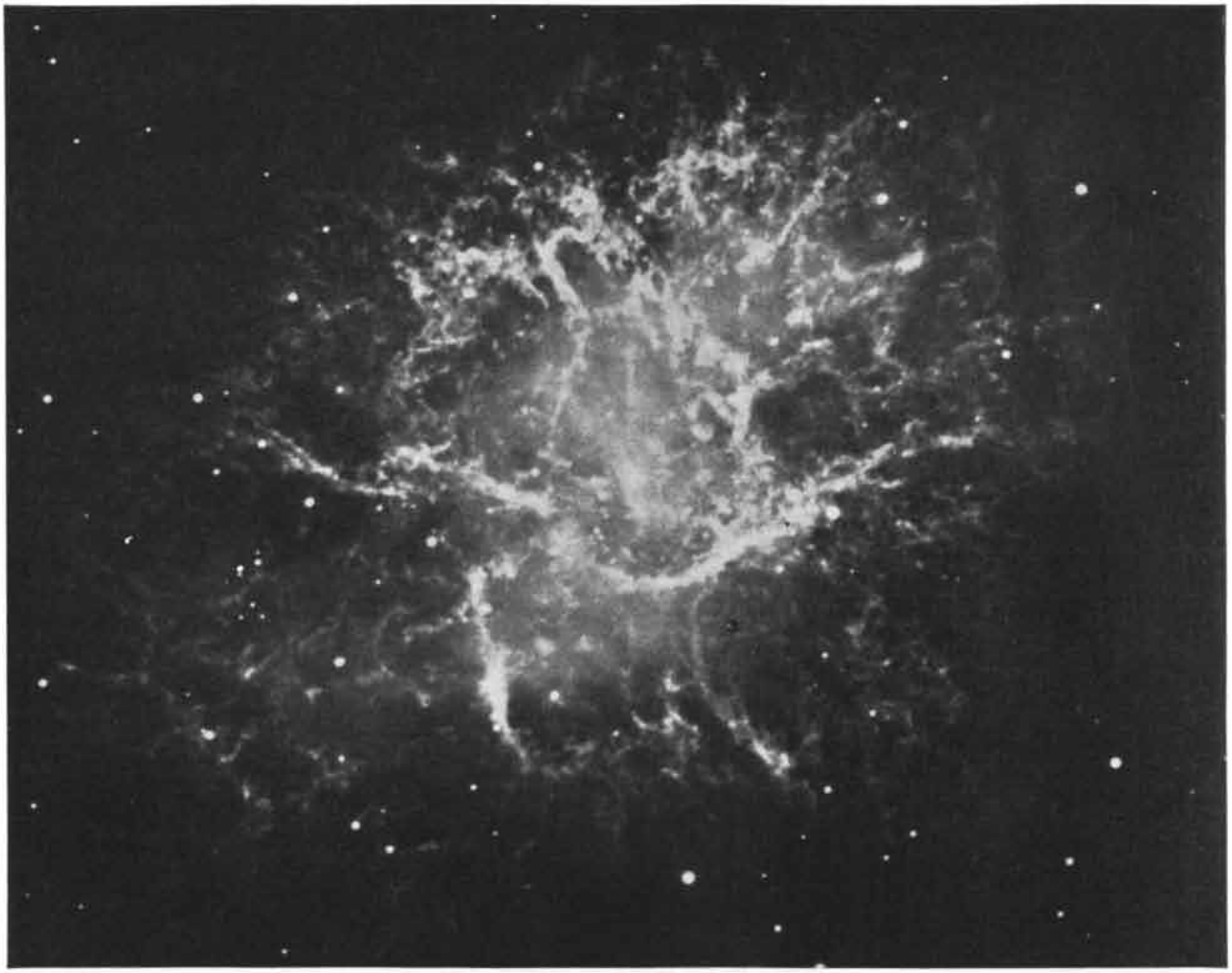
These findings, derived from researches to which the founder of the theory of relativity inspired us, return by an unforeseen route to theoretical physics. What follows is a striking demonstration of how psychology and physics can collaborate.

Physicists, considering velocity and time, have always been trapped in a kind of vicious circle: velocity is defined in terms of time, yet time cannot be measured without having recourse to the notion of velocity. It would be far more satisfying to be able to start from a notion of velocity that is independent of time. A French physicist, J. Abelé, starting from our child psychology, has conceived the idea of escaping from the vicious circle by defining velocity according to the notion of passing. This idea permits him to explain why the velocity of light must be considered invariant—a necessity which was somewhat mysterious in the initial exposition of the theory of relativity. In Abelé's scheme velocity, conceived as a simple passing, is not measured directly: successively higher velocities are calculated in an additive way by a series of superimposed passings. We construct the additive function by introducing an algebraic commutative group and a logarithmic expression. From this additive function we can derive the law of the "composition of velocities" of relativity theory. Moreover, by introducing the concept of relative motion of bodies in considering two constant velocities in the same direction, we arrive at an expression for invariant acceleration with regard to Lorentz transformations, and above all at a unique expression for bodies in motion which substantiates the constancy of the velocity of light.

It is certainly of no small interest that the psychological study of how young children spontaneously form the concepts of objects, space, time and velocity can lead to new insight into such profound matters as the theory of relativity.



CHILD SEEING DOLLS pushed through two tunnels said they moved at same speed because they emerged at the same time.



THE CRAB NEBULA

It shines with a strange sort of light that gives evidence of a wholly unexpected natural phenomenon. This glowing body of gas is apparently a gigantic electron synchrotron

by Jan H. Oort

On the fourth of July in the year 1054 there was an explosion in the heavens which must have been one of the most spectacular in the history of man on this planet. A star in our galaxy which for billions of years had been invisible from the earth suddenly became one of the brightest in the sky—so bright that it could be seen in full daylight. Strangely, although the event must have been witnessed by practically everybody in Europe, not a single mention of it has been found in any European chronicle. But in China and Japan, where heavenly phenomena were watched intently as astrological signs and were recorded in the imperial annals, the "guest star," as the Chinese called it, was described in some detail.

The Chinese chroniclers located the exploding star at a position in the sky "several inches southeast of *T'ien-kuan*" (Zeta Tauri in the constellation of the Bull). After the initial burst, which for three weeks was brilliant enough to be visible by day, the "guest star" gradually faded, and two years later it had disappeared from view to the naked eye.

But in the 18th century, when telescopes had come into general use, astronomers picked up a nebula at the location of the vanished star. There can be little doubt that this object, now called the Crab Nebula, is the debris of the 1054 explosion. The Chinese descriptions also establish that the explosion must have been a supernova of "Class I." Supernovae of this order have been observed by modern astronomers only in galaxies outside our own—too far away to give us much information. The Crab Nebula therefore provides a unique opportunity to see what becomes of a star after a great explosion. What is more, it has presented, upon inspection with modern instruments, a strange and totally unexpected physical phenomenon which is now exciting keen interest as a possible key to some major current mysteries of the universe.

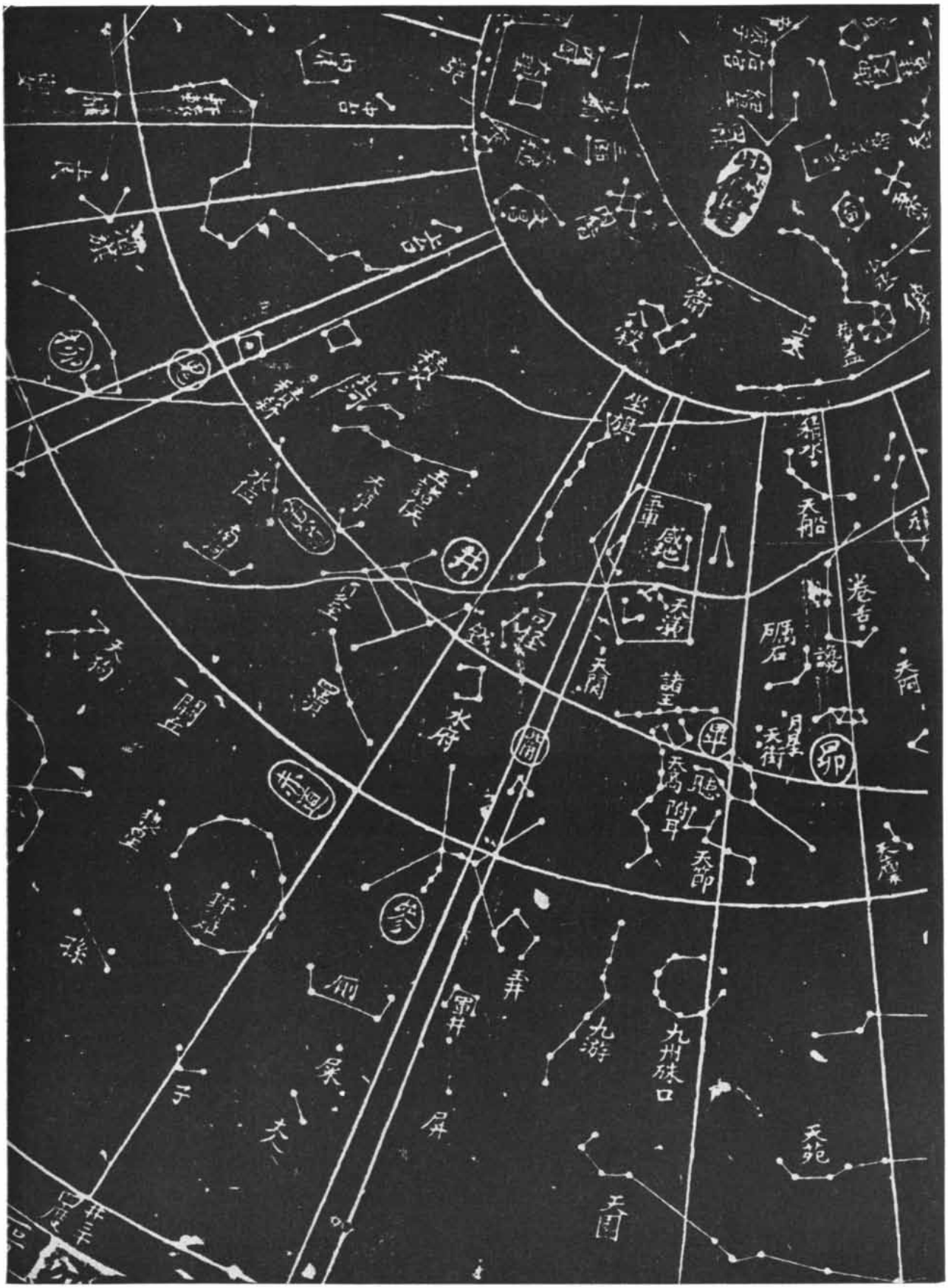
Exactly what sets off the explosion of a star is not known. As George Gamow has pointed out [see "Supernovae," by George Gamow; SCIENTIFIC AMERICAN, December, 1949], the star must develop some kind of internal instability which results in the sudden release of an enormous amount of energy, throwing masses of material into space at velocities so high that the debris soon escapes from the star's gravitational pull and goes on expanding indefinitely. The Crab Nebula is expanding at about 1,100 kilometers (680 miles) per second. It now occupies a space about six light-years in diameter. The mass of the material thrown out by the explosion of the star is estimated to be between one tenth and one hundredth of the mass of our sun. At the center of the Nebula we can see two small stars, one of which is thought to be the surviving core of the original star.

The phenomenon that I shall discuss in this article is illustrated by two contrasting pictures of the Crab Nebula, made with different color filters [*see photographs on opposite page*]. The first was taken through a filter which absorbs much of the light from the Nebula and lets through mainly certain wavelengths emitted by hydrogen and nitrogen atoms. In this picture, based on the selected strong emissions of light, the Nebula seems to consist of a multitude of filaments; actually the filaments form a kind of shell, made up mainly of hydrogen and helium atoms, surrounding the central part of the Nebula.

The second picture bears hardly any resemblance to the first. It was made with filters which absorb all of the stronger lines (wavelengths) of light ordinarily emitted by radiating atoms. What comes through is a continuous spectrum of light spread evenly over a wide band of wavelengths. There is something very puzzling about this "continuous" radiation, as it is called. Rarefied gases in space, when in the glowing state, always emit light with particular intensity at certain discrete wavelengths ("emission lines"). The curious thing is that the light of the structures we see in this picture shows no special emission lines. Yet there can be no doubt that it comes from extremely rarefied gaseous material.

In 1953 a Soviet astronomer, I. S. Shklovsky, suggested that this unusual continuous radiation came not from atoms but from free electrons moving at high speed in a magnetic field. His hypothesis was based on a discovery by the U. S. physicists F. R. Elder, A. M. Guzewitsch, Robert V. Langmuir and H. C. Pollock. They had observed that electrons accelerated to very high velocity in a synchrotron, where their motion is bent into a circular path by a magnetic field, radiated an intense light. This "synchrotron light," according to the classical laws of electromagnetics, is due to the acceleration, or bending, of

CRAB NEBULA was photographed through two different color filters with the 200-inch telescope on Palomar Mountain. The filter for the upper picture passed the individual wavelengths that make up the line spectra of incandescent hydrogen and nitrogen. The filter for the lower picture screened out these wavelengths. The light that came through proved to give a continuous spectrum rather than a series of bright lines.



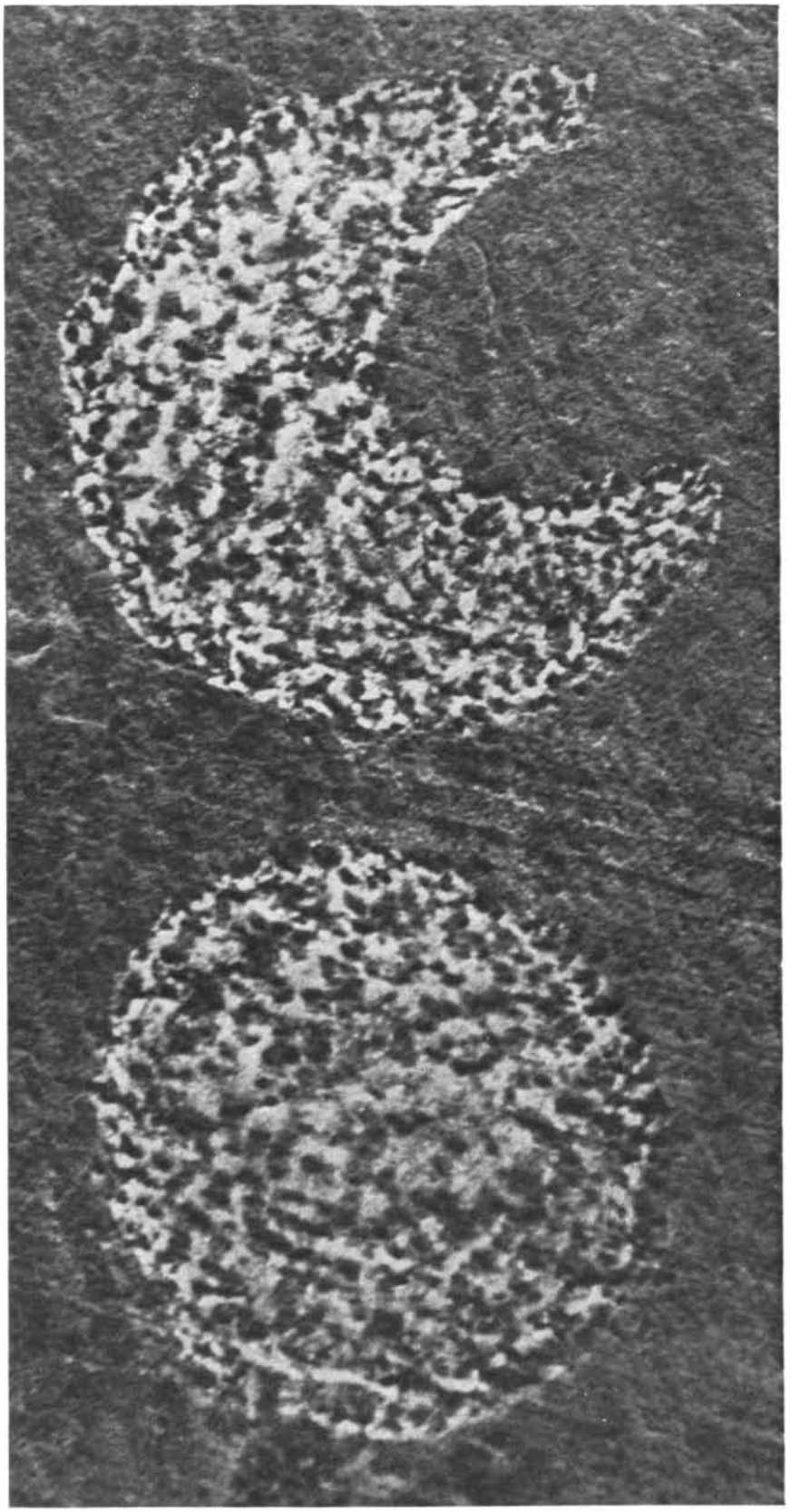
CHINESE STAR CHART was made about 1200 A.D. At right center is a constellation of six stars in a straight line. Above its left end are the Chinese words *T'ien-kuan*, and above them is a dot signifying a star. *T'ien-kuan* is the modern Zeta Tauri, which is immediately adjacent to the Crab Nebula. The Chinese identified the "guest star," or supernova, of 1054 as being close to *T'ien-kuan*.

the electrons from a uniform straight path. Unlike common light, which is generated by the vibration of electrons in their small orbits within an atom, the radiation of the electrons accelerated in the synchrotron has a continuous spectrum instead of discrete emission lines. Shklovsky proposed that the continuous light observed in the Crab Nebula might be generated by the action of a magnetic field in the Nebula upon very high speed electrons.

He suggested also that the same synchrotron action could account for the strong radio emissions from the Crab Nebula. The discovery of radio broadcasts from space, and the pinpointing of such emissions in the Crab Nebula and other radio "stars," has been one of the great surprises in astronomy in this century. There has been much speculation about how these radio emissions are generated [see "Radio Galaxies," by Martin Ryle; SCIENTIFIC AMERICAN, September, 1956]. According to Shklovsky's hypothesis, electrons of extremely high velocities in a magnetic field radiate continuous light, and those of slightly lower energies radiate at radio wavelengths. Shklovsky's idea therefore would answer two questions which have puzzled astronomers: the mystery of the strange light from the Crab Nebula and the origin of the radio broadcasts from the Crab and other radio "stars."

It is an attractive theory but at first thought a dubious one, because it seems implausible that a synchrotron mechanism like the very special one created in a laboratory operates in nature. However, there is a way to test whether the light from the Crab Nebula is truly of the synchrotron type. The light from electrons accelerated in a synchrotron is polarized: that is to say, the light waves vibrate only in the direction perpendicular to the magnetic field. Is the continuous light of the Crab Nebula polarized? This is easily determined by photographing it through polaroid screens.

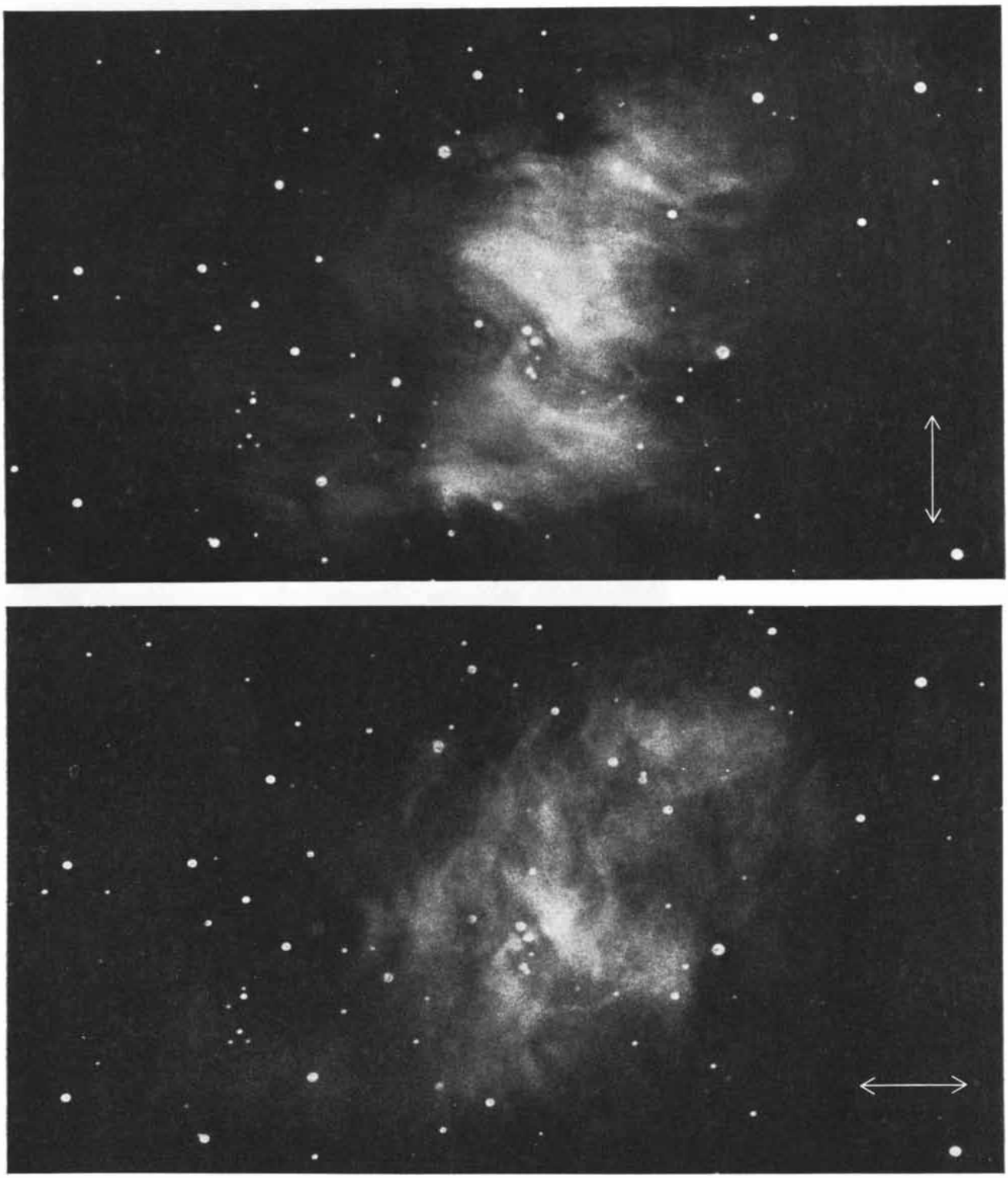
The Soviet astronomer V. A. Dombrovsky was the first to establish that the light is in fact polarized. His pictures showed a considerable polarization of the light from the Nebula as a whole. Later Theodore Walraven of the Netherlands explored the Nebula in more detail and found that the polarization varied greatly in different regions. Pictures made by Walter Baade with the 200-inch telescope on Palomar Mountain portray the polarization in still more detail [*see photographs on the next two pages*]. They indicate that all the light



INDIAN ROCK CARVING may very well represent the supernova which gave rise to the Crab Nebula, according to a study made by William C. Miller of the Mount Wilson and Palomar Observatories. The carving was found in Navaho Canyon in northern Arizona. Chinese records indicate that the nova flared up on the morning of July 4, 1054. Before dawn on July 5, 1054, the crescent moon stood two degrees north of the position of the Crab Nebula. Thus the carving seems to represent the supernova below the moon.

in the "continuous light" picture of the Crab Nebula is polarized, and they show further that over the whole of the brighter part of the Nebula the polarization is predominantly in one direction, indicating that the magnetic field in this region likewise must be mainly in one direction. From the detailed pictures we can obtain a rough picture of the structure of the magnetic field in the Crab Nebula [*see photograph at top of page 58*].

We have every reason, then, to believe that the continuous light of the Nebula is actually synchrotron light; it would be extremely difficult, if not impossible, to explain the observed polarization on any other basis. Having reached this conclusion, we can also plausibly assume that the radio emission of the Nebula is generated by the same mechanism. The radio emission should be more intense than the continuous light emission, because radio-emitting electrons (having lower energies) are

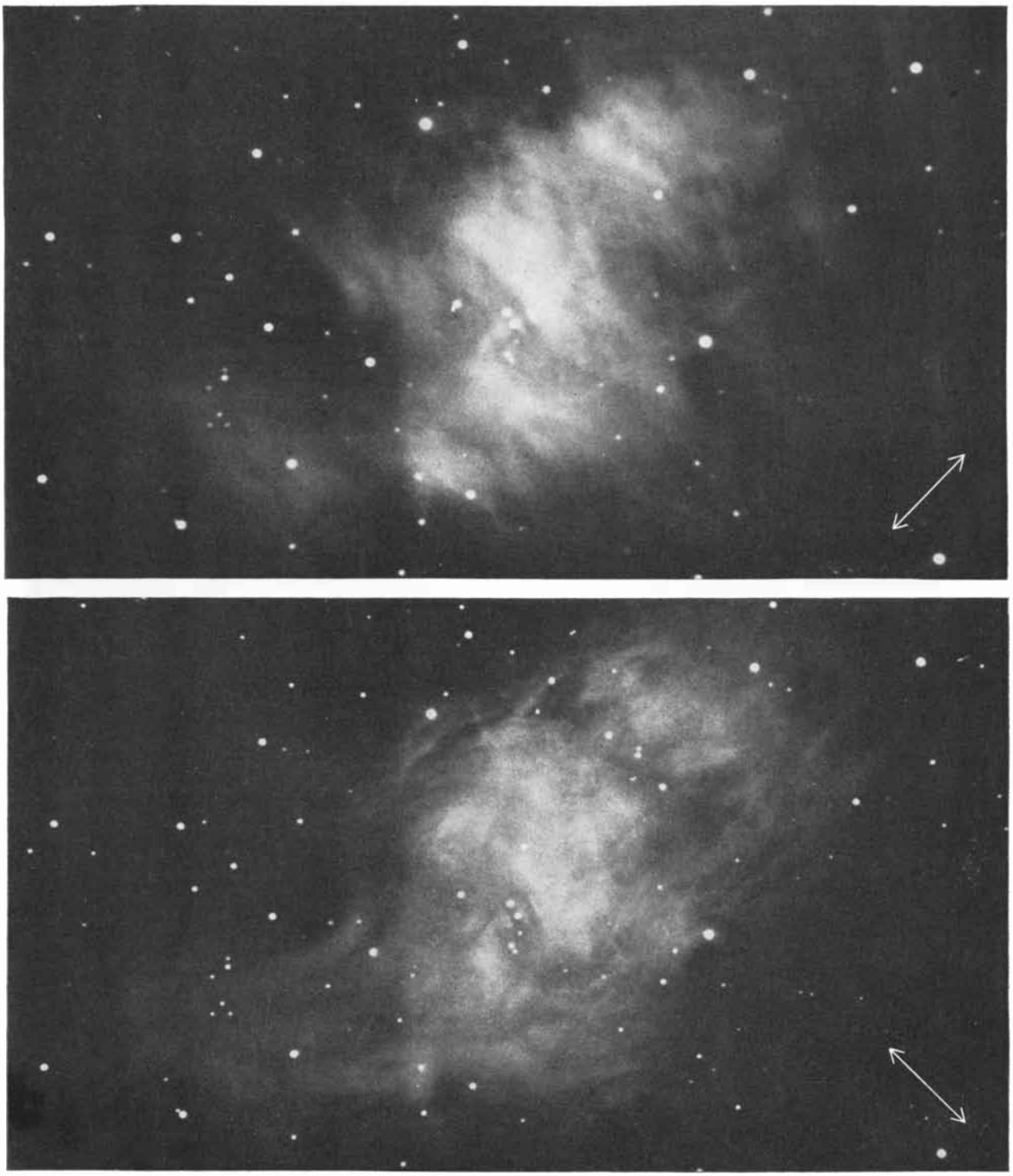


POLARIZED LIGHT from the Crab Nebula is seen in these four photographs made with the 200-inch telescope. The white arrow in the lower right corner of each picture shows the direction of electric vibration of the light waves admitted by a polaroid filter on

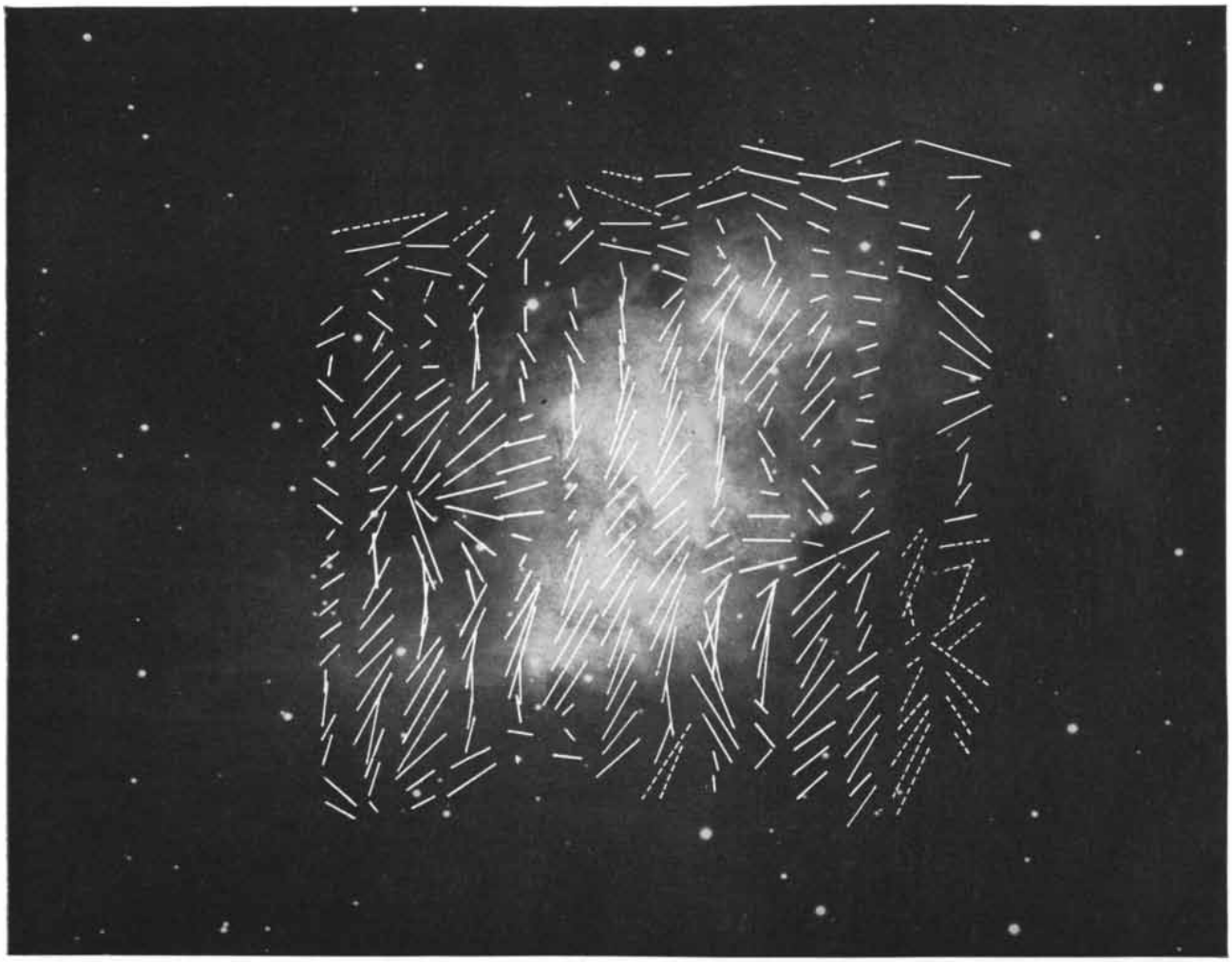
likely to be more abundant than the extremely high-energy luminous electrons. Observations show that the radio emission is in fact much stronger.

From the light emission we can, by theoretical arguments, form an estimate of the strength of the magnetic field and of the energy of the luminous electrons. Their energy must be extremely high—considerably higher than the highest attainable in our most powerful laboratory accelerators. But there is one place, directly accessible to us on the earth, where we can find particles with energies comparable to those of the luminous electrons in the Crab Nebula. This place is in the cosmic rays that rain high-speed particles on us from space.

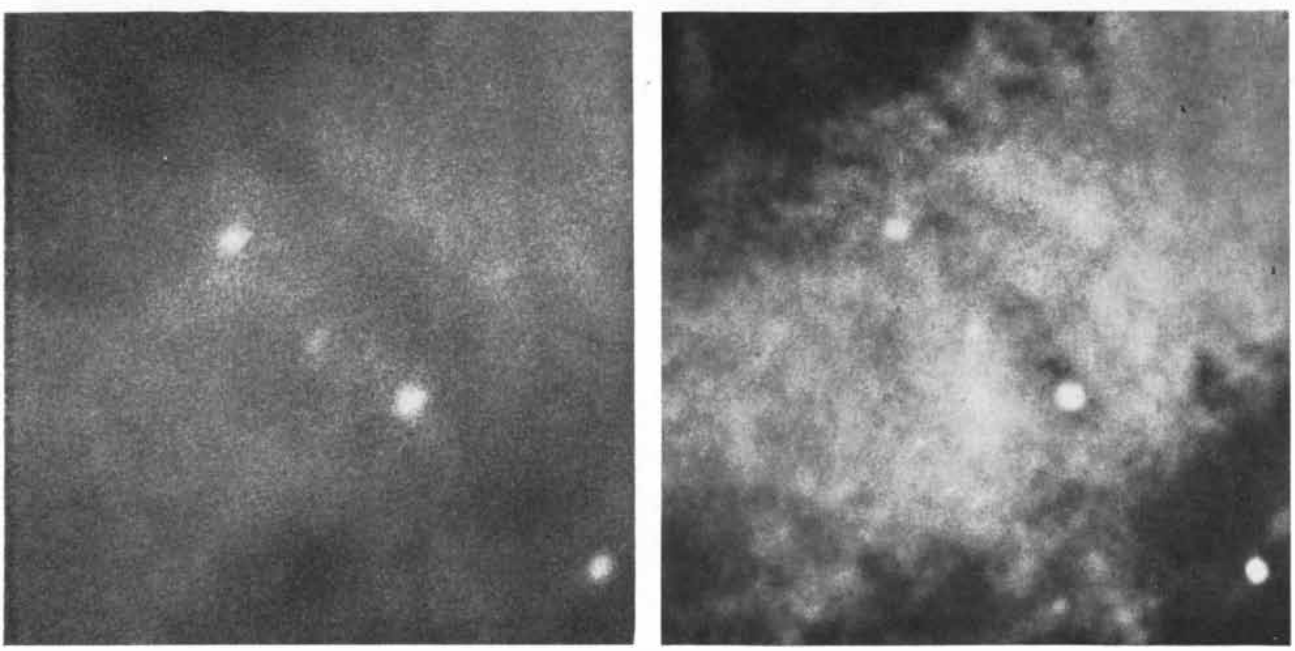
The discovery that the Crab Nebula is a veritable nest of high-energy particles suggests a new explanation of the cosmic rays, whose origin has long been a mystery. Most of the cosmic-ray particles may come from supernovae or



each exposure. The "synchrotron" magnetic field must be perpendicular to this direction of polarization. The linear structures appearing in each photograph are also perpendicular to this direction. They are thus seen to trace out the nebular magnetic field.



POLARIZATION PATTERN over the Nebula is traced out by lines drawn on this photograph. Each segment gives the direction of polarization in its region, and the length indicates the fraction of light polarized. Broken lines represent uncertain measurements.



BRIGHTNESS CHANGES in the Nebula can be seen in these photographs of a region in its northwest portion. Both plates were made with the 100-inch telescope on Mount Wilson, the one on the left in November, 1924, and the one on the right in October, 1938.

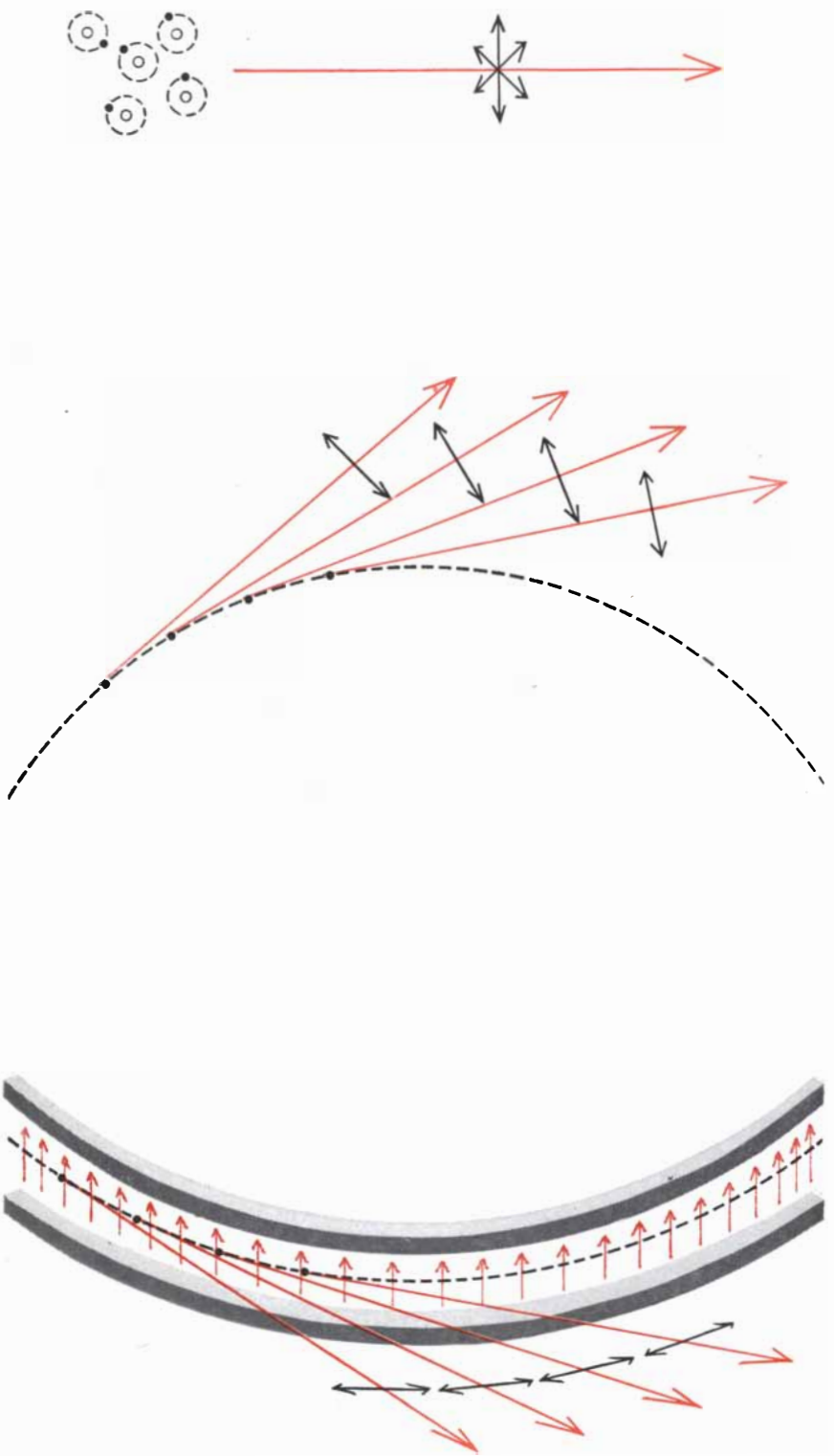
other unstable stars. It is estimated that explosions of the Crab Nebula type alone could account for about 10 per cent of the cosmic rays bombarding the earth.

Even if we suppose that cosmic-ray particles come from supernovae, it does not follow that we understand how they acquired their tremendous energies. It is highly improbable that the energy of the luminous particles we now observe in the Crab Nebula stems from the force of the explosion in 1054. The particles originally ejected must have slowed down long ago. More likely the supply of luminous particles is continually being replenished by new accelerations.

Our own sun produces cosmic-ray particles, though on an incomparably smaller scale than the Crab Nebula. These particles are associated with the eruptions of the sun's atmosphere called solar flares. Apparently charged particles are accelerated to high speeds in some manner by the strong and rapidly varying magnetic fields which invariably accompany a solar flare. It is interesting that emission of radio waves by the sun also increases greatly during a solar eruption.

We can conceive that the central part of the Crab Nebula is still emitting high-speed particles. This brings us to the question concerning what has become of the exploded star. What exactly is left of the original star?

I have mentioned that at the center of the Nebula we can see two small objects which look like a double star. The southerly member of the pair is believed to be the remnant of the old star. But if this fragment is still a star, it must be totally different from any star we have ever observed. From its vicinity, about every three months, a tiny ripple of light emerges and moves outward through the Nebula, becoming lost to sight a few months later in a strongly luminous region. The ripples move with about one tenth of the velocity of light. They are polarized in a way that identifies them as synchrotron light, and this means that they must contain high-energy electrons. It seems likely that the ripples originate in the atmosphere of the remnant of the old star. It is tempting to suppose that the remnant erupts every three months and emits a new stream of particles which replenishes the supply of luminous electrons giving the Crab Nebula its strange aura of synchrotron light.



SYNCHROTRON RADIATION arises from free electrons moving in curved paths. When electrons (*black dots*) belong to individual atoms in a gas (*top*), the light they radiate (*colored arrow*) vibrates in all directions perpendicular to the path of the ray (*black arrows*). Electrons traveling a circular path (*center*) radiate light in their direction of motion, and the vibrations are restricted to the plane of the orbit. Diagram at bottom is a schematic view of an actual synchrotron, showing a section of the magnets which hold the electrons on a circular path. Vertical colored arrows give the direction of the magnetic field, long colored arrows direction of radiated light, black arrows direction of polarization.

What of the Crab Nebula's radio emissions? Astronomers are fully as interested in these as in its synchrotron light. If the acceleration of electrons is

responsible for the Nebula's radio broadcasts, other radio "stars" in the sky may be generating their broadcasts by the same process; in fact, this is the only plausible explanation of strong radio emissions that has yet been offered. Unfortunately it has not been possible to confirm the hypothesis directly, because the other intense radio sources in the sky, with one exception, show no synchrotron *light* of the sort emitted by the Crab Nebula—possibly because their electrons are not accelerated to the velocity necessary for light emission.

The one exception, however, is remarkably interesting. A giant galaxy in the constellation Virgo that emits strong radio signals has a wisp of continuous light near its center. Baade has established that this light is polarized—that is, it is synchrotron light. The "wisp" in the Virgo galaxy is about 100 times bigger than the Crab Nebula. If it stemmed from the explosion of a star, it must have been a truly gigantic explosion—the disintegration of a superstar at least 100,000 times more massive than our sun!

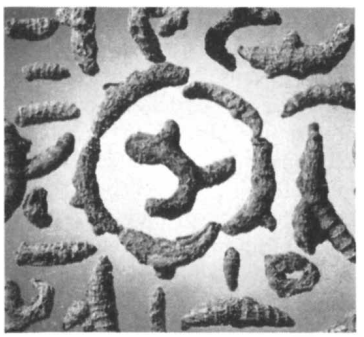
SYNCHROTRON LIGHT is detectable in this giant galaxy in the constellation Virgo, photographed with the 200-inch telescope. The wisp of light near the center has a continuous spectrum and is polarized. This source is some 100 times larger than the Crab Nebula.

Kodak reports to laboratories on:

a pH indicator from Alleppey . . . shortening the wait in the radiologist's waiting room . . . copy negatives on a film with a peculiar H & D curve

A bright, cheerful yellow

About 150 miles up the west coast from Cape Comorin, the tip of India, there stands the town of Alleppey. Each year farmers around Alleppey set out rhizomes (underground root-like stems) of a plant known to botanists as *Curcuma longa*. At harvest time they dig up



the new crop of rhizomes. These are then dried and milled to a yellow flour called turmeric, which is used to color the curries of India.

Some of the rhizomes get shipped to a factory in Rochester, N. Y., which turns out mustard to put on hot dogs and hamburgers. Americans like their mustard to be a bright, cheerful yellow rather than its greyish-brown self. Turmeric imparts the preferred color and adds a little flavor as well.

From the mustard people we buy modest amounts of turmeric and percolate hot acetone through it. In this simple manner we obtain sharp melting crystals of *Curcumin* (Eastman 1179), which is nothing more than 1,7-bis(4-hydroxy-3-methoxyphenol)-1,6-heptadiene-3,5-dione.

From an acidified solution containing boric acid and *Curcumin* one can obtain a red, alcohol-soluble reaction product, formed in proportion to the amount of boric acid present. There is a Ph.D. thesis in the archives of one of the midwestern universities which suggests that this red substance represents a loose combination of the borate radical with one of the two hydroxyls in *Curcumin*. At any rate, this reaction is the basis of a method for measuring boron in soils and plant tissue. We shall be pleased to send you an abstract of the method.

The big thing about *Curcumin* is that it changes from yellow to red over the pH range 7.5 to 8.5 and from red to orange over the pH range of 10.2 to 11.8. This gives it a place on the list of 52 *Eastman pH Indicators*.

Now, should you care to reveal to us that you are interested in pH indicators, do you know what we are going to do? We are going to send you ABSOLUTELY FREE a brand-new edition of our celebrated chart (suitable for framing) that shows the pH range and color changes of ALL the *Eastman pH Indicators*. That's what we are going to do.

What's more, we'll not only send you the abstract and/or the wall chart, we'll also, if you like, send you a copy of our new Eastman Organic Chemicals List No. 40, which catalogs some 3500 highly purified organics. Make your requests to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

Good for the doctor, too

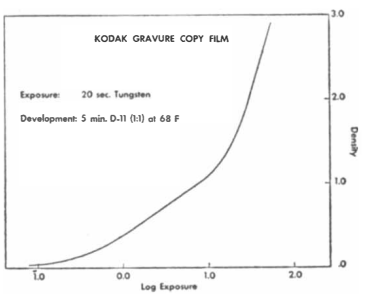
Because of a new product of ours, we are pleased to think there will be some reduction in the vast number of people-hours tensely spent in medical waiting rooms fidgeting and staring at magazines. The vehicle of benefaction bears the name *Kodak X-Omat Processor*.

It's good for the doctor as well as the patient—the patient referred for radiological examination. Into one end of this machine the x-ray technician inserts a sheet of film she has just taken from the exposure cassette; six minutes later it rolls out the other end (10 feet away), processed under ideal chemical conditions, dry, and ready for the radiologist's interpretation. Hitherto, radiographic processing has taken at least 45 minutes. Usually longer. Meanwhile, the patient is losing time out of his life and occupying high-rent space.

It takes some 15 years of intellectual fortitude, study, observation, and pecuniary strain to turn a college freshman into the kind of doctor of medicine who knows how best to use a sheet of x-ray film. There are only about 4,000 such radiologists in the United States. Whatever lets them serve more people in a working day and requires no change in the painfully learned correlations of characteristic shadows to the ills of the flesh would seem to serve the interests of the human race.

Information about the Kodak X-Omat Processor is given out by Eastman Kodak Company, Medical Division, Rochester 4, N. Y. It processes all standard sizes of sheet film in any order, from 5″ x 7″ up. Twenty 5″ x 7″ sheets per minute is typical of the capacity. Doesn't have *to be x-ray film, we suppose.*

Are YOUR highlights washed out?



Just as some fortunate people are able to turn the pages of a Brahms score and hear the lovely music in the mind, so also a few (perhaps not quite so fortunate) can look at this curve and say, "Yup, a good long straight-line portion and then, as you go to your higher densities, your contrast starts going higher and higher. That's funny. An H & D curve is supposed to have a shoulder. Where contrast falls off when you get past the straight-line part. This shoulder is inside out. *Kodak Gravure Copy Film*, eh? Ought to be good for making copy negatives from pictures where the highlights are washed out. You could get some of the old lost zip back. Why did they have to wait till now to come out with it?"

Because we didn't know how to make it properly till now, that's why. If you're so anxious, why don't you call up a Kodak dealer right now and order some?

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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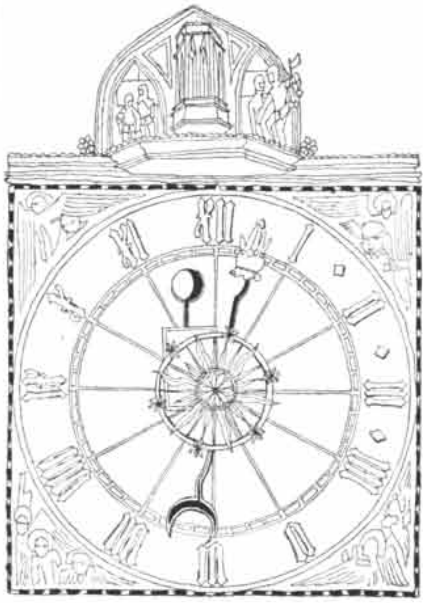
SCIENCE AND



Collapse of Symmetry

Physicists have just experienced a rude but exhilarating shock of the kind that historically has marked turning points in science. A basic "law" has failed them. Nature, which they had supposed to be absolutely symmetrical as between right and left, has turned out to have an intrinsic "handedness," or twist.

The principle of right-left symmetry has been an article of faith since the beginnings of quantum mechanics. It says, for example, that if an experiment in atomic physics—any conceivable experiment—were watched directly by one observer and in a mirror by another, there could be no way of deciding which was seeing the mirror image. In the language of quantum mechanics, it is said that nature conserves "parity." Parity, which has one of two values, odd or even, is a characteristic of the equations that describe a physical system. Every body or group of bodies has a certain parity, just as it has a certain energy, charge and momentum. Parity, like energy, was believed to be strictly conserved. Any isolated system with, say, even parity would keep this parity forever, regardless of any changes in its components. And it can be shown mathematically that a world which conserves parity is one that is symmetrical to interchange of right and left.

Last month three different groups of experimenters announced that they had caught nature in the act of exhibiting a preference as to direction, hence violating the conservation of parity. The virtually simultaneous discoveries were no accident. All three groups had been inspired to the search by the suspicions of a pair of theoreticians, Tsung Dao Lee of Columbia University and Chen Ning Yang of the Institute for Advanced Study in Princeton.

Like all physicists in their field, Lee and Yang had been brooding about the strange behavior of certain recently discovered particles. Two of the particles presented a particularly baffling problem. These are the so-called tau and theta mesons, members of a group known as K particles. Tau and theta mesons are formed in certain atomic collisions and decay after about a hundred-millionth of a second. The tau decays into three pi mesons (pions) and the theta into two. But until they decay the tau and theta particles are absolutely indistinguishable. Their mass, charge and lifetime have proved to be identical within the limits of error of the most accurate measurements that can be made. Are they really different? Other particles are known to have more than one mode of decay. Physicists were strongly tempted to think of tau and theta as the same particle with two different ways of decaying. But the parity principle forbade this. The conservation of parity would be violated if one particle could decay either into two or three pions, because those two systems have opposite parity. It seemed, then, that tau and theta must be different. Yet the idea of two different particles with exactly the same measurable properties remained extremely unpalatable.

A number of physicists pointed out that the puzzle could easily be solved if parity were not conserved, but most of them dismissed the idea as almost unthinkable. Lee and Yang did not. They reflected that the tau and theta decays are members of a newly recognized class of physical events which are termed "weak interactions." (A hundred-millionth of a second is a long time on the atomic scale. The force that breaks down the tau and theta mesons must be very weak if it takes so long to produce its effect.) They proposed that tests be made on these weak interactions accessible to laboratory experiment, to determine whether parity was conserved.

The first experiment was done by Chien-Shiung Wu of Columbia University together with a group of workers at the National Bureau of Standards. The weak interaction they selected for

THE CITIZEN

study was the beta decay (emission of an electron and a neutrino) of the radioactive substance cobalt 60. Since the cobalt nucleus has a charge and a spin, it acts as a magnet. Dr. Wu and her colleagues subjected a sample of cobalt to a strong magnetic field to line up the spins in one direction. (Thermal jostling of the atoms was minimized by cooling the sample almost to absolute zero.) Then they observed the emission of beta particles. As expected, most of the beta particles came out in a direction along the axis of the nuclei's spin. To conserve parity, an equal number of particles should have been emitted in each of the opposite directions along this line. But many more emerged in one direction than in the other! It was as if there were a preferred "forward" direction—in this case the direction of travel of a left-hand screw. In short, symmetry was destroyed.

A second experiment with mu mesons gave similar results. Leon M. Lederman and Richard L. Garwin of Columbia University found that mu mesons with their spins aligned also emit electrons in a preferred direction. Further corroboration was provided by V. L. Telegdi and J. I. Friedman of the University of Chicago, who studied the decay of pi and mu mesons in photographic emulsions.

Thus the world we live in has an essential twist, like the thread of a screw. (The twist is reversed for "anti" particles. If there are galaxies made up of antimatter, their inherent screwiness is opposite to ours.) The entire field of weak interactions will now be intensively studied by experimental physicists, who will try to discover just what laws govern such reactions.

To theoreticians the new development means a greater freedom for speculation. With their theories no longer obliged to conserve parity, they will have "more room for the exercise of mathematical imagination," as one of them puts it. Out of the new freedom may come a more satisfactory view of the ultimate nature of things.

Slow Time

A long-standing dispute about the behavior of time in the theory of relativity appears to have been settled. The question is: Would space travelers moving at close to the speed of light

age more slowly than people on the earth? It has been debated in the pages of *Nature* for several months (the arguments were summarized in this department of SCIENTIFIC AMERICAN in December, 1956). According to Frank S. Crawford, Jr., of the University of California, the answer is definitely "yes," at least if the travelers are mu mesons.

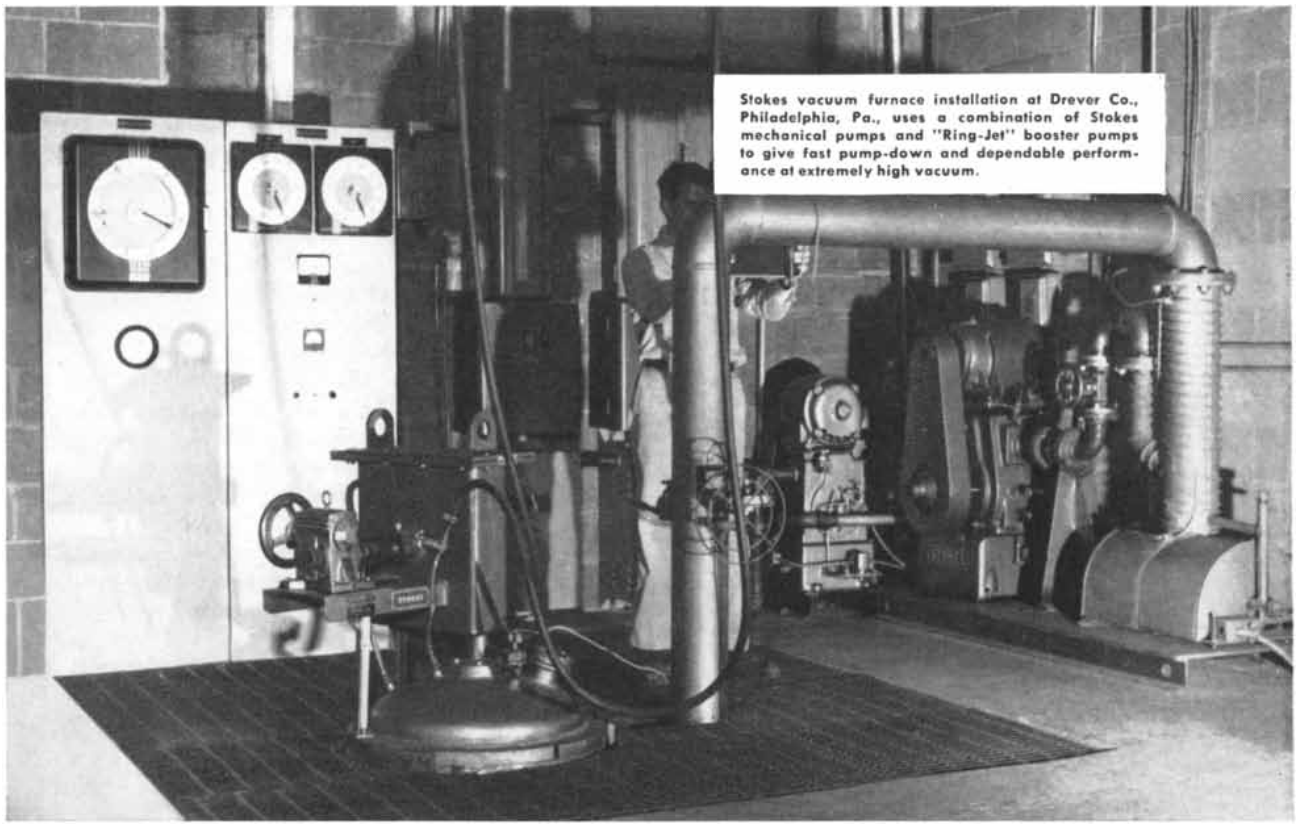
A number of physicists have suggested that the issue could be tested by measuring the half-lives of fast-moving radioactive particles. If they decayed more slowly while in fast motion than when standing still, this would be proof that matter ages more slowly in rapid motion. Crawford reported in a letter to *Nature* that the experiment has been performed by cosmic-ray physicists in studies of mu mesons. These particles are formed in the upper atmosphere and travel at high speed toward the earth. They are unstable and decay into electrons. Comparisons of the intensity of mu mesons on mountaintops and at sea level show that their half-life in flight is about 30 millionths of a second, against only two millionths of a second at rest. The difference seems to be evidence for a relativistic fountain of youth.

Pyrophoricity

One day last summer New York newspapers announced an explosion in a small atomic energy plant with these headlines: "Blasts Rip Secret A-Lab in Queens"; "Atoms on the Loose in Queens Explosions." The explosions had nothing to do with nuclear fission. A small lump of powdered thorium had suddenly and unaccountably blown up, in turn detonating larger quantities of the metal nearby.

Atomic energy workers have been troubled for some time by the tendency of certain metals to explode or burn spontaneously, like a pile of oil-soaked rags. The behavior is called pyrophoricity, and its causes are not well understood. Many of the metals used in nuclear technology, notably uranium, plutonium, thorium and zirconium, are pyrophoric. The Atomic Energy Commission is sponsoring extensive research into the phenomenon. Some of the problems were discussed recently in *Nucleonics* by Richard B. Smith of the AEC's Safety and Fire Protection Branch.

Fundamentally metals explode for the same reason that oil-soaked rags do: slow oxidation produces heat which is stored in the material, finally building up to ignition temperatures. Loosely compacted powders, which have large amounts of surface to be oxidized, and whose internal air spaces trap heat, are



Stokes vacuum furnace installation at Drever Co., Philadelphia, Pa., uses a combination of Stokes mechanical pumps and "Ring-Jet" booster pumps to give fast pump-down and dependable performance at extremely high vacuum.

Vacuum furnace gives superior results in commercial heat-treating . . .

The Drever Co., of Philadelphia, recently became one of the few commercial heat-treaters to offer the unusual qualities made possible by vacuum heat-treating. Using a Stokes high vacuum retort and pumping system with a furnace setting made by a Drever division, this company has been obtaining metallurgical properties in standard and special alloys that are not possible by conventional controlled atmosphere techniques.

Magnetic grades of steel, for example, can be given a grain-growth and de-gassing treatment, and come out perfectly bright and oxide-free. Copper can be bright annealed to extreme ductility, without danger of hydrogen embrittlement. Drever has been using the furnace with notable success for oxygen-free sintering of reactive metals such as titanium compacts, which come from the furnace in readily workable condition. Furthermore, the vacuum furnace eliminates the operating costs and hazards of hydrogen atmospheres.

Stokes has specialized in the design and production of vacuum furnaces for many leading organizations, both for basic research and for full-scale production work. If you are planning to explore the unlimited potential of vacuum metallurgy, take advantage of the extensive experience and broad line of equipment that we have to offer . . . ready to serve you.

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most likely to explode or burn. However, on occasion even solid pieces of metal have been known to do so. Presumably the process begins with a flaking or crumbling of the surface. Water hastens oxidation, and wet metals therefore are more likely to burn spontaneously than dry ones. Imprisoned hydrogen is thought to play an important role.

Several incidents like the one in New York City have been reported:

Zirconium scrap stored in open bins took fire after a heavy rainstorm, and 159,000 pounds of the metal burned up.

Two men died and two others were seriously injured when they opened a one-gallon can of zirconium powder. The metal exploded as soon as the cover came off.

Three flat plates of compressed uranium powder were observed to be swelling, and were removed from the building they were in. The next morning one of the plates exploded and "took off like a rocket," hitting a tree 30 feet away. A lump of solid uranium the size of a yeast cake burst spontaneously into flame while resting on a piece of dry ice.

Cracked Earth

A tremendous break in the earth's crust two miles deep, 20 miles wide and 45,000 miles long has been discovered by geologists of Columbia University. The great trench winds around the globe from a point in central Asia northward across the Arctic, down through the mid-Atlantic, around the Cape of Good Hope, across the Indian Ocean, across the Pacific, up the North American coast and ends at Alaska. A branch extends into the Arabian Sea and joins the famous Rift Valleys on the African continent.

According to Maurice Ewing, director of Columbia's Lamont Geological Observatory, current earthquake activity along the trench shows that the cracking of the earth's crust is still going on. Bruce Heezen, another member of the laboratory, pointed out that the path of the fissure is evidence against the theory of continental drift, for a good deal of the trench does not follow the lines of separation between continents.

Radiation Industry

One industrial application of high-energy radiation has completed the transition from laboratory to factory. Irradiated polyethylene is being mass-produced. The General Electric Company, which manufactures the material in the form of thin sheets, has announced that

DOW CORNING

SILICONE NEWS

Smart Marketers Sell "Convenience"

- Silicone insulation makes possible "Powermatic" toaster
- Perk-up electric percolator with Silicone laminate
- New "jet fast" window cleaner made with Silicones

CONVENIENCE, CONVENIENCE AND STILL MORE CONVENIENCE — that's what today's buyers demand. And they're getting what they want — thanks to Dow Corning Silicones. Here are a few examples of how silicones aid manufacturers in providing features that spell more convenience — and more sales.

LOOK, NO HANDS—Now McGraw Electric has produced a "Powermatic" Toastmaster that takes a slice of bread from your hand, lowers it lovingly, toasts it just right, then wafts it gently back up, all under its own power. Nothing to push or pull. Secret? A tiny motor insulated with Dow Corning Silicones.

The motor, which is toasted at 400°F right along with the bread, would not be possible without silicone insulation. And Dow Corning silicone insulation can take years and years of toasting without damage. That's been proved in thousands of hard-working industrial motors and transformers. Add it all up and you have a more convenient, super-skilled appliance that does everything but butter the toast for you! No. 45

DUNKING ALLOWED — An accidental dip in dishwater won't wreck the electrical connections in the new Mirro-Matic Percolator, made by Aluminum Goods Manufacturing Company. Reason? The plug-in

insulators are now fabricated from silicone-glass laminate. Why? The silicone laminate has only one hundredth the moisture absorption of the phenolic insulators formerly used . . . a big difference when you're dealing with electricity! Silicone-glass also has greater physical strength, more heat resistance . . . it's more reliable all around. Yet, the silicone laminate doesn't cost a penny more . . . plain low-cost stampings are used instead of molded parts. More savings are realized through less breakage during assembly. No. 46

FRY PANS, TOO — find strong sales appeal in easy washability and controlled electric heat. The Sunbeam Automatic Frypan gets its extra convenience from Silastic* seals that protect the electrical connections. Silastic, Dow Corning's silicone rubber, keeps them dry even when the Frypan is almost totally immersed in water. No. 47

GOT WINDOW "PAINS"? Window-cleaning has always been one of the most miserable household chores. But now to the rescue: new "Jet Spray Bon Ami", an aerosol bomb that does all the dirty work. You just spray it on, wipe it off and the glass sparkles like new again. It's that simple.

At the press of a button, the Bon Ami bomb sprays foam containing Dow Corning Silicones. Remaining on the window pane after the foam is wiped away, the silicones form an invisible water repellent film that keeps the glass sparkling longer and makes it easier to clean next time.

The foam, by the way, prevents splatter and "run-off" . . . a special convenience to housewives. Jet Spray is fine for other surfaces, too: tile, enamel, chrome, painted wood to name a few. No. 48

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

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it is increasing its annual production to 1.6 million pounds. In two years it expects to go up to three million.

Irradiated polyethylene differs from the ordinary plastic in that its long molecular chains are cross-linked by the action of bombarding electrons. The linkage gives it much greater resistance to heat. So far the material has been used chiefly as an electrical insulator. There may soon be other commercial applications. W. R. Grace & Company says that it is experimenting with irradiation of molded polyethylene products, with a process developed by the Sequoia Process Corporation of California.

Margin of Safety

The National Committee on Radiation Protection, which has hitherto concerned itself only with occupational radiation hazards, has just proposed standards for exposure of the general population. It recommends that the exposure to man-made radiation from all sources be limited to a cumulative total, up to the age of 30, of 10 million roentgens for every million persons in the population, or an average of 10 roentgens for each person. This limit was suggested by the genetics committee of the National Academy of Sciences.

The National Committee reduced the maximum permissible average exposure for industrial workers from 15 to five roentgens per year.

Vaccine for Pseudo-Flu

The Army now has a potent vaccine to fight the influenza-like virus infections that hospitalize thousands of military recruits each year. A field test conducted at the Walter Reed Army Institute of Research reduced hospitalization for these diseases by 98 per cent.

These microbes, called adenoviruses, came to attention in 1937 when doctors suspected that certain ills resembling influenza were not due to the influenza virus. The first of the viruses was finally tracked down in 1954. Since then, 11 types have been found in human adenoids, tonsils, conjunctiva and respiratory tracts. But while research workers could isolate the viruses, they had great difficulty in preparing a vaccine. Laboratory animals failed to respond to the viruses. The investigators grew the virus in human tissue cultures, adapted it to a synthetic culture containing kidney epithelium from monkeys and made the vaccine by killing the virus in the infected kidney broth with formalin and incorporating it in a mineral oil. When

The emphasis is shifting

It used to be that you would design an airframe for payload—and provide *minimum* required instrumentation.

The emphasis is shifting.

In this new age of electronic missile guidance and identification, the chicken is now the egg and the cart pulls the horse. Instrumentation comes first—after which a mobile container is designed that will carry it with greatest efficiency.

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it was tried at Fort Dix, where an adenovirus epidemic was in full swing, only one of 311 vaccinated recruits came down with the infection, against 61 among 313 controls who received a placebo. The vaccine is completely safe.

Health Survey

The U. S. Public Health Service has begun an ambitious study of disease and accident rates in the nation. The survey is the first of its kind since 1936. It will include new facts (*e.g.*, overweight, smoking, smog exposure) and will be conducted from year to year at the rate of 3,500 interviews per month. Clinical examinations and medical records will be used to supplement the household interviews, and Census Bureau experts will help to develop the sampling methods. The results of the survey will be published every six months. They will be used extensively in administrative and medical planning and will probably suggest a number of new hypotheses for medical research.

Penicillin's Action

Two biochemists have proposed an explanation of how penicillin kills bacteria—long a mystery. James T. Park of the University of Pennsylvania and Jack L. Strominger of the Washington University School of Medicine in St. Louis believe the drug prevents the bacteria from building their cell membranes.

Park and Strominger analyzed the make-up of the cell wall in *Staphylococcus aureus* and then found that when they treated the bacteria with penicillin, the nucleotides that apparently serve as building blocks for the cell wall accumulate within the cell. This suggests that penicillin somehow interferes with the putting together of the nucleotides, as a result of which the bacterium is unable to build its wall material and eventually ruptures the wall as it grows.

House-Hunt

When a beehive gets overcrowded, the bees solve the problem by swarming. Half the inhabitants—50,000 to 80,000 strong—fly away with the old queen to a new abode, after a new queen has been raised for those that stay behind. This uprooting is a stringent test of the insects' social organization. M. Lindauer of the University of Munich has discovered how their remarkable system of dance communication enables them to meet the challenge.

As a colony prepares to swarm, re-

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(2) SITE INVESTIGATIONS — to evaluate and select best available location.
(3) PREPARATION OF REPORTS — to fulfill all existing A. E. C. permit requirements.
(4) TRAINING — of several months duration to prepare personnel for the A. E. C. license examinations.
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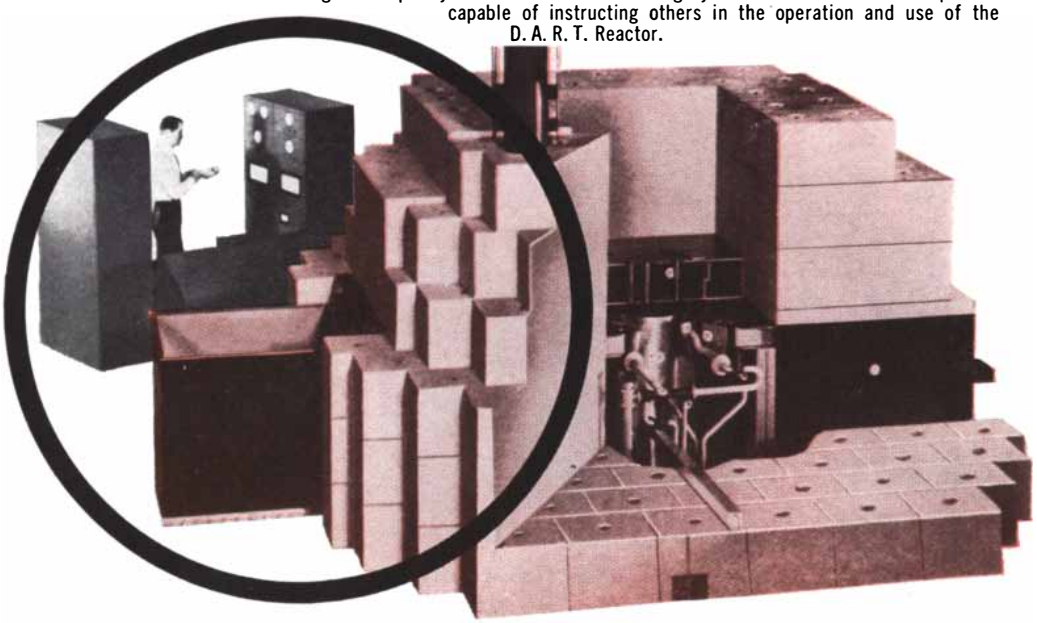

CUTAWAY OF D. A. R. T. (DAYSTROM ARGONAUT FOR RESEARCH AND TRAINING) REACTOR

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Additional information about all phases of Daystrom's new D. A. R. T. Program can be obtained by writing to Mr. A. Stanton, Director, Domestic Sales or Mr. K. Kirchholtes, Director, Foreign Sales.

SEE DAYSTROM D.A.R.T., SWIMMING POOL AND MEDICAL REACTORS AT BOOTH 404 ATOMIC EXPOSITION AND NUCLEAR CONGRESS

ports Lindauer in *Nature*, some of the older forager bees leave off their hunt for food and go out looking for building sites. They inspect hollow trees, holes in the ground, boxes set out purposely by an experimenter and other likely places. On their return to the hive the scouts go into their dance on the honeycombs, signaling the distance and direction to the real estate they have found. To announce a first-class site the bees dance with great vivacity for as long as an hour. A less satisfactory location elicits only a few short and perfunctory steps. The scouts then go out on a second expedition to look over the most highly praised sites. Each returns and campaigns for the one he likes best. Eventually a unanimous agreement is reached and the swarm takes off for its chosen new home.

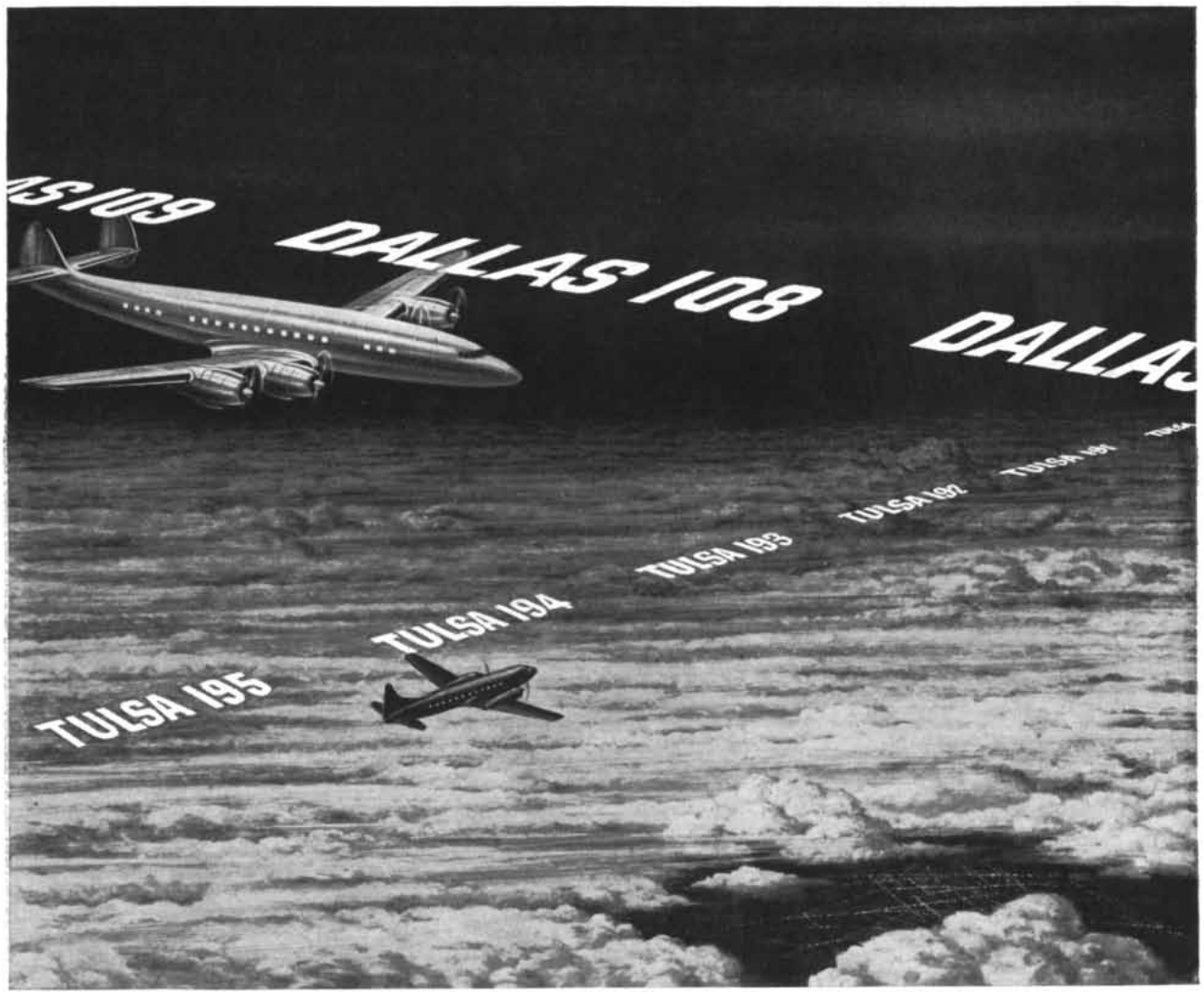
In only one case did Lindauer find a swarm that was unable to make up its mind. The choice had narrowed to two sites and the partisans kept up their competitive dance for 14 days with neither side giving in. Then they stopped and the group proceeded to commit mass suicide. It built a new hive in the nearest available bush, and froze to death the following winter.

A remarkable number of details are taken into account in judging a site. The chief factor appears to be shelter from the wind. Another is size; the bees choose a hole just big enough to accommodate their numbers. Distance from the old hive also is important. The bees prefer the more remote locations, presumably to avoid an overlap with the foraging area of the old hive.

Steroid Cycle

The first complete determination of the synthesis of steroids, both in plants and animals, has been reported by William G. Dauben and co-workers at the University of California. They suggest that it may now be possible to find a chemical which will block the formation of the steroid cholesterol, a substance believed to be associated with hardening of the arteries.

Dauben's group found that the synthesis of steroids in man begins with acetate, a common by-product in the burning of fatty acids. Acetate is converted in a series of steps into an isoprene, which is then converted successively to squalene, to a triterpene and finally to a steroid. The chemists traced the biosynthetic pathway by feeding radioactive acetate to slices of fresh liver and following the progress of the acetate with Geiger counters.



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Life ...on the Chemical Newsfront

LIVELIER DURABLE COLORS add appeal to new accessories for the home such as the sturdy but lightweight laundry basket shown here. Introduction of Cyanamid's CYAN Blue Toner XR 55-3760 has broadened the range of colors and brought to the makers of plastic and rubber products better color efficiency. This new Cyanamid pigment combines the well-known permanence and durability of Copper Phthalocyanine Blues with unique redness of shade and outstanding ease of dispersion. **(Pigments Division)**

NEW POLYESTER SEWER PIPE JOINTS speed installation and virtually end trouble with cracked joints caused by settling earth, corrosive sewage and root penetration. A cast collar of reinforced LAMINAC® Polyester Resin, highly resistant to temperature extremes and sulfur-active bacteria, is used to restrain a live rubber gasket. The spigot, with gasket, can be forced easily into the pipe bell by hand, forming a tight seal which permits immediate testing and back filling. Manufactured by Gladding, McBean and Co., Los Angeles, the new "Speed Seal" pipe is based on research by National Clay Pipe Manufacturers, Inc.
(Plastics and Resins Division)

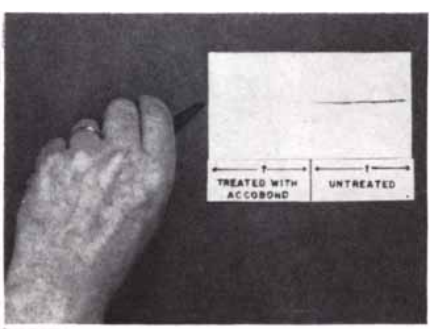
WASHING DIRT OUT, NOT IN, is the secret of new effective rug and upholstery detergents. The trick is to wet under and float off dirt and oils without saturating the fibers and soaking the dirt in "to stay." Limited wetting action at room temperature makes AEROSOL® 22 Surface Active Agent ideal for use in dry and wet types of rug and upholstery cleaners. Its efficiency as a detergent is aided by high tolerance to hard water and excellent foaming properties. Low percentages can be absorbed onto sawdust or other fillers —or incorporated into filler pastes or liquid formulations. **(Industrial Chemicals Division, Dept. A)**

A WIDER RANGE OF COLORS FOR DACRON† polyester fiber and more uniform shades on acetate are now possible thanks to a new Cyanamid dye-bath additive. CYANATEX® Dyeing Assistant EM, acting as a carrier, increases the diffusion rate of dispersed dyes under practical dyeing conditions. The results are improved color value, reduced dyeing time and lower temperature requirements. Relatively non-toxic, CYANATEX Dyeing Assistant EM is an emulsion which dilutes directly into prepared dye baths and requires no bath adjustments, solvents or other additives. **(Organic Chemicals Division)**

†Trademark of E. I. du Pont de Nemours & Co. (Inc.)

PLATINUM IS BOOSTING OCTANES in a refining process utilizing Cyanamid's AEROFORM® PHF Platinum Catalysts in the reforming of petroleum naphthas to high-octane fractions. Originally developed to produce war-scarce aromatic chemicals, catalytic reforming is now proving a boon to refiners in meeting the challenge of high-compression engines. Working with refiners and utilizing its own basic research facilities, Cyanamid is continuously developing the physical and catalytic characteristics of AEROFORM and other catalysts to keep pace with the dynamic technology of the petroleum industry.

(Industrial Chemicals Division, Dept. A)



IMPROVED ADHESION of refrigerator enamel to steel is one application of surface treatment to promote better bonding of paint, lacquers, plastics and other surface coatings. Cyanamid's new ACCOBOND® Bonding Agents are water-soluble resins used to treat metal, leather, wood, concrete and other materials where they act to improve the adhesion of coatings by altering the characteristics of the surface. A typical scratch test used to evaluate adhesion is shown in the inset. ACCOBOND agents are applied as very dilute solutions, followed by oven or air drying. **(New Product Development Department, Dept. A)**

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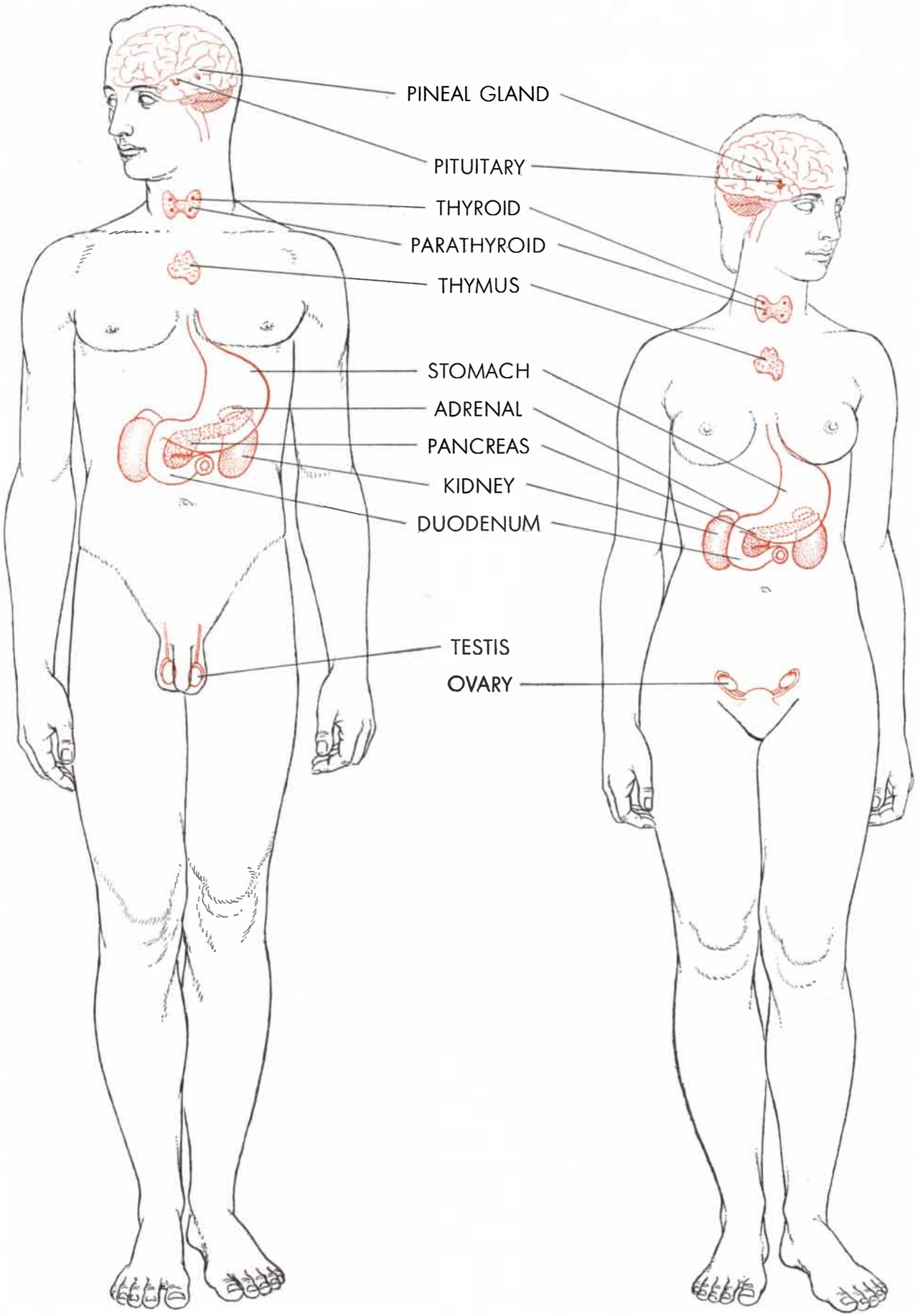


HORMONES

These potent biological substances are called the chemical messengers of the body. They may also be viewed as members of a larger system which integrates the phenomena of life

by Sir Solly Zuckerman

When a cockerel is castrated, it fails to develop into a rooster. Normal development of the secondary sexual characters that mark a male fowl depends upon a chemical substance which is secreted by the testes and transported by the bloodstream to all parts of the body, including the germ buds of the feathers and the region of the comb and wattles. The maleness and femaleness of most animals is determined in this chemical way.

The idea that something of this kind happens in the body came early in man's speculation about his physiological workings. Aristotle made observations about the effects of castration, and so did many after him. John Hunter, the distinguished 18th-century English anatomist, went a step further and experimented on transplanting the testes. When they were regrafted to another part of the abdominal cavity, the animal developed normally. This implied that the mechanism of their effects must be chemical rather than nervous, for the original nerve connections of the testes to the body were cut by the operation. But it was not until 1849 that A. A. Berthold, a young German zoologist, made a detailed study of the effects of removal and replacement of testicular tissue and so discovered the principle of what is now called endocrine action. His short paper on the subject provides the essential foundation of the modern study of hormones.

Soon afterward the observation by Claude Bernard, the famous French physiologist, that the liver "secretes" sugar into the blood led to the general understanding that there are special endocrine glands which pour their secretions directly into the bloodstream. The whole concept was given a specific meaning when, in 1904, the English physiologists Ernest Starling and William Bayliss conceived the endocrine system as a complex of chemical messengers which coordinate the functions of different tissues of the body. Starling observed that these "hormones," as he named them, "have to be carried from the organ where they are produced to the organ which they affect, by means of the bloodstream, and the continually recurring physiological needs of the organism must determine their repeated production and circulation through the body."

Modern endocrinology, in spite of all the attention it has received, remains essentially an empirical science, for we have only a vague understanding of the fundamental mechanisms of endocrine action. We observe the physiological effects of hormones, but we know little about how they act upon cells. We have nothing like a full list of the hormones themselves, or of the organs that produce them. The usual method of identifying a hormone is to remove the organ suspected of secreting a chemical messenger, analyze the effects of its removal and then try to extract the active agent. But obviously these methods are inapplicable to an organ such as the lungs, whose removal would mean immediate death. We have no present means of determining with certainty whether or not such organs secrete hormones, although they may well do so.

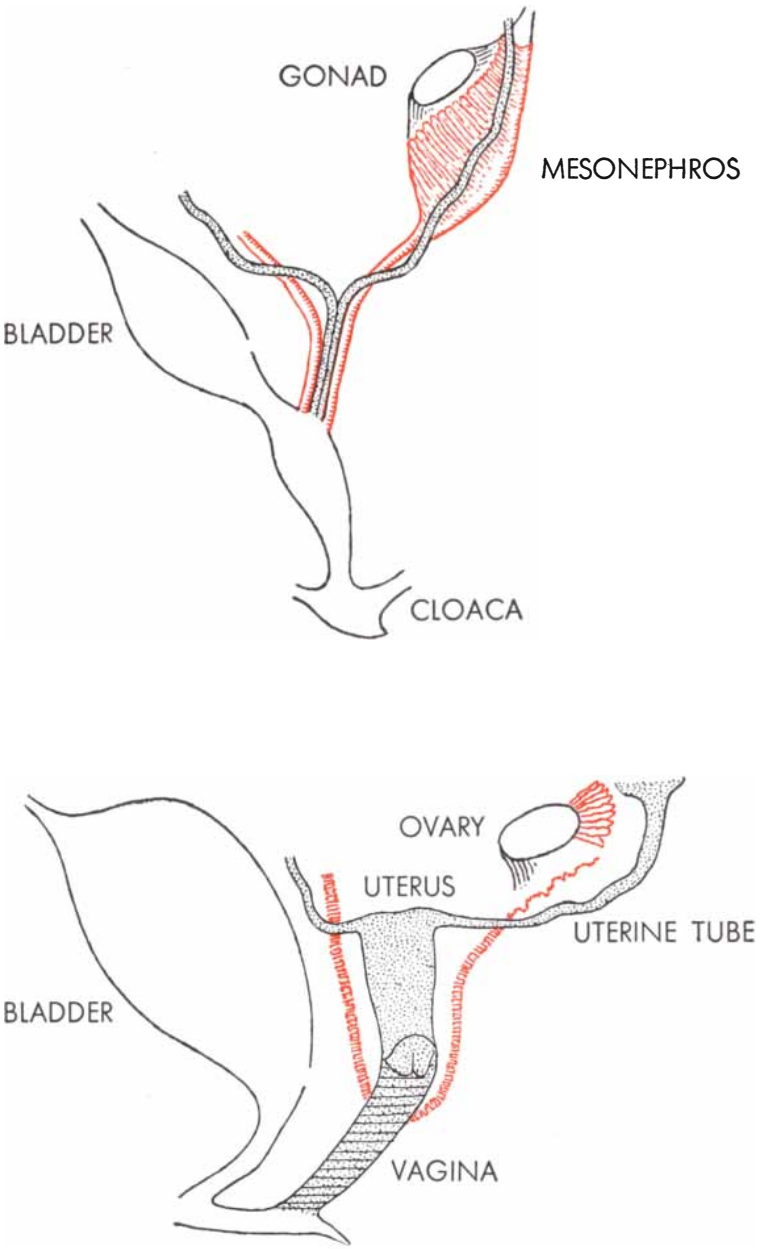
Of the established endocrine organs, the most important is the pituitary gland, attached to the base of the brain. It has two lobes. The posterior lobe secretes hormones which stimulate the contractions of the uterus during childbirth and also the release of milk from the mammary gland. Posterior lobe secretions also control the amount of fluid filtered by the kidneys. Hormones of the pituitary's anterior lobe control the functioning of most of the other endocrine organs of the body. They include the thyrotrophic hormone (TSH), which acts upon the thyroid gland; the adrenocorticotrophic hormone (ACTH), which stimulates the cortex (outer part) of the adrenal glands, and the gonadotrophic hormones (FSH and LH), which control the secretion of sex hormones by the ovaries and the testes, respectively. In addition, the anterior lobe produces a growth hormone, somatotrophin (STH), which acts on the whole body.

Other endocrine organs are the pancreas, which secretes insulin; the parathyroids, four beads of tissue embedded in the back of the thyroid; the adrenal medulla, the core of the adrenal glands; certain cells lining the first part of the gut; the pineal gland, attached to the brain, and the thymus gland, behind the breastplate.

Effects on Growth

We know that hormones are concerned in almost every living process, including every phase of the growth of the body. If an immature animal is deprived of the anterior lobe of its pituitary gland, it ceases to grow or mature. To grow it must be supplied with the growth hormone (STH), and for sexual maturation it requires the gonad-stimulating hormones (FSH and LH). The growth of the body as a whole is also influenced by the male sex hormones produced by the testes. This is shown by the fact that about the time of puberty

HORMONE-SECRETING ORGANS of man are outlined in color in the figures on the opposite page. Except for the gonads, the organs are the same in the male and female.



GONADAL SYSTEM of vertebrates is sexually neutral in the early embryo (*schematic drawing at top*). The mesonephros, an excretory organ, retains its function even after birth. If the embryo develops into a female (*center*), the outer tubes (*color*) regress while the uterine tube, uterus and vagina form from the inner ones. In the male (*bottom*), the inner tubes practically disappear while the outer ones (*color*) form the seminal vesicles and ducts from testes.

the male begins to grow bigger than the female. Indeed, it is through hormones that the animal's sex itself is determined. In the early stages the embryo is sexually neutral, possessing tissues out of which either female or male reproductive organs can be formed. If the embryo is a genetic male, its embryonic gonad produces hormone which promotes the development of masculine organs and suppresses the feminine.

The development of the body is also profoundly affected by the hormones of the thyroid gland (thyroxine and triiodothyronine). Removal of this gland from a young animal will inhibit growth, delay bone formation and prevent proper development of the reproductive system. These disturbances of growth combine to produce cretinism. The physical basis of the retardation of mental development in cretins has recently been clarified by experiments on rats. In an animal deprived of thyroid hormone there is a reduction in development of the network of dendrites, the tendril-like processes which act as contacts between nerve cells, and also in growth of the nerve axon, down which impulses are fired from one nerve cell to the next. As a result the animal's reflex responses are considerably slower than normal. The nerve cells of such an animal can be stimulated to resume normal growth by giving it thyroxine, if the hormone is supplied before it is too late. The treatment restores some, but not all, of its adaptive behavior.

The parathyroid glands also influence growth, by their control over calcium and phosphorus metabolism, and of course so too does the adrenal cortex; when it ceases to pour its secretions in normal fashion into the bloodstream, not only growth but life itself must stop.

Effects on Metabolism

Hormones regulate metabolism in the body in intricate and far-reaching ways. Consider the metabolism of sugar. For good health the supply or level of sugar

MALE HORMONE TESTOSTERONE was injected into the 18-day-old chick at left by Hans Selye of the University of Montreal. The injection resulted in male characteristics. The normal chick at right, which is the same age, lacks precocious comb and wattles.

in the blood must be held fairly constant. Four factors enter here: (1) the rate of use of sugar for energy by the tissues; (2) the rate of absorption of sugar by the blood from the intestines and of reabsorption from the fluid filtered by the kidneys; (3) the release of sugar from the carbohydrate-storing tissues (*e.g.*, the liver and muscle), and (4) the formation of sugar from fats and proteins. In all these processes hormones play a part. Insulin, produced in the pancreas, speeds up the rate at which the tissues use sugar. If the body is deprived of this hormone, by removal or poor functioning of the pancreas (as in the disease diabetes mellitus), the level of sugar in the blood rises considerably. This can lead to death, unless insulin is given to depress the blood-sugar level. On the other hand, if the anterior lobe of the pituitary gland, as well as the pancreas, is removed from an animal, it may survive for months, in spite of the lack of insulin. Evidently the anterior pituitary normally has something to do with supplying sugar to the blood, and its removal therefore reduces the sugar level.

The pituitary apparently acts indirectly to promote both the formation of sugar and its release into the bloodstream. For example, the pituitary hormone ACTH stimulates the adrenal cortex to secrete hormones which in turn stimulate the tissues to synthesize glycogen (animal starch) from proteins. Again, the anterior pituitary causes the thyroid to release a hormone which speeds up the oxidation of sugar by the tissues and also affects the rate at which sugar is absorbed into the bloodstream through the gut.

The metabolism of proteins likewise is considerably influenced by hormonal reactions. So too is the retention or shift of water between and within cells, which is determined mainly by the movement of sodium and potassium ions across cell membranes. One of the hormones involved in water metabolism is aldosterone, produced by the adrenal cortex: it promotes the retention of sodium and chloride in the tissues and stimulates the excretion of potassium. Other hormones that affect the body's retention of water are the hormone serotonin (found in brain tissue and in certain cells of the gut) and an antidiuretic hormone of the posterior pituitary. The sex hormones also influence water metabolism to some extent.

Controls

These examples illustrate that hormones play a vital part in the orderly development and functioning of the body, in general metabolic processes and in specific bodily adaptations such as the cyclic changes in the female reproductive organs. How are all these mechanisms organized into an orderly pattern of operation?

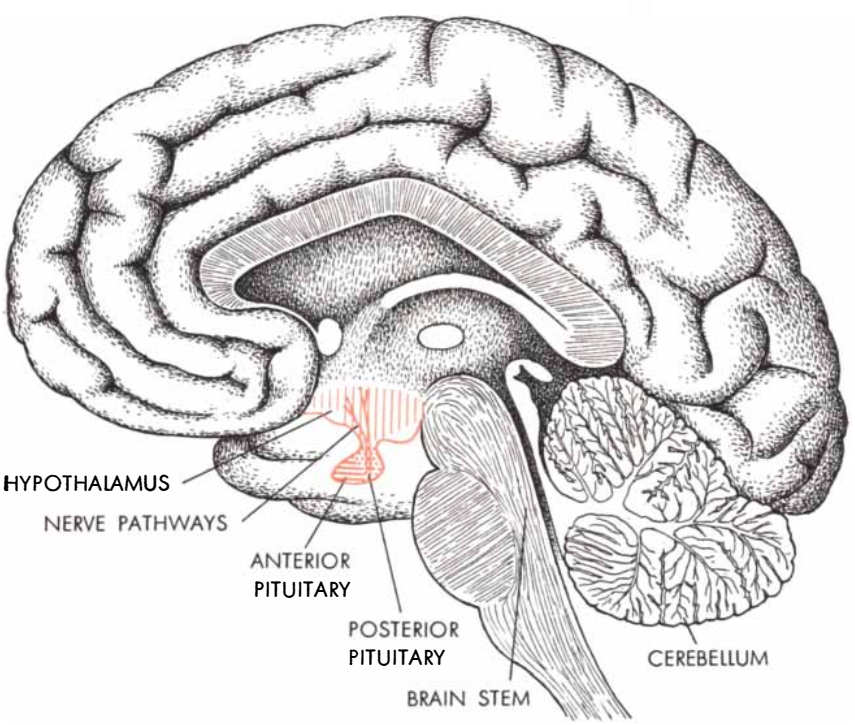
The pattern of control seems to be made up of sets of reciprocal interactions between the endocrine organs. For example, the anterior pituitary and the adrenal cortex are parts of a feedback system. The pituitary hormone ACTH stimulates the adrenal cortex to secrete its steroid hormones. If one adrenal gland is removed, the ACTH stimulation causes the cortex of the remaining adrenal to increase in size. If, on the other hand, the anterior pituitary lobe is removed, the resultant lack of ACTH leads to a considerable atrophy of the cortex of both adrenal glands. If ACTH is then injected, the adrenals return to their usual size. It appears that under normal conditions the concentration of adrenal cortex hormones in the bloodstream controls the secretion of stimulating ACTH by the pituitary: when this concentration is high, less ACTH is released; when it is low, the release of ACTH increases. The same sort of "push-and-pull" mechanism is believed to operate in other cases of hormones stimulating a specific target organ. The secretion of sex hormones by the ovaries and testes is subject to a similar feedback control, and the various sex hormones in turn interact with each other. Thus the effects of estrogen, one of the two hormones produced by the ovaries, may be neutralized by an extra output of progesterone, the other ovarian hormone.

There is considerable ignorance about how all these sets of interactions are organized into a pattern. One possibility

is that a chain reaction involving several endocrine organs may be called forth by a general metabolic condition or need of the body. For example, during exercise the muscles require more sugar. This single need may call a number of hormonal processes into play. Insulin stimulates the transformation of glycogen in the liver and muscle into glucose. The release and conversion of this glycogen is also promoted by adrenalin from the adrenal medulla, which is activated by nerve impulses during exercise or stress. In addition, the secretion of adrenalin apparently stimulates the anterior pituitary to secrete ACTH, which in turn causes the adrenal cortex to release hormones that promote the synthesis of glycogen from protein. Adrenalin may also stimulate the anterior pituitary to produce ACTH indirectly by way of its effects on the hypothalamus, to which the posterior part of the pituitary is connected. Finally, it has been suggested that a low level of sugar in the blood itself directly stimulates the secretion of ACTH. These various possibilities indicate the complex interplay of events that must be involved even in a single metabolic process.

The problems become still more complex in responses in which the nervous system plays a part. An example is the seasonal reproductive behavior of animals whose breeding is conditioned by the length of the day, or exposure to light. A female ferret, which is sexually dormant during the autumn and winter, can be brought into heat at that time by keeping it in artificial light for a few hours after sunset each day. But it will not respond if it is blind or if its pituitary gland or its ovaries are removed. The chain of reactions clearly follows the sequence: stimulation of the retina by light, transmission of impulses along the optic nerves to the brain, stimulation of the anterior pituitary to secrete the gonadotrophic hormone, which stimulates the ovaries to secrete estrogen which in turn produces sexual heat, marked by swelling of the genital organs. The main gap in our knowledge here is: How do the nervous impulses reaching the brain via the optic nerves trigger the secretion of gonadotrophic hormone by the anterior pituitary?

The hypothalamus, at the base of the brain, is connected to the pituitary by a stalk of nerve fibers. These are known to pass to the posterior lobe, but whether any reach the anterior lobe of the pituitary, which produces the gonadotrophic hormone, is still unsettled, in spite of considerable study. If they do, one might suppose that nerve impulses directly activate the anterior pituitary to release the hormone; if not, we might assume that the hypothalamus sends a chemical messenger to the anterior pituitary by way of the bloodstream. But unfortunately the whole problem is made completely mysterious by the experimental finding that the anterior pituitary can secrete the gonadotrophic hormone even when its nerve and blood-vessel connections to the hypothalamus are completely severed!



SECTION OF THE HUMAN BRAIN indicates the close relationship between the pituitary and the hypothalamus. The two structures are connected by a stalk of nerve fibers. It is not clear, however, whether the hypothalamus stimulates the secretions of the pituitary.

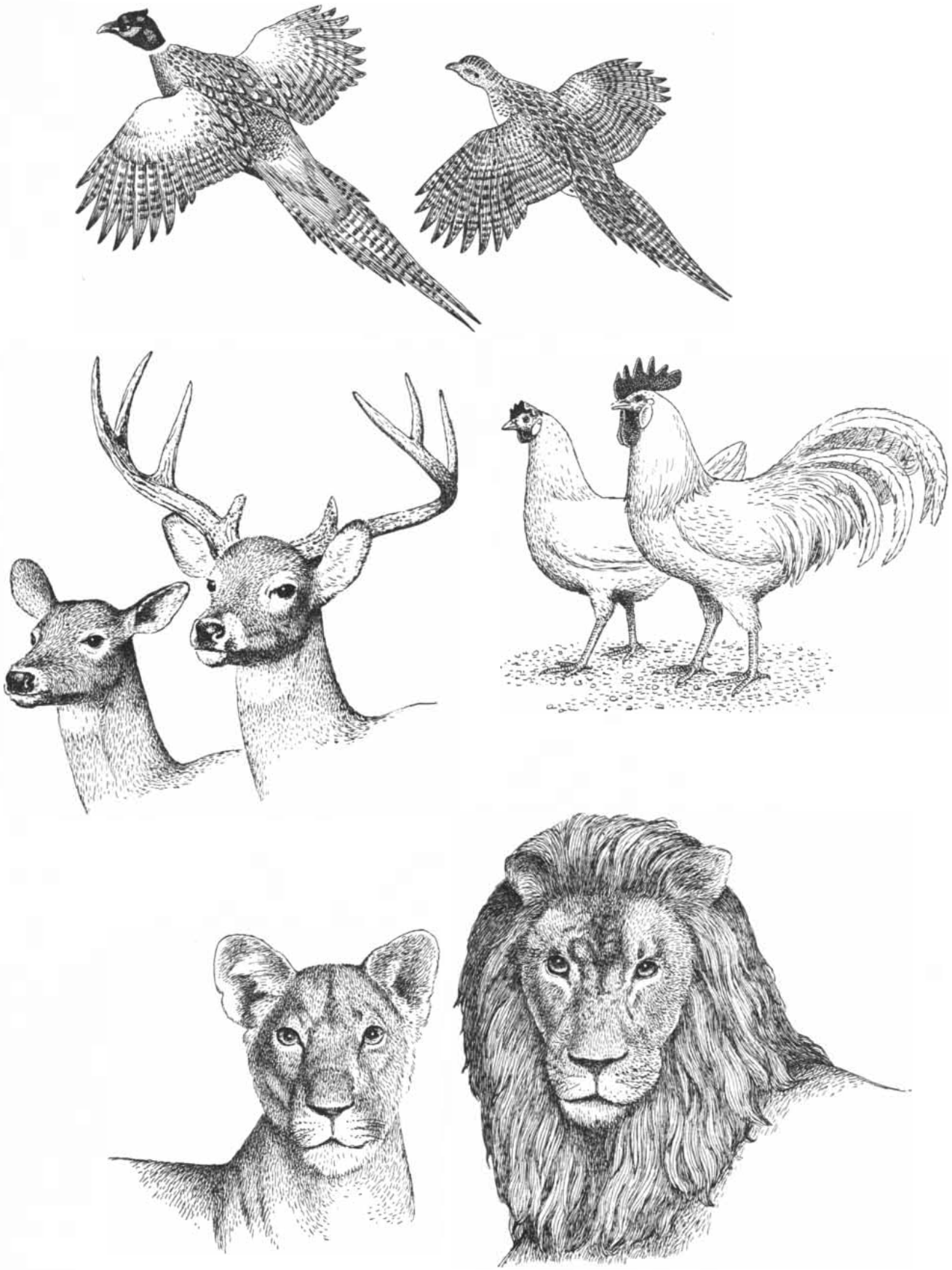
Hormones from Nerve Cells

There is considerable evidence, however, that the hypothalamus itself does produce hormones—hormones previously supposed to be secreted by the posterior pituitary. The hormones in question include oxytocin, which triggers labor contractions of the uterus and the release of milk by the mammary glands, and vasopressin, which raises blood pressure and reduces the excretion of urine.

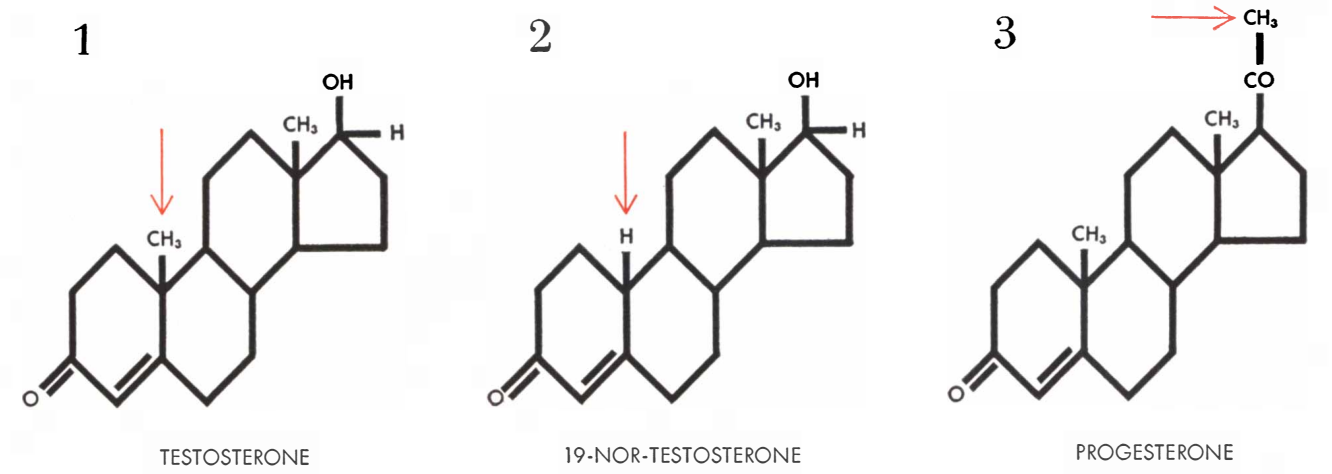
Some years ago the anatomist Ernst A. Scharrer (now at the Albert Einstein College of Medicine) drew attention to the fact that certain nerve cells in the hypothalamus contained what looked like secretory granules. He therefore argued that the hypothalamus, in addition to being a primitive motor center of the brain, was also in effect a secretory organ. Similar granules were later found also within the nerve fibers of the pituitary stalk. When the stalk was tied or cut, secretory material collected in the fibers immediately above the knot, and the part of the posterior pituitary below the ligature rapidly became depleted of such material. Other experiments showed that extracts of the hypothalamus have the properties of the hormones that had been thought to be produced by the posterior pituitary. It is now believed that the hypothalamus is the source of the hormones and the posterior lobe of the pituitary is essentially a storehouse for them, although very likely it also modifies them chemically.

Action in the Cell

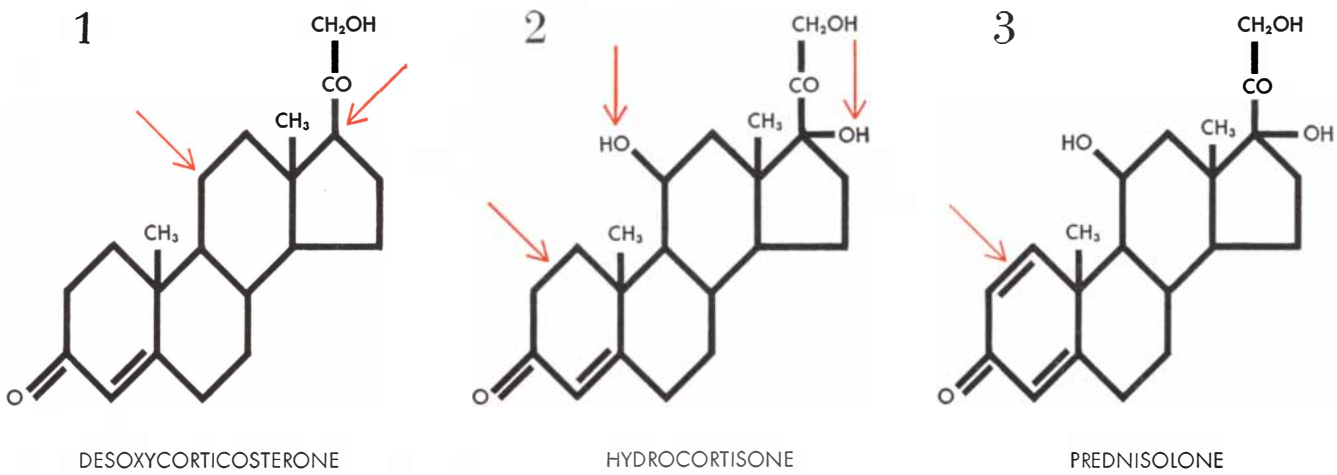
The concept of nerve cells secreting hormones immediately raises some provocative questions. For example, can the same cell generate a nerve impulse and secrete a hormone? However, the whole subject of the way hormonal mechanisms operate at the cell level is clouded by ignorance. It is tempting to suppose that hormones act in the cell by regulating enzyme reactions, which are involved in all metabolic transformations (*e.g.*, the



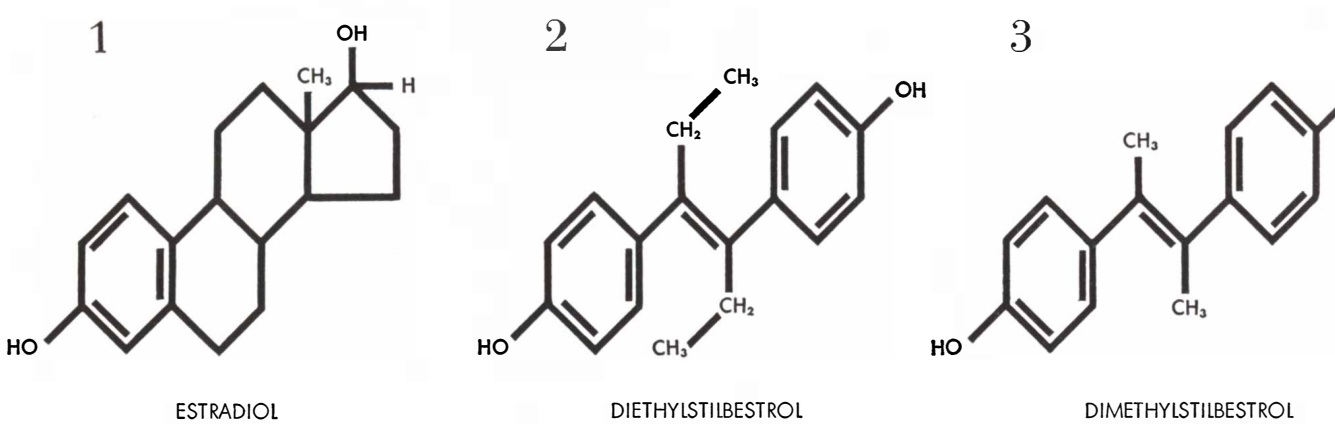
SECONDARY CHARACTERISTICS of male and female animals are brought out by hormones acting in concert with hereditary factors. Estrogen produces the plumage of the female pheasant (*top right*). Testosterone causes the development of comb and spurs in the white leghorn rooster (*right center*), the antlers of the white-tailed deer (*left center*) and probably the mane of the lion (*bottom*).



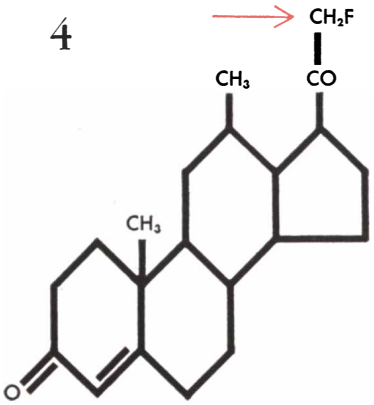
ANDROGENS and related compounds have the molecular structures depicted in these diagrams, in which carbon rings are abbreviated. The arrows in the diagrams emphasize significant differences in structure. Male characteristics are induced by compounds 1



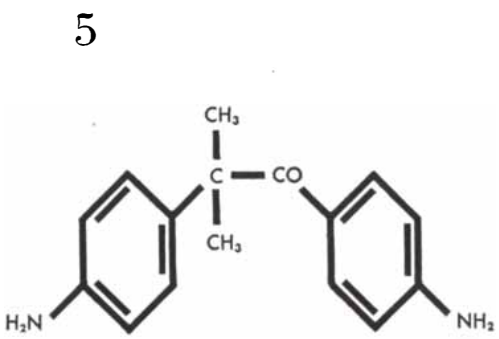
ADRENOCORTICAL STEROIDS and related compounds are important in the treatment of certain diseases. Compounds 1 and 4 are associated with retention of sodium and water, while 2 is associated with excretion of sodium and water and with carbohydrate-



ESTROGENS and related compounds do not all have the configuration of four joined rings characteristic of the steroid hormones. Estradiol (1) is the natural female hormone. Synthetic compounds 2 and 3 are closely related but only 2 has estrogenic properties.

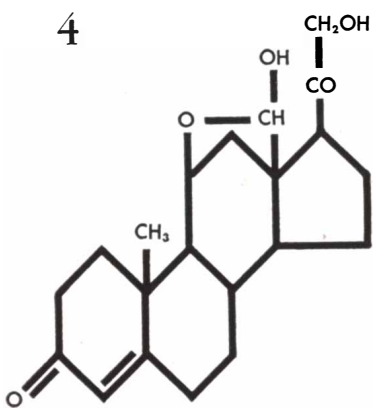


21-FLUORO-PROGESTERONE



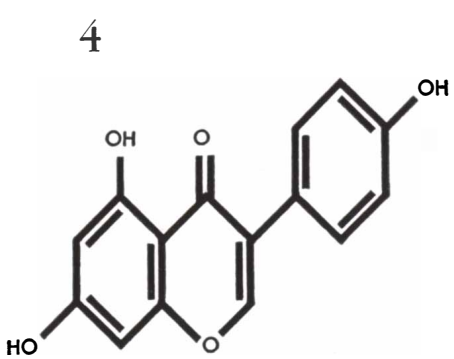
AMPHENONE-B

and 2, but 1 is considerably more potent. Progesterone (3) is produced by the ovary. Compounds 4 and 5 have properties similar to 3, even though the structure of 5 is unrelated.



ALDOSTERONE

forming properties. Both 2 and 3 may be made synthetically; 3 is the more potent.



GENISTEIN

Genistein is extracted from subterranean clover, a spreading species of clover genus.

conversion of liver glycogen to glucose). If so, they must act in a great variety of ways, because the hormones are chemically very diverse: those secreted by the adrenal cortex and the gonads are steroids; insulin is a protein; the gonadotrophins are glycoproteins; the posterior pituitary hormones are polypeptides; thyroxine is an amino acid combined with iodine; adrenalin is an amine derivative. A further indication of the hormones' chemical versatility is the fact that a single hormone may act upon various enzymes: estrogen is apparently able to influence at least six enzyme reactions.

Yet all the enzyme systems with which we are acquainted appear to be able to function without the intervention of any hormone, and it has not yet been possible to trace the physiological action of hormones to their chemical action. According to some authorities, it is even possible that hormones exercise their effects not by modulating the action of particular enzymes but by influencing energy transfers. For example, it has been suggested that estrogens increase the availability of energy to the cell by altering the physical state of a part of the cell where glucose is formed. By so doing they provide energy for the synthetic processes which underlie cellular division. In addition, estrogens possibly regulate the permeability of tissues to water, partly by altering the ground substance in which the cells of the body are embedded.

Hormones which apparently differ only slightly in molecular structure sometimes have vastly different effects. In some cases, on the other hand, compounds of very different structure produce the same effect [*see formulas in bottom row at the left*]. There is no obvious explanation for such facts, but in the case of the natural estrogen estradiol and the synthetic estrogen stilbestrol, the similarity of their biological effects may be due to a correspondence of interatomic distance between the two hydroxylic groups of the molecule.

Among the difficulties which prevent any real understanding of the relation of chemical structure to hormonal action is the fact that the experimentalist can rarely be certain that an isolated hormone is chemically identical with its form in the body. There is always a danger that the extracted, "chemically pure" hormone has lost some of the activities which it normally exercises in the body. It frequently turns out, too, that several pure substances are isolated from extracts of an endocrine organ and it is difficult to decide which of them is the natural hormone. For example, several clearly defined estrogens have been isolated from the ovaries. Are they all normal secretions, or are some laboratory artifacts? And in view of the chemical transformations that natural estrogens undergo in the body, can we be certain which of its natural forms is the one that acts on estrogen-sensitive tissues? Again, of some 30 different steroids isolated from the adrenal cortex, only a few are biologically active. Which of them is the important hormone? We still do not know how many active steroids the adrenal cortex produces under normal conditions, and what their respective effects are on the metabolism of carbohydrates, proteins and minerals. Studies with radioactive tracers may soon answer some of these questions, however. Such studies have already helped greatly in elucidating stages in the chemical breakdown of hormones before their excretion from the body.

One of the remarkable features of the endocrine glands is the capacity of the same cell to produce a number of different hormones. We have just seen that the cells of the adrenal cortex make several different biologically active steroids. From just a few types of cells in the anterior pituitary come diverse secretions which stimulate the thyroid, the gonads, the adrenal cortex, the mammary glands and other organs, not to speak of body growth in general. In the testes the same cells can produce male and female hormones. In fact a stallion gives forth more

estrogen than a mare does, except during a brief period of the mare's gestation!

Most hormones are produced only by a specific organ and effect a specific reaction. In some cases the target is a reaction that takes place throughout the body: for instance, the adrenal hormone aldosterone affects the water balance of all tissues. In others the target is a specific organ: the pituitary gonadotrophin acts basically on the testes or ovaries. Yet, to add to the complexity of the hormonal system, there are deviations even from this fundamental concept of specificity. The adrenal cortex can produce sex hormones; the gonads, conversely, can secrete substances with the properties of adrenocortical hormones. Some specialized reactions may be triggered by several types of stimulation: for example, menstrual bleeding, normally brought on by cessation of stimulation by ovarian hormone, can also be induced experimentally by certain adrenocortical steroids.

Hormones and Disease

In view of the complex, interlocking character of the endocrine system, it is not surprising that a derangement of the functioning of an endocrine gland produces far-reaching effects. A marked deficiency of secretion by the adrenal cortex results in Addison's disease, which manifests a variety of symptoms—extreme weakness, wasting, gastro-intestinal disturbances, a pronounced darkening of the skin—and was almost invariably fatal until the recent development of hormonal treatment. On the other hand, overactivity of the adrenal cortex may lead to various disorders: among other things, it may cause women to develop masculine characteristics, because it produces steroids with the properties of the male sex hormone. When the anterior pituitary gland functions poorly, growth of the body is impaired and puberty is delayed; development of the reproductive organs may even fail altogether. Conversely, overactivity of the pituitary leads to gigantism or, in an adult, to overgrowth of the head, hands and feet—the condition known as acromegaly. In the case of the thyroid gland, underfunctioning in childhood produces cretinism, and in adulthood it leads to a strange thickening of the skin, loss of hair, great lethargy and mental slowness. Overactivity of the thyroid (called Graves' disease) results in the familiar symptoms of a high rate of metabolism, great excitability and protruding eyes. And of course everyone knows that a deficiency of secretion of insulin by the pancreas is responsible for diabetes.

NERVE CELL of the hypothalamus secretes the dark-staining material which fills the cell body (*top*) and most of its long, thin axon. The material exudes from the end of the axon. This preparation was made from a dog's hypothalamus by Walther Hild of the University of Texas School of Medicine in Galveston. It is magnified 1,100 diameters.

The results of derangement of the endocrine system are so pervasive that it is natural to suspect it of complicity in various systemic diseases. The estrogenic hormones are chemically related to some of the hydrocarbons that induce cancer when applied to the skin of rats and mice. These hormones stimulate the growth of cells in the reproductive organs of women, including the breast. Could they initiate malignant growth in those organs? So far all that has been proved is that estrogenic stimulation does play a part in the triggering of cancer in strains of mice genetically susceptible to the disease. Paradoxically, estrogen can be used as a treatment for certain forms of cancer—for example, cancer of the prostate.

Hans Selye of Montreal has grouped together arthritis, hypertension and kidney disease as a set of disorders resulting from derangement of the pituitary-adrenal system. The basic idea is that when the body is subjected to some general stress (such as extreme cold or shock), the adrenal cortex immediately releases and becomes temporarily depleted of its steroid hormones. If the stress continues, the anterior pituitary secretes so much ACTH as to overstimulate the adrenal cortex. This leads to pathological results, including rheumatoid arthritis. Popular interest in the idea was excited when it was found that ACTH and cortisone had an almost miraculous effect in relieving the symptoms of rheumatoid arthritis. However, the relief lasts only so long as the hormones are being administered, and if administered too long, they frequently have dangerous side effects.

The "adaptation syndrome" has been hailed as a "unified concept of disease." This seems too sweeping and overambitious a view. Nevertheless it is difficult to exaggerate the importance of the study of endocrinology. The past 10 years have seen the development of the concept of secretions by nerve cells, the synthesis of the hormones of the pituitary posterior lobe, the discovery of such potent adrenal hormones as aldosterone and hydrocortisone and the complete working out of the structure of the insulin molecule. They have also brought to light the

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SECTION OF a 26-foot long extruded architectural bronze I-shaped mullion. Such shapes will extend full height of building at about 4½-foot horizontal spacings.

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Illustration at right shows scale model. Architects: Mies van der Rohe and Philip Johnson. Associate Architects: Kahn & Jacobs. General Contractor: George A. Fuller Company. Architectural Metals Fabricator: General Bronze Corp.

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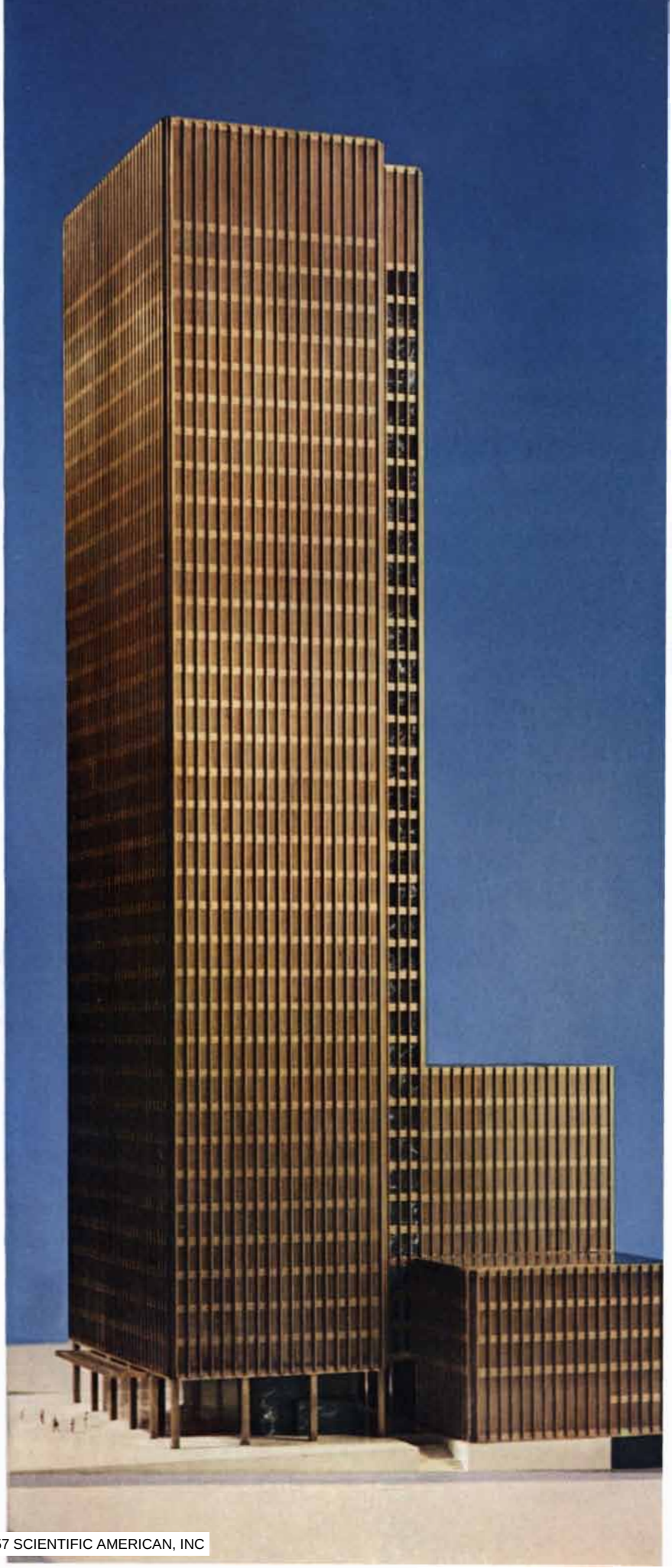

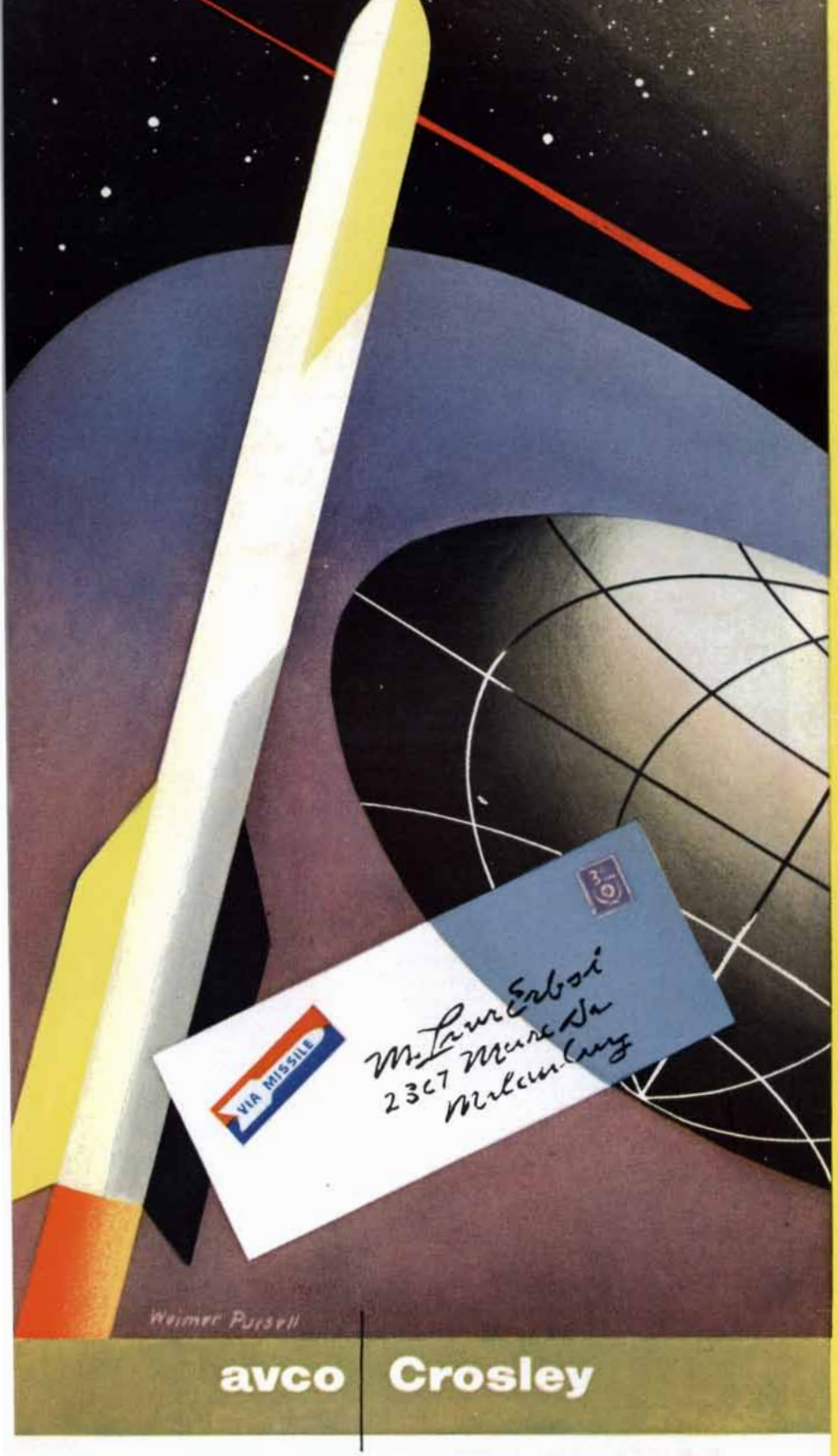

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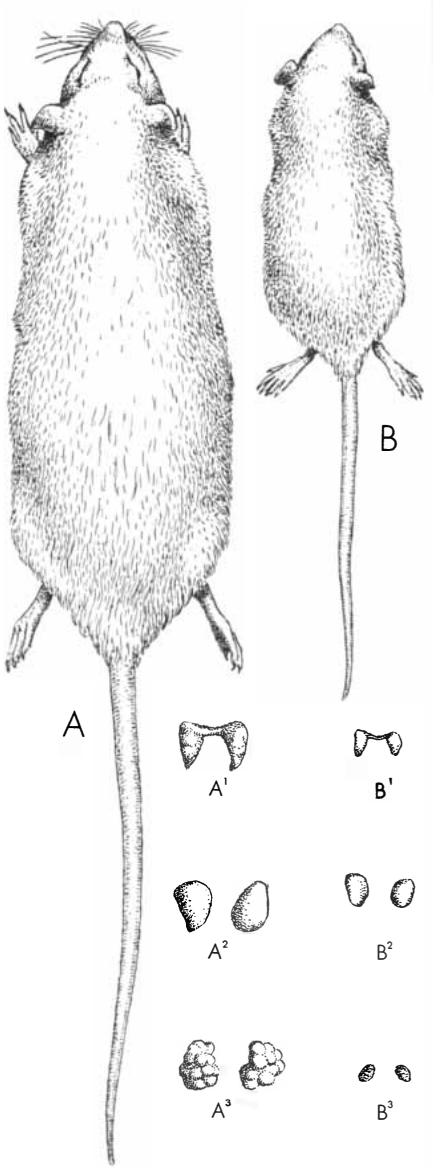
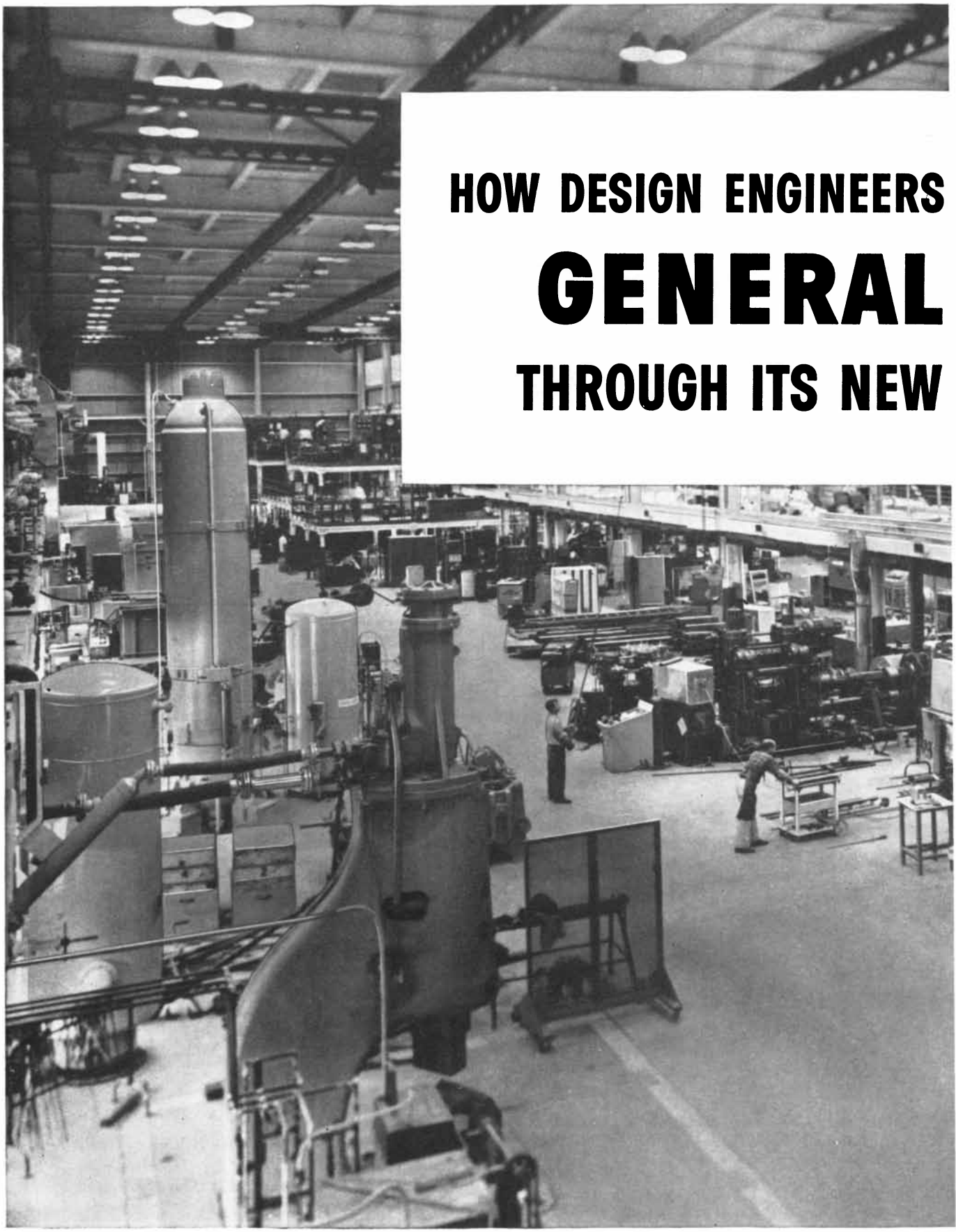
possible roles of hormones in immunological reactions, in the genesis of cancer and in the control of fertility—a subject which may have enormous importance for the future welfare of the world. Other vast fields of endocrine action have been found in invertebrate animals and in plants. Hormones are no longer regarded merely as chemical messengers in the bloodstream. They play a part in almost every, if not every, living process.



EFFECT OF PITUITARY HORMONE on growth may be demonstrated in the rat. The pituitary was removed from one of two littermates 36 days after birth, at which time both rats had the same weight. After several months the normal animal (*left*) had tripled its weight and had matured while the other (*right*) had gained little weight and was maturing much more slowly. At left are the thyroids (A1), adrenals (A2), and ovaries (A3) of the normal rat, and at right are glands (B1, B2, B3) of operated rat.



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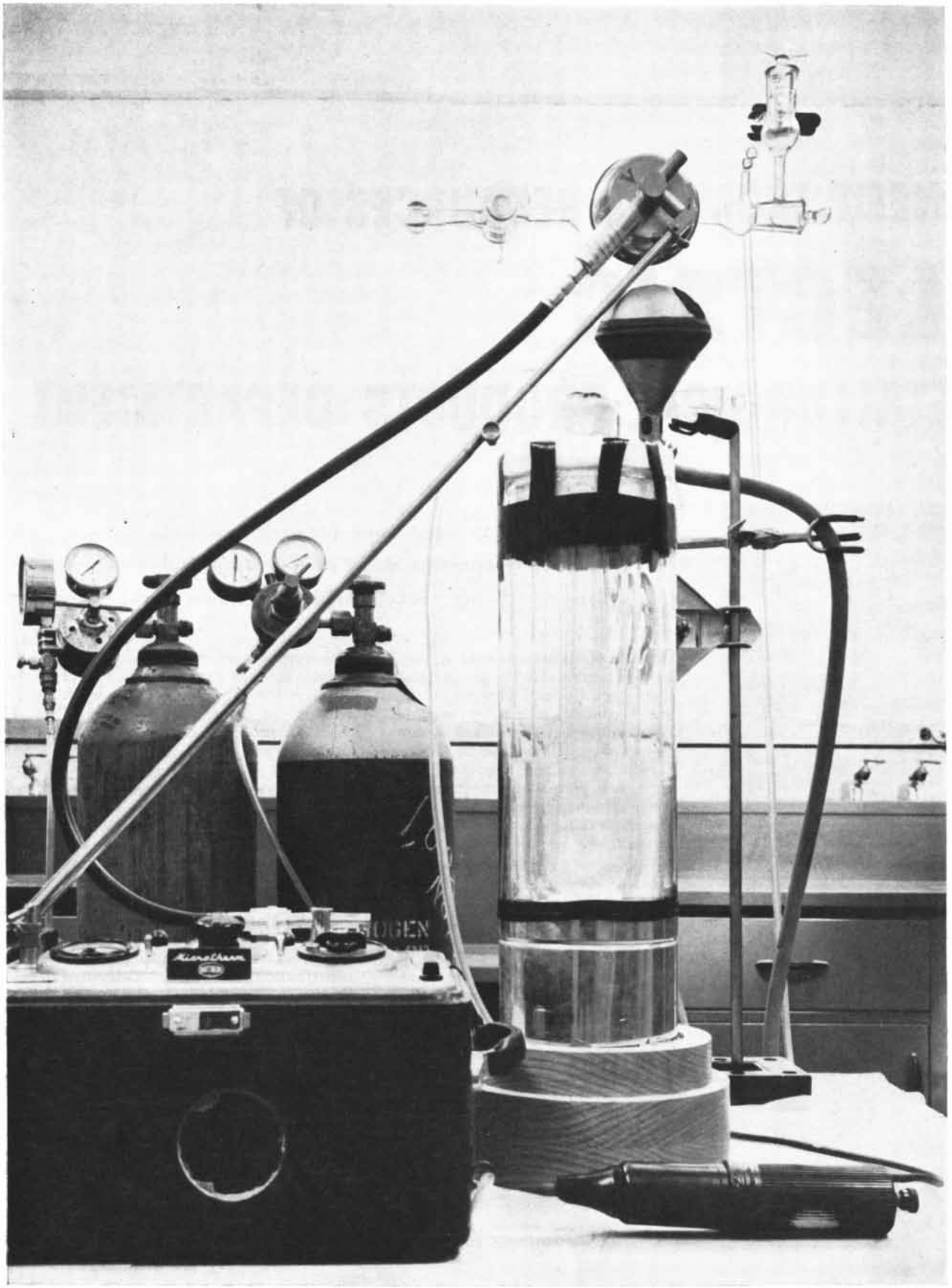


DEWAR FLASK in which radicals are frozen is the vertical glass structure at the right. The box in the left foreground is a high-frequency generator. Behind it are tanks of gaseous nitrogen and helium. The cylinder lying in front of the flask is a spark coil.

FROZEN FREE RADICALS

Molecular fragments, which normally have a fleeting existence during chemical reactions, can now be preserved by rapid cooling. The study of their properties is an exciting new field of research

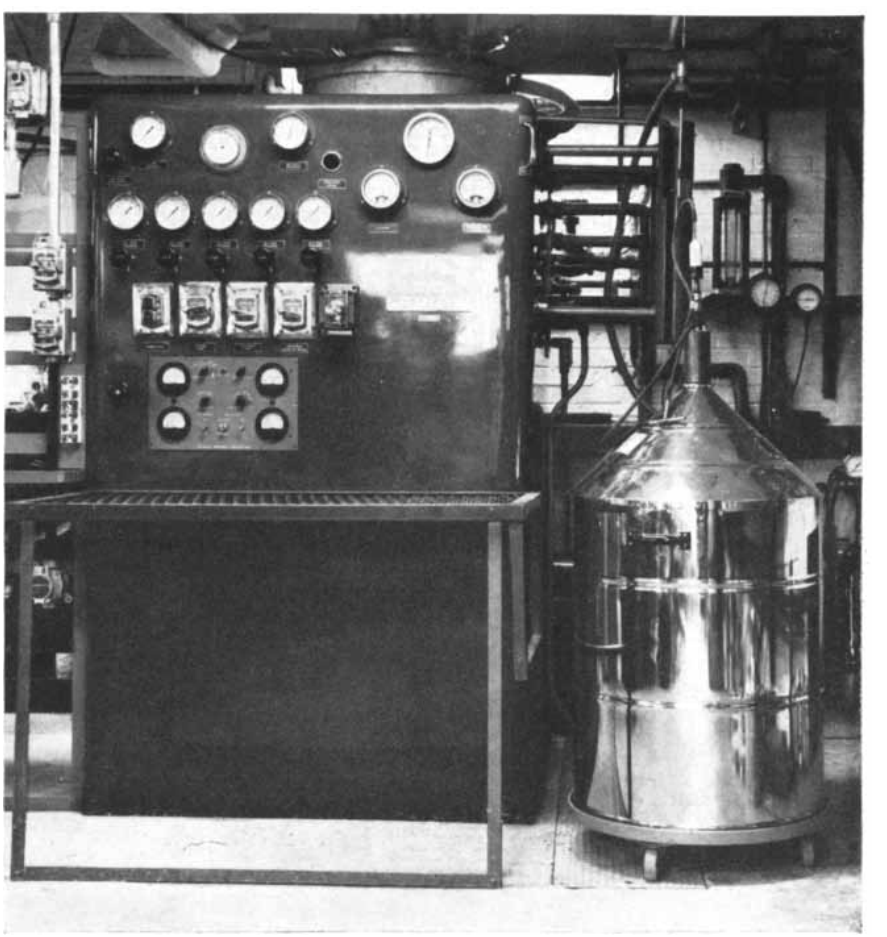
by Charles M. Herzfeld and Arnold M. Bass

Almost everywhere we look in the universe we can see the dance of free radicals. They are present in an ordinary flame, in an electric arc, in the atmosphere, in the stars, even in the cold interstellar dust. Free radicals are fragments of matter which for the most part have only a fleeting existence. If we understood their behavior fully, we would have a master key to understanding what makes the chemistry of the universe go. One of the most exciting physicochemical developments of recent years is the discovery of ways to halt the dance of the free radicals—to freeze them in their tracks so that we can examine them at our leisure. What the investigators have seen already is so startling and so stirring to the imagination that it is no exaggeration to say it has opened a new field of science.

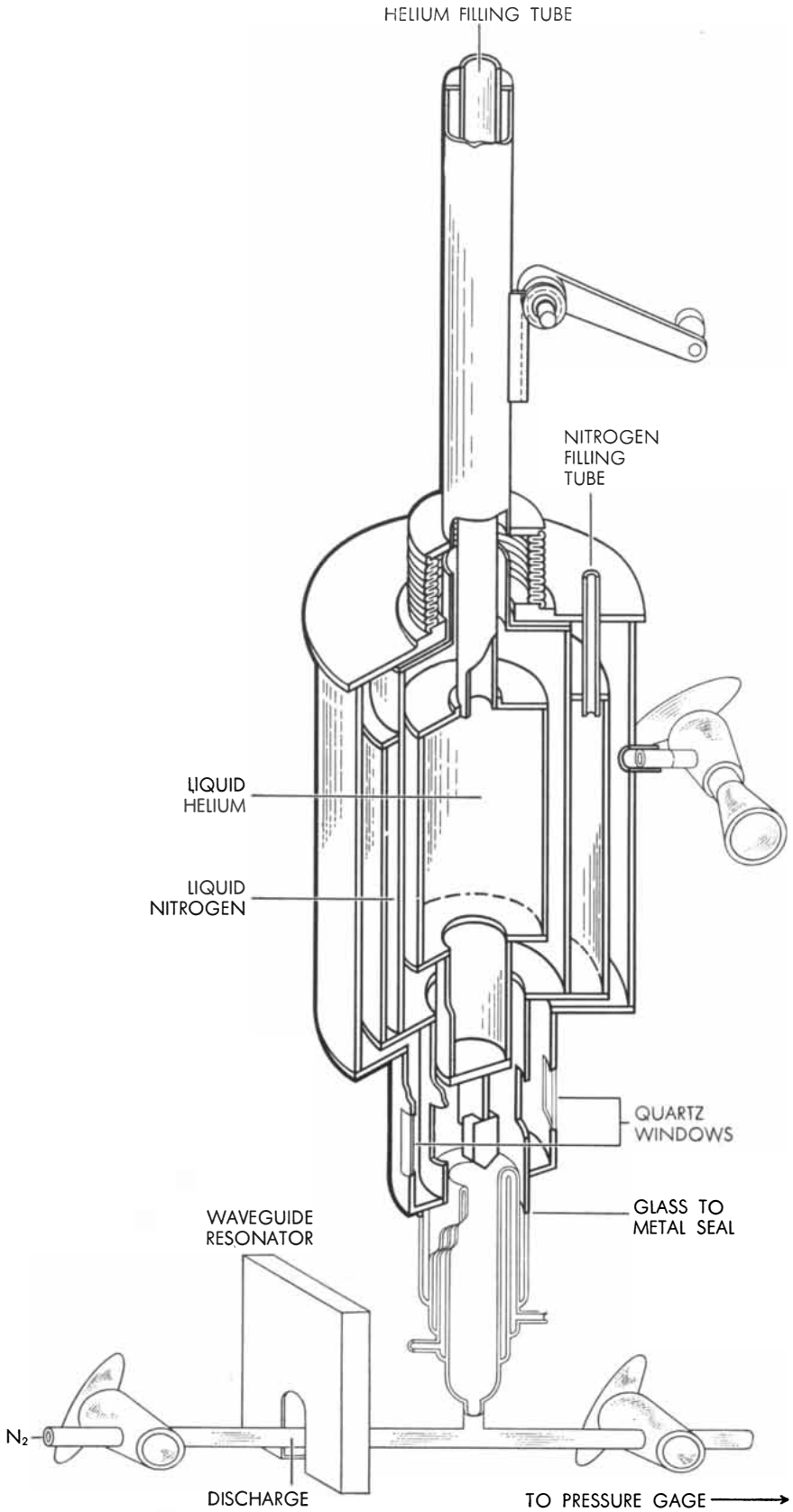
What is a free radical? We can illustrate what it is and what role it plays by considering an atom of chlorine. The atom may be freed by sunlight breaking up a molecule of chlorine gas (Cl_2). In the presence of hydrogen, the chlorine atom attacks a hydrogen molecule (H_2), forming the comparatively stable product HCl and releasing a hydrogen atom. Now it is the hydrogen atom's turn to act as a free radical: it attacks a chlorine molecule, again producing HCl and freeing a chlorine atom to continue the chain reaction. This in simple outline is the role of free radicals—which may be either single atoms or larger fragments of molecules. The highly reactive fragments start and maintain a chain reaction among comparatively inactive substances. A relatively small number of free radicals (as few as one per thousand molecules) can keep a chain reaction running. Because each step takes only a small fraction of a second, they turn out products at a great rate.

Free radicals almost invariably contain an odd number of electrons, which in part accounts for their activity. (Hydrogen has one electron; chlorine has 17; the hydroxyl radical—OH—has nine; the methyl radical—CH_3—has nine, and so on.)

Not all free radicals are short-lived. There are species which have lifetimes of many days under suitable conditions—*e.g.*, when they cannot react with air. The known long-lived types are mainly hydrocarbons, usually consisting of 30 or more atoms, which can be kept by dissolving them in benzene or similar inert solvents [*see illustration on page 94*]. Such radicals were first isolated half a century ago by Moses Gomberg of the



LIQUID HELIUM for the experiments at the National Bureau of Standards was made by this helium cryostat. The vacuum storage tank at right holds 20 gallons of liquid helium.



FREEZING APPARATUS of the Bureau of Standards is a modified version of one developed at the Johns Hopkins University Applied Physics Laboratory. Nitrogen (N_2) is admitted at lower left and is dissociated by the high-frequency field of the waveguide resonator. Radicals collect on a copper wedge inside the quartz windows. The wedge is connected to a helium reservoir by a copper rod. Liquid nitrogen in outer container insulates the helium.

University of Michigan [see "Free Radicals," by Paul D. Bartlett; SCIENTIFIC AMERICAN, December, 1953].

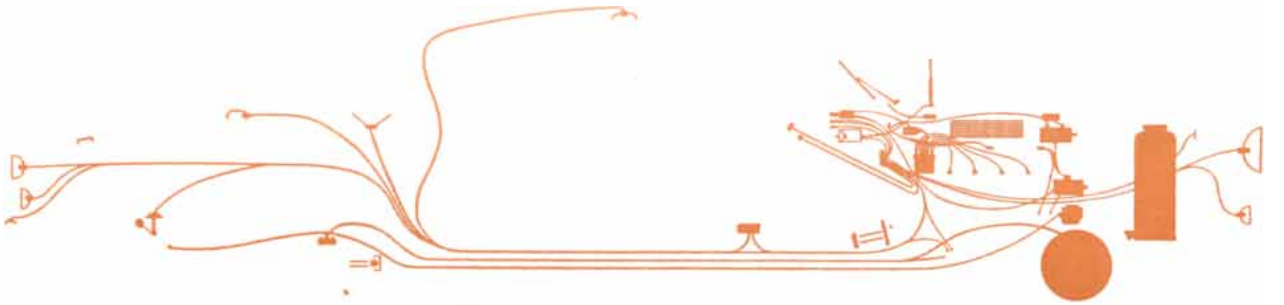
But it is the short-lived radicals, whose lifetimes are usually measured in thousandths of a second, that are most abundant and most interesting. They are generally simple in structure and consist of only a few atoms: the hydroxyl and methyl radicals are typical. Free radicals are generated wherever molecules are broken up by some energetic process: a chemical reaction, heat, an electrical discharge, the attack of ultraviolet light and cosmic rays on molecules in our upper atmosphere. The dust of interstellar space is probably made up of free radicals frozen in the radical state by the extreme interstellar cold.

One of the first scientists to study frozen free radicals was the Norwegian physicist L. Vegard. He believed that certain unexplained wavelengths of the light of the aurora borealis were emitted by particles of solid nitrogen under bombardment by cosmic rays in our upper atmosphere. To investigate the matter he froze some nitrogen at the temperatures of liquid hydrogen and liquid helium, and then bombarded it with very fast electrons and with alpha particles. He did not get the wavelengths he was looking for, but he did produce interesting emissions of light, and he continued his experiments with frozen oxygen, hydrogen and many other materials, including mixtures of various gases. This work, done between 1925 and 1935, unfortunately did not receive sufficient attention. It is now clear that Vegard's experiments revealed some of the properties of free radicals.

In 1948 F. O. Rice and his students at the Catholic University of America hit upon a technique for trapping free radicals and began a series of remarkable investigations. Rice generated the radicals by passing gases through a hot tube (among other ways) and then trapped the products on a cold wall [see "The Chemistry of Jupiter," by Francis Owen Rice; SCIENTIFIC AMERICAN, June, 1956]. He obtained and studied some very unusual free radicals, including sulfur (S_2) and nitrogen hydride (NH).

A number of other laboratories are now investigating frozen free radicals by various techniques. This article is principally a report on some recent work at the National Bureau of Standards, initiated by Herbert P. Broida and John R. Pellam in 1954.

They produced free radicals by flowing gases through a high-frequency elec-



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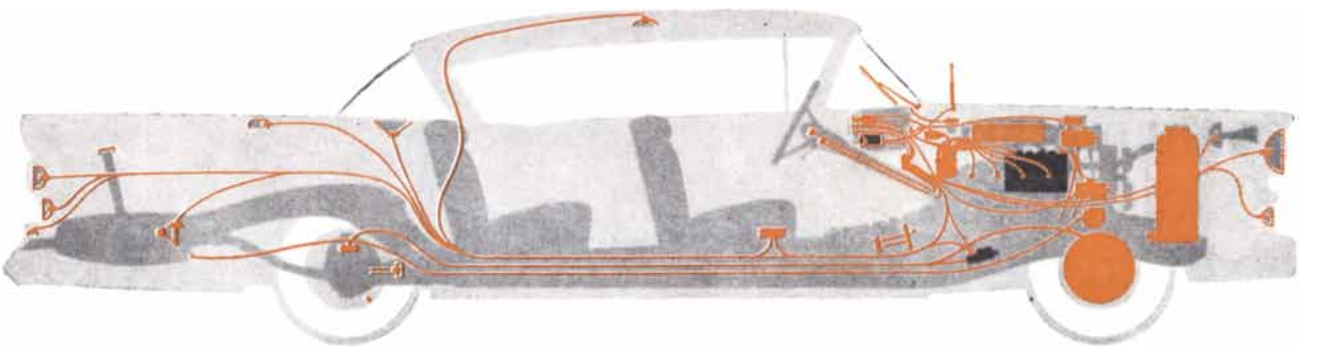

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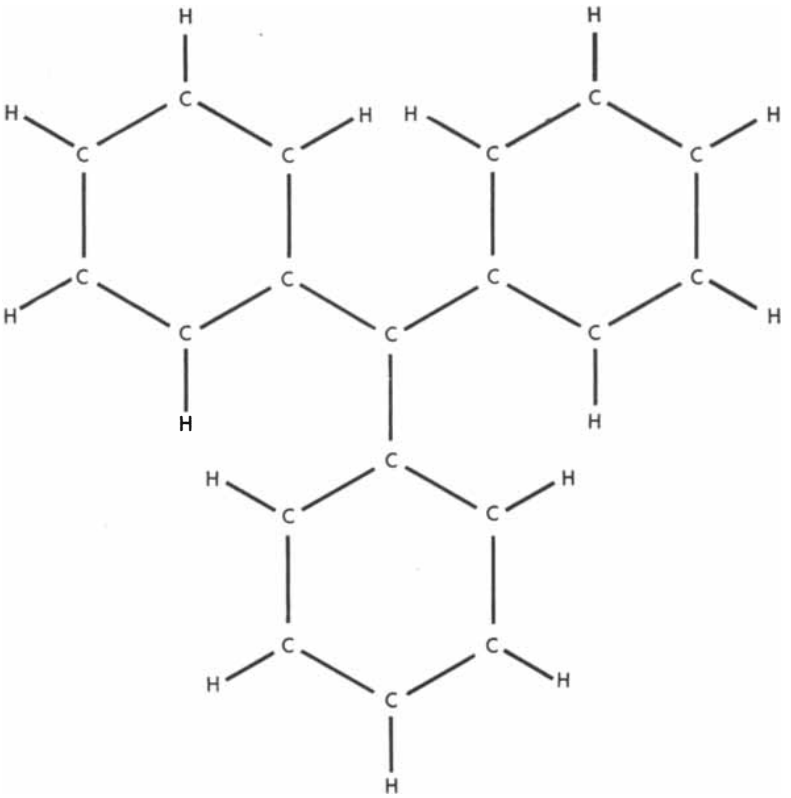
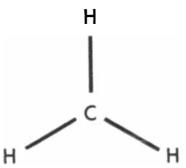
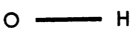


LONG-LIVED RADICAL is typically a hydrocarbon with perhaps 30 or more atoms. This diagram shows triphenylmethyl, first made by the pioneer investigator Moses Gomberg.





SHORT-LIVED RADICALS contain only a few atoms. At left is the methyl radical; at right, the hydroxyl radical. Their lifetimes are normally only a few thousandths of a second.

tric discharge, powered by a 2,450-megacycle medical diathermy unit. This convenient system not only produced considerable numbers of free radicals but also raised them to highly excited states. The products were then rapidly pumped to a surface cooled by liquid helium to about four degrees above absolute zero, where they immediately froze into a solid.

Broida and Pellam first tried a few rapid experiments to test their technique. In one exciting day they obtained a series of spectacular breakdown products from discharges through water vapor, oxygen, nitrogen and hydrogen. Broida and his collaborators proceeded to study the properties of these strange new materials. The experiments of that first day provided grist for years of fascinating investigations.

The most dramatic of the first experiments was the one on nitrogen. When the material produced by the discharge breakdown of nitrogen gas began to freeze on the cold surface, it began almost immediately to emit a bright green glow, so intense that it was visible in a well-lighted room. As more material was deposited on the surface, it gave forth brilliant blue flashes. After the flow was stopped, a blue-green afterglow persisted in the cold solid for several minutes. If the solid was then warmed suddenly (to above 25 degrees absolute), it emitted a flash of blue light, which looked like a flame "burning" through the solid. Upon later recooling to the temperature of liquid helium, a blue-green afterglow appeared again, but now much weaker.

This totally unexpected display naturally demanded immediate analysis with the spectroscope, to identify the substances responsible for it. The spec-

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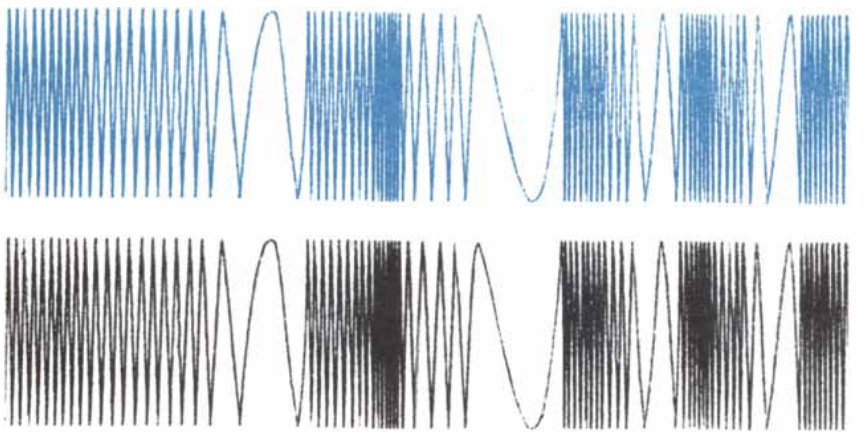

Ball-point inks

If you drew a continuous, unbroken line with a ball-point pen until its ink supply was exhausted, the line would be two to three miles long. Enough to write 50,000 to 70,000 words, compared with the 2,500 to 4,000 words you get from the same amount of fountain pen ink.

Because you would be exhausted long before your ink supply, a mechanical scriber—which produces those mysterious zig-zag lines above—is used to test hundreds of ball-point ink formulations.

The amazing number of words coming from a ball-point pen has enabled ball-points to roll past both fountain pens and mechanical pencils to become the most commonly used writing instruments today.

This would not be so if the ball-point pen remained unchanged, still staining, skipping, smearing, drying up. A better mechanical tool was needed to start with.

Once accomplished, the ink became the most important element, and synthetic organic chemists turned to the key element—the colorant—which is half of the entire ink formulation.

Early ball-point inks were made with the same dyes used for years in fluid inks. But ball-points have different ink requirements: good flow properties, lubricity, solubility, storage stability and—most important—an exceptionally high concentration of dye. Tinctorial value must be twenty times that of a fluid ink.

From research has come a special line of NATIONAL dyes, tailor-made for ball-point inks. Research on both pen and ink has enabled the ball-point to supplant in 15 years the pointed pen, in use for 13 centuries.

Odor control

Odor control presents an ingenious twist on the old question of whether there is any sound when a tree falls in a deserted forest.

We have always had odor-causing sites. But today, with industry expanding and our suburban communities moving further into the country, these odors become a serious problem. Some sources of this problem are sewage plants, landfill garbage, drainage ditches, storm sewers and market area streets.

SOLVAY OZENE (emulsifiable orthodichlorobenzene) is becoming widely used in industrial odor control situations, for dripping into sewage or spraying on garbage and other odor sources.

OZENE works on odors these ways: its own odor serves as a masking agent; it slows down the production of bacteria which cause sulfide odors; it prevents the growth of fungi which speed the decomposition of waste materials.

A dark-colored liquid, OZENE mixes readily with water and can be substantially diluted for economical use.

Biological grade chemicals

Preparing balanced salt solutions for the growth of cultures is typical of the stringent needs of biochemists for extremely high-purity chemicals, products which have been purified even beyond the universally recognized American Chemical Society quality standards for analytical reagents.

Three such "reagent plus" compounds have been added to BAKER & ADAMSON'S line of 1,000 laboratory reagents. These initial chemicals—sodium bicarbonate, sodium chloride and potassium chloride—show very minute trace impurities, materially lower than in similar chemicals produced to A. C. S. specifications.

They are the first in a proposed line of biological grade chemicals made especially for such important scientific applications.

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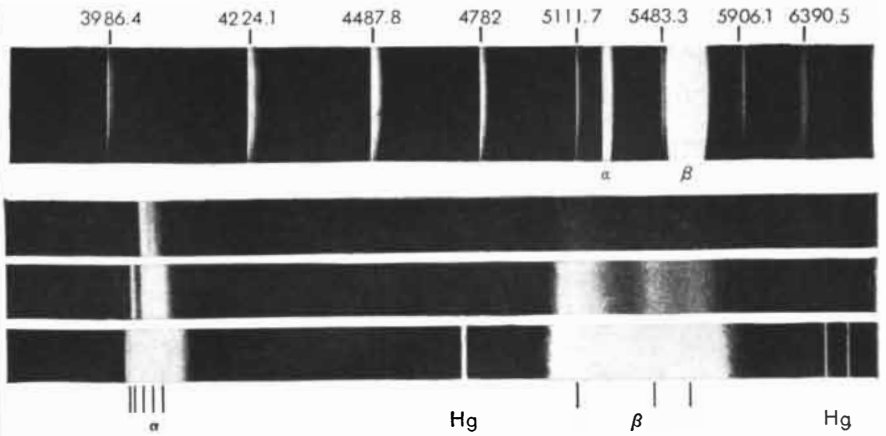
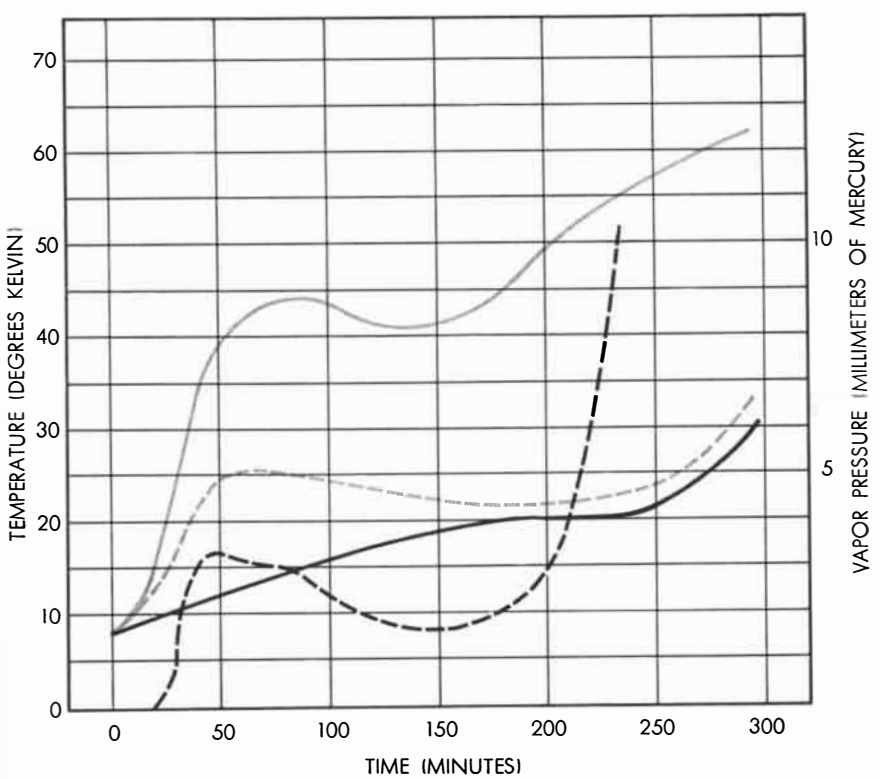


SPECTRUM OF GREEN GLOW from solidified nitrogen radicals (*above*) has two especially bright bands, marked "alpha" and "beta." These are magnified (*below*) to show five lines in the alpha band and three in the beta. These lines are emitted by excited nitrogen atoms. Lines marked "Hg" are from mercury spectrum, superimposed to help in measuring wavelengths. Remaining lines in upper spectrum, whose wavelengths in Angstrom units appear at the top, are emitted by nitrogen molecules formed by recombination in the solid.

tra showed five closely spaced lines of intense emission in the blue-green region, three broad bands in the yellow region and many weaker bands distributed over the whole visible spectrum (a pattern just like the one Vegard had found in his nitrogen experiments nearly 30 years earlier). There was little doubt that most of the green light came from isolated, excited nitrogen atoms, and the presence of such atoms has recently been confirmed by studies of the magnetic properties of the material by C. K. Jen and S. N. Foner at the Applied Physics Laboratory of the Johns Hopkins University. Other features in the spectra were identified as originating from NO, NH and excited nitrogen molecules.

Further information has been obtained by heat measurements. For this



WARMING OF SOLID NITROGEN from a gas discharge is shown by the solid gray curve. The rapid increase in temperature in the first hour is probably due to heat released by recombining atoms. The broken gray curve and solid black curve show warming behavior for solid molecular nitrogen and an empty chamber, respectively. Broken black curve shows how the pressure of gas in the chamber increases as the solid warms and vaporizes.

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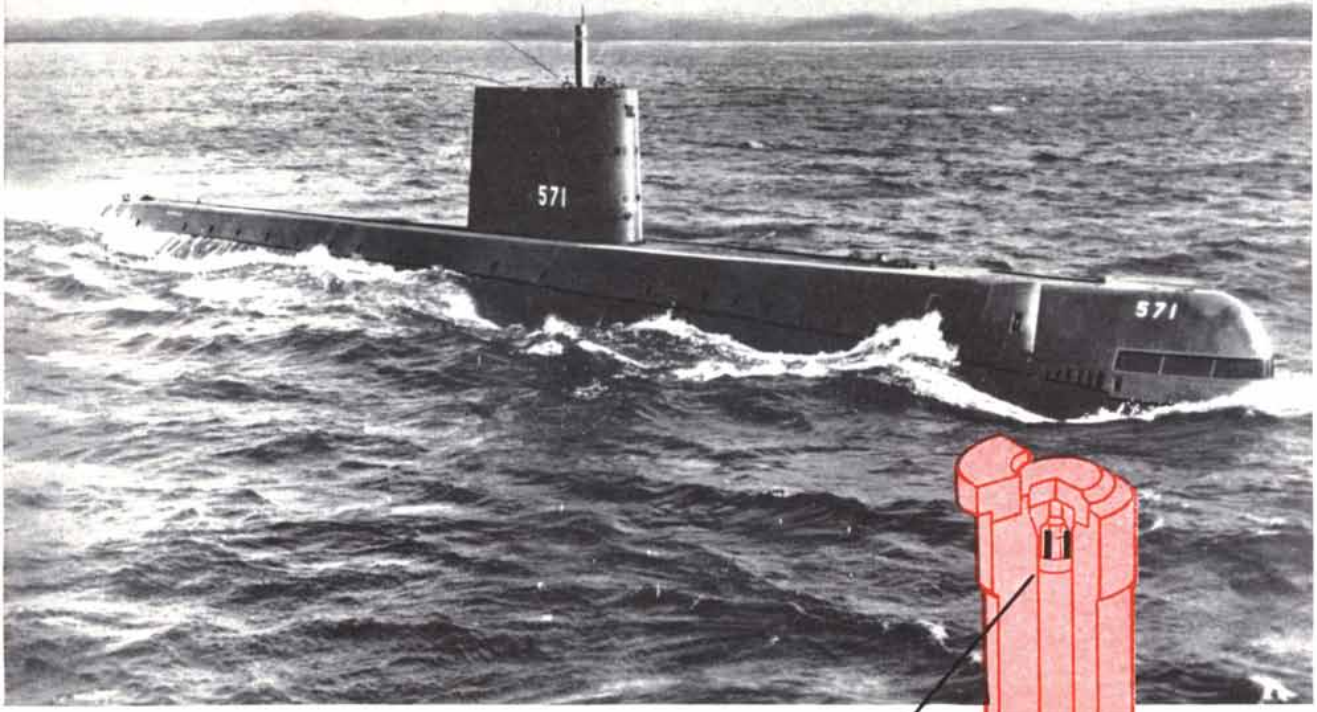

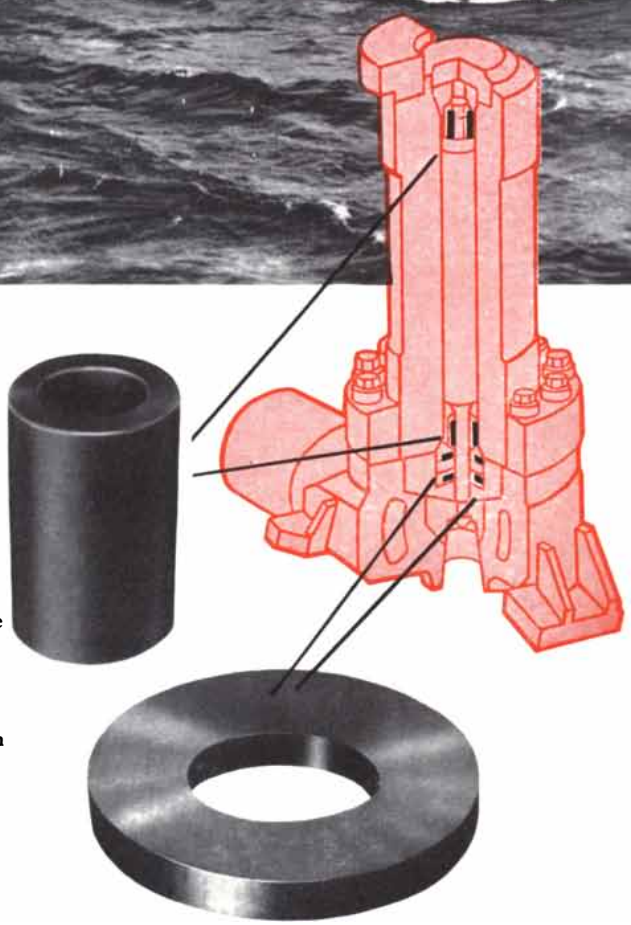

Working closely with the Atomic Energy Commission, the Westinghouse Electric Corporation designed and built the power plant for the NAUTILUS, first atomic-powered submarine. The soundness of every engineering principle, every individual part—including the GRAPHITAR pump bearings—has now been proved by the more than 50,000 miles the submarine has steamed, approximately half was submerged. These Westinghouse-designed pumps are hermetically sealed within the integrated pump and drive motor. All leakage past the pump seal is contained within the flooded motor while the purely electrical elements are contained in "cans" to exclude the water.

The GRAPHITAR pump bearings in the power reactor of the Nautilus have withstood high speeds, extreme temperatures, and great pressures, and have come through this test-period with a perfect performance record . . . their only lubricant, radioactive hot water!

This same GRAPHITAR that has proved its ability to help harness the power of the atom is available for use in performing equally tough jobs in your product, too . . . why not get full information today.

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97

Tailoring Molecules *for* Rockets

by Dr. David Z. Lippmann

A member of the Chemistry Department Staff at Reaction Motors, Inc., Dr. Lippmann specializes in combustion processes and theoretical analysis. He received his B. S. and M. A. in Chemistry at the University of Texas and his Ph. D. in Physical Chemistry at the University of California at Berkeley. He has been with RMI for three years.

The practical future of rocket power depends upon a great many factors—not the least of which is the solution of the problems facing the rocket propellant chemist. The ultimate rocket chemicals—whether nuclear, solid, liquid (mono- or bi-propellant), hybrid or the new "exotic" chemicals —must lie within the limited parameters of certain rigid requirements. This discussion deals with some of those basic considerations which influence the chemist's search for improved high energy rocket propellants.

The conventional rocket motor is a heat engine which converts the chemical energy of propellants into heat and the heat into kinetic energy. Propellants react in the combustion chamber of the rocket motor, releasing heat and forming gaseous products, which expand through a nozzle; the expansion converts part of their heat energy into kinetic energy. The gases, now moving at high velocity, are exhausted to the rear, and by the reaction principle they impart a forward force, measured in pounds of thrust, to the motor.

The thrust exerted by a rocket motor is proportional to the exhaust velocity of the reaction products. To produce a high exhaust velocity, the reaction of the propellants must yield a large quantity of heat per unit mass and this heat must be converted into kinetic energy efficiently.

The heat produced is the difference between the heat of formation of the propellants and the heat of formation of the reaction products; so the propellants should have large positive heats of formation and give products with large negative heats of formation. Because of the requirement for large heat of reaction per unit mass (not per mole), only the lightest elements are used in propellants. The most desirable elements are hydrogen, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, magnesium, aluminum and silicon; elements heavier than chlorine are rarely used. The heats of formation of propellants are maximized by incorporating high energy groups such as $-C\equiv C-$, $\rangle N-N\langle$ and $-OO-$ into the propellant molecules.

The efficiency of conversion of heat into kinetic energy is inversely proportional to the mean molecular weight of the reaction products. Therefore propellants are designed to give light products, such as H_2, H_2O and CO.

These three requirements, i.e., that the propellants have large positive heats of formation, that the products of reaction have large negative heats of formation, and that the products have low molecular weights, cannot all be optimized simultaneously. A good propellant must have an optimum balance among them. In addition, a propellant should have other desirable properties, such as stability and high density.

The chemistry laboratories at RMI, in support of the applied research, development and production of advanced rocket power systems, are staffed with a team of specialists, highly qualified in many phases of chemistry and chemical engineering. This team is constantly working toward the achievement of this optimum balance of properties in their search for advanced rocket propellants. The well-rounded program of research, analysis and evaluation which contributes to this goal includes such typical activities as mathematical analysis, theoretical chemistry, propellant formulation, combustion chemistry, organic and inorganic synthesis, physical properties and analysis, with special sections devoted to solid and liquid propellant research.

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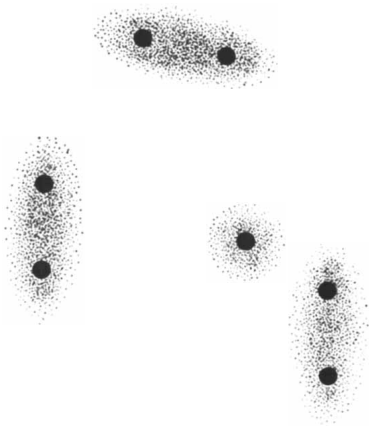
If you desire one or more reprints of Dr. Lippmann's article, or would like to receive additional information about RMI, write to our Information Services Coordinator. Reaction Motors, Inc., 20 Ford Road, Denville, New Jersey.



TRAPPED ATOM (*single dot*) **is shown among several nitrogen molecules** (*double dots*). **The light emitted by the frozen solid indicates that each atom is located much nearer to one molecule than to the others.**

purpose the products are trapped in a small, low-temperature calorimeter. As the temperature of the solid is allowed to rise, the frozen radicals gradually gain in mobility, until they are able to diffuse through the solid with sufficient freedom to find partners with which to combine. In so doing they emit considerable heat. From the heat liberated, the number of free radicals originally trapped can be estimated. In the case of nitrogen the proportion of free nitrogen atoms in the condensed solid amounts to at least one fifth of 1 per cent.

All the experimental evidence indicates that at four degrees absolute free radicals survive for many hours in their isolated state. The reasons for this are not yet precisely clear. The most likely reason is that in the solid material condensed on the cold surface, the free radicals are separated from one another by unreactive molecules and atoms in a rigid framework. When the temperature is raised, the framework "gives" slightly, allowing the radicals to wander far enough to combine with each other. Thus two nitrogen atoms may meet and form the stable nitrogen molecule. In this process they give off just as much energy as is required to tear apart the two atoms of a nitrogen molecule. About half of the energy released on combination is radiated as light by the newly formed molecule, and the rest is in the form of heat. The color of the light emitted is a measure of the energy required to break up a given molecule.

The bright blue-green glow which is so spectacular a feature of the freezing of nitrogen atoms gives us considerable

What kept her from falling apart?

The Statue of Liberty was once in danger.

Not from a foreign foe. Not from a crackpot's bomb. This peril was less exciting . . . *but no less destructive.*

It was corrosion — corrosion that had been at work ever since Liberty first raised her torch above the salty waters of New York harbor.

Relentless and merciless in its attack, the acrid, smoggy sea air had loosened and weakened the rivets holding the statue's huge sheet metal plates together. Miss Liberty was dangerously close to falling apart at the seams!

Something had to be done, that was clear. But *what?* Re-riveting wasn't practical. Too many hard-to-get spots in the statue.

This problem was put to an expert — a fastenings manufacturer. His solution: Self-tapping screws of Monel* nickel-copper alloy. Monel alloy to keep corrosion at arm's length. And self-tapping screws to pull the plates up snug and tight — from *outside* the statue!

So 65,000 self-tapping Monel alloy screws were used to "run up the seams" of Miss Liberty's robes. The job was done in 1938 . . . easily . . . neatly. And from the looks of these corrosion-resisting fastenings today, Miss Liberty's worries are over for a long time.

Do you have a metal problem? One that involves corrosion . . . stresses . . . fatigue . . . high or low temperatures . . . or some other unusual factor? Suppose we get together and talk it over. Monel alloy — or one of our other Inco Nickel Alloys — may be just the metal *you* need.

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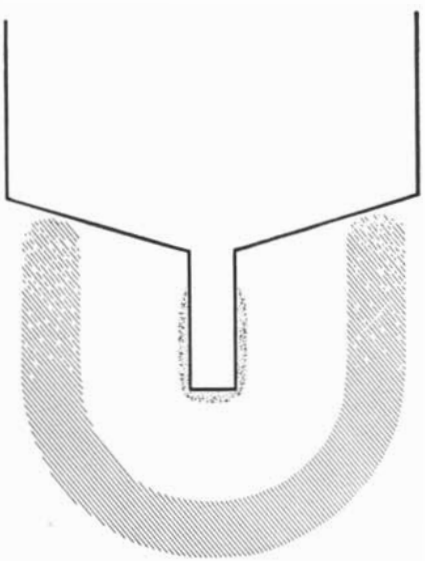
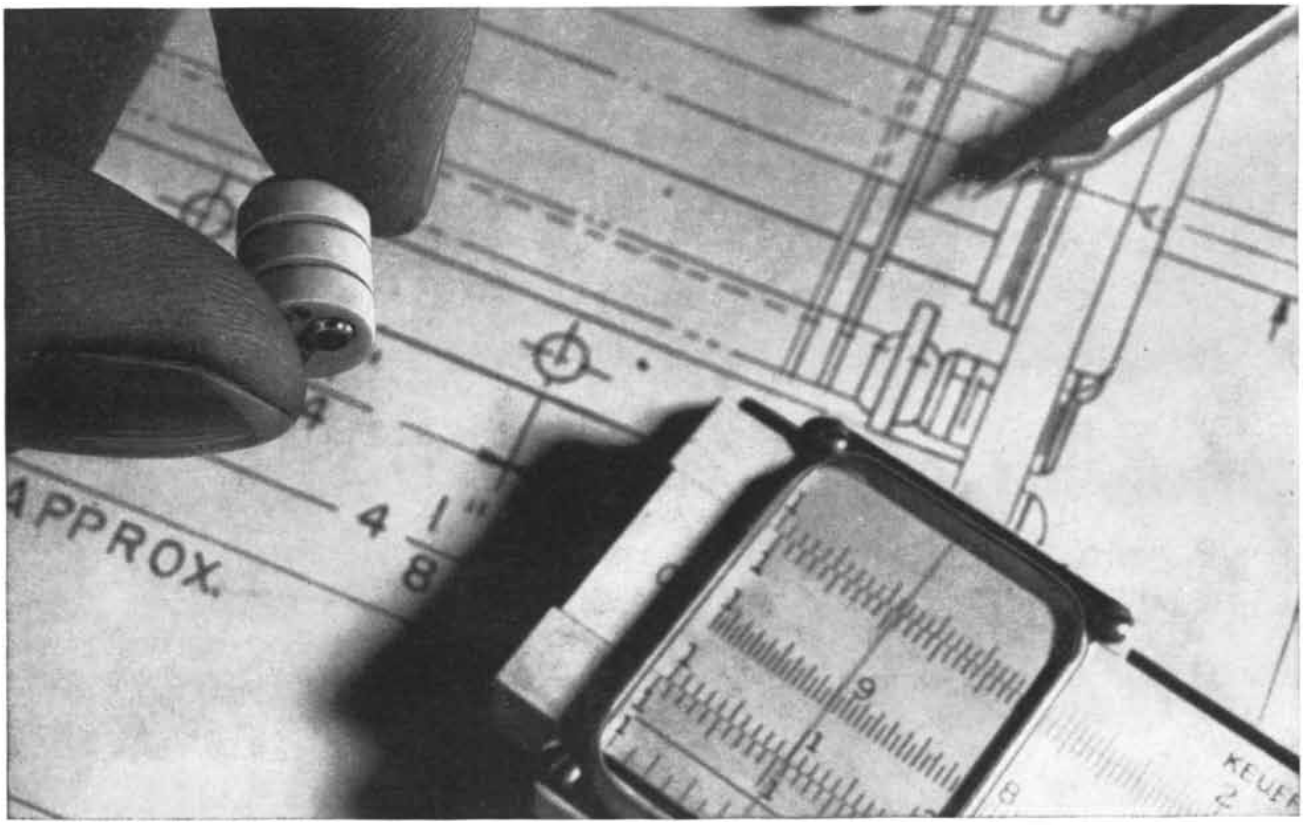
information about the way the atoms are trapped. The five intense emission lines and the measured lifetime of the afterglow are interpreted to mean that each nitrogen atom is trapped near a nitrogen molecule in a particular geometrical relation to it [*see diagram on page 98*]. This interpretation is based on calculations of the disturbance of the motion of the electrons in the atom by the electrons in the molecule. The calculations, and magnetic experiments by Jen and Foner, indicate that the disturbed nitrogen atom is not bound to the nearby molecule, or at most only very weakly linked to it. There is a possibility that "super-nitrogen" molecules, consisting of three nitrogen atoms tightly bound together (N_3), may be formed by the free radicals, but so far we have no evidence of this. In any event, such a molecule could not emit the five blue-green spectral lines.

While the nitrogen phenomena are the most colorful, the experiments with oxygen produced results which in some ways are no less interesting. When molecules of oxygen gas are broken up by an electrical discharge, the material trapped on the cold wall is very complex and variable. Because it emits no light, it has been investigated through its absorption of light. Under some conditions it forms a clear, glassy deposit which absorbs light in a rather complex way—some 25 separate bands or lines of absorption distributed over the whole



FROZEN HYDROGEN (*stippled area*) **collects on metal cooled by liquid helium. It is surrounded by glowing gas** (*hatching*).



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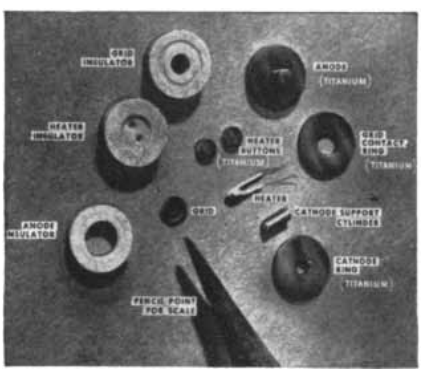

These are the essential components of the initial micro-miniature tube General Electric developed for UHF-VHF television receivers. The metal parts are titanium.

Tubes of micro-miniature construction will mean more compact assemblies for everything from TV receivers to guided missile controls.

Nearly all metal parts in this tiny G-E micro-miniature receiving tube are titanium. For among titanium's unique properties is its ability to absorb performance-limiting gases which may be found in vacuum tubes. It makes possible more stable emission, substantially longer tube life.

But titanium's advantages are not limited to the electronics industry. The aircraft designer, for example, likes its light weight and high strength. And its exceptional resistance to most forms of corrosion adds years to the life of products operating in corrosive atmospheres.

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visual spectrum and extending into the ultraviolet and the infrared. When warmed to about 20 degrees absolute, the deposit changes to a violet-colored solid. This has been identified as a mixture of oxygen and ozone, with a fairly high concentration of ozone. Further warming of the violet substance produces additional ozone in large quantities. By this method about 30 per cent by weight of the oxygen that originally flowed through the discharge has been converted into ozone. Conventional ozone-producing equipment seldom yields more than 6 per cent of ozone from oxygen. Since ozone is an important chemical with many uses, the frozen-radical method may have commercial possibilities as a production process.

Besides nitrogen and oxygen, the Bureau of Standards laboratory has studied free radicals produced from hydrogen, water vapor and ammonia gas. The products trapped after the breakdown of hydrogen molecules emit no visible light, but the gas surrounding the deposit emits a blue-green glow, quite different from that of the nitrogen radicals. The deposit has been proved to contain free hydrogen atoms, most directly by experiments by Jen and Foner. The breakdown of water yields unusual substances which absorb light in a peculiar way, but they have not yet been identified. The trapped products from ammonia gas emit a blue glow which disappears as soon as the discharge is stopped.

The experiments described in this article have barely scratched the surface of a vast field. By such studies we can expect to obtain a clearer picture of the roles free radicals play in electric arcs, flames, interstellar dust, comets, stars and galaxies. The method further provides a powerful new tool with which to probe the structure of solids. The spectra of the light emitted by the free radicals trapped in a solid can give information about the arrangement of the atoms and molecules in the solid, about the forces acting on them, about the movements of atoms and about reactions between atoms and molecules.

The efficiency of the method described for producing ozone suggests the possibility of a new industry of very low temperature chemistry. It may eventually become possible to make new chemical compounds having quite unusual characteristics, and to find more efficient methods of producing familiar substances, such as ozone and hydrogen peroxide (H_2O_2), through the control of free radicals.

Case for comfort control

A twist of the knob on the handsome plastic case, and the lady has dialed the precise amount of heat—and comfort—that will be maintained through the night by her new automatic blanket made by Fieldcrest. She probably hasn't given a second thought to the little control box she adjusted so easily.

The manufacturer, however, thought about it quite carefully when he chose Tenite Acetate as the material for the case. Why this plastic? First, because it offers a fine, handsome finish and a wide selection of brilliant colors that are part of the plastic and can't chip off. And second, because its toughness means durability for the end-product.

Yet, with all these advantages, Tenite Acetate is actually more economical than many other molding materials. Manufacturers of everything from toys to clocks, from shoe heels to lamp shades, have found they can make quality products at lower cost when they use Tenite Acetate.

If you need a material that is beautiful, serviceable, and economical, look into the properties and advantages of Tenite Acetate—as well as of Eastman's two other plastics, Tenite Butyrate and Tenite Polyethylene. For more information, write to EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

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GALEN

This renowned physician of the ancient world established experimental physiology. Although the customs of his time forbade the dissection of the human body, he learned much about it by operating on animals

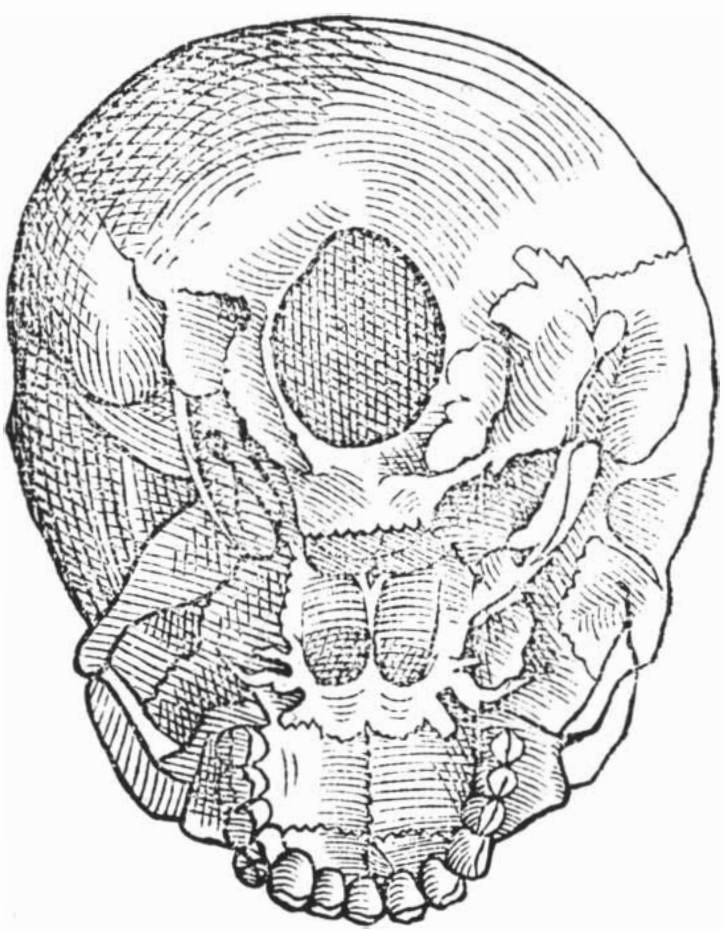
by Frederick G. Kilgour

Galen of Pergamon towered above all other anatomists and physiologists of the ancient world. He established experimental physiology almost single-handed. Indeed, he ranks as one of the greatest experimental scientists in all history, certainly the foremost in ancient science. His life is also better known than that of any other ancient scientist, because his voluminous writings contain more autobiography than any other ancient Greek's.

Galen was born in 130 A.D. in or near Pergamon, about 50 miles due north of Smyrna in modern Turkey. His mother "was so irascible that she would sometimes bite her serving maids, and she was constantly shouting at my father and quarreling with him, worse than Xantippe with Socrates." In contrast his father Nicon stood out in his memory as "a most good-tempered, just, efficient and benevolent man." Nicon, a farmer, was no ordinary tiller of the soil but a cultured Greek, learned in geometry, arithmetic, architecture and astronomy. He conducted his son's education until the boy was nearly 15 and then sent him to study with various philosophers in Pergamon. When Galen was 17, Nicon had a dream indicating that his son should study medicine. Accordingly Galen studied anatomy with Satyrus in Pergamon for the next four years. His father died during this period and left Galen a bequest which made him practically independent financially for the rest of his life. The young man pursued the study of medicine and anatomy for seven more years in Smyrna, Corinth and Alexandria.

When, at the age of 28, Galen returned to Pergamon, the high priest of the medical temple, who was also the head of athletic games, appointed him physician for the gladiators—the equivalent of a present-day boxing commission doctor. In the brutal games of that time the athletes regularly incurred serious wounds. Galen evidently found the work interesting, for he served several years.

When war put an end to the games, he went to Rome to do research and practice medicine in the capital of the Empire. Galen was to spend the next 30 years of his life there, but in 167 he interrupted his stay and fled back to Pergamon because a great plague broke out in Rome. This apparent display of cowardice has been a matter of great controversy among his biographers. Today it would be most unethical for a physician to beat such a retreat. Apparently that was not the case in Galen's time, however, for he himself related the reason for his departure without embarrassment. In any case, he did not escape exposure to the plague. Not long after he left Rome for Pergamon the Emperor Marcus Aurelius summoned him back to the encampment of the Roman army at Aquileia, and Galen had no sooner arrived than the plague erupted among the soldiers. This time Galen saw the plague through, staying behind with the army after the



SKULL is depicted from underneath in a 1535 translation of Galen's *De Ossibus*. Galen obtained bones from "broken up" tombs and monuments.

PATRIS INSOMNIVM

INDEX
IN LIBROS OMNES GALENI

PER IVNTAS VENETIIS EXCVSOS

Qui non ſolum Medicæ artis accuratas obſeruationes (nam præcipuus hic ſcopus eſt) ſed alia quoq; plurima, ceu luculentũ quoddam ac perelegãs corollarium continet earũ rerum, quibus tum Philoſophos, tũ humaniorum literarum ſtudioſos carere indigniſſimũ uidebatur. opus adeo uarium uſuſq; multiplicis, ut Medicis Philiatriſq; Narthecium refertiſſimum medicamentorum, ac totius Medicinæ ſeminarium: cæteris uero Promptuarium literarum omnium & antiquitatis habeatur:

CHRISTOPHORO MADRVTIO TRIDENTI EPISCOPO PRINCIPI ILLVSTRISSIMO DICATVM

A Bartholomæo Syluanio Medico authore.

Apud hæredes Lucæantonij Iuntæ Florentini.

VENETIIS M. D. XLII.

CRISIS PRÆCOGNITIO

GALENI DOCTORES

AMANTIS DIGNOTIO

HEPATICI COGNITIO

PALESTRITE CVRATIO

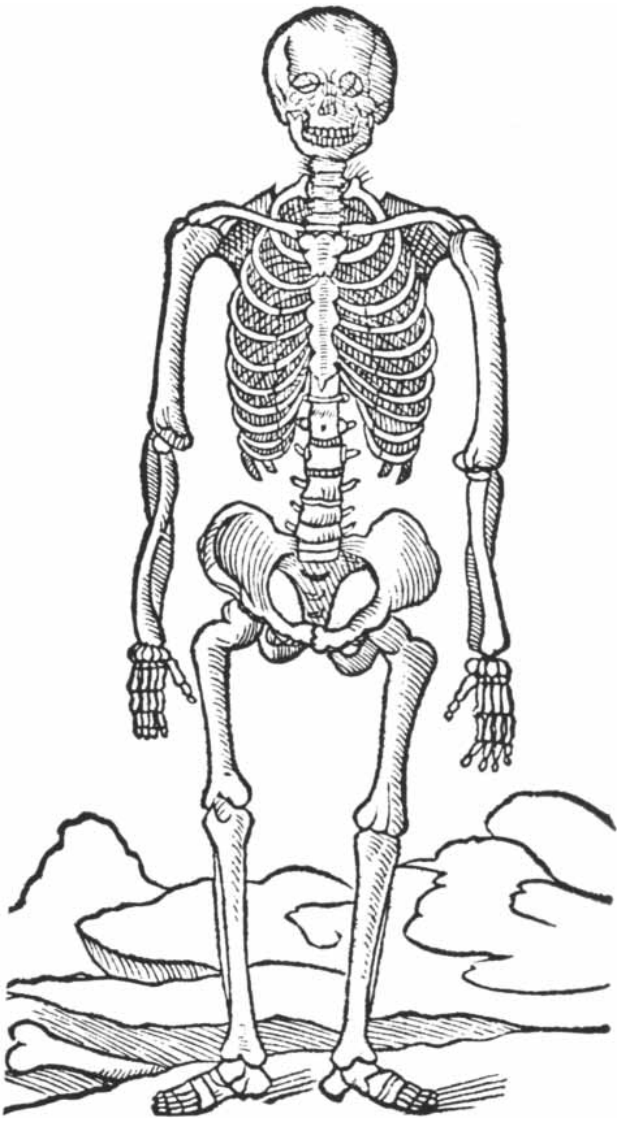
Emperor left Aquileia and returned to Rome.

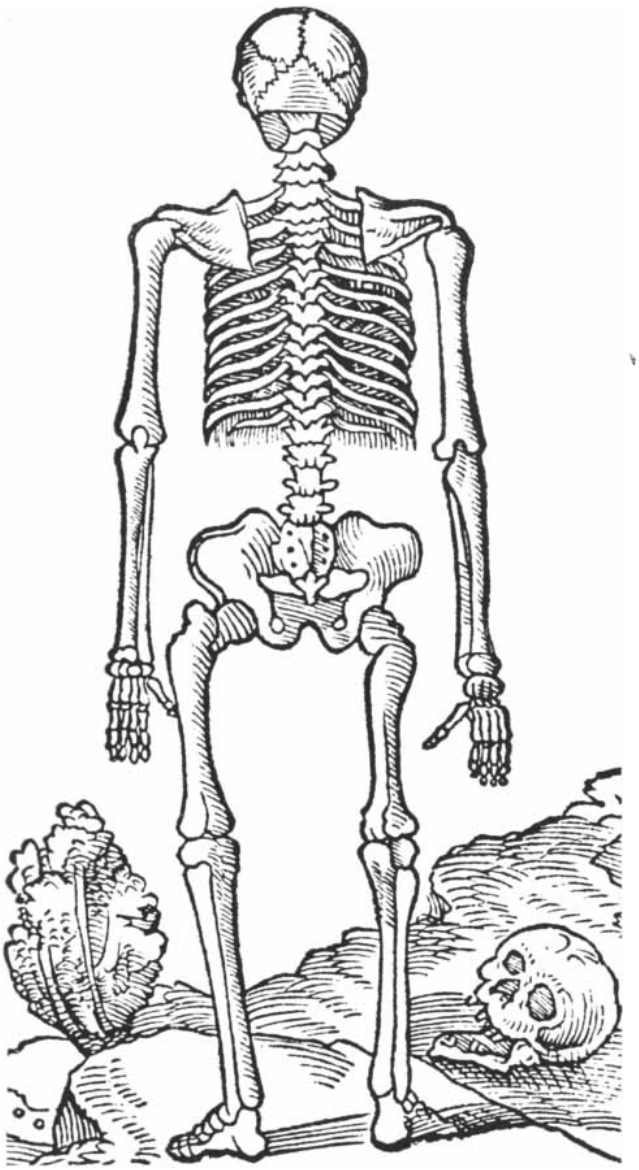
During his three decades in Rome Galen poured out an almost ceaseless stream of books and essays. A collection of his writings published in the early 19th century by C. G. Kühn ran to more than two and a half million words, and the collection was by no means complete. Galen lost some of his manuscripts in a fire which gutted Rome's Temple of Peace in 192, and in recent years scholars have discovered Arabic versions of previously missing publications, including part of his book *On Anatomical Procedures* and the entire text of *On Medical Experience*. There are undoubtedly still more to be uncovered.

Galen divided his writings into two major groups: "those directed against swindlers" and the educational works on medical science. His polemics against "swindlers," which inveighed against human folly, have given Galen the reputation of being as bad-tempered as his mother. Actually he seems to have been a comparatively mild man—it was the time that was violent. He appears to have had few close friends, and he never married.

When Galen began his studies of anatomy and physiology, medicine was almost entirely innocent of a scientific basis. Hippocrates' initiation of rational medicine had been a *tour de force* founded only on shrewd observation, and the lesser men who followed him in the 500 years before Galen were split into squabbling sects, like the homeopaths, hydropaths, naturopaths, osteopaths, Thomsonians, Grahamites, etc., of the 19th century. Galen set out to develop systematic descriptions of the human body. He was handicapped by the fact that it was forbidden to dissect the dead. The only part of human anatomy that he could investigate in toto was the skeleton, which he often did "where tombs or monuments have been broken up." For the rest he relied on dissections of animals, including monkeys, and on examinations of tissues exposed in patients with disease or wounds. While he was studying with Satyrus at Pergamon,

GALEN'S ACTIVITIES are poetically outlined in the illustration on the opposite page. The illustration is the title page of the index volume of a collection of Galen's works published in Venice in 1541 and 1542, more than a thousand years after his death. In the bottom panel Galen performs a physiological experiment on a large live pig.





HUMAN SKELETON is somewhat fancifully portrayed from front and back in these woodcuts from the same translation of *De Ossibus* (*On Bones*) mentioned in the caption on page 105. The translation was made by Ferdinand Balamio, physician to Pope Leo X.

there was an epidemic of "carbuncle" (probably anthrax) which destroyed areas of skin and flesh in many of the victims. Galen wrote later: "Those of us who had seen Satyrus dissecting any of the denuded parts, easily recognized them and made a complete diagnosis, telling the patients to make some movement which we knew to be carried out by such and such a muscle, and sometimes diverting or drawing aside the muscles to observe an adjacent large artery, nerve or vein. We saw that all the other physicians were like blind men without any knowledge of the parts exposed."

Galen did not add a great deal to previous knowledge about the human bones, but he contributed hugely to knowledge of the muscles. He discovered many not previously recognized, and in all described about 300 muscles, some of which still bear the names he gave them. These were all muscles of the skeletal system: Galen put the involuntary muscles (of the heart, stomach and so on) in a separate category as "muscle-like" tissues. He was also confused about the attachment of the muscles, and mistakenly described the tendons as made up of nerves and ligaments.

Galen was the first to demonstrate that muscle has but one action—contraction. He proved by experiments that the movement of a muscle during its relaxation was produced by the contraction of an opposing muscle. He went on to establish that each muscle has only one direction of contraction. From the fact that the tongue can move in six different directions, anatomists had supposed that a muscle had various motions, but Galen dissected the tongue and found that it had at least as many muscles as directions of movement. His experiments in cutting muscles gave surgeons for the first time a sufficient understanding of muscular functions to realize what functions would be lost when muscles were cut through in surgery or were severed by a wound.

Attempting to discover what "force" caused muscles to contract, Galen came to the conclusion that the force originated in the brain and was communicated to the various muscles by the nerves. He arrived at this idea as a re-

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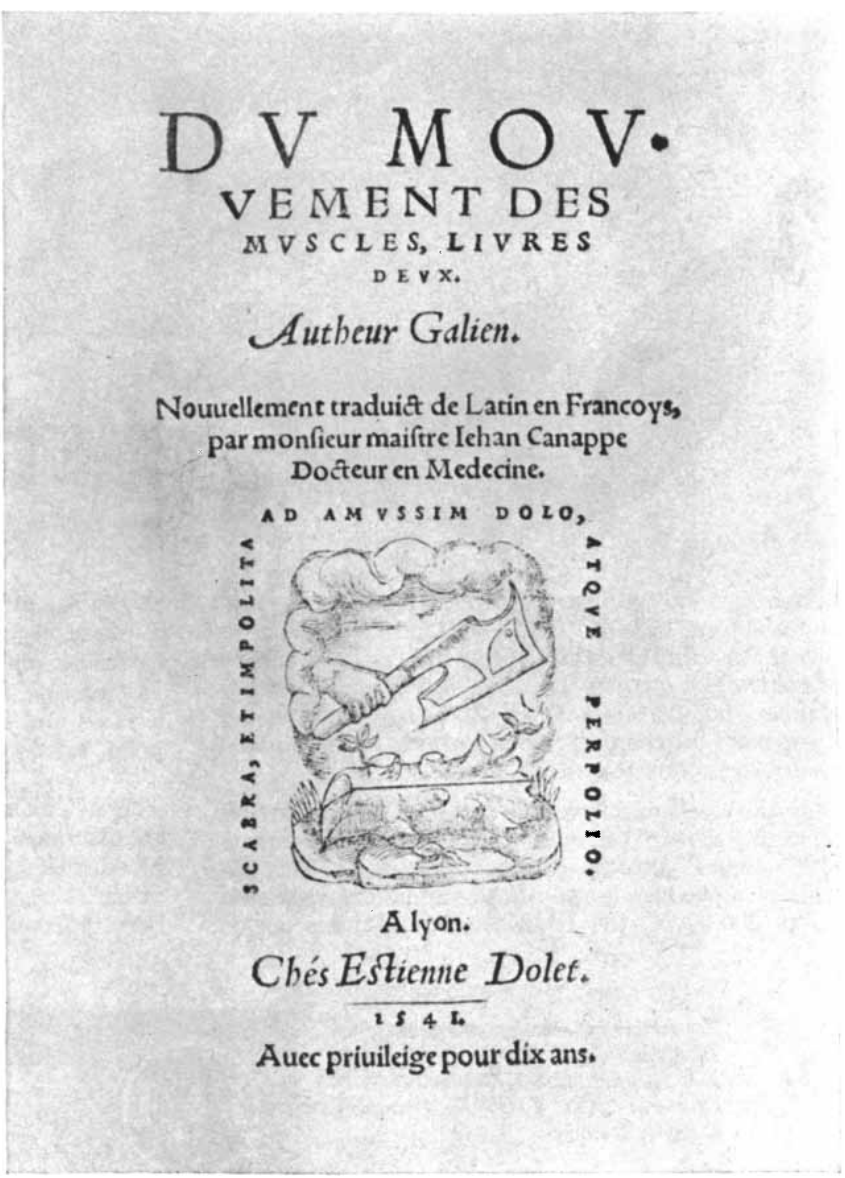
sult of a wonderful series of experiments on the nervous system, particularly the spinal cord. Operating on experimental animals, he systematically cut the cord at one vertebra after the other down the backbone. He found that when he severed the cord between the first and second vertebrae in the neck, the animal instantly stopped breathing and died. Further down, the animal survived and retained certain functions. When he cut the cord between the sixth and seventh vertebrae, for instance, the chest muscles were paralyzed but the animal was able to breathe by means of its diaphragm. When he cut below the eighth vertebra, the arms escaped paralysis. He also observed that when the cord was cut only half way through, only one side of the body was paralyzed. In this way Galen mapped the control areas of the cord. In addition he investigated various peripheral nerves and established that in general the interruption of a nerve caused loss of motion and sensation below the block but not in the part of the body between it and the brain.

Galen's most celebrated work on the nervous system had to do with the nerves that control the movements of the vocal cords. These laryngeal nerves, two in number, are called "recurrent," because they start in the upper chest from the vagus nerve (coming from the brain), loop down under arteries not far from the heart and rise again through the chest and neck to the larynx. Galen discovered them accidentally one day while he was cutting nerves in the chest



GALEN'S EXPERIMENTS ON MUSCLE were described in his book *On the Movement of Muscles*. This is the title page of a French translation of the book, published in 1541.

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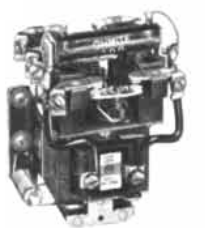

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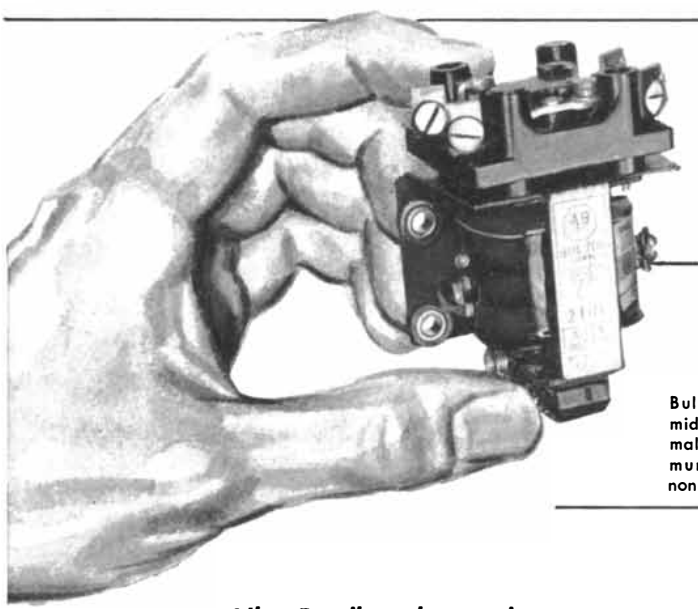

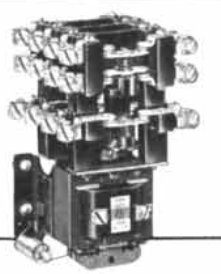

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of a pig to observe disturbances of respiration. In the midst of the operation the pig suddenly stopped its squealing. (Galen later gave a public demonstration of this dramatic phenomenon.) He realized at once that he must have cut the nerves controlling the larynx, and he was able to trace the nerves via the vagus to the brain. One important result of this discovery was to settle an old controversy about the seat of intelligence. Hippocrates and others had placed it in the brain, but Aristotle had insisted it must lie in the heart, among other reasons because the voice seemed to originate from somewhere in the chest. Galen's discovery solved the problem by showing that the voice was actuated by nerves from the brain.

Galen proceeded to apply his new knowledge of the nervous system in seemingly hare-brained treatments which astounded his contemporaries. Pausanias, the Sophist, had lost sensation in three fingers of one hand. His physicians, after vainly trying to treat the hand for a month, called in Galen. Galen at once asked whether Pausanias had had a recent injury in the upper part of his body. Yes, he had tumbled out of his "car" on a stone and hurt the upper part of his back. Galen put applications on the area of the back injury, instead of on the hand, and Pausanias soon recovered feeling in his fingers.

The cure provoked a physiological argument between Galen and the other attending physicians. They maintained that if injury to a nerve from the spine were really the source of the trouble, the patient should have lost not only sensation but also the ability to move the fingers. But Galen replied, correctly, that the sensory and motor nerves had separate attachments to the cord. This was fully established in the 19th century by Sir Charles Bell and François Magendie; the Bell-Magendie law says that the anterior roots of spinal nerves are motor, and the posterior, sensory.

Galen developed a concept of the overall physiology of the body which sounds peculiar today and is often derided but which actually provided the seed from which modern ideas grew. He said that after food has been ingested into the alimentary tract, it passes through veins to the liver. That organ, he went on, changes the food into blood, imbued with "natural spirit." Most of the blood then goes to the right ventricle of the heart, entering it via the great vein, the *vena cava*. Galen knew that blood flows from the right ventricle to the lungs, through the pulmonary arter-

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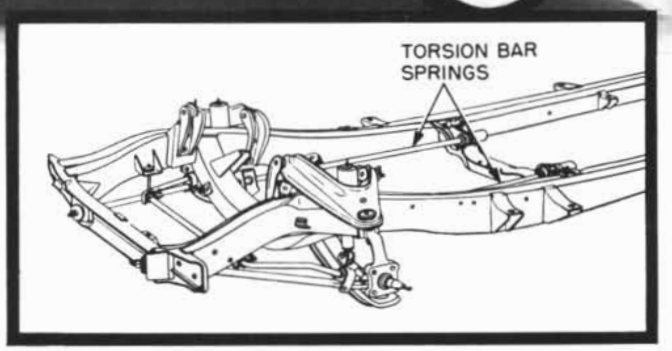

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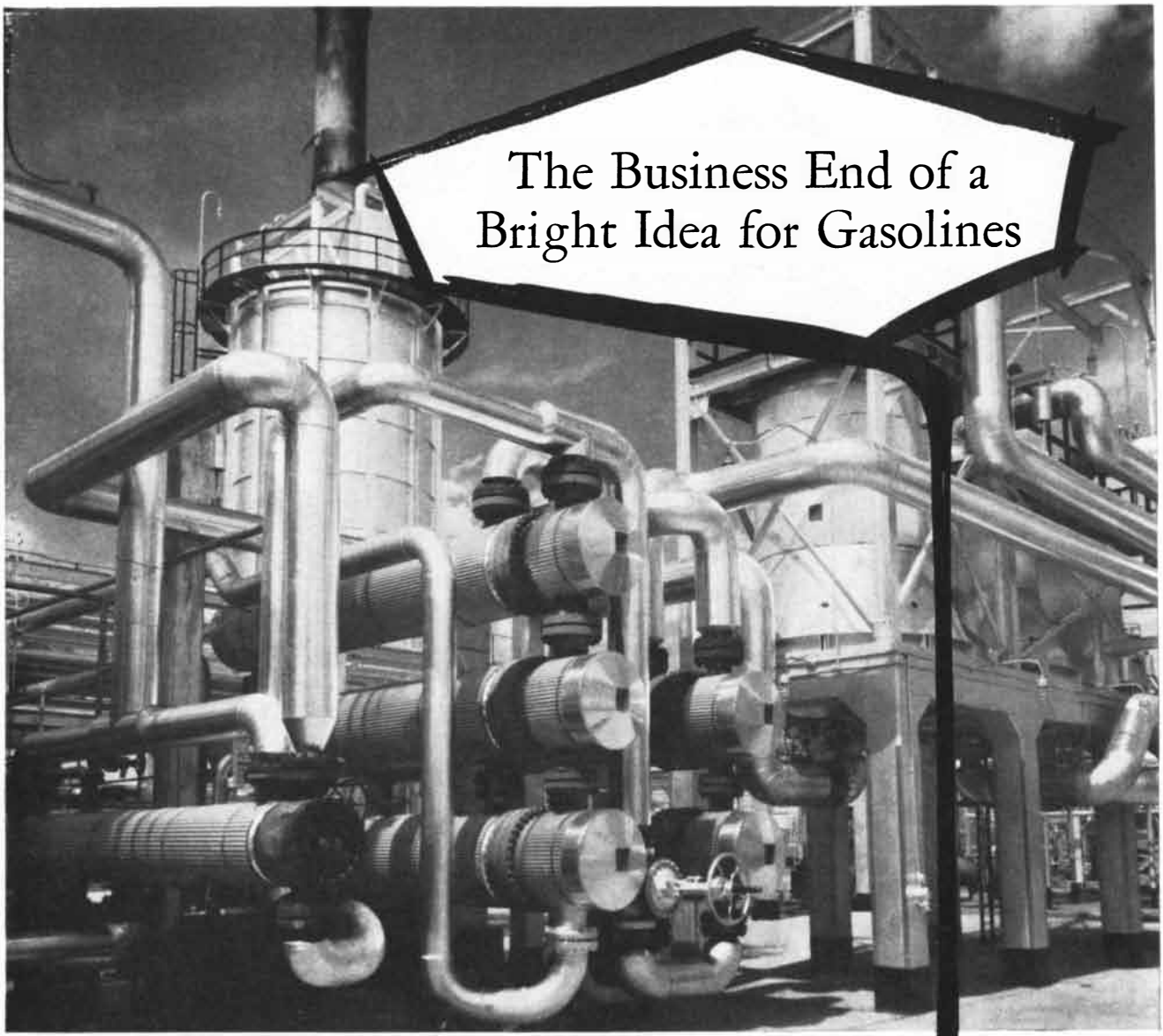
ies. But lacking knowledge of the function of the lungs and of the heart-lung circulatory system, he had to explain how blood got into the main arterial system of the body. To make this event possible, he postulated that some of the blood in the right ventricle passed into the left ventricle through tiny pores in the wall between them. In the left ventricle the blood received "vital spirit" (coming from the lungs) and acquired a crimson color. The vitalized blood then was transmitted by the blood vessels to nourish all parts of the body. Blood reaching the brain took on "animal spirit," and the resulting concoction (which Galen never succeeded in detecting) went through the nerves.

If these ideas seem laughable, they become less so when we realize how radical a change in point of view they represented. Galen suggested a coherent idea of the functions and flow of the blood. He demonstrated by experiment that the arteries contain blood—not air, as some of his predecessors had believed—and he also established that the arteries and veins were connected in some way; he proved this by showing that when an animal's arteries were cut, the veins as well as the arteries became emptied of blood. Furthermore, with a few changes Galen's general concept of the body's physiology comes reasonably close to modern ideas. If we substitute oxygen for "vital spirit," and nerve electrical potential for "animal spirit," the system begins to approach a 20th-century description. Galen provided the foundation from which experimentalists during the last four centuries have developed present-day theories.

Galen returned to Pergamon in his sixties and devoted himself to writing, compiling two autobiographical books which he called *On the Series of My Books* and *On My Books*. He died in Pergamon about 200 A.D., at the age of 70 or so. Not for well over a thousand years did anyone approaching his stature in medicine arise in Europe. When, in 1543, Andreas Vesalius published the first of the great modern works on human anatomy, his work was based for the most part on Galen, though he corrected many of Galen's errors and added new observations. William Harvey's famous treatise on the circulation of the blood in 1628 also took its departure from Galen; indeed, he discussed Galen's experiments as if he were a contemporary. Fourteen hundred years after Galen the early modern investigators began to advance from the point where Galen had left off.



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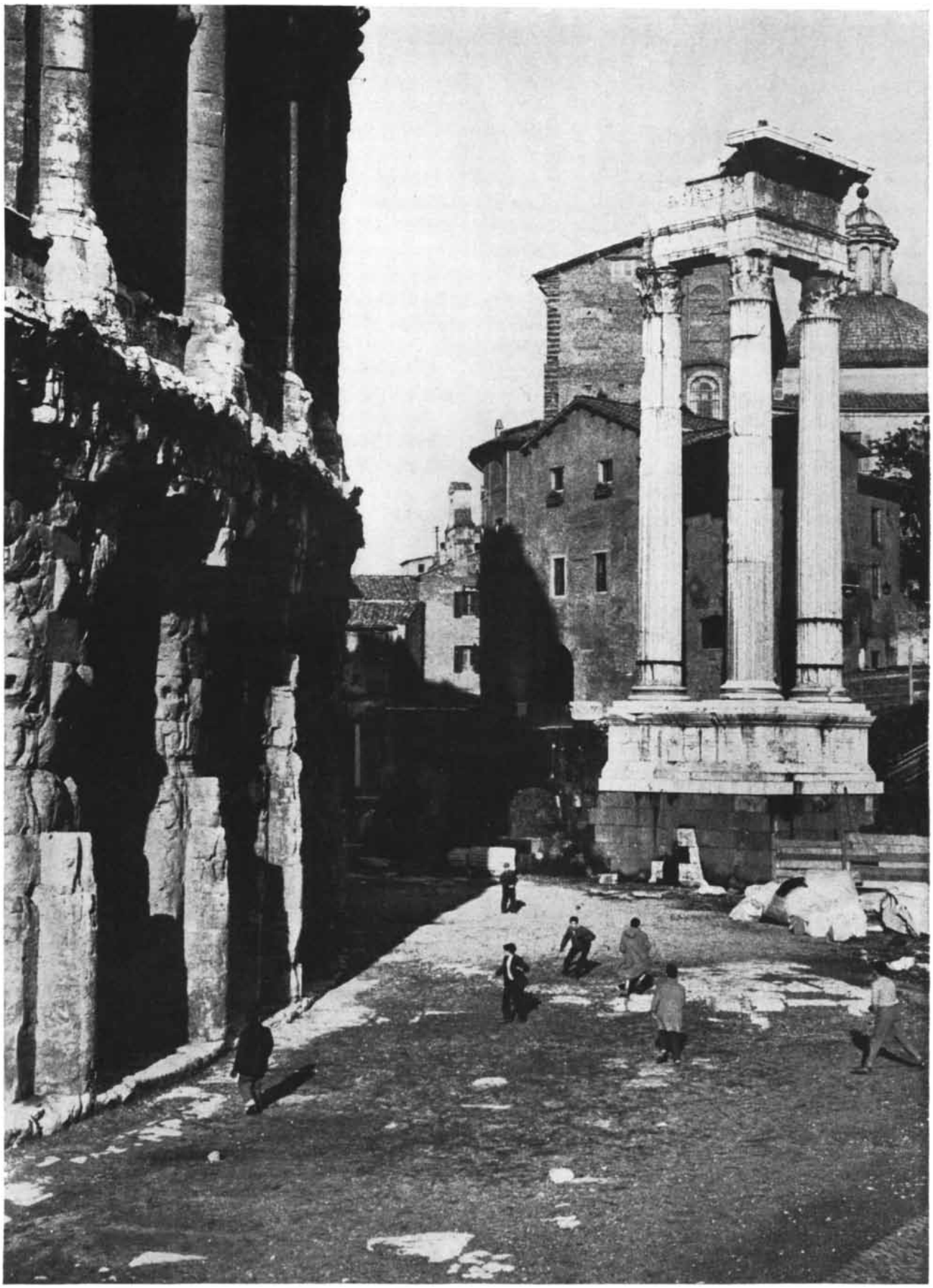


Boys of the ancient Roman ghetto play football beside the Teatro Marcello (left), *finished in the first century A. D.*

The Jewish Community of Rome

How do social forces mold the evolution of man? The answer is sought by a geneticist and a sociologist, father and son, in a community which has kept its identity for 2,000 years

by Leslie C. and Stephen P. Dunn

In a world in which geographical distance is rapidly shrinking and peoples may migrate across oceans overnight, it may seem that the varieties of mankind are likely to merge in the future into one race. Technology and population pressures are breaking down the natural barriers which in the past have separated peoples and made for cultural and biological differentiation. But there is another side to the story. Human groups may be segregated by social as well as by natural factors. History suggests that even within the increasingly close-knit world society, groups of people may be sequestered and evolve along more or less separate paths.

For students of human evolution this is an exceedingly interesting problem. How potent an isolating force is social custom and tradition? Does it keep a population biologically as well as culturally distinct from its neighbors? These subtle questions have always been difficult to investigate in any clear-cut way, but fortunately there are tools today which make it possible. One of them is the identification of blood types, a convenient instrument for determining genetic differences between peoples.

We decided to undertake such a study, and looked about for a suitable group to examine—an isolated people forming an enclave within a larger society. We found such a group in what may seem an unlikely place—in the midst of a large city. It is the ancient Jewish ghetto of Rome.

The ghetto community of Rome is probably the oldest still in existence on the European continent. Strictly speaking it is no longer a ghetto so far as formal restrictions on its residents are concerned, but it is actually still a distinct community. For more than 2,000 years its members have been more or less segregated from the rest of the city of Rome. We set out to investigate two questions: First, to what extent is this group today culturally different from other Romans? Secondly, has the long isolation of the Roman Jews made them in any way biologically distinct from their fellow citizens?

Jews apparently first came to Rome around 160 B.C., after the Roman Senate concluded a treaty of peace and friendship with the Maccabean king of the Jews in Palestine. When the Roman Empire later wiped out the Jewish national state, in 70 A.D., great numbers

The Via della Reginella has not changed since the days of the ancient ghetto

A ragpicker passes the tortoise fountain at the entrance of the Via della Reginella. Ragpicking is a main occupation of the ghetto

The synagogue of the ghetto is at left; the church where the Jews of the ghetto were once forced to worship is at right

of Jews were brought to Rome as slaves. They were soon freed and became Roman citizens. They were allowed to practice their religion unhindered; indeed, throughout the centuries, under the Christian Emperors and later under the Popes who ruled Rome, they were the only non-Christian religious group permitted to exist at all. At the height of the Roman Empire the Jewish population of Rome grew to about 50,000. But from the beginning the Jews were placed in a special category. After Christianity was adopted as the state religion, their position deteriorated. They were segregated by all possible means from contact with Christians, barred from public office and the liberal professions—in which some of them had previously achieved high positions—and in general relegated to the status of second-class citizens.

During the long barbaric period after the collapse of the Roman Empire the Jews went into a decline along with the rest of the Roman population. About 1160 a Spanish traveler, Benjamin of Tudela, found only 200 male Jews of canonical age in Rome. But it seems that the anarchy and absence of a settled policy had worked to the advantage of the surviving Jews, for Benjamin reported that they were living in peace and prosperity, with no special taxes to pay, which surprised him greatly.

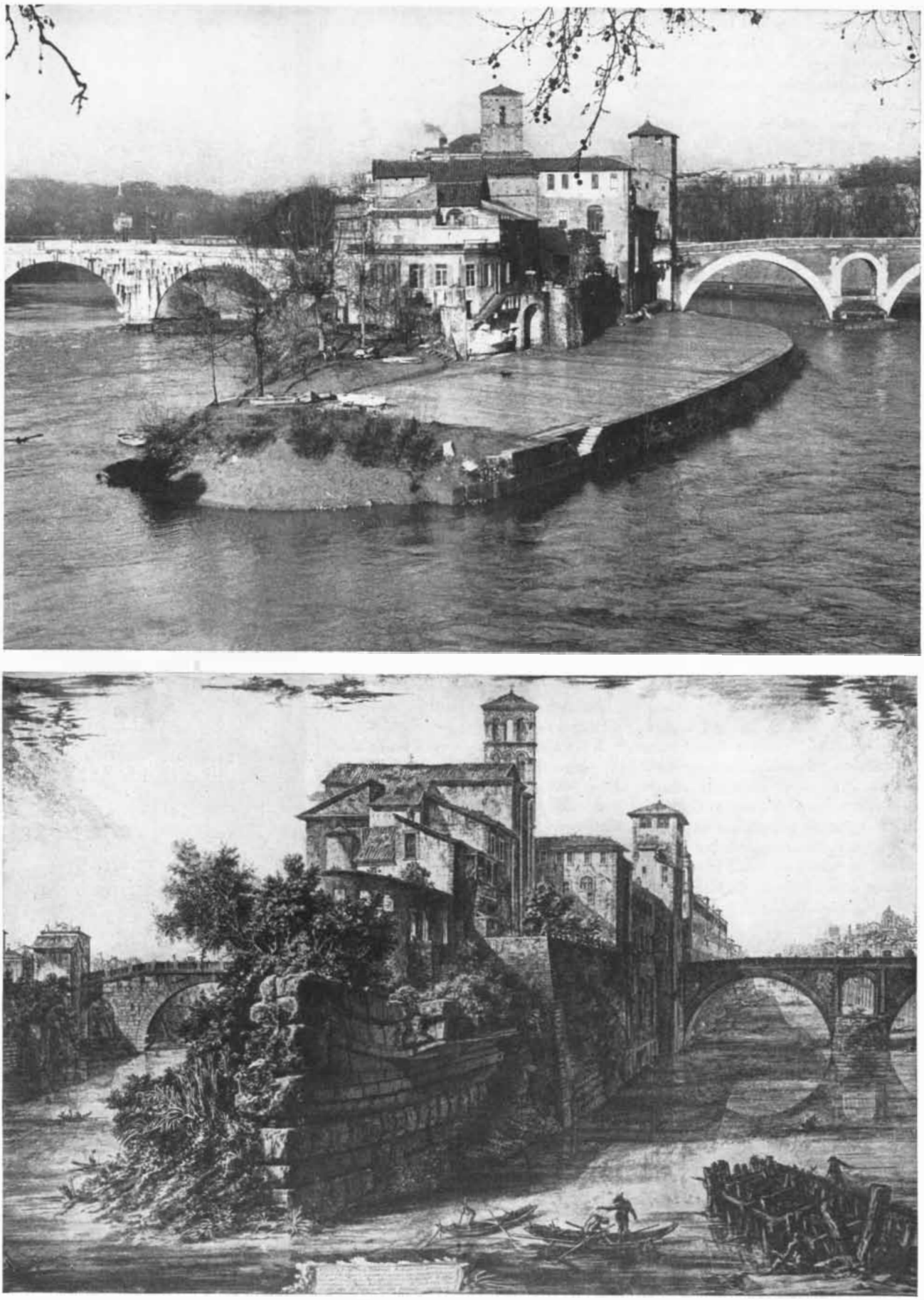
When the Popes assumed political control of Rome, the Jews' position again deteriorated. They were excluded from many callings, were required to wear a distinctive sign, and strenuous efforts were made to convert them to Catholicism. The Jewish population of Rome remained at a few thousand, but it was suddenly increased in 1492 when Ferdinand and Isabella expelled the Jews from Spain and southern Italy. About half a century later this large population was consigned to a walled ghetto. Giovanni Pietro Caraffa, upon becoming Pope, immediately promulgated a severely restrictive Bull on the Jews. He confined them to a small district—the unhealthiest in the city—and forbade them to own real property, to engage in any profession or trade except dealing in old clothes and scrap metal, and to have anything to do with Christians. Most of this legislation remained in effect for 300 years—until 1870. The Papacy relaxed some of the economic restrictions from time to time, for it soon discovered that if it bore down too hard on the Jews, the city's prosperity suffered. The Jews had a virtual monopoly of banking operations, because Christians were largely excluded from this line of endeavor by the Church's ban on usury, then construed as meaning any financial transaction involving credit.

The Jewish community in Rome was taxed for a lump sum, Jewish officers being charged with the apportionment and collection of the tax. Over the course of centuries this taxation reduced the community to chronic indebtedness and destitution, the effects of which can be seen to this day.

About a century after the establishment of the ghetto, a Papal order declared a rent freeze to prevent profiteering by the Christian landlords who owned the ghetto dwellings. This provision went under the name *jus gazzaga*, from a word in Talmudic Hebrew meaning a perpetual leasehold. It had the effect of partly abrogating the ban on Jewish ownership of real property, since leases held under *gazzaga* came to constitute, in most respects, actual property. Rents could not be raised except by express order of the Curia, the Papacy's agency in charge of temporal affairs. The effect, however, was to anchor the Jews in medieval houses. With rents frozen, the landlords made no effort to improve the buildings in the ghetto and allowed them to fall into poor repair. Even today most of them have no heating, sanitation or running water. In 1849 a flood of the Tiber rendered the ghetto area uninhabitable, and the Jews had to be quartered elsewhere until repairs could be carried out.

Liberation for the Jews of Rome finally came in 1870 when the army of King Victor Emmanuel seized the city and made it the capital of a new nation. The new regime repealed all the old laws, including the seclusion of Jews in a ghetto. Thereafter Jews who had a little free capital or a little more initiative than the rest began to move out of the ghetto area and set up business and residences elsewhere in the city. Many of them came to have only the most tenuous connections with the original community. In recent years some ghetto people have been moving out to working-class districts on the peripheries of the city, forming "colonies" of the ghetto. Today the Jewish community of Rome, with some 12,000 listed members, is not a homogeneous group and is widely dispersed in the city. The ghetto district has the aspect of a relic—its small population religiously conservative and extremely poor.

We concentrated our attention on the people still in the ghetto area and a closely related group across the river in a district called Trastevere. The old ghet-



The ghetto hospital on the Isola Tiberina (top) *has changed little since it was depicted by Piranesi in 1775* (bottom)

to community now occupies no more than a few square blocks on one bank of the Tiber. Many of its buildings, still lived in, are 400 or 500 years old, and it has remains going back to classical Rome. Trastevere, on the other side of the river, is a large, heterogeneous area; there the Jews live in small clumps in the midst of a predominantly Christian population. But they give evidence of being a recent overflow from the ghetto area. Altogether the ghetto and Trastevere Jews (whom we called "the small community") number some 4,000 persons.

How cohesive and culturally distinct is this group? We were able to obtain several objective measures of their isolation and homogeneity. To begin with, their community life is centered in a common core of institutions—temple, clinic, hospital, orphanage, school and welfare agency. Although these services are financed and for the most part administered by outsiders, the members of the small community regard them as their own. Many of their children are brought up in the same Jewish school from kindergarten on.

In the second place, the marriage records show that the members of the "small community" seldom marry outside their own group, contrary to what one finds in many other Jewish communities. The present generation, their parents and their parents' parents, with remarkably few exceptions, were born in Rome—which means that they were natives of the city's Jewish community. The Jews of the small community are, in fact, more Roman than the Romans.

The ghetto people are further distinguished by their poverty and their occupations. Most of them follow one of two callings—ragpicker or pushcart peddler. A few own small shops. Well-to-do Jews living elsewhere in Rome commonly remark that the ghetto Jew "doesn't like to work," but his extreme poverty is rather a sign of his independence. He would rather make a poor living, or none at all, on his own than have security by working for someone else. Few ghetto Jews seek manual or industrial jobs, skilled or unskilled (but it must be remembered that Rome has few factories).

Not the least of the characteristics that mark the ghetto Jews is their self-identification with their community. They show no hesitation or embarrassment in speaking of themselves as belonging to the "ghetto," while other Jews in Rome protest against the word. When asked where he lives, a ghetto-dweller may reply "right in the middle," leaving the rest of the phrase to be understood. On the other hand, non-ghetto Jews attempt to deny its existence or to describe the area as merely a place where Jews without money live. One whom we interviewed insisted that "as soon as you rise a little bit [above the ghetto], there's no longer any difference [between Jews and Christians]; a man may have five friends all Jewish, or five friends all Catholic; this has no importance." Such assertions were often made with considerable heat and a defensive air, as if the continued existence of the small community were a blot on the good name of Italian Jewry.

All the criteria that we examined proved clearly that the remnant of the ancient Jewish community of Rome is in fact a distinct cultural subgroup within the city—set apart by separate descent, institutions, economic status, occupational preferences, a strong in-group feeling and "backward" ways. This brings us to our second question: Are the ghetto Jews also distinguishable biologically from other Romans?

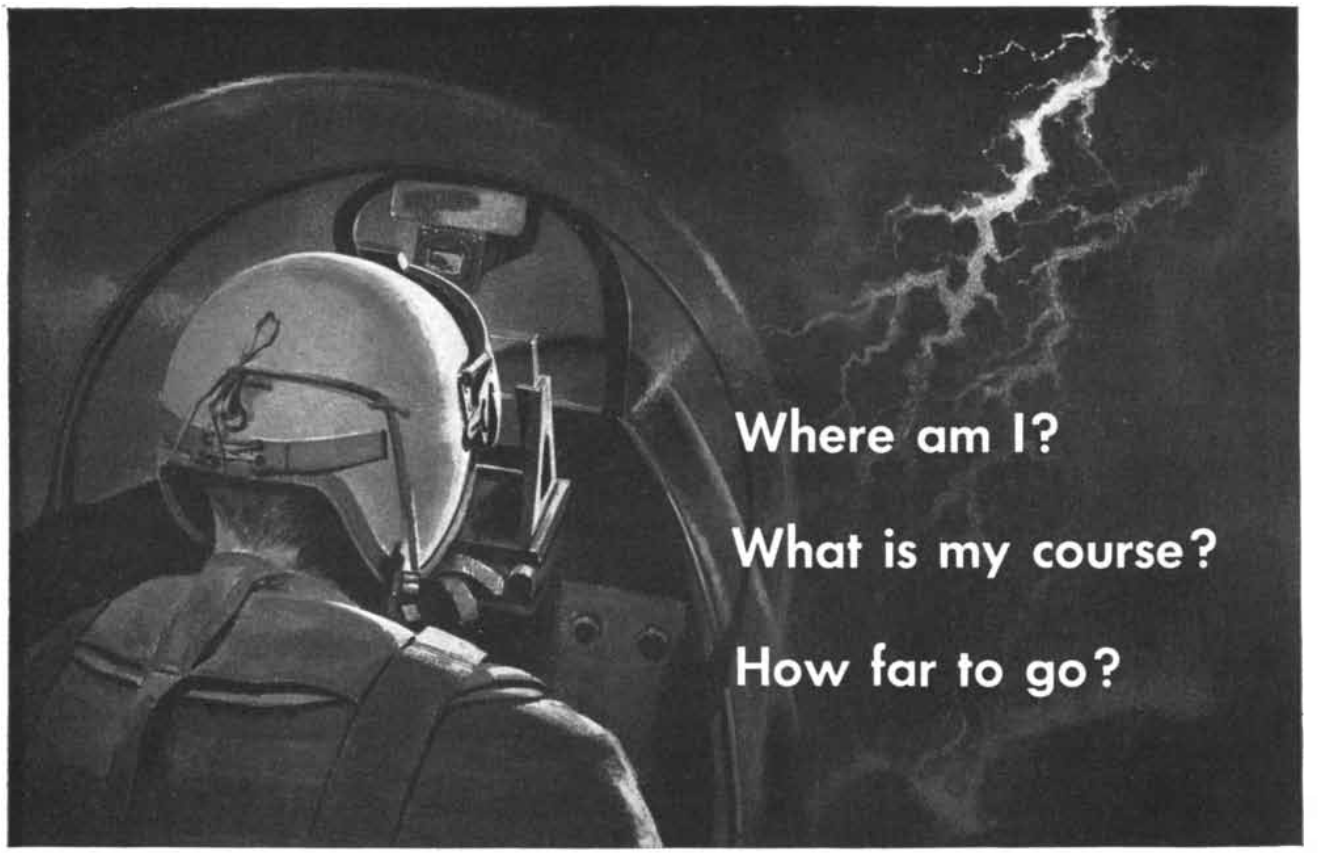
Inbreeding within this small population, continued over many centuries, would be expected to preserve or produce a distinct genetic pattern, and perhaps even peculiar genes which are not found at all in the surrounding population. By the usual methods of physical anthropology any such differences would be extremely difficult to detect. But the remarkable blood studies of recent years, whereby biologists have discovered dozens of blood types and identified them with particular genes, have provided anthropologists and geneticists with a sharp tool for dissecting human heredity [see "Rh and the Races of Man," by William C. Boyd; SCIENTIFIC AMERICAN, November, 1951]. By this method significant differences in blood-gene frequencies have been found among the populations of the world. Most American Indians, for example, have group O blood; there are only a few with group A and almost none with group B. European populations have less O, more A and increasing frequencies of B as one goes from west to east toward Asia. Asia has the highest frequency of group B in the world. In Africa populations south of the Sahara are distinguished by very high frequency of an Rh gene which is rare on other continents. In some parts of the world blood differences have even been found between neighboring populations (*e.g.*, segments of the Brahman caste) which are forbidden to intermarry by religious or other prohibitions.

We proceeded to type the blood of a large sample of the Roman ghetto population. From each of some 650 persons

(mostly grouped by families) we collected a small sample of blood—about five cubic centimeters. The samples were then classified by tests with various types of antiserum at a serological laboratory in Milan under the supervision of Ruggero Ceppellini and his competent staff. Each person's blood was described in terms of eight different classification systems (*i.e.*, Rh, the A, B, O groups and six other special typings).

By and large the Roman ghetto Jews showed the blood-gene pattern characteristic of the peoples of the Mediterranean region, which of course includes the Italians and the ancestral Jewish population in the Palestine area. But, as we had hoped, there emerged two peculiarities which marked the Roman Jews off sharply from other Italians. Nearly 27 per cent of them were of blood group B,

The family of Esecchia di Porto (right center) *was one of those studied by the Dunns*



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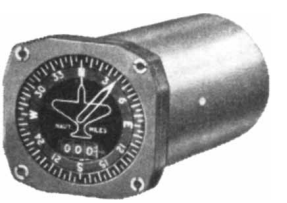
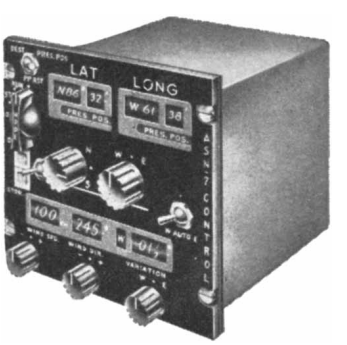


FLIGHT INDICATOR of this system displays ground track, required course, heading error, and distance to the destination.



COMPUTER CONTROL feeds wind, variation, and destination data into the system. It displays present position, wind speed and direction, variation, and destination coordinates.

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whereas among Catholic Italians not more than 11 or 12 per cent have B blood. And the Jewish group was distinctly marked with an Rh gene which is rare among Italians, or for that matter among Europeans generally. This gene (known as r′ or Cde) was present in about 5 per cent of the ghetto members—a frequency five to 10 times higher than in non-Jewish Italians. The peculiarity of this gene is emphasized by the fact that blood-typing laboratories had long been puzzled by an unusual serological reaction that it sometimes produces; they had found it difficult to decide whether the blood was Rh-positive or Rh-negative. It now appears that the peculiar reaction is due to the interaction of the rare gene with two common Rh genes.

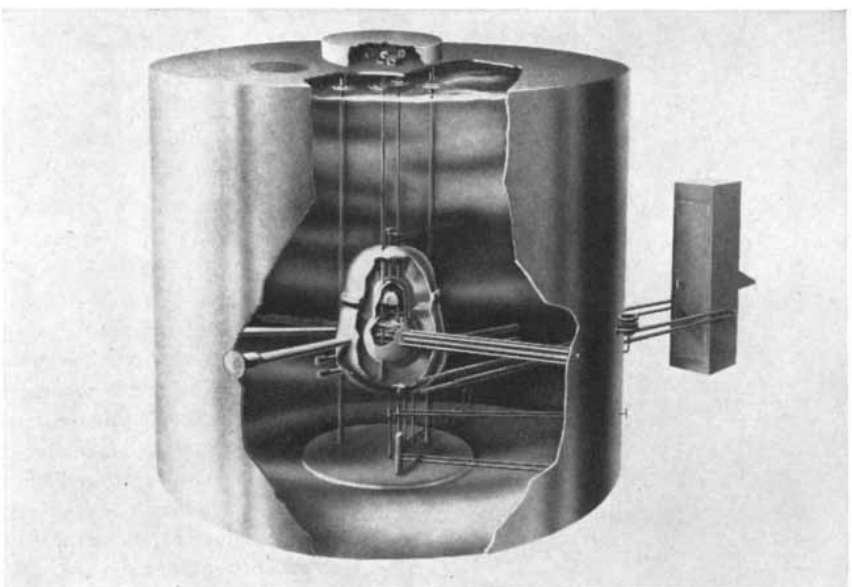
The ghetto population of Rome, then, does show definite biological differences from the rest of the Roman population. The blood tests confirm that this group has been genetically isolated in the midst

Emma di Nepi enters synagogue on the arm of her father to marry Nicolo di Castro

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

One-man Laboratory Reactor designed for industry, hospitals and schools—available for $55,000*

A new atomic tool that will speed and broaden nuclear research and training has been designed and developed by ATOMICS INTERNATIONAL. Here is a low cost instrument that even a moderately-budgeted hospital, industrial or educational laboratory can use to teach and conduct research in nuclear science.



New Laboratory Reactor provides a neutron flux of 10^8, a gamma ray flux of 10^6.

The Laboratory Reactor (LR) is a 5-watt, solution-type nuclear reactor. It can be operated and maintained by one person. It is 8-feet high, 8-feet in diameter. Power requirements are 110-volts at 60 cycles. It is completely fabricated at the factory and shipped as a unit—manufactured and installed in about 6 months. It has a wide range of applications.

As a laboratory instrument for research programs, the LR permits qualitative analysis by the neutron activation method—including measurement of coatings on metals, moisture testing, and liquid level monitoring. It will produce more than 100 different radioisotopes, about 40 of which have half-lives short enough to eliminate the need for costly contamination controls and waste handling systems.

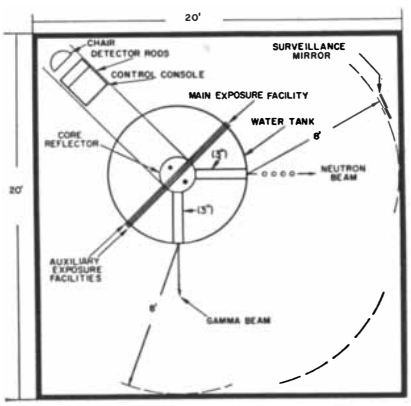
The LR can perform medical research functions such as genetic mutation studies, tracer research on plants and animals, radiation chemistry, and testing by the danger coefficient method. Equipped with facilities to conduct several experiments simultaneously, the reactor is ideally suited as a teaching tool in nuclear engineering, nuclear physics, radiochemistry and radiobiology. The basic behavior of neutron chain reactions, response to control elements, and the effect of delayed neutrons are a few of the 40-odd experiments that can be performed on the Laboratory Reactor.

The core of the reactor is a stainless steel sphere with an overhead convection recombiner. The fuel is uranyl sulphate enriched in uranium 235. The core is enclosed in a 6-inch lead reflector-shield. The complete 3500-pound unit—32″ high, 24″ wide—is centered in an 8-foot tank filled with water which serves as a biological shield.

The gas recombining system is contained in the core tank. A cylindrical screen above the core solution holds platinized alumina catalyst pellets which recombine hydrogen and oxygen gases formed during reactor operation. These fission product gases—valuable in experimental programs—can be withdrawn from the core through special gas lines.

The LR operator handles all controls and detection equipment from a control console adjacent to the reactor. Two cadmium control rods move vertically through the core—driven by electric motors manually controlled by the operator. The lead-weighted rods are attached to an electromagnet which releases automatically to let the rods fall by gravity into the core and shut down the reactor in event of a scram.

Instrumentation provides safety, low-cost and flexibility. At startup, three boron-lined neutron counters are fully inserted in detection tubes in the water tank. As power level increases, the operator withdraws the counters. Rate circuits—adjusted in response time constants—provide two ¼-second circuit channels for safety and observation and one 2-second channel for accurate power recording.



The LR can be installed in a 20x20-foot floor area.

ATOMICS INTERNATIONAL, a division of North American Aviation, Inc., is a major reactor builder—experienced in the design, construction and operation of nuclear reactors for research and the production of power. If you are interested in the LR—or any phase of reactor development—ATOMICS INTERNATIONAL is staffed and equipped to serve you. Please write, Director of Technical Sales, Dept. SA-71, ATOMICS INTERNATIONAL, P.O. Box 309, Canoga Park, California. Cable address: ATOMICS.

*F. O. B. LOS ANGELES

ATOMICS INTERNATIONAL
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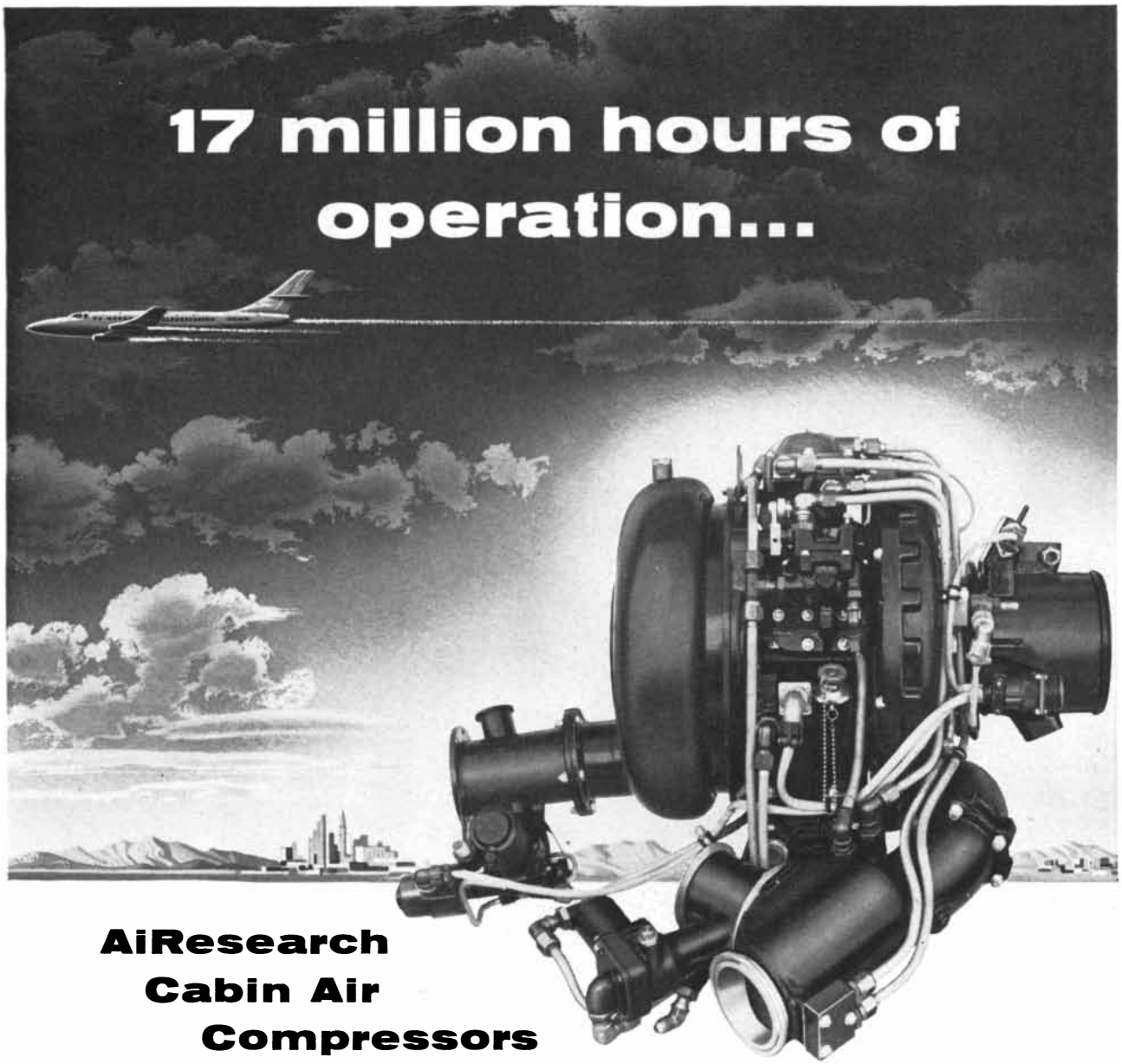
PIONEERS IN THE CREATIVE USE OF THE ATOM

A housewife pours water into a sewer outside her house, which has no running water

of the metropolis in which it has been living for centuries. The question naturally arises: How does it compare with other Jewish populations? Will other isolated Jewish communities show the same blood-gene peculiarities? Do the Jewish groups dispersed over the world have a common blood-gene pattern? These interesting questions may be answered by studies now being made by serologists in Israel, who are examining the blood of the Jewish groups that have come to Israel from various parts of the world. No clear conclusions have yet been reached, but the analyses have already indicated some trends. It appears that Jews generally have a higher frequency of group B blood than their non-Jewish neighbors. On the other hand, there are also some clear-cut blood differences between Jews in different parts of the world. The Roman ghetto community has a considerably higher B frequency than most other Jewish groups examined.

Our study of the Jewish community of Rome obviously has an intrinsic interest simply as a historical examination of a particular community, but it may also have some general significance concerning human evolution. We think we have established that the Jews of the Roman ghetto did maintain their cultural and biological identity as a distinct subcommunity within a larger one, and that social forces can shape man's biology.



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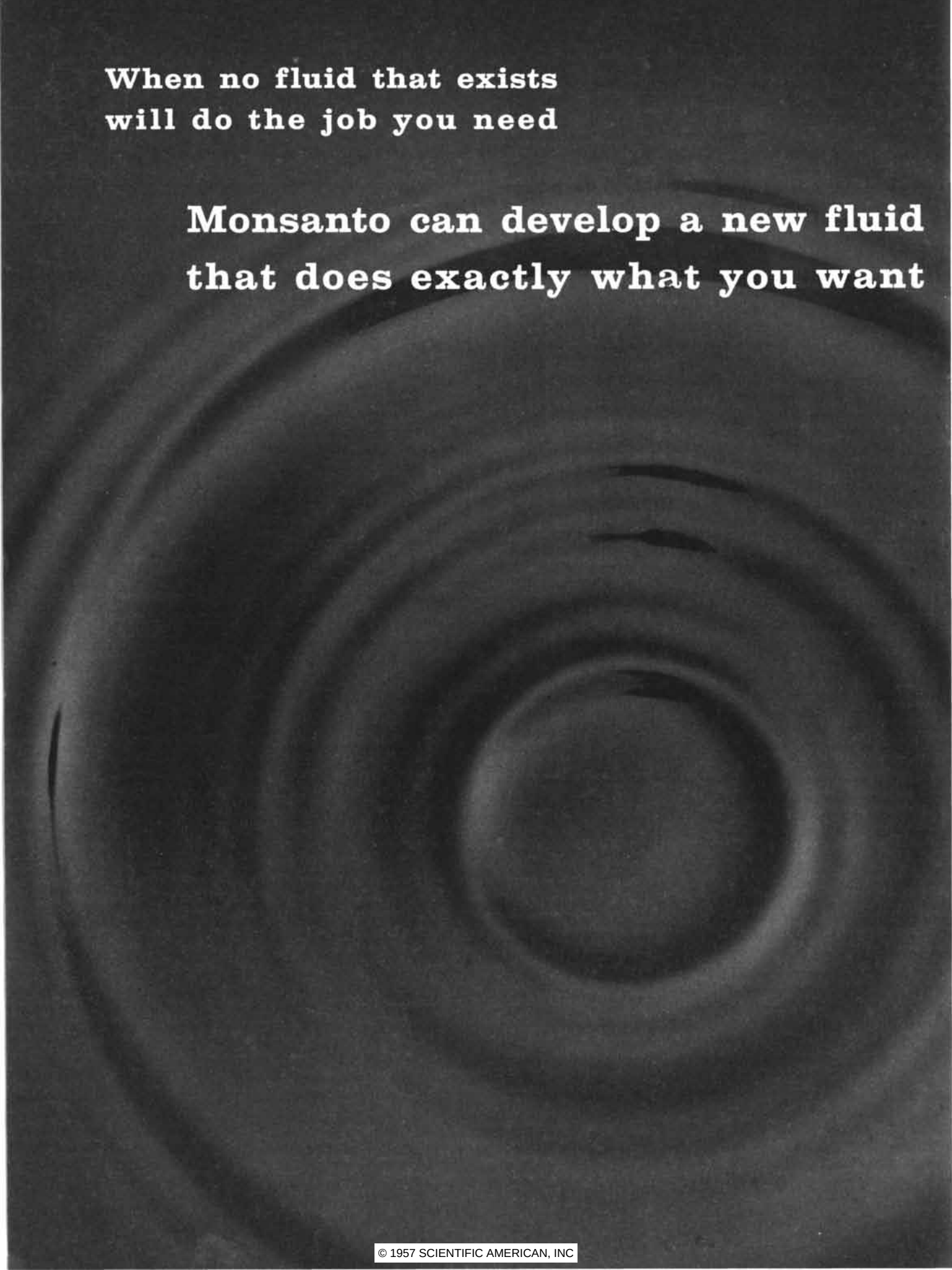

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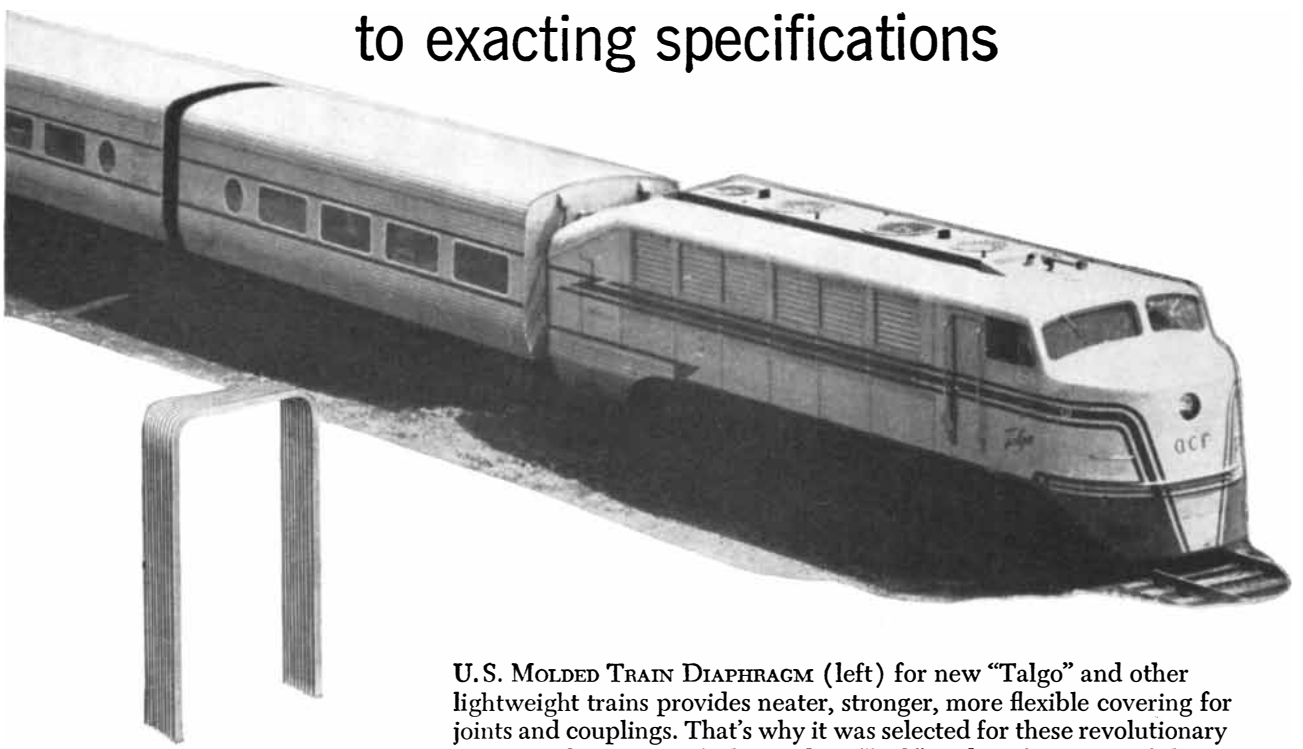

U.S. Molded Train Diaphragm (left) for new "Talgo" and other lightweight trains provides neater, stronger, more flexible covering for joints and couplings. That's why it was selected for these revolutionary trains. To keep up with the modern "look" and performance of this new railroading design, this "U.S." bellows-type diaphragm flattens out or compresses as the train takes curves at speeds never before attained. To do this and still retain its shape and strength, the diaphragm was carefully engineered of cloth-inserted, fire-resistant neoprene rubber, produced to the exact specifications of the customer,

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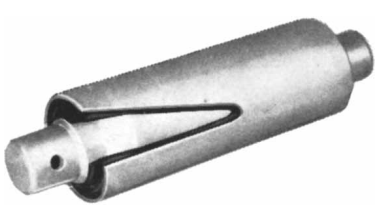

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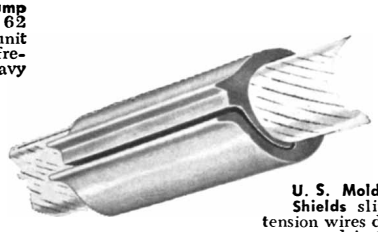

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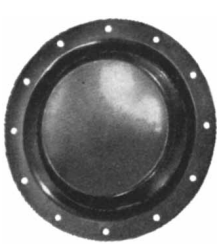

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PURSUIT OF A DISEASE

Porphyria, a rare hereditary condition which may become fatal when patients receive drugs, was found to be unusually common in South Africa. It has been traced to an early Dutch settler

by Geoffrey Dean

. . . I found
A thing to do, and all her hair
In one long yellow string I wound
Three times her little throat around
And strangled her.

—Robert Browning
Porphyria's Lover

Most doctors know in their hearts that they have been inadvertently responsible for the death of some of their patients. This is the story of a curious disease called porphyria, from which many persons have died because, to relieve their pain, physicians have unwittingly given them common drugs which can make the disease fatal.

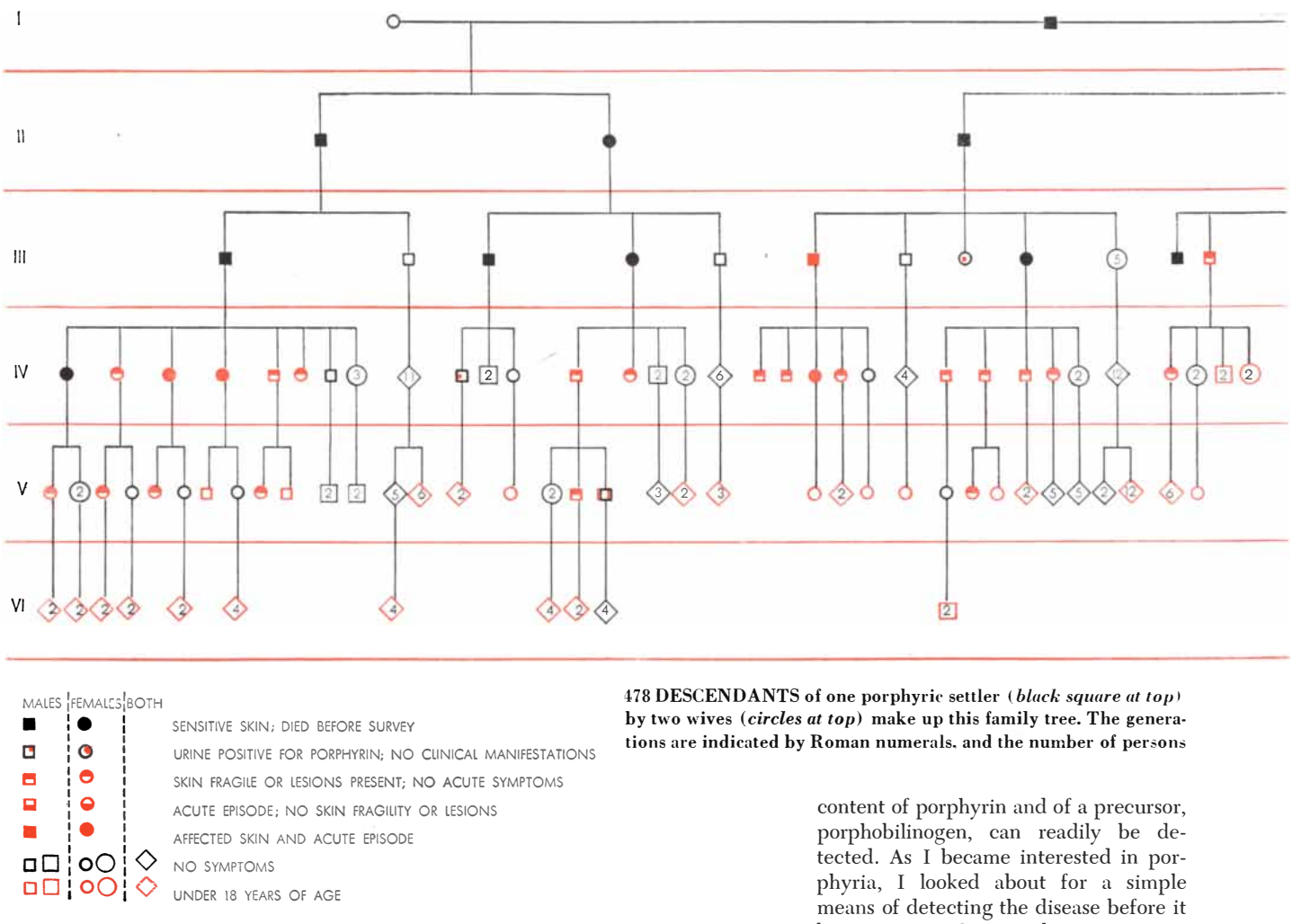
In 1947 I left England for South Africa and started practice as a consultant physician in Port Elizabeth in the Cape Province. I was soon struck by the marked differences between that country and Britain in the incidence of certain diseases. For instance, multiple sclerosis, one of the commonest nerve diseases in England, was practically nonexistent among South Africans. On the other hand, I shortly encountered several cases of an unfamiliar and at first completely mysterious ailment. The patients exhibited certain definite symptoms, ending in paralysis. I can best relate the symptoms by describing two cases.

An intelligent, middle-aged businesswoman had complained for many years of pain in her abdomen and had seen many doctors. Repeated examinations and X-ray investigations had failed to reveal any cause for her pains. Physicians had prescribed sedative drugs on a number of occasions; she found that the drugs only made her feel worse. She was often very emotional and was considered rather unstable and neurotic. Twice surgeons had made exploratory operations on her abdomen. After the first operation, which was followed by heavy doses of sedatives, she had severe abdominal pains and appeared mentally disoriented. It was five months before she was strong enough to leave the hospital. I examined her in 1950 after her second operation, for which she had been given a barbiturate anesthetic. She was very emotional and complained bitterly of pain in her abdomen and limbs. Her muscles were weak, her skin extremely sensitive. She rapidly became totally paralyzed, and in spite of all our efforts she died.

The second patient I examined was a young nurse, aged 19. She had been in a very nervous state, had taken barbiturates and had then become hysterical and complained of acute abdominal pain. A surgeon, suspecting she had an intestinal obstruction, had operated on her under a barbiturate anesthetic but found no pathology. A few hours after the operation she had an epileptic fit, and within two days she, too, became paralyzed and died.

In both of these cases there was an

CUTANEOUS FORM OF PORPHYRIA causes blisters and easy abrasions of the exposed skin, especially on the backs of the hands. The healed wounds result in depigmented scars.



478 DESCENDANTS of one porphyric settler (*black square at top*) by two wives (*circles at top*) make up this family tree. The generations are indicated by Roman numerals, and the number of persons

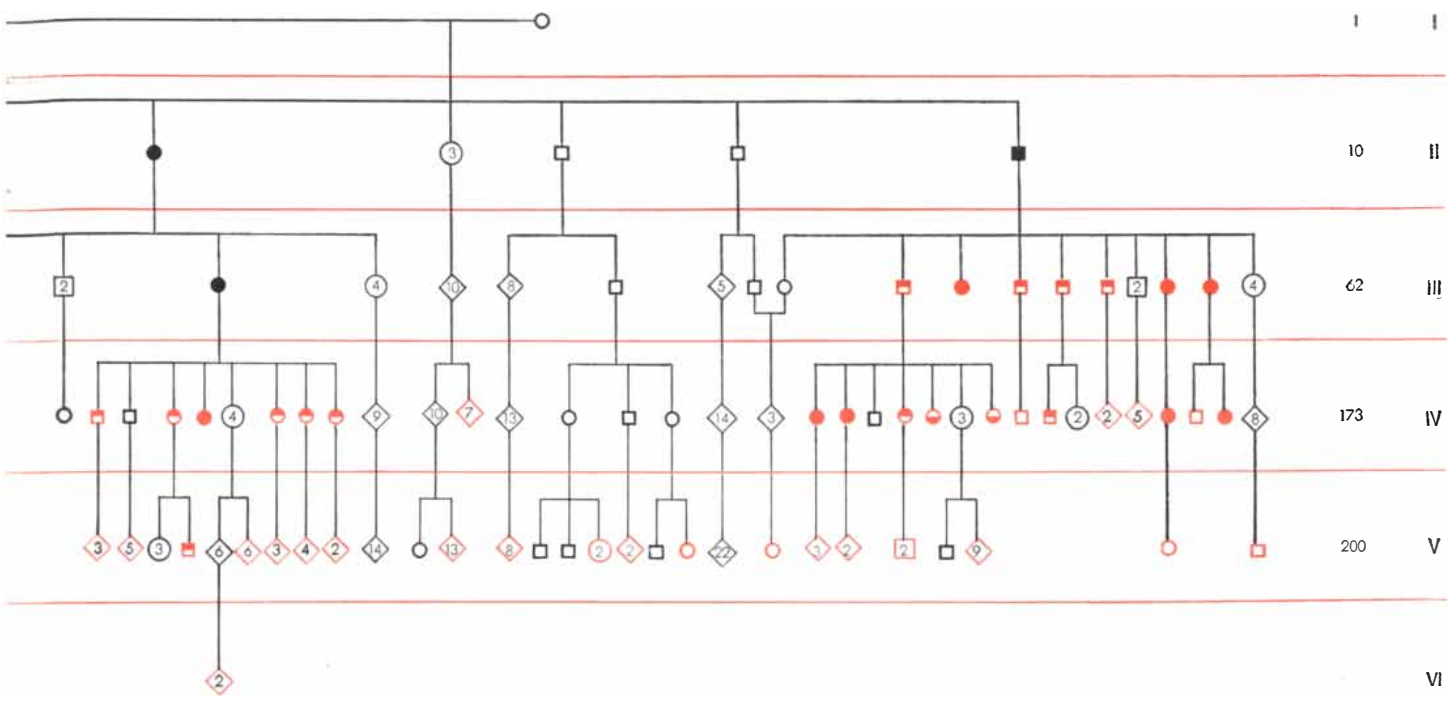
outstanding clue which enabled me to identify the disease of which they died. Urine specimens of the first patient became dark after standing in sunlight for some hours. The nurse's urine was "port wine" in color. Thinking about the symptoms, I had already begun to suspect porphyria, and analysis of the urine with a spectroscope confirmed the suspicion. On exposure to ultraviolet light the urine emitted a brilliant red fluorescence—the distinctive mark of the pigment porphyrin. Porphyrin (from the Greek *porphyros*, "purple") is an essential pigment forming part of the hemoglobin molecule and of certain other respiratory agents, including chlorophyll. Its presence in excessive amount in the urine means that the body fails to metabolize porphyrin properly. The hereditary form of the disease is called porphyria.

Until the past few years porphyria was regarded as a very rare disorder—a medical curiosity. A few cases of "acute porphyria," with symptoms like those I have mentioned, had been identified in women. Two other forms of the disease had been described. One of them, chiefly affecting men, was marked by the fact that the exposed skin, especially on the back of the hands, blistered and abraded easily. The other, appearing in babies, was recognized by the skin sensitivity and by a pink tinge in the teeth and bones, due to deposits of porphyrin. This disorder had also been found in cattle and was known as "pink tooth disease."

It quickly became evident that in South Africa porphyria was far from a rare disease. In the next two years I discovered 11 more acute cases. Most acute attacks of porphyria had been misdiagnosed in the past, partly because the existence of the disease was almost unknown among physicians and partly because the acutely stricken patient usually died before a full clinical investigation could be made.

Once the disease is suspected, however, the diagnosis is comparatively easy. In acute cases the urine's tell-tale content of porphyrin and of a precursor, porphobilinogen, can readily be detected. As I became interested in porphyria, I looked about for a simple means of detecting the disease before it became acute. Fortunately H. D. Barnes, a biochemist and spectroscopist at the South African Institute for Medical Research in Johannesburg, was able to refine the spectroscopic technique to discover even a slight excess of porphyrin in the urine. Later I found that the simplest test for use in the consulting room was to dissolve a small fragment of the subject's feces and examine the solution under ultraviolet light, which brings forth the red fluorescence of porphyrin.

As I examined more patients, the fact emerged that porphyria ran in families. Often it developed that relatives of the patients also had had acute attacks; men in the family had a tendency to sensitive skin on the back of the hands. By 1953 I had traced 13 family groups and found that 216 members of these families had porphyria. I concluded that the disease was a hereditary disorder, transmitted by a dominant gene, and that the acute and cutaneous forms were merely different manifestations of the same disease. (The third form, the congenital type that shows up in babies, probably



in each generation is totaled at the right. For compactness, numbers inside large symbols are used to represent more than one person. The pattern indicates that about half the children of parents with the gene inherit the disorder. The acute form of porphyria was found in 13 of 36 porphyric women and in one of 24 affected men. Two persons had excess porphyrins without the other symptoms.

is inherited as a Mendelian recessive and is not related to the first two.)

All of these families with porphyria were of Afrikaner stock. Of South Africa's white population of just under three million, about two million are Afrikaners, descended mainly from Dutch and French Huguenot settlers who were brought to the Cape in the latter part of the 17th century by the Dutch East India Company to feed and supply ships en route between Europe and the East Indies. The early settlers in South Africa were a healthy, hard-working, happy people, fortified with the Bible, guns and a stable government. An Afrikaner woman would marry young, often at the age of about 14, and would usually have a large family (even today families with 10 to 16 children are not uncommon). About one million of the present white population carry the names of 40 very prolific and genetically successful original settlers. Some of these family names are more than 30,000 strong. The only parallel to the South African settlers' procreation that comes to mind is the increase of the 12 sons of Jacob, of the Old Testament, during their 400 years' sojourn in Egypt.

This history is important for the unraveling of the question as to why porphyria is unusually common in South Africa, as we shall see. To obtain a genealogical picture of the disease, I set out to trace back the relatives of the young nurse who had died of acute porphyria. She came of a family of farmers in a nearby district. Her father had the typical sensitive skin, and he had inherited it from his father and grandfather. This great grandfather of the nurse was still remembered by a very old man in the district, and I undertook to find all his descendants. He had had 10 children; it was established that he had a total of 478 descendants, of whom 434 were still alive. My problem was to find out the whereabouts of these 434 persons and obtain specimens of their urine for spectroscopic examination.

The task took two years and a great deal of persistence. Many of the descendants had left South Africa; some were living as far afield as Germany, France, England and the U. S. One woman had married a Fuller Brush salesman from Wales and had not been heard from since they had left in 1920 to live in France. I wrote to the Lord Mayor of Cardiff, the salesman's home town, and was most pleasantly surprised to receive my quarry's address in France two weeks later from the chief constable of Cardiff, who had traced the man through a brother in Cardiff. The woman, it developed, had died in Paris in 1929 of an illness which had been diagnosed as black-water fever but bore the typical signs of acute porphyria.

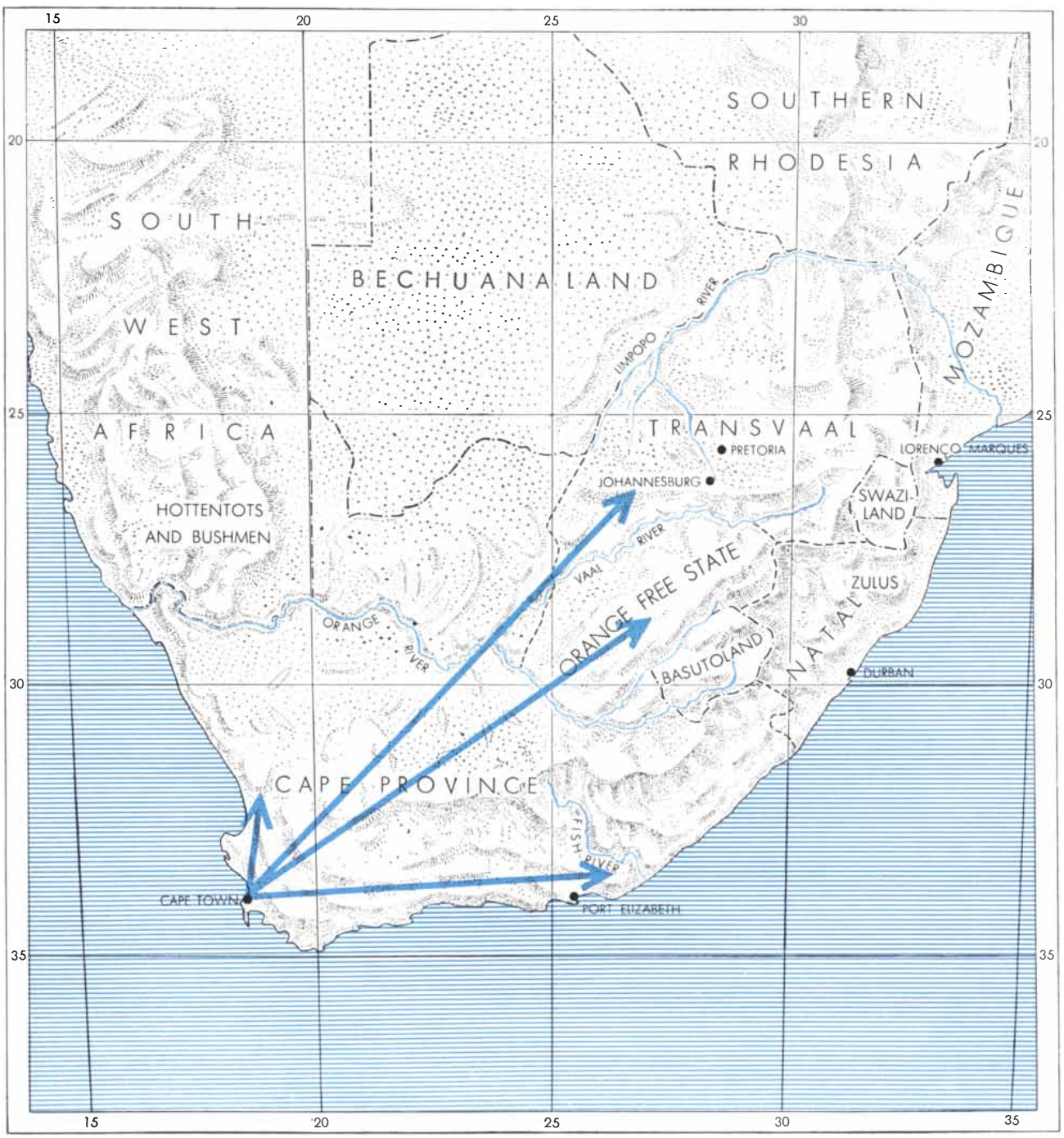
The trail of illness, with the same characteristic story, was indeed remarkable. After two years' search I traced a woman descendant to Cape Town. I wrote her the usual letter, including a warning against taking barbiturate sedatives. Three days later her daughter replied, saying that her mother was at that very moment in the hospital desperately ill with acute porphyria. She had long suffered the typical symptoms of severe abdominal pain, nervousness and a sensitive skin; a week before my letter arrived her doctor had prescribed drugs, whereupon she had become severely ill and hysterical and had been taken to the hospital. My warning had come just too late. Four days after the first letter from the daughter, I received a second: the woman had become paralyzed and died. The urine specimens showed that the disease was indeed acute porphyria and that the daughter also had inherited the disorder.

We traced another descendant to New

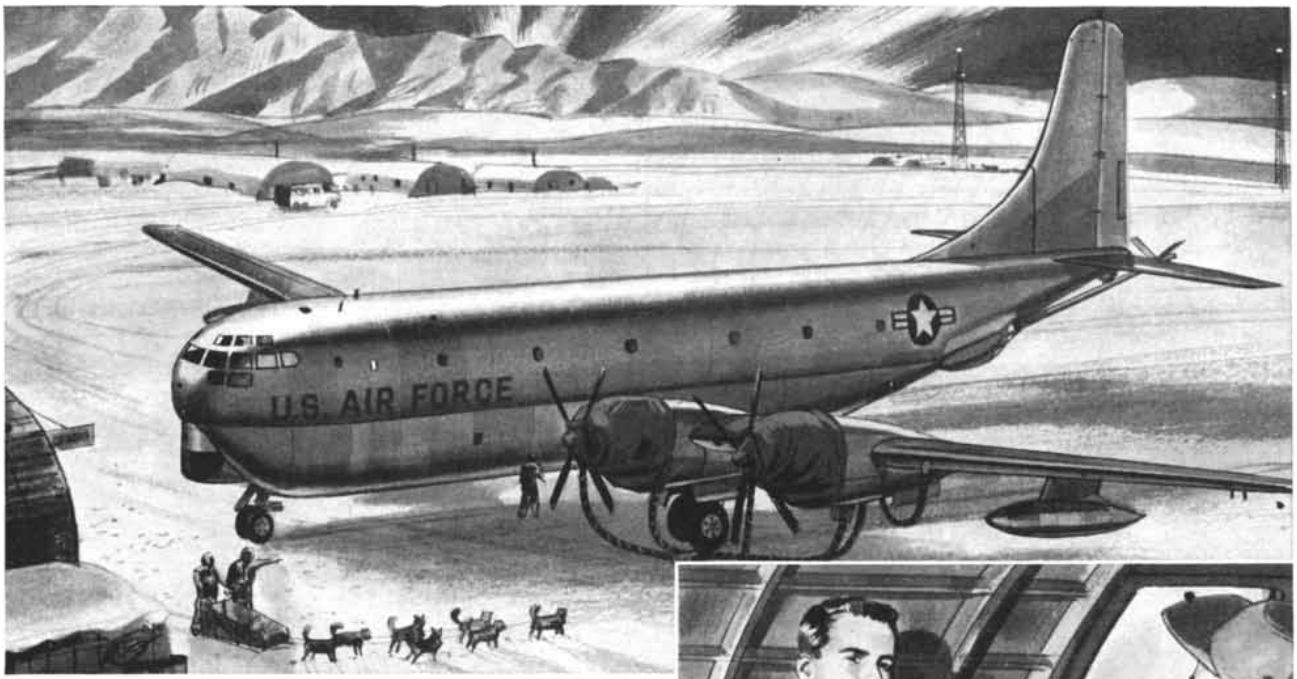
York City, where she had migrated to seek the best medical opinion about her health. She had long complained of what were considered neurotic symptoms. Three weeks after writing to her, I read in a South African paper that she had committed suicide. This upset me greatly, because I feared that my letter about porphyria, although carefully worded, might have been a precipitating factor. It was a relief to learn a few days later that her suicide was entirely unrelated to the letter. That this patient was a porphyric was indicated not only by her symptoms but also by the fact that three of her sisters and a brother had the disorder.

There were, on the other hand, many cases in which my letters arrived in time to help—but the warning was not always heeded. After establishing that a mother and her married daughter were porphyrics, I warned them of the danger of certain drugs and asked them to show the letter to any doctor they consulted in the future. Despite these precautions, one of them allowed her doctor to give her a barbiturate anesthetic without showing him the letter, and the other took drugs in the hope of producing a miscarriage. Both had attacks of acute porphyria. Fortunately they then showed the warning letter to the attending doctor in time to save their lives.

Most of the descendants cooperated with my requests for assistance in the



SPREAD OF PORPHYRIA in South Africa is indicated by the colored arrows on this map. In 1686 the first porphyric came to Cape Town, and since then his descendants have carried the gene to other parts of the Cape Province, Orange Free State and Transvaal.



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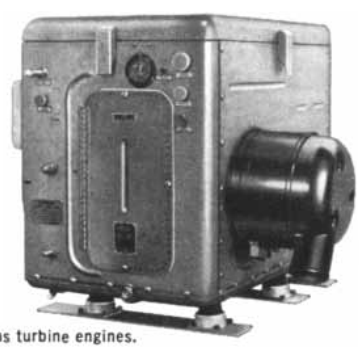

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study, but a few ignored my letters or refused point blank to help, some apparently thinking it might be a slur on the family to admit a familial disease. I searched out the hard core of resisters personally. One man I eventually ran to earth in a saloon. After some drinks together he agreed to supply a specimen: he proved to be a porphyric. An extremely religious family told me that they could not cooperate because they did not believe in doctors and trusted completely to "divine healing." Only after joining them in long evening prayers did I obtain what I required. A recalcitrant schoolteacher finally gave in after nine letters and two telephone

SOLUTIONS OF FECES from a normal person (*upper left*) and from a porphyric (*upper right*) are the same color in daylight. In ultraviolet light the normal solution is green (*lower*

calls, sending her specimen with a note: "To get rid of my old man of the sea!"

Eventually we succeeded in obtaining a specimen from every one of the 434 living descendants of the nurse's great grandfather. We learned that 5 of his 10 children were porphyrics, and in turn there were 16 in the third generation, 32 in the fourth and 7 in the fifth—a total of 60 adults with the disease. Later we found by analysis of feces that 21 children in the fifth and sixth generations had inherited the defect, though they showed no illness. Of the 60 adults, 36 were women, and most of these women had suffered from attacks of abdominal pain. We established that eight women

left) and the porphyric solution is red (*lower right*). Occasionally a great excess of chlorophyll in the specimen gives a falsely positive result and the diagnosis requires quantitative analysis.

and one man of the deceased descendants had died with typical symptoms of acute porphyria.

This study demonstrated that porphyria is inherited as a Mendelian dominant characteristic, at least in South Africa, and that the acute, chronic cutaneous and symptomless phases are all merely versions of the same metabolic defect. Transmission of the defect is not sex-linked, but women are more likely to have acute attacks and men more likely to show the skin effects.

It is altogether clear that the disease is very common in South Africa. During eight years of consultant practice I have diagnosed 46 acute and 76 nonacute cases of porphyria, and 541 other cases have been detected in their families. Screening tests of samples of the South African population have confirmed the high frequency of the disease: among 700 nurses examined, eight cases were found, and among 600 inmates of a mental hospital there were six cases.

Porphyria is much less common in other parts of the world, but research in recent years has shown that it is not as rare as was formerly believed. Jan Waldenström has identified several hundred cases in Sweden, and Cecil Watson of Minneapolis and Louis A. Brunsting of the Mayo Clinic have proved it is not uncommon in the U. S.

My findings about the high incidence of undiagnosed porphyria in South Africa were at first doubted, understandably, by my colleagues. I recall warning a dermatologist who was just starting in practice about the disease: he informed me that he knew all about it and would not miss a case. A year later his own secretary, who had long complained of vague symptoms, was found to be a porphyric. Another colleague in town operated on his secretary, and she developed an acute attack of porphyria after the operation. This doctor had the misfortune to hire a new secretary who also turned out to have the disease. Still another doctor, who had been paralyzed for five months by an attack of porphyria, nevertheless took barbiturate sleeping tablets and precipitated a second very severe attack. Porphyrics, even when they have full knowledge of their disorder, do not easily appreciate the grave danger of drugs and find it difficult to resist taking sedatives when they have acute pain.

It is this property of the disease that makes it so perilous, not to say deadly, today. In the earlier days in South Africa men who worked in the sun may have been troubled with sores and blisters on

THE PLENTIFUL RARE EARTHS

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

a report by LINDSAY

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

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

SOME USES FOR RARE EARTHS

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

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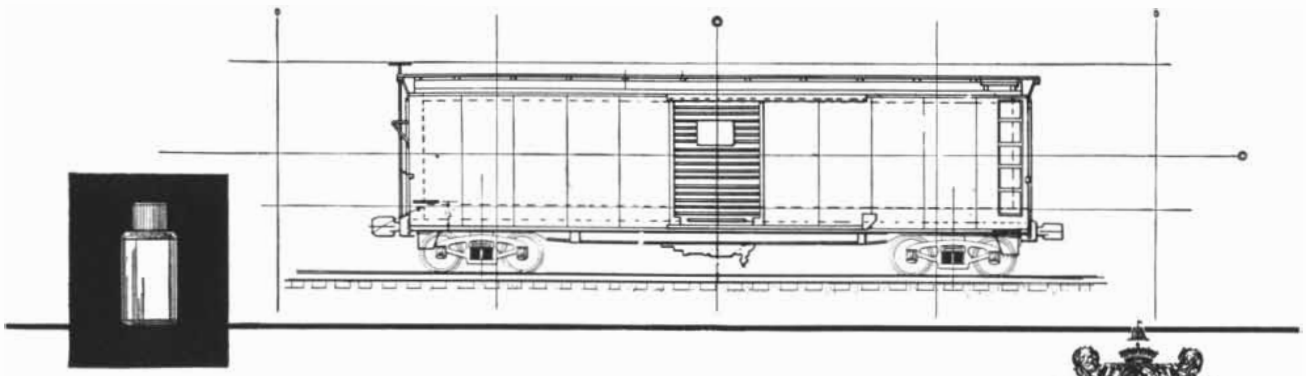

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their hands, particularly if they drank much brandy, but the sores were not serious and the old Dutch remedies were harmless. Porphyrics were much better off then than they are today. Nowadays, with barbiturates and other sedatives almost a household nostrum in most of the civilized world, porphyria has become a most serious affair. Many drugs besides the barbiturates can precipitate acute porphyria. And there is as yet no specific treatment either for the attacks or for the underlying metabolic defect, although with earlier diagnosis and understanding of the nature of the disorder most patients can be saved: of the 46 acute cases that have come to me, all but the first three and a later one recovered.

A patient in an acute attack must have first-class medical and nursing attention and requires a high level of nutrition. Usually intravenous feeding is necessary. As for prevention of attacks, doctors should be cautious about prescribing drugs and should consider the possibility of porphyria in the case of an apparently neurotic patient complaining of abdominal pain. If an operation on a porphyric is necessary, gas, oxygen and ether should be used in preference to other anesthetics. One woman, who had had two exploratory operations for porphyric pains, suggested that she should have tattooed on her abdomen: "I have porphyria—do not open me!" This would appear rather a drastic measure, but all cases of porphyria should be given a letter of warning which should be shown to any doctor they consult.

Porphyrics do best if they understand the nature of their disorder, avoid drugs, eat well and take very little alcohol. They are apt to acquire a much happier frame of mind once they realize that their symptoms are not due to imagination or neurosis.

During the past five years I have been working steadily on the family tree of porphyria in South Africa. It is an extremely difficult and time-consuming job, but I expect to be able to publish soon a master tree which will trace the disorder to a single source: one of the early Dutch settlers who came to South Africa in 1686. This man happened to have a large number of children and grandchildren who inherited his gene for porphyria. Rapid multiplication of his descendants did the rest. The gene is now fairly widely distributed in the Afrikaner population. Despite this the Afrikaners have been a genetically successful people. Conceivably the gene for porphyria may even be associated with hereditary advantages; we do not know.

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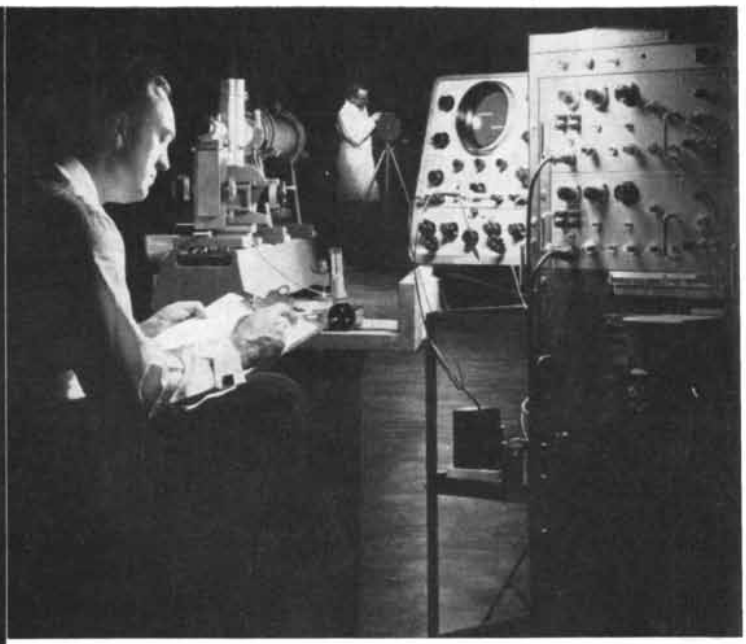

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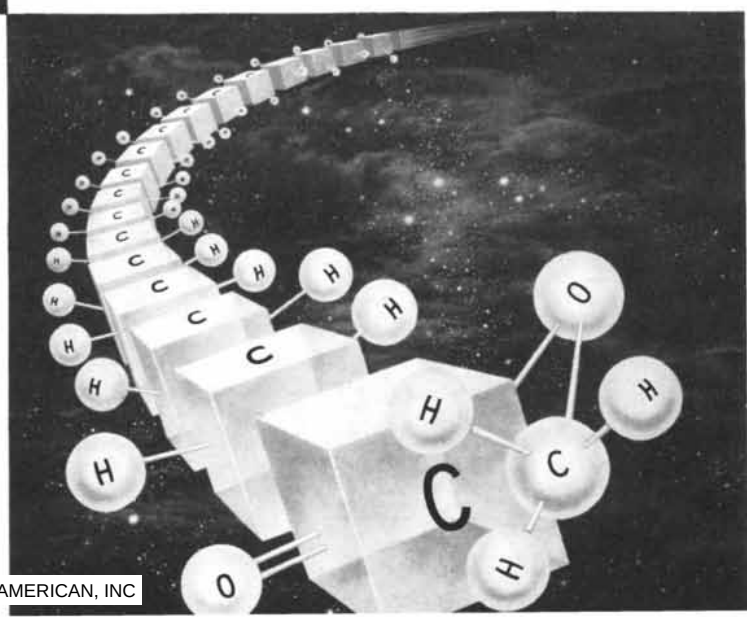

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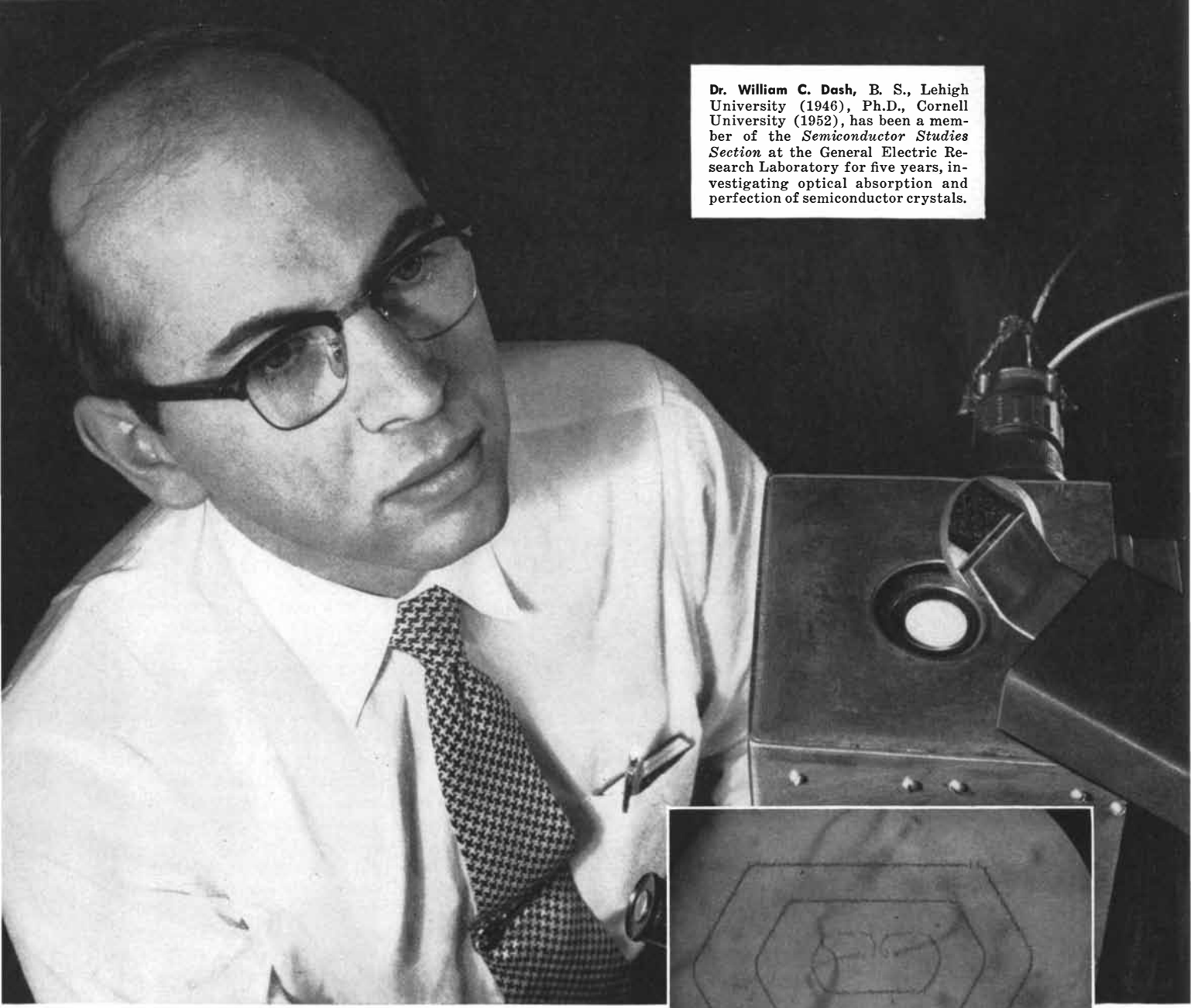

Dr. William C. Dash, B. S., Lehigh University (1946), Ph.D., Cornell University (1952), has been a member of the *Semiconductor Studies Section* at the General Electric Research Laboratory for five years, investigating optical absorption and perfection of semiconductor crystals.

Looking into silicon

Dr. William C. Dash of General Electric develops a new technique for studying dislocations in silicon crystals

Infrared light passes through silicon and reveals pattern of dislocations on the screen of the "snooperscope."

Silvery wafers of silicon used in semiconductor research — and in the manufacture of transistors — are as opaque as a brick wall to visible light, but highly transparent to infrared. Dr. William C. Dash of the General Electric Research Laboratory has adapted the "snooperscope," an infrared-sensitive device developed during World War II, as a convenient means of looking into silicon crystals.

Recently Dr. Dash and his associates devised a method of precipitating copper along the rows of out-of-line atoms inside silicon crystals so that these flaws — called *dislocations* — can be seen by the snooperscope. Since physicists now explain many aspects of crystal behavior — how they grow and why they bend — in terms of dislocations, the Dash technique is an important new tool for learning more about the solid state. Dislocation patterns predicted by theory have actually been seen for the first time on the screen of Dr. Dash's snooperscope.

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BOOKS

A classic examination of what is meant by the word "cause"

by James R. Newman

DETERMINISM AND INDETERMINISM IN MODERN PHYSICS, by Ernst Cassirer. Yale University Press ($5).

Nearly a century ago William Kingdon Clifford observed to the British Association for the Advancement of Science: "In asking what we mean by [cause] we have entered upon an appalling task. The word represented by 'cause' has 64 meanings in Plato and 48 in Aristotle. These were men who liked to know as near as might be what they meant; but how many meanings it has had in the writings of the myriads of people who have not tried to know what they mean by it will, I hope, never be counted."

Scientists and philosophers today are still in no closer agreement among themselves as to the meaning of "cause." What is causality? Is it a hypothesis? A principle? An indispensable crutch of thought? How is causality related to determinism? Has modern physics, in undermining the latter notion, subverted the former? The word cause, said Bertrand Russell, is so inextricably bound up with misleading associations "as to make its complete extrusion from the philosophical vocabulary desirable." Even if this drastic measure were justified, one could not expect it to be adopted overnight. Meanwhile thoughtful men continue to mull the question, for it is held to be crucial not only by philosophers and psychologists but by those who work at the extreme boundaries of physical science—the theorists concerned with the behavior of very small things and those concerned with the structure of the universe as a whole.

The late Ernst Cassirer (who fled from Hitler's Germany and died in the U. S. in 1945) reflected on the concept of cause for many years. He was a man of wide and varied philosophical interests, thoroughly trained in the philosophy of the exact sciences. His *Determinism and Indeterminism* was first published in Sweden in 1936. It appears now in an excellent English translation by O. T. Benfey of Earlham College in Indiana, with a preface by Henry Margenau of Yale University.

Physical science has moved rapidly in the last two decades, and one might suppose Cassirer's essay to be out of date. But as Margenau points out, Cassirer fully understood the revolution in physical thinking that was taking place, and his appraisal of its implications was ahead of the day. Many physicists saw no reason to construe Werner Heisenberg's uncertainty principle as forcing any profound revaluation of the meaning of reality. In some quarters the supposed downfall of determinism was taken as an occasion for jubilation: free will was restored and the human spirit no longer had to be regarded as a trolley running in predestined grooves. Cassirer shared neither of these opinions. It was no use pretending, he felt, that everything in physics was as tidy as before, except in certain special regions where the broom would not quite fit into the corners. Nothing short of a reform of the concepts of "physical system" and "physical state" was called for. This would show the directions that physics should take and the limits inherent in its methods, but at the same time it would also permit the retention of causal descriptions. To Cassirer's mind the new theories of physics promised not chaos but a renaissance.

His book surveys the evolution of the notion of cause. He begins with a discussion of Pierre Simon de Laplace's famous dictum that an "all-embracing spirit" which knew all about the universe at a given instant could by mathematical analysis discover everything that had happened in the past and everything that would happen in the future. For Laplace this was "an effective metaphor" serving to contrast the concepts of probability and certainty. But the underlying theme was gradually transformed into a broad principle of far-reaching significance in the evolution of physical thought.

It was not a new theme. It was in fact the "pregnant summary" of that world view from which sprang the great philosophical systems of the 17th century—the systems of classical rationalism.

"That everything is brought forth through an established destiny," wrote Gottfried Wilhelm von Leibniz, "is just as certain as that three times three is nine. For destiny consists in this, that everything is interconnected as in a chain and will as infallibly happen, before it happens, as it infallibly happened when it happened. . . . Mathematics . . . can elucidate such things very nicely, for everything in nature is, as it were, laid off in number, measure and weight or force. If, for example, one sphere meets another sphere in free space and if their sizes and their paths and directions before collision are known, we can then foretell and calculate how they will rebound and what course they will take after the impact. . . . From this one sees then that everything proceeds mathematically—that is, infallibly—in the whole wide world, so that if someone could have a sufficient insight into the inner parts of things, and in addition had remembrance and intelligence enough to consider all the circumstances and to take them into account, he would be a prophet and would see the future in the present as in a mirror."

The clever fellow with the synoptic eye had not yet been born, nor was he likely to be. Still, he embodied an ideal for science as well as philosophy. One might say that if all men were virtuous, there would be eternal peace, and though one recognized that all men were not virtuous and would never be, still the cause of peace would be furthered by encouraging virtue. Similarly, though one recognized that a complete understanding of the universe is impossible, one could hope to learn the laws of phenomena by extending and improving observations.

Among the philosophers who attacked this treatment of causality were David Hume and Immanuel Kant. Hume took the position that causality exists only in the mind, because our knowledge of the physical world is founded entirely upon sensations. We see a moving billiard ball

collide with another at rest; the second ball is set into motion; we conclude that the motion of the second ball was caused by the first. In truth we know nothing of the actual forces at work; all we know is that there is a regularity in the behavior of our cognitive powers. The causal idea emerges from the fact that imagination and understanding "cannot escape the constraint of association and the force of habit."

Kant also rejected the notion that cause is a simple relation between things, but unlike Hume he granted that there is an orderliness in nature as well as in the mind—a lawfulness of "outer" occurrences to which the orderliness of "inner" occurrences is related.

In the 19th century the field theories of electricity and magnetism forced a radical revaluation of the old theory of matter. Statistics introduced into science a new method and a new instrument of description. Thermodynamics led to an important change in the world view of physical nature "in the formal as well as in the material sense." It was no longer possible to rest on a simple "contact" theory of causation. There were philosophers who had rejected this notion long ago; now physicists had to abandon it. Nature was not to be entirely explained in terms of hard objects bumping into each other. The existence of hard objects was doubtful, and even if they existed, they appeared to bump into each other from a distance. The concept of continuity was in danger; the jurisdiction of dynamic laws was curtailed; the causal principle itself became the subject of irreverent debate.

Ernst Mach put his finger on an important point, related to the views of Hume and Kant. However one may define the causal principle, he said, it is certainly not a natural law in the usual sense of the words. There is no cause and effect in nature as such, "for nature is present only once, and those same events to which we refer when we say that under the same circumstances the same consequences occur do not exist in nature but only in our schematic reproduction of it." Hermann von Helmholtz expressed himself along similar lines. The assumption of causality could be justified only as a means of obtaining a "conceptual grasp of nature." Although we cannot be certain *a priori* that orderliness pervades every corner of the universe, it is an indispensable regulative principle of thought, the only guide to inquiry. If no regularity were perceivable, "our intellectual activity would necessarily come to rest." The investigator must have faith in a kindlier Nature (God, said Einstein, is not malicious). He must give heed, according to Helmholtz, to only one counsel: "Trust the inadequate and act on it; then it will become a fact."

We may ask how statistical laws fit into this philosophical view. In classical physics a distinction was made between dynamical and statistical laws—between the "determined" and the "undetermined." The behavior of a falling body, described by the laws of motion, was determined; the behavior of a gas, described by the laws of statistical mechanics, was undetermined. What did this distinction mean? For one thing, of course, it implied that some laws were "exact," while others were mere approximations. This did not mean that the individual molecules of a gas do not obey the laws of classical mechanics; it meant that in dealing with a horde of them it was feasible only to treat them statistically. But statistical laws were a makeshift, inferior to exact laws.

The classical distinction between determinism and indeterminism posed a second and more important difficulty. If the behavior of a gas was "undetermined," what became of causality? The formulas of Leibniz and Laplace made predictability the criterion of causality. Since statistical laws could prophesy only what was likely to happen, they were not only inferior to exact laws but threatened a failure of the causal principle if they were accepted as complementary descriptions of nature.

Helmholtz's view gave an answer to these difficulties. His definition of causality was not tied to predictability. He did not belittle the importance of prediction in science, in technical mastery of nature, in everyday life. Yet it seemed sheer anthropomorphism to insist that unpredictable events lay outside the causal relation. It might well be there were phenomena which would forever elude exact description, which could be encompassed only by statistical laws, but this could not be taken to mean that such phenomena stood above the orderliness of the universe. Max Planck, writing on causality 50 years later, was even more explicit. He pointed out that "even in classical physics it is not possible in a single instance really to predict a physical event accurately." Thus if predictability is adopted as the strict criterion for causality, we are confronted with the fiasco of being forever unable to verify causality in any concrete case.

The only escape from this dilemma is to define casuality as a proposition concerning cognitions, not things and events. In Cassirer's words: "We must

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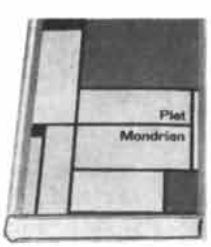

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think of causality as a guide-line which leads us from cognition to cognition and thus only indirectly from event to event, a proposition which allows us to reduce individual statements to general and universal ones and to represent the former by the latter. Understood in this sense, every genuine causal proposition, every natural law, contains not so much a prediction of future events as a promise of future cognitions."

More than half of Cassirer's book is devoted to this interpretation of causality, with particular reference to quantum mechanics. The quantum theory exploded the notion of continuity; it created a special body of laws for small things, inapplicable to large things; it dethroned determinacy and made randomness king; it made philosophers take to their beds and physicists flee to shelter. The quantum theory, as Planck aptly remarked, is a "dangerous foreign explosive which has caused a gaping rift throughout the entire structure [of classical physics]." But the worst was yet to come. To handle the quantum theory mathematically and deal with the dual nature of matter (behaving both as waves and as particles), it was necessary to devise a quantum mechanics. Now quantum mechanics is a statistical discipline. It presents no exact description of an individual particle and makes no exact prediction of its behavior. However, it can make very accurate predictions as to large aggregates of particles, and can show certain correspondences between quantum and classical mechanics. For example, Heisenberg conceived a matrix which corresponds to the momentum or energy of electrons, and combined the matrices according to laws "in the same way the corresponding quantities in classical mechanics are combined by the equations of motion." Quantum mechanics thus has been able to incorporate the laws which were the foundation of classical mechanics.

And yet, as must be evident, the methods of quantum mechanics represent a profound change in outlook—a change which was crystallized in Heisenberg's principle of indeterminacy, enunciated in 1927. All statements in physics, he said, are relative to the means of observation used. This limitation can be disregarded in experiments with things of ordinary size, but it is decisive in the realm of the very small, just as a grain of sand is insignificant in the gears of a cement mixer but becomes disastrous in the gears of a watch. Since we are dependent on instruments, there is a limit "not only to our experimental technique but also to the formulation of physical concepts." Suppose we wish to determine the position of an electron. If we were to try to locate the position of the electron through some ultramicroscope, the precision with which we could locate it would depend upon the wavelength of the "light" used to define it. Unfortunately, however, the shorter the wavelength, the more massive the effect of the light upon the electron's motion. Therefore it is "basically impossible to measure simultaneously the position and velocity of an electron with any desired accuracy." If we increase the accuracy of one measurement, we decrease the accuracy of the other.

What are the implications of the uncertainty principle? Does it constitute a denial of causality? Heisenberg said yes. Since there are limits to the accuracy of measurement, there are limits to the predictability of the path of a particle. We cannot predict the future, he said, because it is impossible to obtain an exact knowledge of the present.

Many physicists share Heisenberg's opinion. Some, including Albert Einstein, have argued that quantum mechanics may one day be refined or supplemented to encompass individual events. Cassirer took a different view. He felt that quantum mechanics represents the finest meshed net we can hope to throw about physical reality, but he vigorously rejected the idea that acceptance of the uncertainty principle entails the abandonment of causality. Taking Helmholtz's interpretation of causality as independent of predictability, he reasoned that uncertainty is not fatal to the causal principle. Indeed, quantum mechanics itself could not exist without making use of "pure and typical causal principles," namely, the laws of conservation of energy and momentum.

Planck once pointed out that whether a physical quantity is "observable in principle," or whether a given question is meaningful in physics, is not a matter to be decided *a priori*. It depends entirely on the theory we adopt, for the theory shapes our instruments, our methods, our interpretations. We are not simply cameras or mirrors. Between the thing observed and the observer there is an uncertainty, an uncontrollable ripple, one might say, produced by the interaction of the seer and the seen. The new physics disenchants us as to the firmness and fixedness of substance. "We no longer have absolute, completely determined entities, from which we can immediately read off the laws and to which we can attach them as their attributes." The content of our empirical knowledge consists of no more than the "totality of observa-

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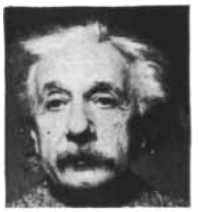
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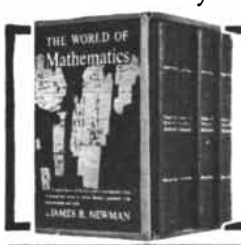

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tions which we group together in definite orders . . . and which we can represent by theoretical laws." Quantum mechanics does not deal with things whose laws we seek to discover; instead, from observation we constitute the things. Atomic physics deals "with the nature and structure not of atoms but of the events which we perceive when observing the atom."

The causal principle can be united with diverse conceptual schemes, but each amalgamation must be effected with care: causality is not a shoe that fits every foot. Cassirer reminds us that causality has had many trials in the history of physics. It was thought to be endangered, for example, when Newton introduced "action at a distance," involving the "occult" force gravitation. But the causal principle endured; and the exertions to preserve it have deepened our insight.

We now understand that there are in physics, as in other spheres of thought, unaskable, which is to say, meaningless, questions. (For example, what is the location of an electron during its jump from one orbit in the atom to another?) Many intuitively obvious notions have turned out to be untenable. What all this means is that some situations "are not empirically definable for us." Nature is much queerer than we can suppose. It does not mean, however, that nature is capricious or that causality is dead. "What quantum mechanics does," said P. A. M. Dirac, "is to try to formulate the underlying laws in such a way that one can determine from them without ambiguity what will happen under any given experimental conditions. It would be useless and meaningless to go more deeply into the relations between waves and particles than is required for this purpose." This is in fact all that the causal principle requires. So long as observable events can be described with precision in mathematical language, the postulate of the "comprehensibility of nature" which the causal principle contains is fulfilled.

Louis de Broglie and David Bohm have attempted what is called a "causal interpretation of the quantum theory." Richard P. Feynman has proposed a theory of quantum electrodynamics in which time flows "backwards" (see the review of *The Direction of Time* below). Other new approaches have been offered. But it is my impression that most physicists and philosophers are today a little weary of the causality debate; at least they seem to feel that until another breakthrough is made, further discussion is not apt to be very fruitful. Cassirer's interpretation now enjoys, as Margenau remarks, greater popularity than when it was first propounded. There are certainly weaknesses and unresolved points in his treatise, which critics will have no difficulty sticking their knives and needles into. But I have no hesitation in recommending this work of a sensitive, sure thinker. Cassirer's study is spacious, subtle and insightful. He has laid out in clear perspective one of the most complex and vexing questions of thought.

Short Reviews

THE DIRECTION OF TIME, by Hans Reichenbach. University of California Press ($5.50). This book is the last major work of a gifted and vigorous philosopher. The late Professor Reichenbach made many valuable contributions to the analysis of the theory of probability, relativity theory, quantum mechanics and the logical foundations of science. In this book he summarized his conclusions and brought his point of view to bear on the baffling problem of time—its qualitative, or topological, attributes, such as order and direction. His major premise is that time order is reducible to causal order. This idea was first conceived by Leibniz, but it was not until Einstein formulated the special theory of relativity that the causal theory of time could be "definitely established." The Lorentz transformations, which in effect express the special theory of relativity, permit the reversal of the time order of certain events, namely of those which cannot be connected by causal chains. Einstein was thus led to his criticism of the absolute concept of simultaneity. He showed that the accepted time order between events can be preserved "only if the events in question can be connected by signals, that is, by causal chains." To insist, therefore, that time order has a meaning independent of causal order requires the rejection of both the Lorentz transformations and the special theory. This would mean the overturn of a large part of modern physics. Order is as easily established in the continuum of time as in the continuum of points on a line. We can fix the position of an event relative to other events just as we can say that a point lies between two others. But direction is quite another matter. In the number continuum the relation "smaller than" has a direction. Does the same structural difference exist between the relations "earlier than" and "later than?" We believe this must be true, but the question is, can it be proved in physics? An irre-

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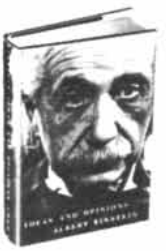

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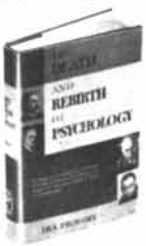

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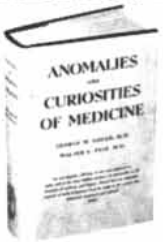

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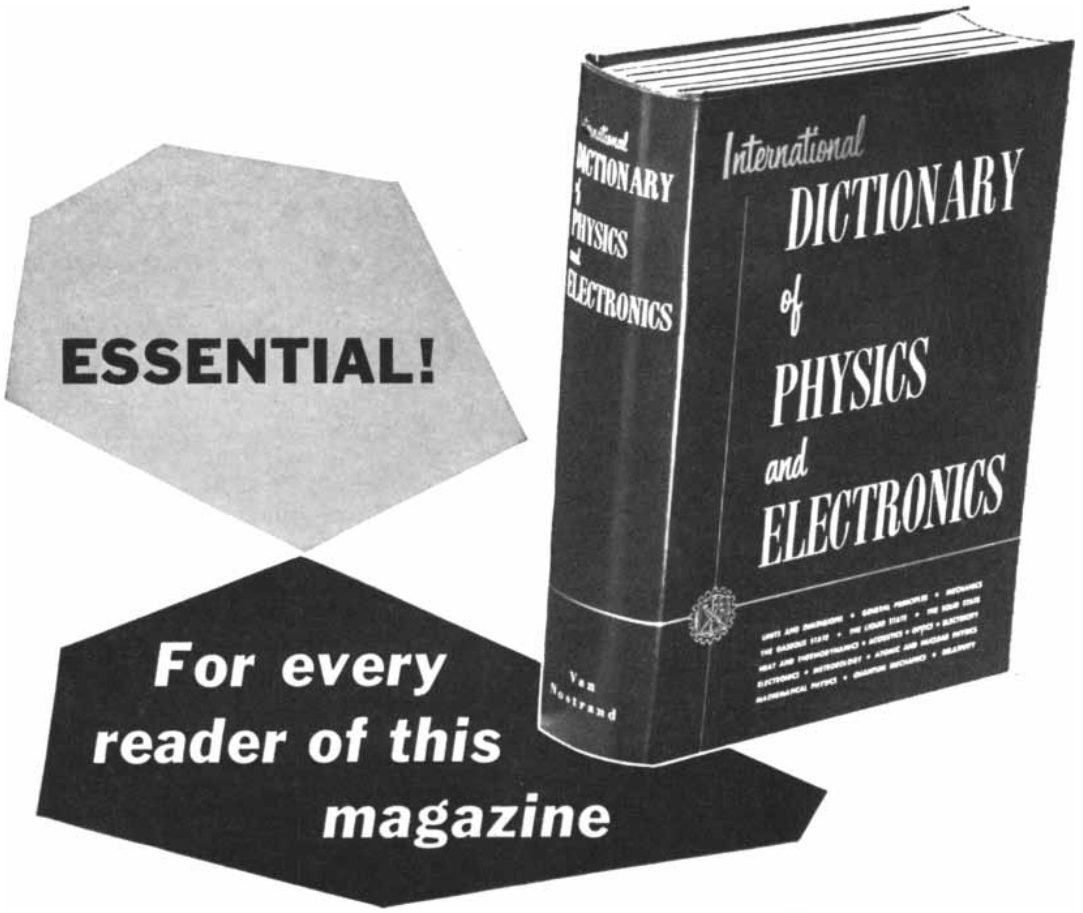
versible physical process, such as burning or the mixing of gases or liquids in a vessel, might be thought to represent a direction in time. But there is a catch, as was shown by James Clerk Maxwell and more fully by Ludwig Boltzmann. For the trend in one direction is only statistical; it does not apply to individual molecules. "The act of becoming is the transition from improbable to probable configurations of molecules." Even so, says Reichenbach, this is the closest we can come to a unidirectional clock. Looking at the universe as a whole, in space and time, is it possible categorically to assert that its entropy is steadily increasing? Reichenbach says no. All one can be reasonably sure of is that certain isolated "branch systems" of the grand entropy curve of the universe evolve in the direction of "positive time." In our own small world, representing a section of time, everything appears to be running nicely downhill. No one grows younger; there are no closed causal chains; we do not re-encounter the past; the entropy bank is steadily getting richer. But there may be such a thing as "supertime," pieced together of separate time threads pointing in opposite directions. This theory provides an answer to the famous paradox of reconciling the reversibility of microprocesses (the behavior of individual molecules) with the irreversibility of macroprocesses, such as the mixing of gases. Reichenbach asserts that quantum processes are as reversible as the processes of classical mechanics. He discusses the fascinating concept, developed by E. C. G. Stückelberg and Richard P. Feynman, that a positron can be regarded as an electron moving backward in time. "The negative unit charge of the electron, which travels in the opposite time direction, has the same physical effects as the charge of the positron traveling forward in time; and therefore the two interpretations cannot be distinguished observationally." There is much to criticize and to question in Reichenbach's essay. He devotes too much space to the background of physics; he sometimes mixes precise logical terms with the loose language of common sense in his proofs; he overtouts the claims of scientific philosophy. But this is an engrossing work, and readers will mourn the fact that its author did not live to write the final chapter, which was to have considered the connection between the subjective experience of time and its objective properties in nature.

DOCUMENTS IN MYCENAEAN GREEK, by Michael Ventris and John Chadwick. Cambridge University Press

($15). Between 1900 and 1905, while excavating the Palace of Minos on the island of Crete, Arthur Evans came upon some 4,000 clay tablets inscribed in three kinds of writing. The tablets could not be deciphered. Similar tablets were found in 1939 and again in 1952 at Pylos by Carl W. Blegen, and in houses outside the great fortress-palace at Mycenae by Alan J. B. Wace. Many men attempted to decipher the tablets, for they were believed to hold the key to a host of questions about the prehistoric civilization of Greece in the Aegean Bronze Age and about the original home from which the Greek people had come. The difficult feat was finally accomplished by Michael Ventris, a young English architect who made a study of the scripts his hobby. The report of his work appears in this splendid volume, which the London *Times* has called a general classic comparable to Newton's *Principia*. In 1952 Ventris turned up a clue which led to the decipherment of one of the three scripts, called Linear B. He showed it to be an early form of Greek, at least 500 years older than the earliest previously recorded. The Mycenaean art and culture were therefore proved to be Greek, and it became possible to trace the development of Greek civilization from about the 16th century B.C. The information on the clay tablets is conveyed in short, often cryptic sentences, frequently without verbs. The writings are not "literature" in the exalted sense—chronicles, epics, liturgies or laws. They are almost exclusively lists of commodities, inventories, tallies, registers of personnel. Some are merchants' records, some are written in the "house of the oil merchant," some in the palaces, some in the "armory." Place names appear, and men's names, also lists of chariots, tripods, furniture and garments. There are additions, subtractions, calculations involving proportion. The Mycenaean computers made blunders, some of which they erased and others they left for us to discover with glee. The Mycenaean cities Knossos and Pylos had a *wanax* (king). We read of a "warleader," a mayor, a messenger, a herald; of huntsmen and woodcutters; of masons, carpenters and shipbuilders; of bronzesmiths, goldsmiths, cutlers and bowmakers. Cloth weaving was a woman's occupation: there were carders, spinners, weavers and flax makers. Eumedes the unguent boiler, Brithawon the potter and Thisbaios the shepherd find their way into the lists, as do a physician, bakers, soldiers and warship rowers. The specialization of labor went far be-

yond that in Homer's time, many hundreds of years later. Slavery existed, but some slaves were so privileged as to be required to contribute to the master's revenue. Wheat and barley were the principal cereals; olive oil was common; the condiments included coriander, celery, fennel, mint, pennyroyal and sesame. Among the livestock recorded on the tablets are sheep, goat, pig, ass and deer. In the royal palace at Pylos the furniture included "one chair of spring type, inlaid with men's figures in gold, and with a pair of gold finials, and with golden griffins and with griffins of kyanos," and "three drainable tubs for bath water." No less elegant was the military equipment: chariots inlaid with ivory, swords with gold studs on the hilt, chariot wheels bound with silver. A census records 37 women bath pourers at Pylos. also sundry nurses, headband makers, musicians, sweepers and their children. Ventris and Chadwick cover in this book 300 selected tablets. They give a detailed account of how the tablets were translated, together with a Mycenaean vocabulary. The story of their decipherment of Linear B (Linear A has not yet been fathomed) is an exquisite example of imaginative, disciplined scholarship. It is tragic that Ventris was killed in an auto accident in September, 1956.

THE ANATOMY OF NATURE, by Andreas Feininger. Crown Publishers ($5.95). This book offers 176 photographs in support of the theory that nature's forms are functional "in the best sense of the word." Their beauty, Feininger says, is the resultant of "definite purpose"; the forms are "derived from necessity." None of this is very clear, but many of the pictures are superb and more than make up for the sentimentalism and the philosophical dissertations. They include portrayals of galaxies, great trees, tumbleweeds and funguses, magnificent skunk cabbages, the skeleton of the cholla cactus, layers of sedimentary rock, mountains cut by erosion, fossil ripple-marks, dried mud-flats, tremendous sand dunes in Death Valley, water drops delicately held in a spider's web, ice feathers on a windowpane, marvelous electrical discharge patterns, magnified insect wings and nightmarish beetle heads, reed stalks resembling fluted Greek columns, the skeleton of an exquisite four-foot Gaboon viper with 160 pairs of hinged ribs, the weathered jawbone of a cow, the skull of the crucifix catfish, the teeth of a skate and of a marine snail, the helical structure of the nautilus, timbers ravaged by shipworms. An illustrated section at the end describ-



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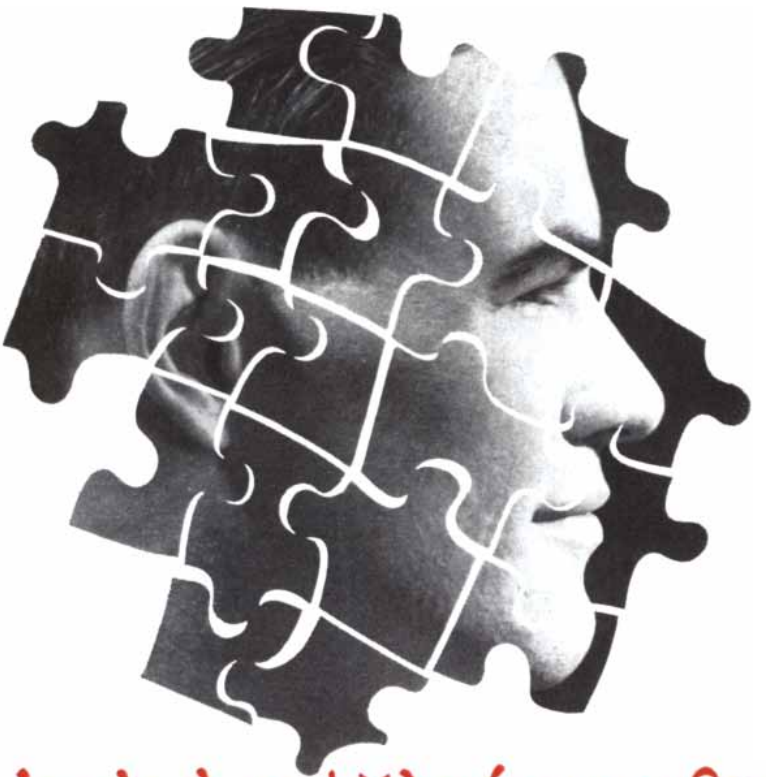
ing special techniques in nature photography is understandable but discouraging: the only one who can take pictures like Feininger is Feininger.

PROCEEDINGS OF THE THIRD BERKELEY SYMPOSIUM ON MATHEMATICAL STATISTICS AND PROBABILITY, edited by Jerzy Neyman. University of California Press (*Theory of Statistics*, $6; *Probability Theory*, $6.50; *Astronomy and Physics*, $6.25; *Biology and Problems of Health*, $5.75; *Econometrics, Industrial Research, and Psychometry*, $5.75). These five volumes comprise papers delivered at the third Berkeley symposium held in 1954 and 1955. They embrace a remarkable diversity of subject matter, including purely mathematical studies, the color and luminosity of the stars, the statistics of clusters of galaxies, problems of genetics and epidemiology, the struggle for existence, value measurement, learning models, psychometric research, problems in contagion, the use of statistics in medical diagnosis. Most of the studies were aided by military funds.

INTERNATIONAL DICTIONARY OF PHYSICS AND ELECTRONICS, edited by Walter C. Michels and others. D. Van Nostrand Company, Inc. ($20). This useful work is unique. It presents in a single volume of 1,000 pages definitions of a wide variety of terms used in pure and applied physics. Here are explained clearly and succinctly Goudsmit's and Uhlenbeck's assumption, Ampere's law, Rolle's theorem, relativity theory, resistance boxes, Maxwell's equations, transistors, elliptic functions, cyclotrons, loop antennas, piezoelectric effects, fuses, the Hartley unit of information, infrared photography, television, and thousands of other laws, relationships, equations and principles, as well as instruments and apparatus. Some of the definitions are short, some quite full, as circumstances require. There are many helpful line drawings and diagrams.

PROGRESS IN NUCLEAR ENERGY, SERIES I: PHYSICS AND MATHEMATICS, edited by R. A. Charpie, J. Horowitz, D. J. Hughes and D. J. Littler. McGraw-Hill Book Company, Inc. ($12). In this first volume of a new series, papers presented at the Geneva Conference on the Peaceful Uses of Atomic Energy are summarized and "coordinated by critical reviews." Among the topics treated are cross sections and neutron yields, neutron resonances in fissionable materials, homogeneous critical assemblies, the physics of fast reactors, highly enriched intermediate and thermal assemblies.



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MATHEMATICAL GAMES

Some old and new versions of ticktacktoe, plus the answers to last month's puzzles

by Martin Gardner

Who has not as a child played ticktacktoe, that most ancient and universal struggle of wits of which Wordsworth wrote:

At evening, when with pencil, and smooth slate
In square divisions parcelled out and all
With crosses and with cyphers scribbled o'er,
We schemed and puzzled, head opposed to head
In strife too humble to be named in verse.

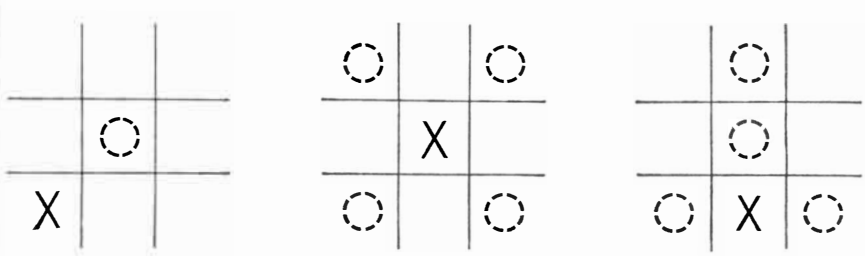
Forms of ticktacktoe were popular in ancient China, Greece and Rome—Ovid mentioned it in his *Art of Love*. At first sight it is not easy to understand the enduring appeal of a game which seems no more than child's play. While it is true that even in the simplest version of the game the number of possible moves is very large—15,120 ($9 \times 8 \times 7 \times 6 \times 5$) different sequences for the first five moves alone—there are really only a few basic patterns, and any astute youngster can become an unbeatable player with only an hour or so of analysis of the game. But ticktacktoe also has its more complex variations and strategic aspects.

In the lingo of game theory, ticktacktoe is a two-person contest which is "finite" (comes to a definite end), has no element of chance and is played with "perfect information," all moves being known to both players. If played "rationally" by both sides, the game must end in a draw. The only chance of winning is to catch an imperfect opponent in a "trap" where a row can be scored on the next move in two ways, only one of which can be blocked.

Of the three possible opening plays—a corner, the center or a side box—the strongest opening is the corner, because the opponent can avoid being trapped at the next move only by one of the eight possible choices: the center. The center opening can be met by seizing one of the four corners. The side opening is in many ways the most interesting, because of its richness in traps on both sides [*see diagrams below*].

A very ancient variant of the game gives each player three counters (one player may use pennies, the other dimes). The two players take turns placing a counter on the board until all six are down. If neither player has won by getting three in a row, each then is allowed to move one counter at a turn to an adjacent empty square, but he can move only vertically or horizontally, not diagonally [*see diagram on page 162*]. The first player has a sure win by placing his first counter in the center box, so this opening is usually barred. After any other opening, the second player must immediately take the center to avoid defeat. This game also ends in a draw with perfect play, but it swarms with potential traps on both sides.

There are variations of the game which permit diagonal moves (one of them attributed to early American Indians). A free-wheeling French version called "*les pendus*" (the hanged) allows any piece to be moved to any vacant



Three openings in ticktacktoe: corner (left), *center* (middle) *and side* (right)

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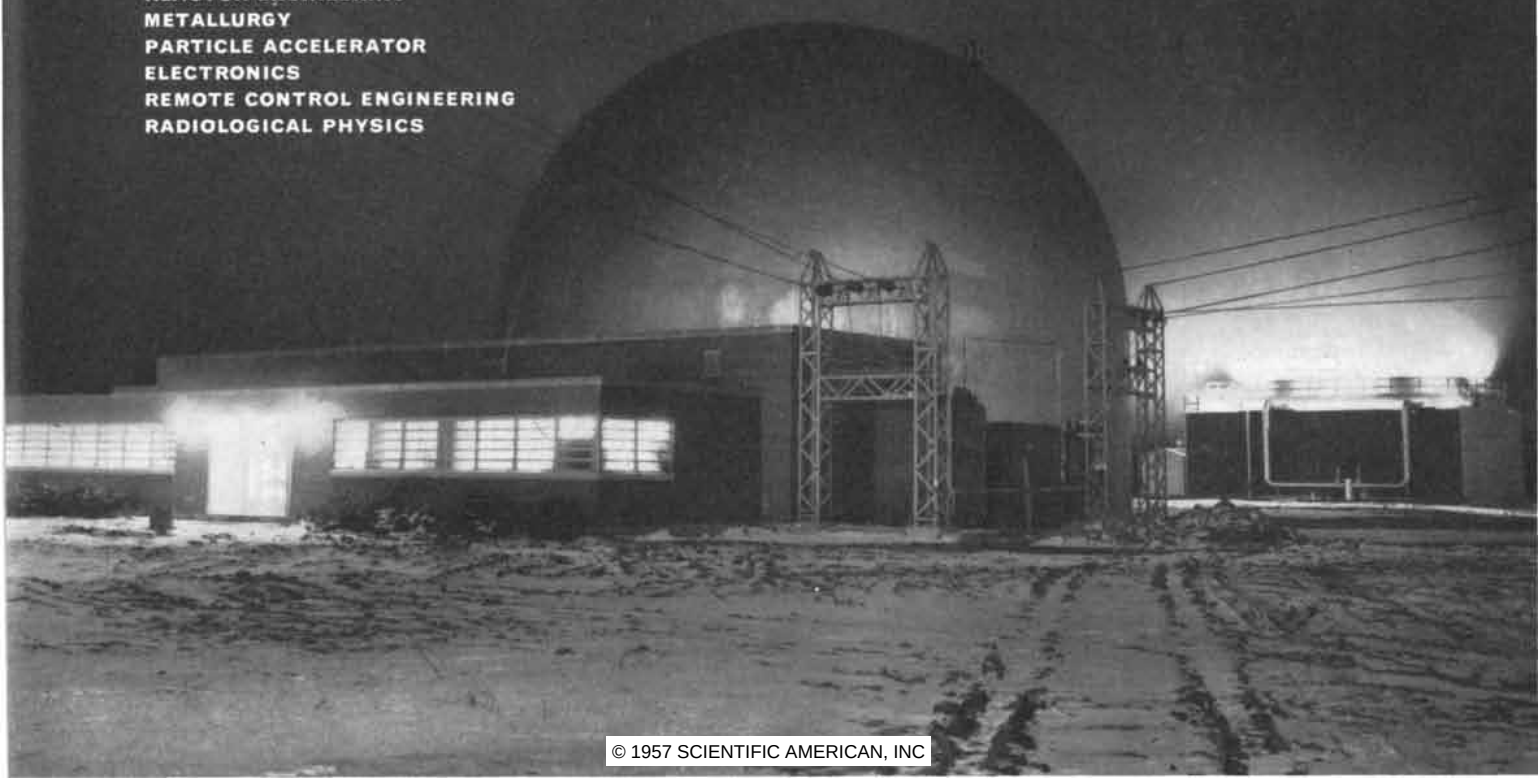


cell. This game is believed drawn if played rationally, whatever the opening.

The moving-counter game can be played with a matrix of 16 boxes (4 by 4), each player using four counters and striving to get four in a row. A few years ago the magician John Scarne marketed an interesting version, called "teeko," on a 5 by 5 board. The players have four counters and can move one space in any direction. The game is to get the four in a row (straight or diagonal) or to assemble them in a square formation on four adjacent cells.

There is a reverse version of simple ticktacktoe in which the first player to get three in a row *loses*. The second player has a decided advantage, but the first player can force a draw if he makes his initial move correctly. (I leave it to the reader to discover what the first move must be.)

In recent years several three-dimensional ticktacktoe games have been marketed. On a 3 by 3 by 3 cube the first player has an easy win, but a more complex version with a 4 by 4 by 4 cube is probably a draw if played rationally.

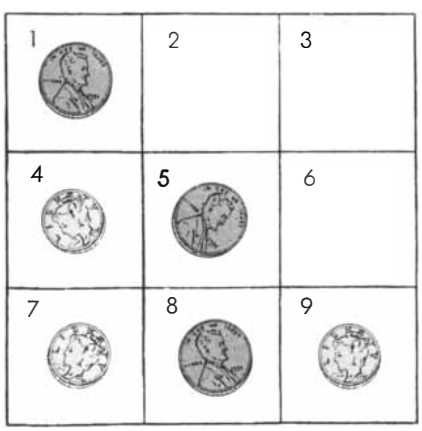
Four-dimensional ticktacktoe can be played on an imaginary hypercube cut into single-layer blocks [*see diagram on page 165*]. In the 4 by 4 by 4 by 4 version the object is to get four marks in a straight line on the hypercube. This is achieved by lining up four marks in a cube formed by piling up in serial order four blocks which occupy the same row or column or main diagonal. In this game the first player is believed to have a sure win, but in the 5 by 5 by 5 by 5 version the game probably must be a draw if played perfectly.

The ancient Japanese game of *gomoku* (five stones) is played on the intersections of a *go* board, which is equivalent to playing on a 19 by 19 square. Players take turns placing counters from an unlimited supply until one player wins by getting five in a line—vertical, horizontal or diagonal. No moves are allowed. The game became popular in England in the 1880s under the name of "gobang."

During the past decade a number of electrical machines for playing ticktacktoe have been constructed. Actually the first robot of this sort was invented by Charles Babbage, the early 19th-century originator of calculating machines [see "The Strange Life of Charles Babbage," by Philip and Emily Morrison; SCIENTIFIC AMERICAN, April, 1952]. Babbage planned to exhibit this machine in London to raise funds for more ambitious projects, but he never built it, because exhibits of other curious machines at the time turned out to be financial failures. A novel feature of Babbage's robot was the fact that, when faced with a choice between equally rational lines of play, the machine made its selection on a random basis through a built-in mechanism, choosing one play if the number of games it had won up to that point was odd and the alternate play if the number was even. "An inquiring spectator," observed Babbage, "might watch a long time before he discovered the principle upon which it [the robot] acted."

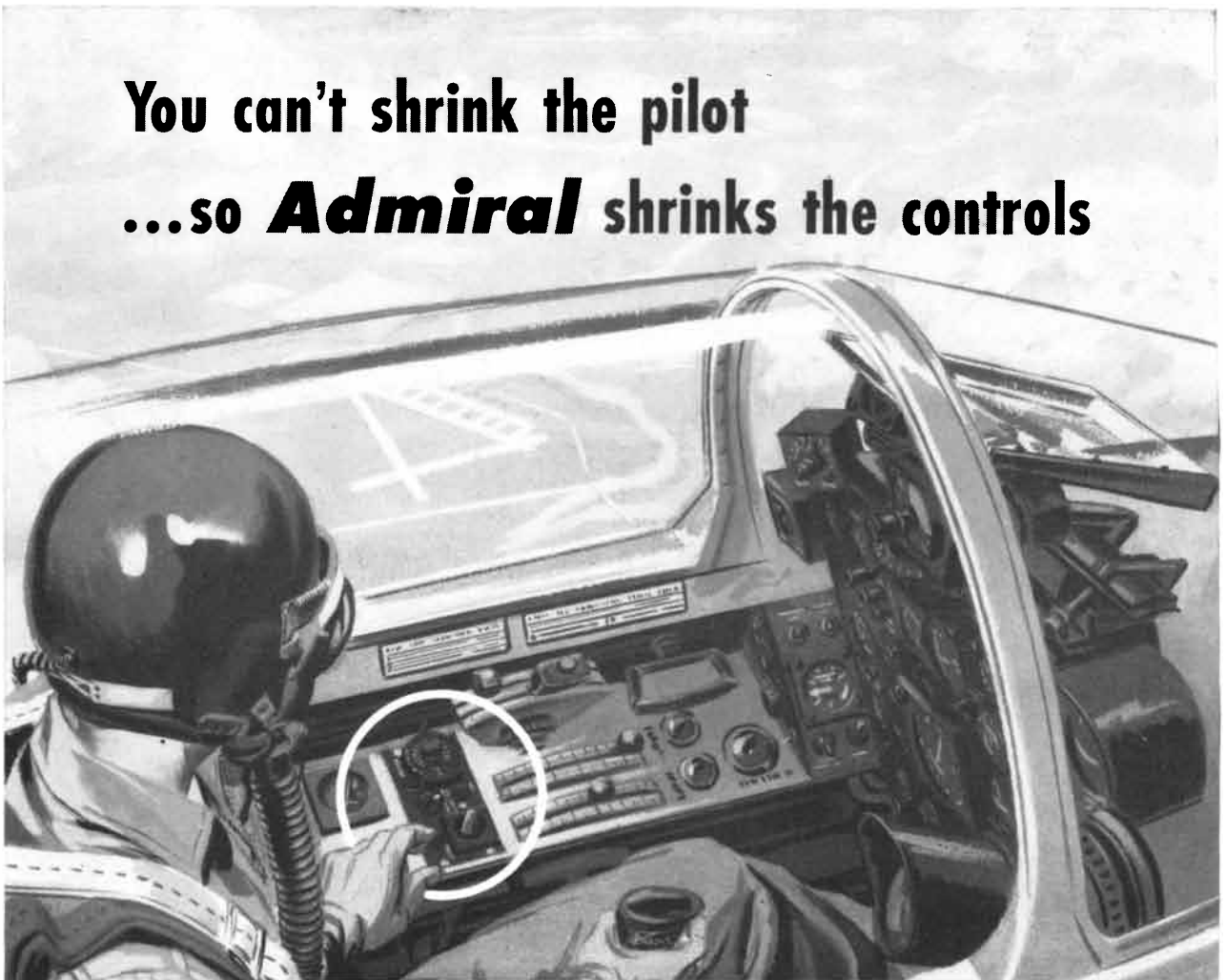
It is not difficult to design a ticktacktoe machine (or program a digital computer) to play a rational game, but the problem becomes more complicated if the machine is to be designed to win the maximum number of games against inexperienced players. The difficulty lies in guessing how a novice is most likely to play. Just how shrewd will he be? To see the sort of complications that arise, let's consider the simple game, identifying the cells by number as on the board depicted below. Assume that the novice opens by taking cell number 8. The machine might do well to make an irrational response by seizing cell 3! This would be fatal against an expert, because the opponent of the machine has a sure win if he next takes cell 9, but an inexperienced player is not likely to hit upon this one winning reply. He will be strongly tempted, in fact, to take cell 4, because this leads to two promising traps against the robot. The machine, however, can now spring its own trap by taking cell 9, followed by 5 on the next move. In short, the machine may win more often with reckless strategies than with safe, rational lines of play, which are apt to lead to a draw.

A truly master player, robot or human, would not only know the most probable responses of novices in general but would also be able to analyze each individual opponent's style of play to de-



The game with moving counters

You can't shrink the pilot ...so *Admiral* shrinks the controls



New transceiver control box reduced to one-fifth former size

The cockpit of a modern fighter plane is packed as tight as a filling in a hollow tooth. As more and more electronic equipment is added to the plane's complement, each new device must fight for space on and behind the instrument panel or console. Now Admiral, maker of the famed AN/ARC27 transceiver, has designed a control box that "moves over" to make room for other needed equipment.

Heart of the new control is an ingenious "mechanical memory" drum that selects any one of 20 preset frequencies with a single knob. Another knob controls three coaxial switches designed by Admiral so the pilot can manually select any of the transceiver's 1750 frequencies. This single compact unit will be universally employed to replace any one of 15 currently used control box combinations. It occupies as little as one-fifth the space and also reduces weight up to 80%.

Here is another instance where Admiral initiated and perfected an important advance in the science of military electronics. Inquiries are invited regarding Admiral's capabilities and production capacity for electronic or electro-mechanical equipment.

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Here members of the Electronics Division discuss systems radar problems related to measurement of missile trajectories. Left to right: K.T. Larkin, radar and command guidance; Dr.S.B.Batdorf, head of the Electronics Division; Dr.R.J.Burke, telemetering; Dr.H.N.Leifer, solid state; S.Janken, product engineering.

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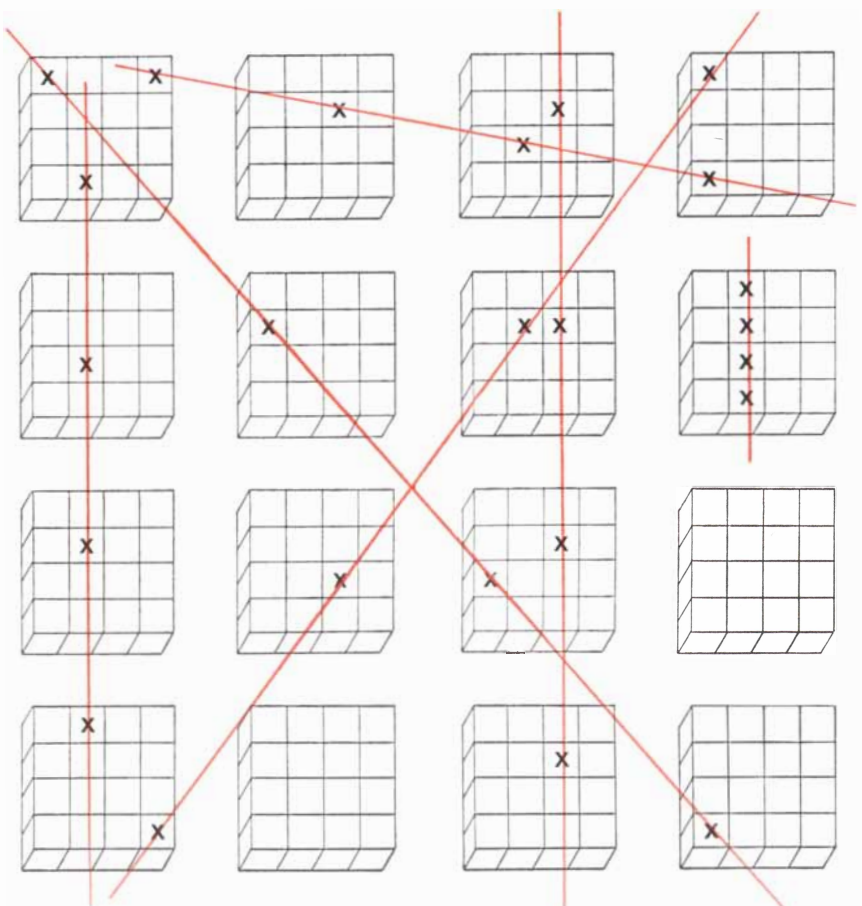
termine what sort of mistakes he is likely to make, and in addition take account of the novice's improvement with increasing experience. At this point the humble game of ticktacktoe plunges us into far from trivial questions of probability and psychology.

Following are the answers to the nine mathematical brain teasers published here last month.

1. Is there any other point on the globe, besides the North Pole, from which you could walk a mile south, a mile east and a mile north and find yourself back at the starting point? Yes indeed; not just one point but an infinite number of them! You could start from any point on a circle drawn around the South Pole at a distance slightly more than $1 + 1/2\pi$ miles (about 1.16 miles) from the Pole—the distance is "slightly more" to take into account the curvature of the earth. After walking a mile south, your next walk of one mile east will take you on a complete circle around the Pole, and the walk one mile north from there will then return you to the starting point. Thus your starting point could be any one of the infinite number of points on the circle with a radius of about 1.16 miles from the South Pole. But this is not all. You could also start at points closer to the Pole, so that the walk east would carry you just twice around the Pole, or three times, or more, toward a limit of an infinite number of circlings of the Pole.

2. In the draw poker game with all cards showing, the first player wins every time if, and only if, he takes four 10s (his fifth card is immaterial) for his starting hand. This prevents his opponent from drawing any hand better than a nine-high straight flush from the rest of the deck. The first player, drawing to his original hand, can then keep one of his 10s and make a royal flush. If his opponent tries to forestall this by drawing four aces, say, the first player can draw a king-high, or at worst a 10-high, straight flush, beating four aces or four jacks, etc.

3. It is impossible to cover the mutilated chessboard (with two opposite corner squares cut off) with 31 dominoes, and the proof is easy. The two diagonally opposite corners are of the same color. Therefore their removal leaves a board with two more squares of one color than of the other. Each domino covers two squares of opposite color, since only op-



Four-dimensional ticktacktoe. Colored lines show some winning plays

posite colors are adjacent. After you have covered 60 squares with 30 dominoes, you are left with two uncovered squares of the same color. These two cannot be adjacent, therefore they cannot be covered by the last domino.

4. The logician points to one of the roads and says to the native, "If I were to ask you if this road leads to the village, would you say 'yes'?" The native is forced to give the right answer, even if he is a liar! If the road does lead to the village, the liar would say "no" to the direct question, but as the question is put, he lies and says he would respond "yes." Thus the logician can be certain that the road does lead to the village, whether the respondent is a truth-teller or a liar. On the other hand, if the road actually does not go to the village, the liar is forced in the same way to reply "no" to the inquirer's question. More complicated forms of the question to the native can be devised, but they all hinge on the same logical principle: namely, that a double negative is equivalent to an affirmative.

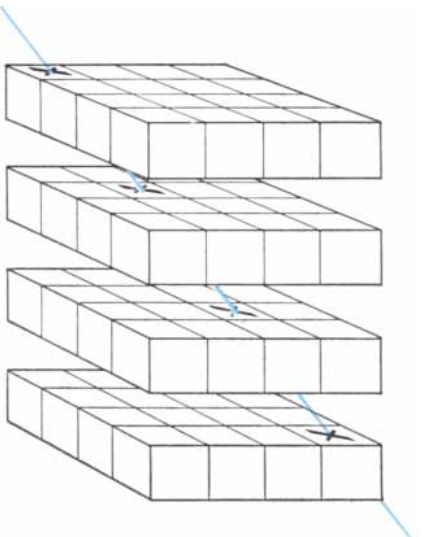
5. You can learn the contents of all three boxes by drawing just one marble. The key to the solution is your knowledge that the labels on all three of the boxes are incorrect. You must draw a marble from the box labeled "black-white." Assume that the marble drawn is black. You know then that the other marble in this box must be black also, otherwise the label would be correct. Since you have now identified the box containing two black marbles, you can at once tell the contents of the box marked "white-white": you know it cannot contain two white marbles, because its label has to be wrong; it cannot contain two black marbles, for you have identified that box; therefore it must contain one black and one white marble. The third box, of course, must then be the one holding two white marbles. You can solve the puzzle by the same reasoning if the marble you draw from the "black-white" box happens to be white instead of black.

6. The answer to this puzzle is a simple matter of train schedules. While the Brooklyn and Bronx trains arrive equally often—at 10-minute intervals—it happens that their schedules are such that the Bronx train always comes to this platform one minute after the Brooklyn train. Thus the Bronx train will be the first to arrive only if the young man happens to come to the subway platform during this one-minute interval. If he enters the station at any other time—*i.e.*, during a nine-minute interval—the Brooklyn train will come first. Since the young man's arrival is random, the odds are nine to one for Brooklyn.

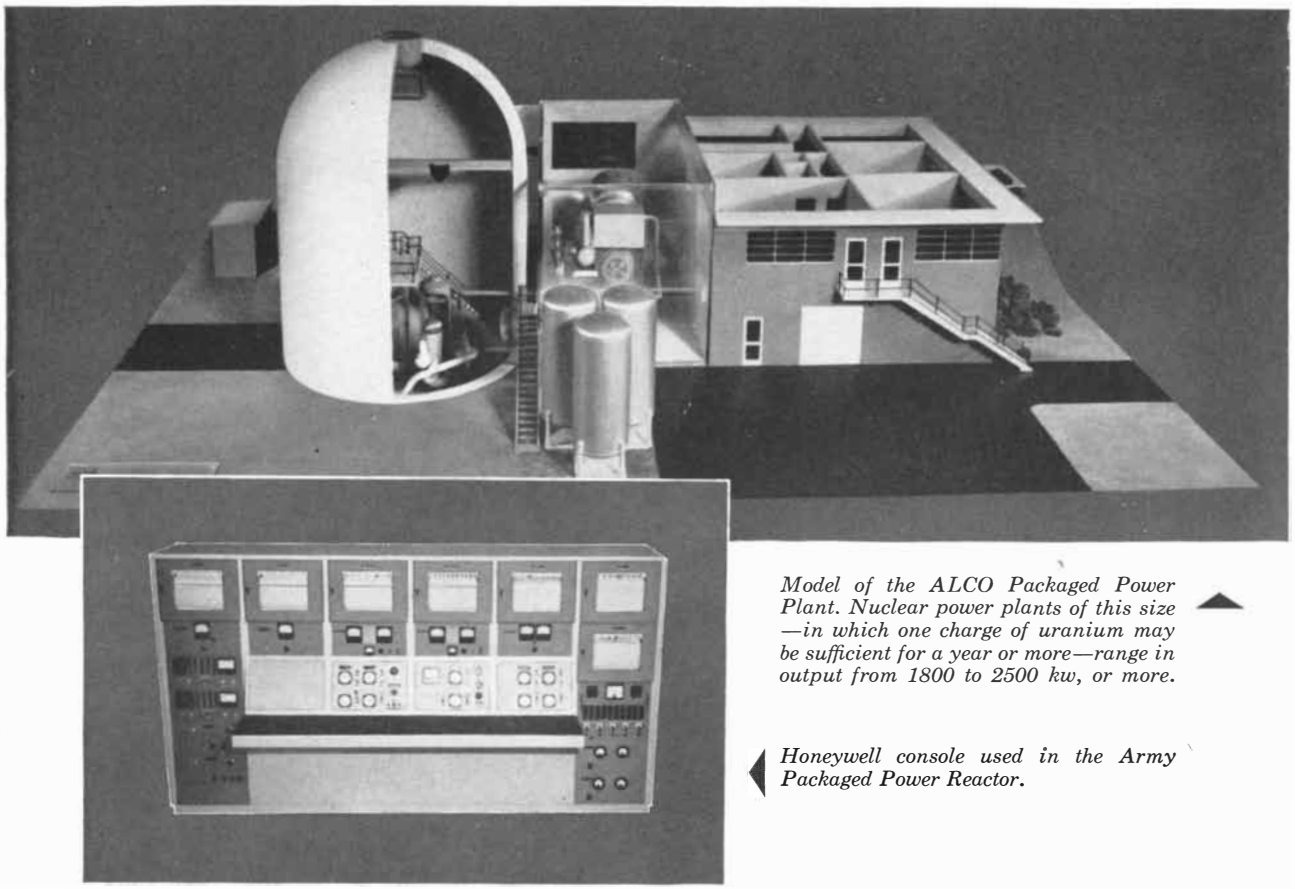
7. There is no way to reduce the cuts to fewer than six. This is at once apparent when you focus on the fact that a cube has six sides. The saw cuts straight—one side at a time. To cut the one-inch cube at the center (the one which has no exposed surfaces to start with) must take six passes of the saw.

8. The commuter has walked for 55 minutes before his wife picks him up. Since they arrive home 10 minutes earlier than usual, this means that the wife has chopped 10 minutes from her usual travel time to and from the station, or five minutes from her travel time to the station. It follows that she met her husband five minutes before his usual pick-up time of five o'clock, or at 4:55. He started walking at four, therefore he walked for 55 minutes. The man's speed of walking, the wife's speed of driving and the distance between home and station are not needed for solving the problem. If you tried to solve it by juggling figures for these variables, you probably found the problem aggravating.

9. The counterfeit stack can be identified by a single weighing of coins. You take one coin from the first stack, two from the second, three from the third and so on to the entire 10 coins of the tenth stack. You then weigh the whole sample collection on the pointer scale. The excess weight of this collection, in number of grams, corresponds to the number of the counterfeit stack. For example, if the group of coins weighs seven grams more than it should, then the counterfeit stack must be the seventh one, from which you took seven coins (each weighing one gram more than a genuine half-dollar).



A win on hypercube *(see page 165)*



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Honeywell console used in the Army Packaged Power Reactor.

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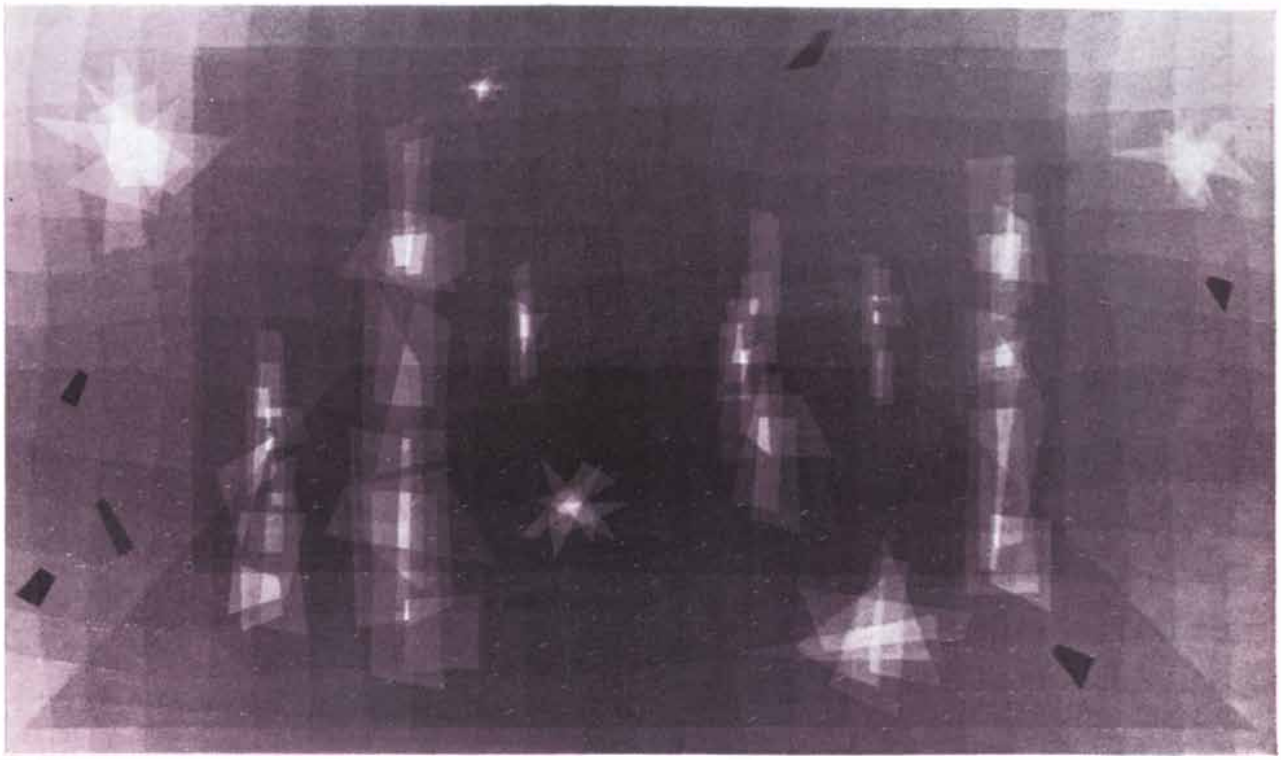

"NIGHT CHESS" a painting by Simpson-Middleman, a doubly gifted team of artists with a scientist's penetrating insight. They portray here "a chess-like game played in a segment of space on a skewed board with pieces of uncertain value against an unknown antagonist. The next move is unforeseen—it will come out of the dark—it will be history's most fateful gambit."

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THE AMATEUR SCIENTIST

Wherein a gifted naturalist and high-speed photographer experiments with hummingbirds

When a housefly lands on the ceiling, does it execute a wing-over, a slow roll or a half-loop? Do rattlesnakes bite? Can the fast deerfly break the sonic barrier? For answers to such questions a good man to consult is Walker Van Riper of Denver, Col., who has been tracking down odd facts concerning animal behavior ever since he retired from the investment banking business 12 years ago. His high-speed camera has proved that rattlesnakes do not bite—they stab [see "How a Rattlesnake Strikes," by Walker Van Riper; SCIENTIFIC AMERICAN, October, 1953]. It has also shown that the deerfly is easily outstripped by many other insects. Van Riper does not yet have a final answer on the housefly's landing performance, but he is currently studying the matter.

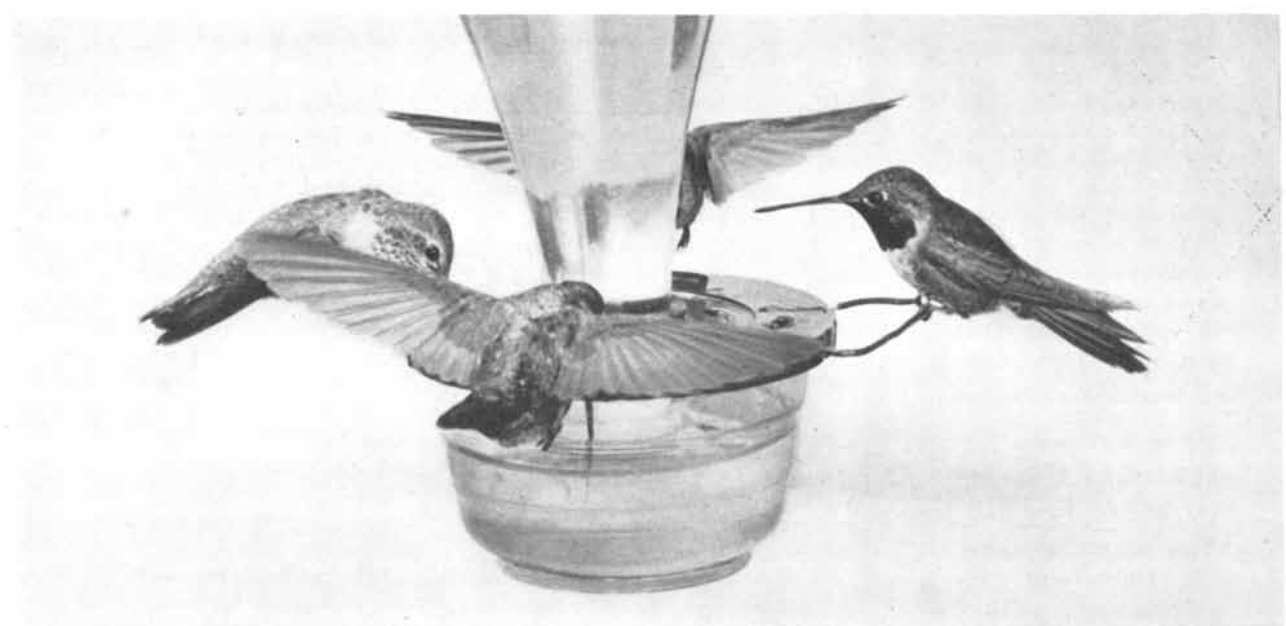
He does much of his work at the Denver Museum of Natural History, where he is an honorary curator. "Van Riper," says A. M. Bailey, director of the Museum, "is the sort of fellow who is the perfect answer to the small museum director's prayer. You couldn't possibly pay him what his extraordinary skills are worth, yet he does the job for the joy of doing it, and does it better than anybody else could do it." Van Riper is inclined to take a more modest view of his accomplishments: "Anyone can help chip question marks from the rough edges of natural science if he puts his mind to it. Take hummingbirds, for example."

Van Riper has written us the following account of his hummingbird studies.

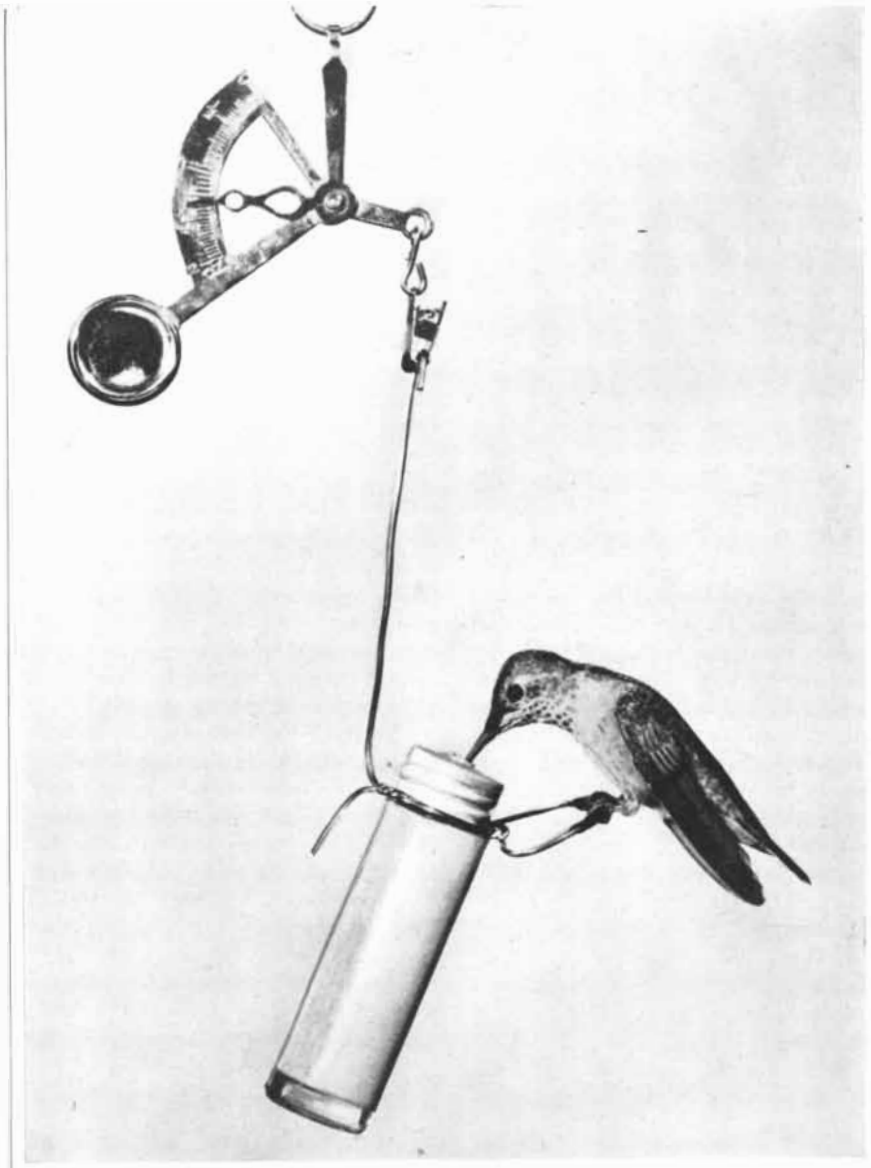
"Probably no other bird is so amenable to intimate observation as the hummingbird. Fairly accurate answers can be obtained to such questions as: What does it eat and how much? How fast and in what manner does it fly? What is its size and weight? How are the young cared for? Besides its convenience as a subject, the hummingbird is the most beautiful, vivacious, bold and interesting of birds.

"These words may sound a bit extravagant, but they are well backed by authority. John Gould, the great British ornithologist of the 19th century, loved the hummers beyond all other birds. His five-volume *A Monograph of the Trochilidae, or Humming-Birds* testifies to this. Eugène Simon, head of the Entomological Society of France, produced a highly valuable work on the classification of hummingbirds which took 30 years in the making. Simon had dedicated his life to the study of spiders, but during an expedition to Venezuela to collect spiders he was 'seduced' by the hummingbirds and decided thereafter to divide his labors between his first love and his second. Considering that there are some 600 species of the Trochilidae, more than in any other bird family, their taxonomy is no mean task. In fact there is a word for a specialist on hummingbirds—'trochilidist.'

"Hummingbirds belong exclusively to the New World. Most of the species are tropical. Only 14 breed regularly in the U. S. On the eastern slope of the Rockies in Colorado we have three species—the broadtailed, the rufous and the calliope. The first is *the* hummer of this area,



Broadtail hummingbirds surround the feeder used in a population experiment. A male is at the right; a female, at the left



Apparatus used in a weighing and feeding experiment

nesting in the mountains, the foothills and in city gardens. It is very similar to the ruby-throated hummingbird, the only species seen in the eastern half of the country.

"The rufous and calliope hummingbirds show up here only during their return migration to Mexico from the north, where they breed in the summer. The rufous probably has the longest migratory movement of any hummingbird: it nests as far north as southern Alaska. It also has another distinction: it was first described by none other than Captain Cook. On his third and last voyage he was given some rufous hummers by the natives of Vancouver Island.

"Usually by mid-July a fair number of the migrants from the north arrive here. The mature males come first and stay only two weeks or so. They are followed by females and the young. The young males often stay into September, sometimes outstaying the resident broadtails. The calliope is the smallest of our hummers, weighing about 2.5 grams—the weight of a dime. You could send about a dozen of them by first-class mail for a three-cent stamp!

"The amenability of hummingbirds to close-up observation and experiment is due primarily to the fact that they are extraordinarily fearless, probably because they have no natural enemies of importance. Coupled with their eagerness for food and readiness to accept artificial food, this makes them excellent laboratory residents.

"The artificial food for hummers is a syrup comparable to the flower nectar on which they usually feed. Hummingbird fanciers have a great variety of notions

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about the best kind of syrup. I recently made a preference test with a mature female broadtail. I set up a series of bottles side by side with different mixtures: sugar solutions in water at various concentrations; sugar, orange juice and water; honey and water; honey, orange juice and water. The bird showed a clear preference for the syrup made of one part sugar to one part water (*i.e.*, equal proportions by weight). Incidentally, the feeding bottles were in my garden: to keep out bees and wasps the aluminum cap had only a tiny hole (an eighth of an inch) which was big enough for the hummingbird's bill; to keep out ants I smeared a band of sticky material around each bottle.

"I next set up an experiment to determine the amount of syrup consumed daily by my bird, together with its relationship to her weight. The hummer fed from a single bottle while resting on a wire perch hanging from a postal scale. By remote control I tripped a camera to photograph the scale reading and record the weight of the bird. It averaged 4.3 grams (less than one sixth of an ounce), and the bird consumed each day an average of 1.8 grams of sugar—42 per cent of her weight.

"Intake of fuel at this rate is astonishing. Oliver Pearson has shown that the hummingbird has the highest metabolic rate of any warm-blooded animal so far measured [see "The Metabolism of Hummingbirds," by Oliver P. Pearson; SCIENTIFIC AMERICAN, January, 1953]. In calories my bird ate 1.7 calories of sugar per gram of its body weight per day—more than 30 times the daily rate of food intake needed by a man doing moderately hard physical labor. And this bird by no means limited her feeding to my bottle: she also ate insects and flower nectar each day!

"For several years I have maintained a hummingbird feeding station in a bit of rough yellow-pine and scrub-oak country on a ranch 25 miles south of Denver,

Male calliope hummingbird, showing the gorget streaked with white

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			0-2	2-3	4-15	0-2	2-3	4-15	1-2	2-3	4-15	1-2	2-3	4-15
• ***SYSTEMS*** *(Integration of theory, equipments and environment to create and optimize major electronic concepts.)*	**AVIATION ELECTRONICS • CONTROLS**		W	W	W C	W	W	W C	W	W	W C			
	DIGITAL DATA HANDLING DEVICES	M C		M C	M C		C	C		C	C			
	MISSILE WEAPONS SYSTEMS • RADAR	M W	W	M W X C	M W X C	W	M W C	M W C	W	M W X C	M W X C			
	INERTIAL NAVIGATION			W C	W C		W C	W C		W C	W C			
	COMMUNICATIONS		C	C N	C N	C	C				C N			
• ***DESIGN • DEVELOPMENT*** **MISSILE WEAPONS SYSTEMS**—Planning and Design--Radar—Fire Control—Servomechanisms—Computers		C M	W C M X	W C M X	W C M X	W C M	W C M	W C M X	W C M	W C M X	W C M X			
AVIATION ELECTRONICS—Radar—Computers—Servomechanisms—Shock and Vibration—Circuitry—Remote Control—Heat Transfer—Sub-Miniaturization—Automatic Flight—Automation—Transistorization—Infrared—Airborne TV		W C	W C X	W C X	W C X	W C	W C X	W C X	W C X	W C X	W C X			
RADAR—Circuitry—Antenna Design—Servo Systems—Gear Trains—Intricate Mechanisms—Fire Control—Information Handling—Displays		M C	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X	W M C X			
COMPUTERS—Systems—Advanced Development—Circuitry—Assembly Design—Mechanisms—Programming—Digital Data Handling Devices		M	C W	M C X W	M C X W	C W	M C X W	M C X W	C W	M C W	M C W			
KINESCOPES (B & W and Color), OSCILLOSCOPES—Electron Optics—Instrumental Analysis—Solid States (Phosphors, High Temperature Phenomena, Photosensitive Materials and Glass to Metal Sealing)			L	L Y	L Y	L	L Y	L Y	L	L Y	L Y	L	L Y	L Y
RECEIVING TUBES—Tube Design—Test and Application Engineering—Chemical and Physical Development—Methods and Process Engineering—Advanced Development			H	H	H		H	H		H	H		H	H
SEMICONDUCTORS—Transistors—Semiconductor Devices—Materials			V	V	V	V	V	V	V	V	V	V	V	V
MICROWAVE TUBES—Tube Development and Manufacture (Traveling Wave—Backward Wave—Magnetron)		H	H	H	H		H	H		H	H		H	H
GAS, POWER AND PHOTO TUBES—Photosensitive Devices—Ceramic to Metal Sealing—UHF and VHF—Super Power			L	L	L	L	L	L	L	L	L	L	L	
COMMUNICATIONS—Specialized Systems—Microwave—Mobile—Aviation—Audio—Propagation Studies—Acoustics—Transducers			C N	C N	C N		C	C	C N	C N	C N			
BROADCAST AND TV—Monochrome and Color Studio Equipment—Cameras—Monitors—High Power Transmitters			C	C	C	C	C	C	C	C	C			
• ***SYSTEMS APPLICATION*** *(Evaluation and Planning—Design and Development—Modification—Specification)*														
MISSILE TEST INSTRUMENTATION (Data Acquisition and Processing)—Radar—Telemetry—Timing—Communications—Optics—Computers		F	F S	Z F S	Z F S	F S	F S	Z F S	F S	Z F S	Z F S			
RADAR—Airborne—Surface—Shipboard—Sonar—Fire Control		F	F S	Z F S	Z F S	F S	F S	Z F S	F S	Z F S	**Z F S**			
COMMUNICATIONS—Radio—HF—VHF—UHF—Microwave—Telephone—Teletype—Telegraph Terminal Equipment—Wave Propagation		F	F S	F S	F S	F S	F S	F S	F S	F S	**F S**			
• ***MACHINE DESIGN*** Mechanical and Electrical—Automatic or Semi-Automatic Machines			L H	L H	H	L	L H	H		L	L			

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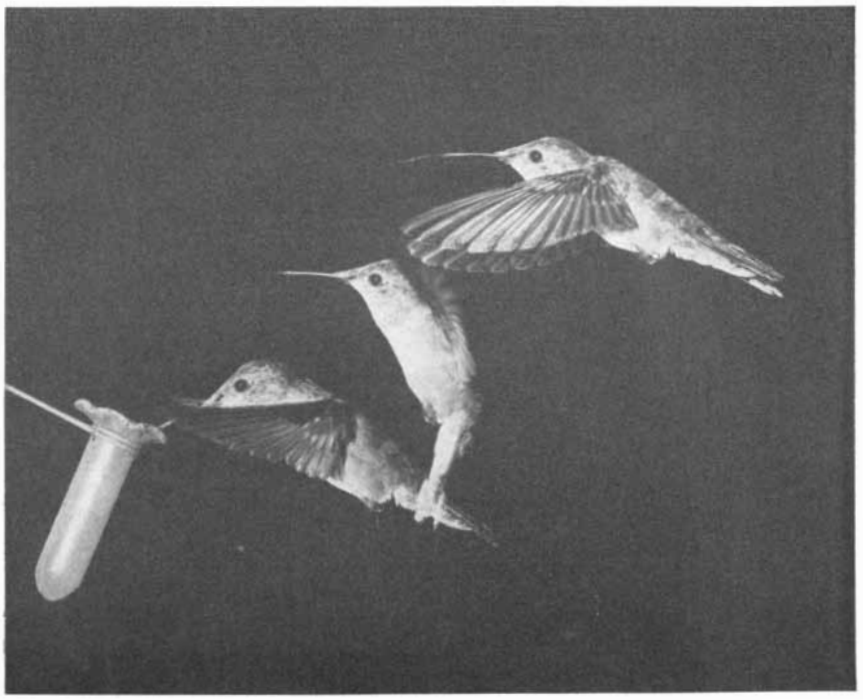

Repetitive-flash photograph shows a hummingbird flying backward from left to right

where it is possible to assemble many more birds than can be attracted to a single city garden. I was able this past summer to take a census of the hummingbird population on the ranch. Early in May I put out some feeders of a new type designed by Erwin Brown [*see photograph on page 169*]. It was made of a five-ounce jelly container with a red lock-top. A hole in the center of the lid admits the neck of a pop bottle, and four eighth-inch holes are spaced around the perimeter. These holes admit the hummingbird bill, but not bees or wasps. The lid is fastened to the bottle with a couple of three-quarter-inch hose washers, one above and one below. The bottle is filled, the cup fastened to the lid, then the whole is inverted and hung. There is little evaporation, and it may be assumed that the entire output of this feeder goes to hummingbirds alone.

"On June 20 I had half a dozen of these feeders distributed in an area about a mile square. I estimated that the number of hummers, all broadtails, then feeding at my station was 66. A few nests had been found and, judging from these, most of the hens in the area were sitting on eggs at the time. By July 11, as these hatched, the population rose to 118.

"At this point the first migrating rufous appeared. The coming of the first male rufous is always an exciting event, for he is spectacularly beautiful. The rufous is sometimes called the golden hummingbird. His back is the color of burnished copper, and he has a gorget (throat patch) which is described as 'of a surpassingly vivid fiery red or metallic scarlet changing to crimson, golden and even brassy green.' The metallic shine and changing hues of the gorget are due to refraction and reflection of the light by minute elements in the structure of the scale feathers.

"The rufous is the most pugnacious and aggressive of our hummers. A bit smaller than the broadtail, but meaner, he takes little time to demonstrate who is boss. Within 24 hours after arrival the rufous males have taken over command of every feeding bottle. In flight they make a distinct buzz, like that of a bumblebee, in contrast to the whistle of the male broadtail. The young male broadtail at first flies with a hum, like his mother, but he acquires whistling wing slots when his second set of feathers develops.

"With the coming of the migrants my hummingbird population jumped to 132. As more broadtail young joined the feeders, it increased gradually to a high of 166 on July 24. The population then declined steadily and was down to 70 by the end of the month. It stayed at that level for most of August, dropped to 39 by September 4 and to zero by the 11th.

"During July, when the population was at its peak, I occasionally supplied only a single feeder, generally a red bowl, in order to concentrate the birds

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AGE:
15 years in missiles; 37 in aircraft.

EDUCATION:
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EXPERIENCE:
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for observation and pictures. This often brought together a flock of 25 or 30 hummers—fighting, chasing, diving and investigating around the bowl. When I sat in my car, some would fly in the window and hover a foot from my nose to look me over. When I put up my photographic apparatus, the birds investigated the camera, lights, lens—everything shiny, and especially everything red. If I held the red bowl in my hands, half a dozen birds would alight on my hands or the rim of the bowl to feed at once.

"It was an easy matter to get pictures of my subjects in all positions—flying, feeding, sitting. Exact positioning is important, especially for color shots of the brilliant male gorgets, which flash in full glory only when the bird is turned toward the light and head-on to the camera. The photography of hummingbirds is a highly interesting art. A few of my friends and I have formed the most exclusive of all scientific societies—the Society of Trochilidographers (photographers of hummingbirds). The art requires the special high-speed electronic flash invented by H. E. Edgerton of the Massachusetts Institute of Technology. An exposure of one 5,000th of a second will stop a hummingbird's wings fairly well; a 20,000th of a second stops them cold. We usually use three lights—two at the camera and one on the background, which would be black without it. Color, as well as black and white, is practical and successful with this setup.

"The pictures on these pages showing hummingbirds in flight were made at a 20,000th of a second. One of them is a rare photograph of a male calliope [*see page 172*]. This little rascal is rather uncommon in our parts, only a few coming through in migration. I had not had more than a bare glimpse of two or three and had never got a chance at a picture until R. J. Niedrach, curator of birds at the Denver Museum, discovered one feeding on a patch of matrimony vine last summer. We tried every trick in our repertoire to introduce the calliope to a feeding bottle, but he was single-mindedly intent on the matrimony vine and would not be enticed. So I

Lowering a hummingbird nest. The nest is at right inside the fork of the two limbs

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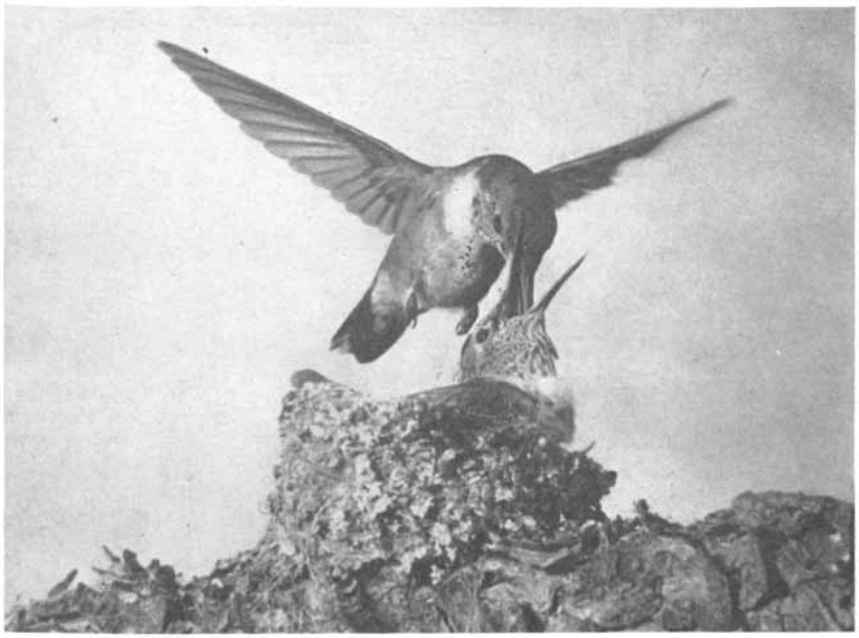

A female broadtailed hummingbird feeds one of her young on the wing

finally had to set up my camera and lights near a prominent plant and wait him out. I made myself as comfortable as possible with a camp chair and umbrella (it was hot) and sat 25 or 30 feet away with a remote-control button on my hand. In a week's waiting I managed to get three or four good shots. I had to take him on a dark background, because a background light spooked him just enough to keep him away from the target spot.

"There is an old argument about whether a hummingbird can fly backward. The Duke of Argyll, in a Victorian work of some merit, held that it was physically impossible for any bird to do this and that observations to the effect that the hummingbird did were purely illusory. The dispute is comparable to the modern one about whether a baseball curves. In both cases the high-speed flash has given a clear answer: a curve can be thrown; the hummingbird can fly backward.

"One of our pictures shows the hummingbird in the act [*see page 174*]. Three flashes were set off in rapid succession. We used a black velvet background—an essential in multiple-exposure photography. The camera shutter was open for a few seconds. The first flash shows its bill dipped in the feeding bottle and starting to withdraw backward; the next two catch it backing up.

"A pair of successive flashes can determine the speed of a flying bird, and three or more will give both speed and acceleration. C. H. Greenewalt, a member of our society, has published some interesting results for nuthatches and chickadees flying to and away from a feeding table. These measurements are of some importance, for ornithological literature is loaded with inaccurate and contradictory figures. I recently looked up the speed of the duck hawk in three natural history books which happened to be lying on my reading table. One gave the speed as 80 miles per hour, another 180 and the third 270! My own incomplete experiments have so far failed to show the duck hawk diving at more than 57 miles per hour.

"Various speeds have been reported for the flight of the hummingbird. My guess is that most of these are greatly exaggerated. In this field it is fairly safe to assume that the better the observation, the slower the speed. Ordinary experience shows that we are very likely to overestimate the velocity of small objects nearby. A bee seems to zip past your nose at bullet-like speed, but it actually does not exceed 10 miles per hour.

"The dive-bombing flight of the male broadtail hummer probably shows him at his greatest speed. A well-known ornithologist once told me that he thought this was the highest velocity attained by any bird. A male broadtail in courtship display before a female flies past her, generally near the ground, soars straight up 40 to 50 feet, poises there for a moment, and then swoops down past her and soars again, tracing a deep U-shaped arc. He repeats this performance several times. His fast power dive produces a loud tinkling whistle, which rises in

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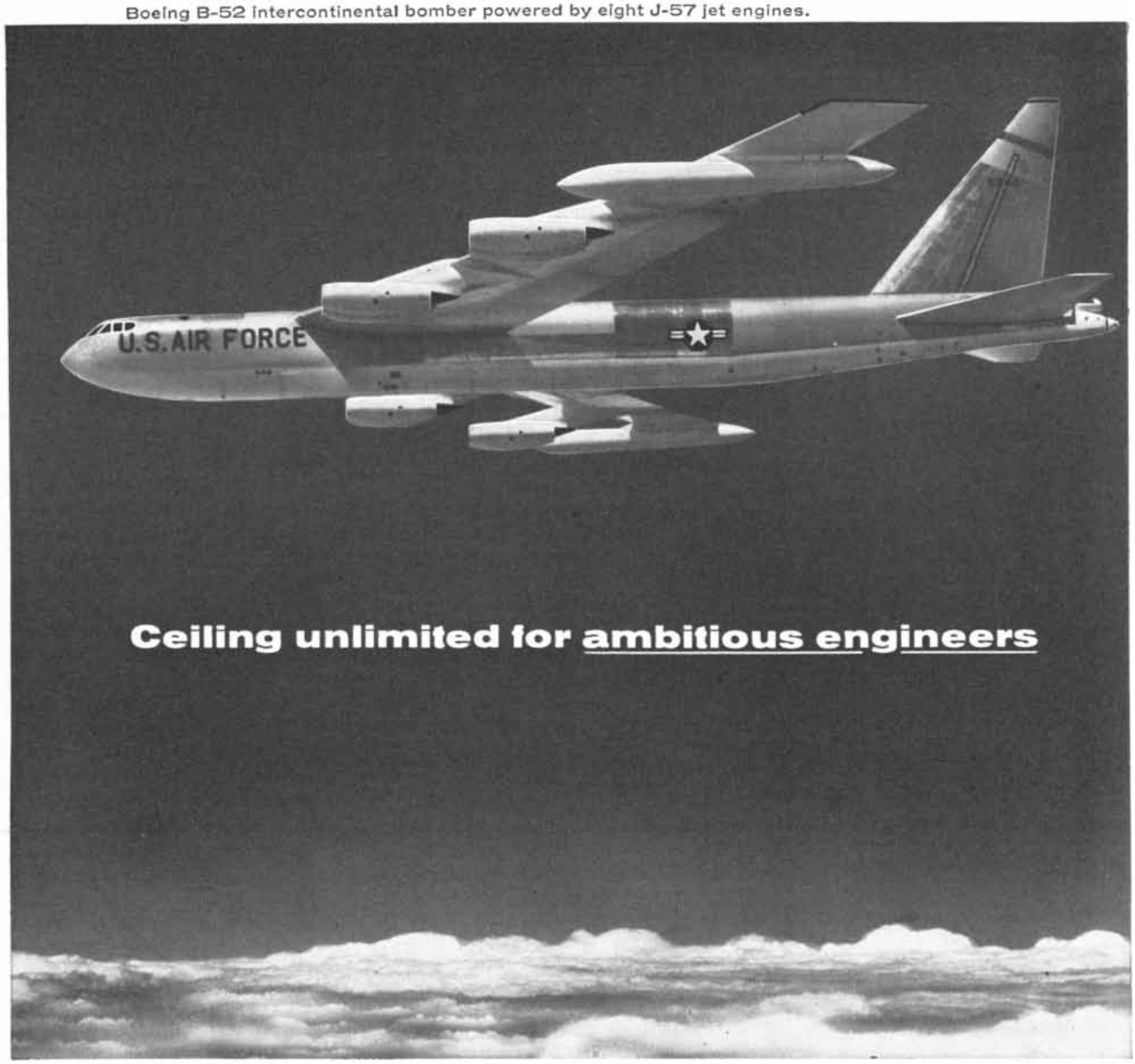

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pitch with increasing wingbeat until he reaches his greatest velocity at the bottom of the dive.

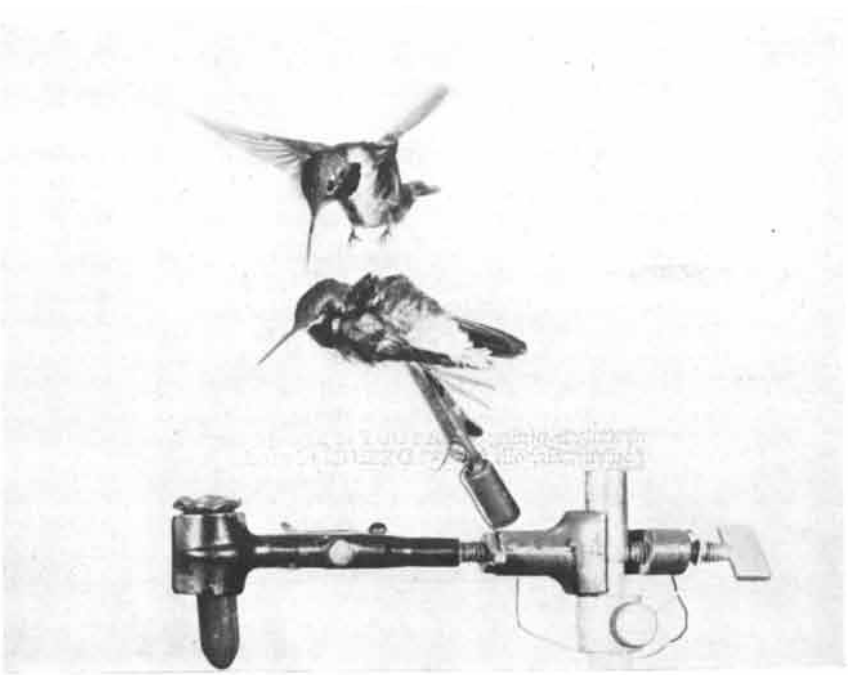
"I set up my camera with the electronical flash timed to go off twice, the interval being a hundredth of a second. This system works satisfactorily to time the diving speed of a barn swallow, but in many trials I was unable to get an accurate measure of the hummer's dive. You have to be a super wing-shot to hit a diving hummer on the nose.

"I was, however, able to get a good measure of the hummer's speed in straightaway flight as one chased another away from his feeding bottle. This maneuver looks faster than it really is; actually it does not exceed the hummer's speed in ordinary level flight. In 14 measurements the chasing speed ranged from around 18 to 24 miles per hour. I think the reason it does not go higher may be that the bird is slowing up as it approaches the intruder, the objective being not to hit him but to make him fly away.

"I attacked the problem of the diving speed in another way, without the camera. I noticed that a female would often perch on a bush near a feeding cup, and this pause would stimulate a male to do his stuff. The male generally soared to the height of the highest tree at the place before diving. After measuring the height of the tree, I timed a considerable number of dives by different birds with a stop watch. Assuming that the velocity reached at the bottom of the dive is twice the average for the whole dive, I calculated the hummer's top speed to be 61.2 miles per hour.

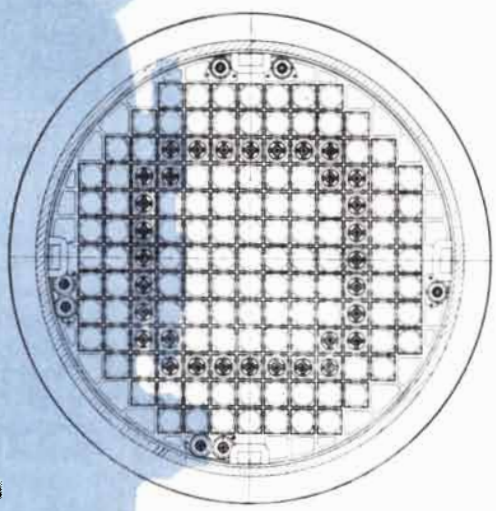
"The hummingbird has been called the most aerial of all birds. It never walks or hops. To turn around on a perch, it takes wing for the turn. If it wishes to move half an inch to one side, it flies there. Sometimes a mother bird will even feed its nestlings on the wing, hovering above the baby instead of alighting on the nest. In order to photograph this I had to lower a nest from a tree to a convenient position near the ground. I sawed off a limb containing a nest of fledglings 25 feet up on a yellow pine, and with ropes I lowered the limb by four stages on successive days. The little hen was a bit disturbed by all this, but not too much. I have tried this nest-lowering stunt several times. It can be done with other birds, but I know of none that will sit as tight as the hummer sometimes does. After I got the limb down to a convenient level, I found that to train my camera on the nest I had to move a branch on the upper side of the nest out of the way. I sawed it through and attached a hinge, so that it could be kept in the accustomed position but could be swung out of the way when I wanted to take pictures of the nest. It turned out that this fold-back of the branch excited the hen just enough so that she fed her babies on the wing more often than not. All of which was just what I wanted.

"The broadtail hen builds the nest,



A male broadtail hummingbird attacks a stuffed rival

the challenge of nuclear power



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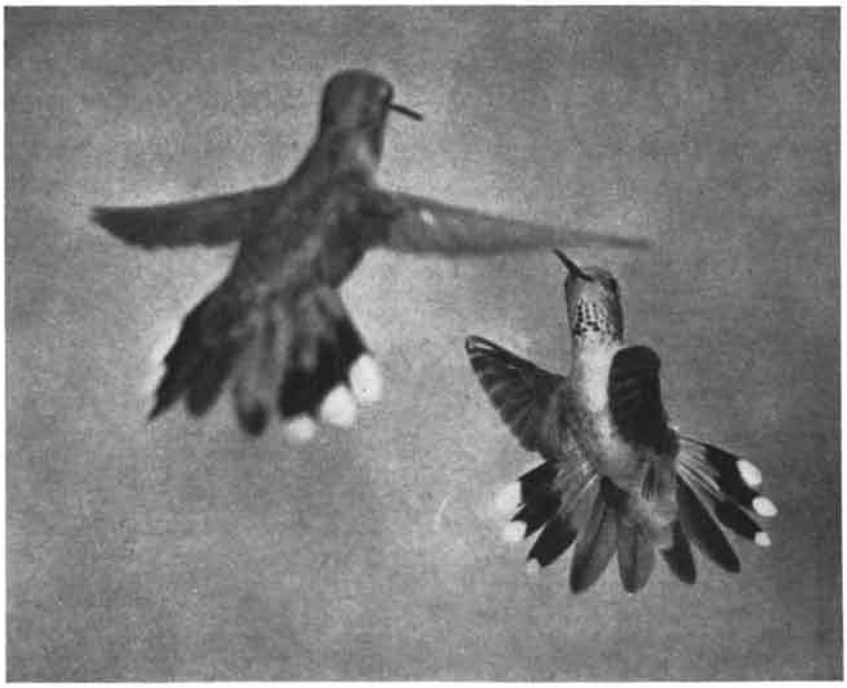

Two female broadtails threaten each other in flight

incubates the eggs and raises the babies with no assistance of any kind from the male. In fact, there is some evidence that she selects the nest site and starts building before she picks out a mate, and, after the briefest possible association with him, returns to the nest and resumes her domestic duties. The mating is so brief that in many years of hummingbird watching I have never seen it, and it has been seen only a few times by others. These little birds are independent individuals: save for the mother's care of the young, they show little tolerance for one another's company.

"The male is never allowed to perch near the nest. Nor is any other bird, for that matter. The female's attack is a kind of dive-bombing: she zips down on an intruder from a couple of feet above, just brushing its back. No harm is done, but the repetition of the act—zip, zip, zip, back and forth—soon drives the objectionable one away. I have seen female broadtails chase many kinds of birds in this way.

"For aggressiveness, though, the males take the prize. Chasing and fighting are the order of the day around the feeding bottles. Occasionally the sound of contact between two birds can be heard, and two or three times I have known of birds being knocked out. The male will peck at its mirror image, at a stuffed hummer and even at just the stuffed head and gorget of a male hummer. Females also fight sometimes with other females. But in both sexes the belligerency usually goes no further than threatening behavior. Its purpose seems to be to chase away an intruder or rival, rather than direct combat.

"Some years ago a party of us trochilidographers, camping in the Huachuca Mountains in southern Arizona, found a young male blue-throated hummingbird which we named 'Junior.' One evening an approaching hawk caused a clatter in a chicken yard about 50 yards away. Tiny Junior, seeing the hawk from his lookout atop a nearby apple tree, went for the hawk and actually put it to flight!

"The life span of the hummingbird is still unsettled. I have known of one which lived five and a half years in captivity and have an unconfirmed report of another that lived to 11. One of my friends had a hummer nest in his garden seven years in succession.

"The act of mating, as I mentioned, has rarely been observed, and the few accounts of it differ greatly. It has been reported to take place both on the wing and on the ground. One report of the calliope says: 'As he passed the female, she fluttered and hung head downward on her perch. The male alighted above her, with vibrating wings, and coition took place in that position.'

"There are still many questions to be investigated. I hope the day will never come when I am satisfied that I know all the answers about the life history of this most fascinating of all birds."

INDEX OF ADVERTISERS

MARCH, 1957

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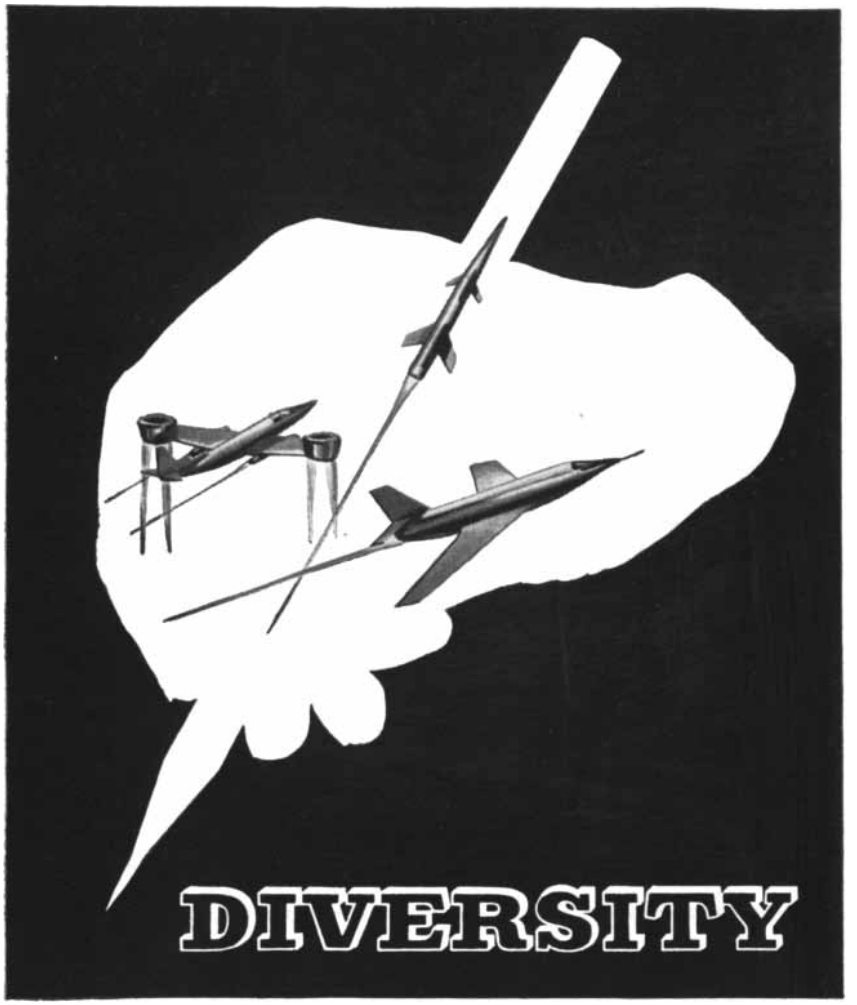

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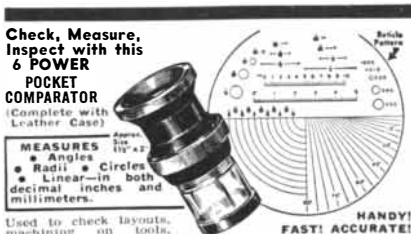

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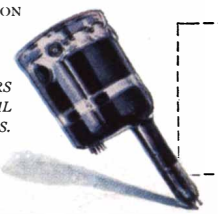

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