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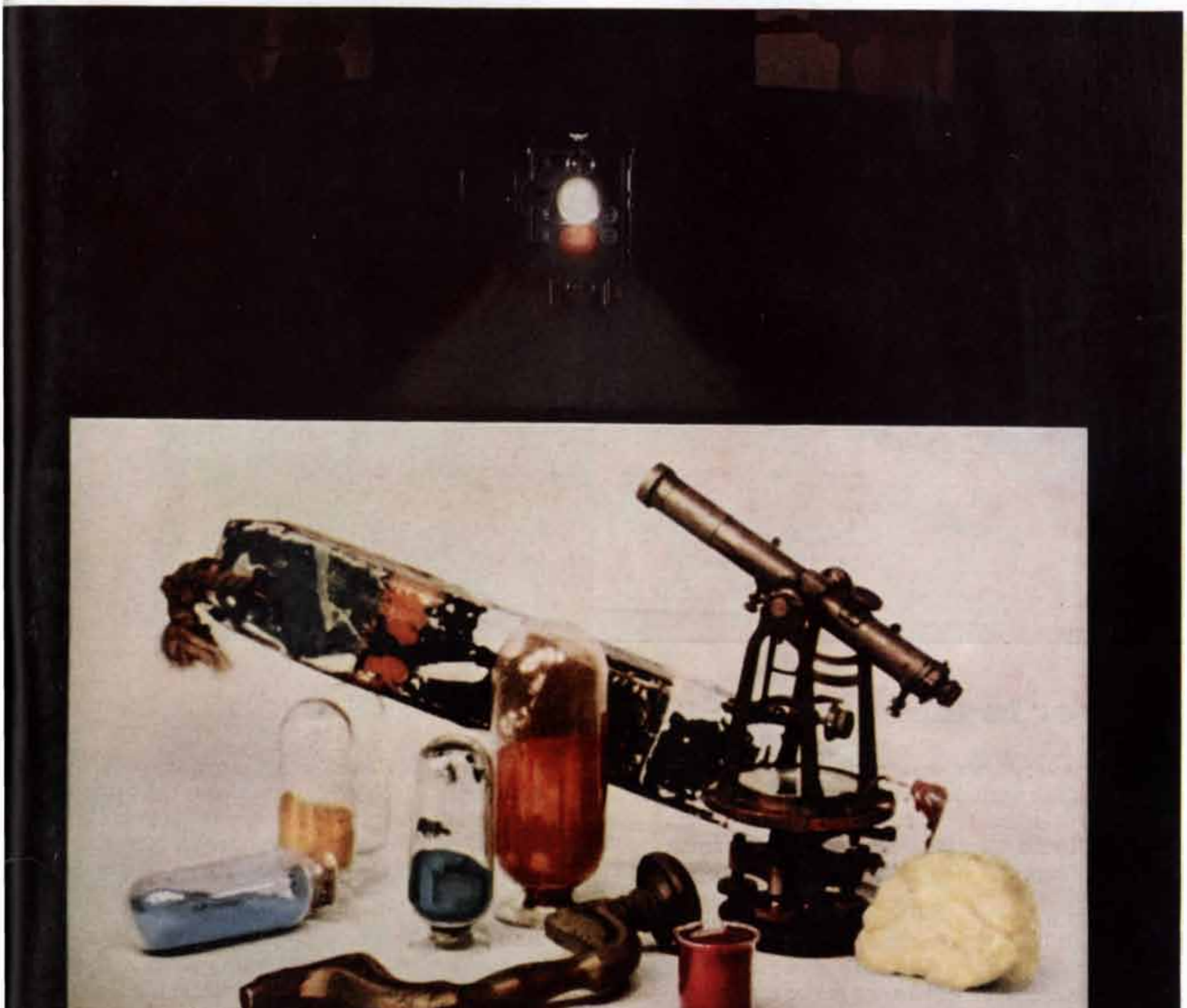

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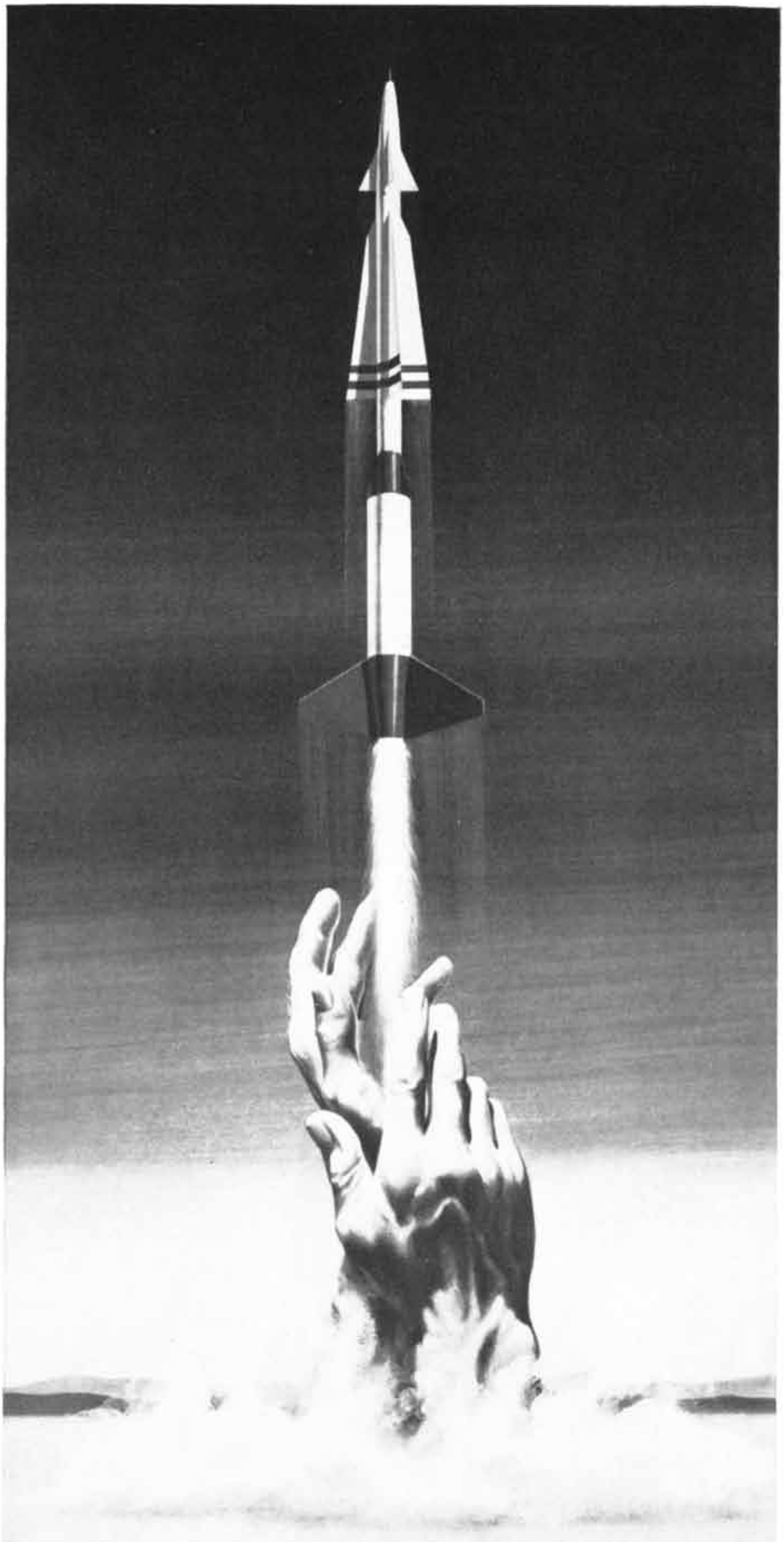

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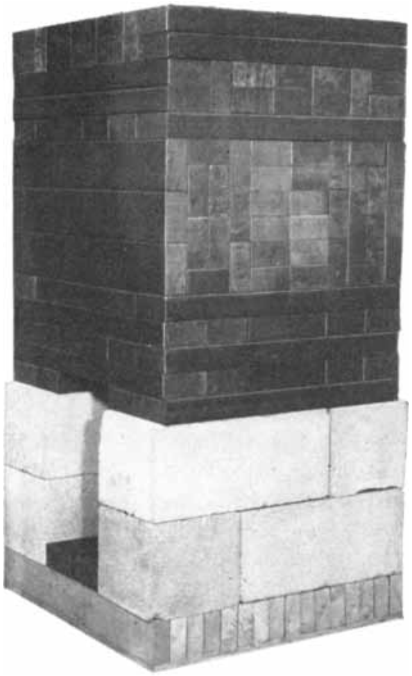

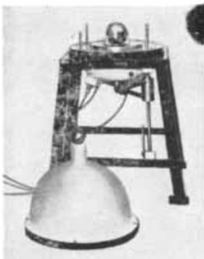

may require reinforced floors; cost approximately $800.00; and are altogether superfluous with the availability of the new **Amperex®** *Type 18515/Type 18517 Low-Level Beta Counter.*

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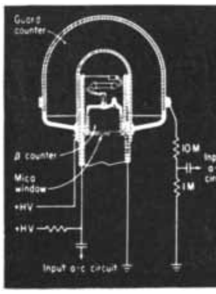

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about their full range of radiation counters, high temperature radiation counters, photomultipliers, photo-sensitive devices, indicator tubes, premium electron tubes and semi-conductors.

THE COVER

The photograph on the cover depicts part of an experiment which suggests that classical theories of color vision are inadequate (see "Experiments in Color Vision," page 84). In the foreground is a translucent screen. Over the top of the screen may be seen a projector with two lens systems. One of these systems is fitted with a red filter; through the system is projected a black-and-white positive transparency, made through a red filter, of the colored objects on the screen. The other lens system has no filter; through it is projected another black-and-white positive transparency, made through a green filter, of the same objects. When the two images, one red and one white, are superimposed on the screen, the objects appear in full natural color!

THE ILLUSTRATIONS

Cover photograph
by William Vandivert

Page	Source
47-49	Irving Geis
50	*The New York Times*
51	Irving Geis
53	Flying Telescope Project
54	Bunji Tagawa
55	U. S. Navy (*top*), Bunji Tagawa (*bottom*)
56-57	U. S. Navy
58	General Mills, Inc.
59	Flying Telescope Project
61	Bettmann Archive
62-66	New York Public Library
85-86	William Vandivert
87	Polaroid Corporation
88-99	James Egleson
100	Rockefeller Foundation
101	Eric Mose
102	Rockefeller Foundation
107-108	Eric Mose
109	Emi Kasai
110	Rockefeller Foundation
112	Eric Mose
118-128	John Langley Howard
132-144	A. A. Moscona
150-158	Bunji Tagawa
164-168	Alex Semenoick
176-184	Roger Hayward

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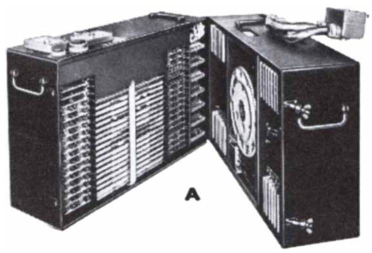
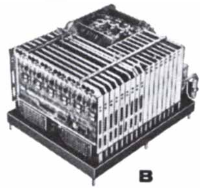


LIBRASCOPE AIRBORNE COMPUTERS*



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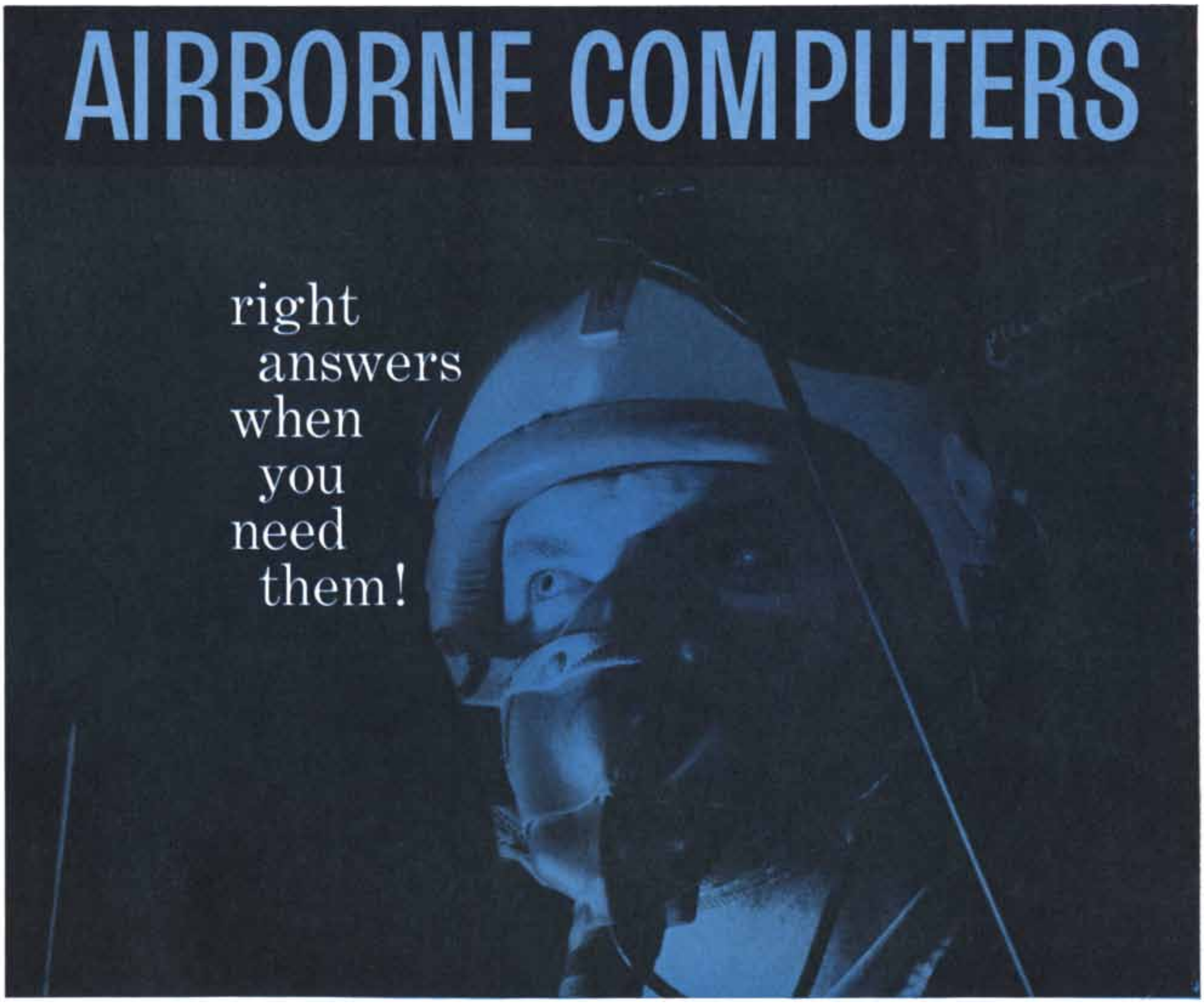

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Typical of Librascope's leadership in airborne digital computers are: **A** Incremental digital computer for Navy aircraft calculating bombing and navigation information. (Developed in 1954.) **B** Small transistorized general purpose digital computer for such problems as auto-navigation for aircraft and missiles. (Developed in 1958.) For detailed information on how Librascope solutions can apply to your computer systems problems, write...

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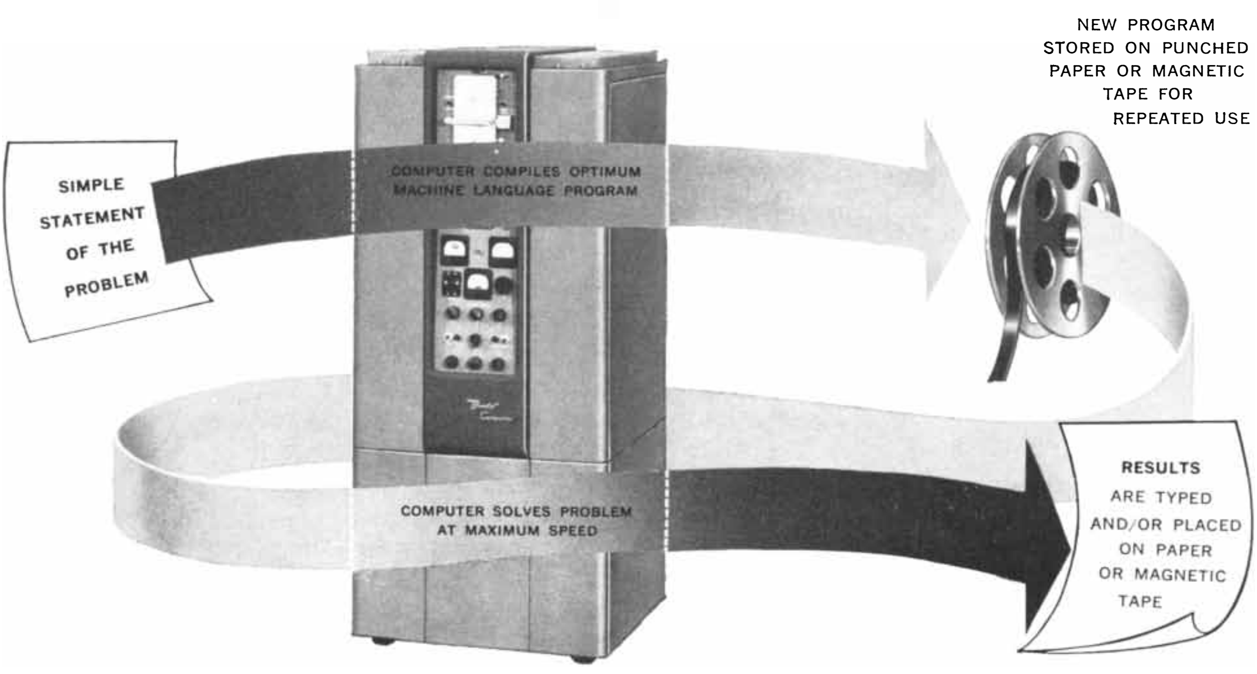

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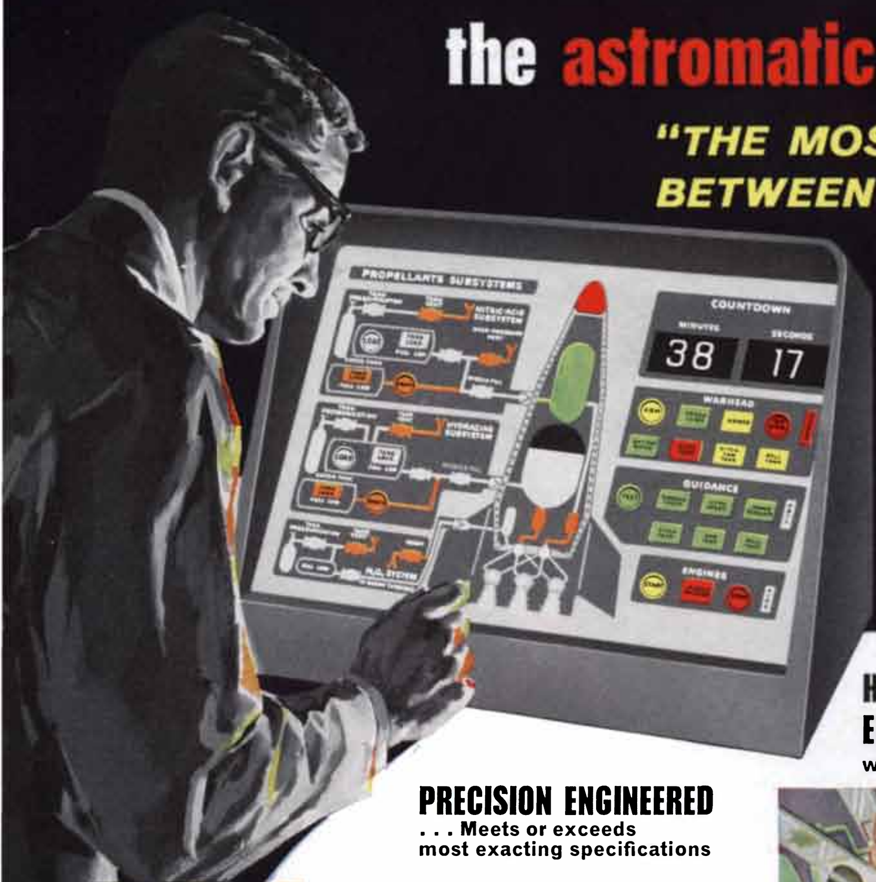

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A Wire and Cable Story

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Nor are the advantages of TFE resins confined to their electrical properties. The resins have almost universal resistance to chemicals, are nonflammable, absorb essentially no moisture. They are totally unaffected by the worst tropical weathering conditions, as proven by more than a decade of outdoor testing. They have excellent impact, fatigue and flex strength, even at subzero temperatures.

Plainly, these resins are the answer to practically all reliability requirements for wire and cable. For example, a hook-up wire insulated with a TFE resin often makes considerable savings possible, because assembly is unhampered by damage to insulation due to hot soldering irons. The heat resistance of TFE resins permits miniaturization; hot conductors will not cut through even a thin layer of insulation. RF cable with a dielectric of a TFE-fluorocarbon resin provides low energy losses and low signal attenuation. Multi-conductor cables for aircraft, missiles and electronic devices are solving complex design problems. Miniature types of cable reduce weight substantially.

If the success or failure of your electronic devices hinges on their reliability under all conditions, you may benefit from a look into the use of wire and cable insulated with Du Pont TFE-fluorocarbon resins. If you haven't checked recently, you may be surprised at the technological advances wire and cable manufacturers have made in using TEFLON TFE-fluorocarbon resins and their amazing properties.

For more information see your local supplier (listed under "Plastics—Du Pont" in the Yellow Pages) or write to: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room T-395, Du Pont Building, Wilmington 98, Del.
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PROGRESS REPORT

Solar-power electrical plants

Development of a self-contained solar-power electrical system for a space vehicle is now beyond the working-model stage at the TAPCO Group. Perfection of a practical small-envelope system involves a number of sub-projects . . . the mechanical effect of meteors on the solar collector, a compact solar boiler system, a simple, long-lived vapor-driven turbo-alternator, a self-erecting radiation collector, and self-contained orientation controls.

Impact effects of micro-meteors on materials suitable for structures exposed and the solar-energy-gathering devices erected on space vehicles are under study. A 150-kv. electric-field accelerator at TAPCO hurls micron-size charged particles against targets of evaporated aluminum on glass or of solid copper. Size, depth, and contour of the craters formed are evaluated for use in designing the shell and collector structure.

To solve the basic problem of knowing "which way is the sun?" TRW has designed a device to continuously direct the collecting mirror so that the sun's rays remain focused on the boiler.

Mercury is the heat-exchange medium for the Rankine cycle power-conversion unit of the TAPCO-developed solar-power electrical system. A simple boiler vaporizes the mercury by using direct solar heat while the vehicle is on the bright side of the earth. A heat-of-fusion storage system keeps the boiler and turbine operating at full power during the dark-side orbit of the vehicle.

The mercury vapor is used to drive a small turbo-alternator. Experience of the TAPCO Group in designing and manufacturing over 2,000 turbo-alternators for APU's extends into the basic design of the solar power system. Additional refinements include an unusual method of using liquid mercury as the bearing lubricant for the rotating machine to avoid problems of wide ambient temperature range, long unattended life of the vehicle, and possible contamination of orthodox lubricants by the vaporized mercury in case of seal failure.

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LETTERS

Sirs:

The moving and well-written article "Joey: A 'Mechanical Boy'" [SCIENTIFIC AMERICAN, March] calls for the following remarks:

As usual in psychiatric case reports, a number of statements are made that are purely interpretative and cannot be proved. Examples: "[Joey] wanted to be rid of his unbearable humanity. . . . We learned that the process had begun even before birth. . . . In his papoose fantasies lay the wish to be entirely reborn in a womb."

Of course there is no harm in poetic interpretation of facts unless such artistic compositions are given as scientific truths. This is too often the case in psychoanalytically inspired material. Far more serious and objectionable are the following remarks:

"Schizophrenia often results from parental rejection. . . . Joey's . . . relationship with his parents . . . was an extreme instance of a plight that sends many schizophrenic children to our clinics and hospitals."

Your nonmedical readers must be told, loud and clear:

1. There is not a shred of scientifically acceptable evidence that parental behavior causes schizophrenia in children. This is only a theory too often supported by interpretive and isolated case-histories of the kind under discussion.

2. Countless numbers of children were born and spent their first years in rejecting environments (concentration camps, prisons, etc.) who *did not* develop schizophrenia.

3. Countless numbers of children born to accepting, loving, even doting parents *did* develop schizophrenia. (I know several dozens of this kind myself.)

4. No human disease is the result of one single cause; diseases have multiple causes, and the problem of apportioning the blame to each of them is far from understood; when it comes to schizophrenia, the mystery is deeper than ever.

Another statement to be seriously challenged is the following:

"It is unlikely that Joey's calamity could befall a child in any time and culture but our own." I do not know of one single epidemiological and geographical study of the world distribution of schizophrenia on which such a statement could be based. On the contrary,

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all available information tends to show that the opposite is true. Schizophrenia is a universal problem. It is mentioned as such in a recent annual report from the Direction of Medical Services of Ceylon, and is a concern to the Indian Medical Research Council. In both countries whose cultures differ from our own the problem is considered acute, and scarce money is spent to meet it.

Finally I could not help a feeling of frustration when I was not told in what condition Joey finds himself now. All we know is that he has now "entered the human condition." To me he was human all along because he was sick and because he suffered. This short statement, in any case, is not a satisfactory way to evaluate a therapeutic procedure. Does the author consider Joey cured? Is he able to face the challenge of life? Is he discharged and taking his place in society? If so, we would be delighted to read it in unmistakable language. But the impression left by the article is that it is not so. If it is not so, then the child has merely switched from one set of delusions to another, merely changed the color of his hallucinations. If he is considered improved, what are the criteria by which this improvement is measured?

But if the child is still schizophrenic, then the treatment used was ineffective, and the cause for his disease is not the cause assumed by the therapist. If such is the case, has not the time come to state frankly that we cannot with current methods cure or improve schizophrenic children? Should we not revise current etiological hypotheses and face the reality of our complete ignorance on this

Scientific American, May, 1959; Vol. 200, No. 5. 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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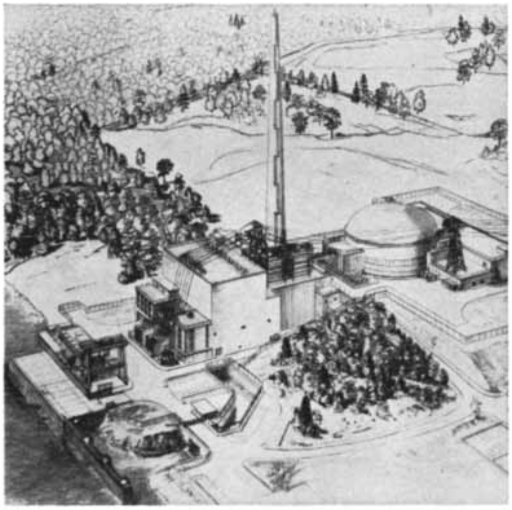
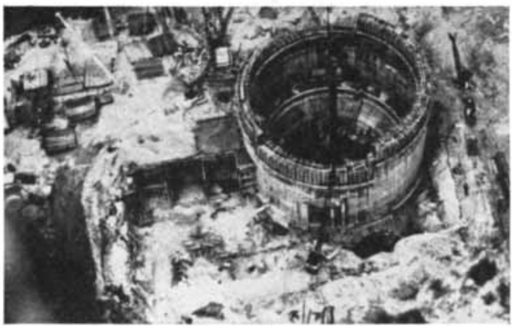
INDIAN POINT... atomic landmark





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subject with the candor and simplicity we wish Joey would use to face life's problems? Maybe fresh ideas would pay off better than old ones have.

JACQUES M. MAY, M. D.

President, The Parents' School
for Atypical Children
Vice-President, League for
Emotionally Disturbed Children
Chatham, Mass.

Sirs:

Dr. May seems to feel that instead of a case report I should have written a balanced analysis on the causes and treatment of childhood schizophrenia. I chose to present a case history just because I agree with Dr. May that much about childhood schizophrenia is still unknown; I preferred to present that about which I am certain, namely this unique case history.

Now to Dr. May's main argument: He writes in his first point that there is no shred of evidence that parental behavior causes schizophrenia. If one assumes that there is some connection between the cause of a disease and the methods which bring about its improvement, then the frequently observed improvement of schizophrenic children who have been placed in an environment other than the parental one suggests that parental attitudes have a great deal to do with childhood schizophrenia.

It is much easier to dispose of Dr. May's second point, that many children born in a rejecting environment do not develop schizophrenia. This argument is about as valid as those once brought forth against the germ theory of contagious disease, namely that this theory is invalid because many people who were exposed to the germs did not develop the disease. The issue is not that some people who are exposed to disease-causing circumstances do not get sick, but that some do get sick due to a combination of exposure and lowered resistance or other predisposing circumstances. The important issue is what additional conditions are necessary for a predisposition to develop into acute childhood schizophrenia. It is my conviction that parental attitude and behavior are the crucial factors which change a slumbering predisposition into fulminant childhood schizophrenia. In speaking of multiple predispositions I think I have also disposed of Dr. May's fourth point. But since at this stage in our knowledge there is nothing we can do about these factors, I prefer to dis-

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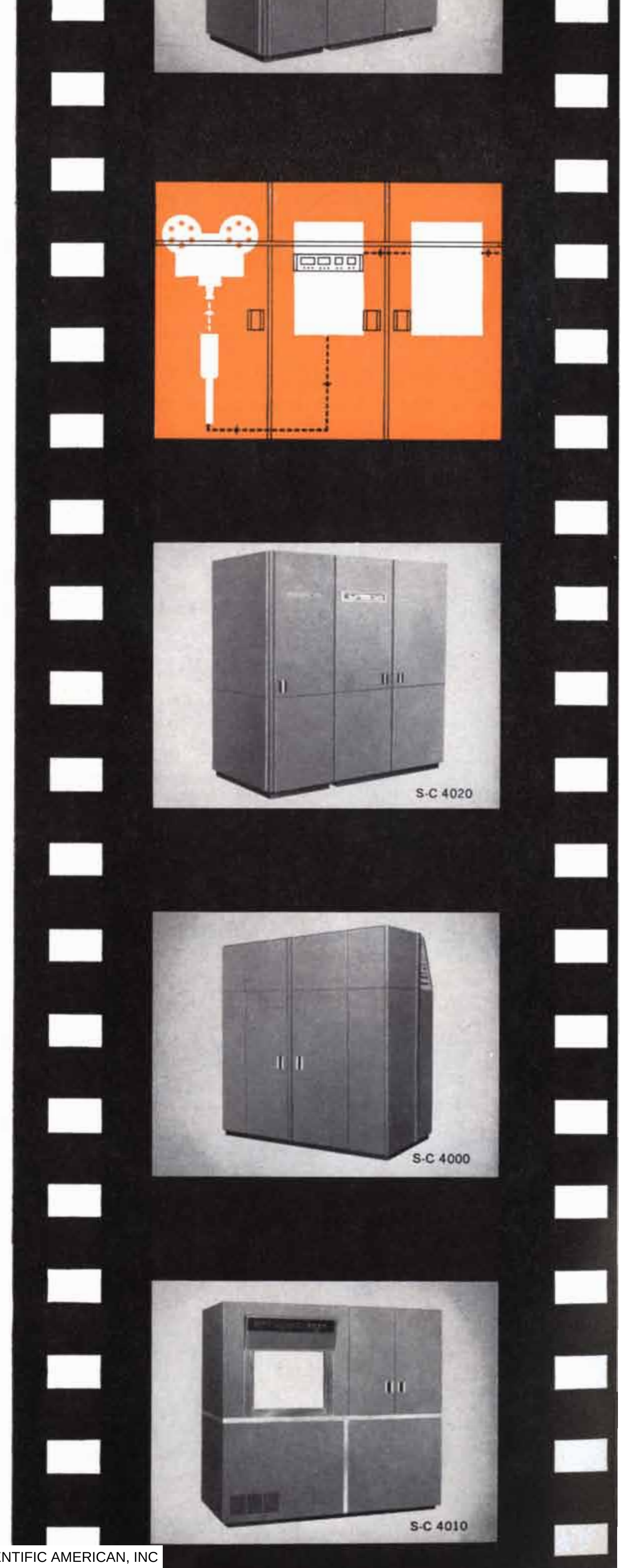

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regard them until we know more about them. In the meantime, I should like to concentrate on those things over which we have some control: first, the environmental and parental factors which provoke the outbreak, and second, the methods which help the individual out of his schizophrenia.

About the third point: I have never seen a child really accepted and loved by his parents who developed childhood schizophrenia. Perhaps Dr. May's word "doting" explains the seeming disagreement, because "doting" to me is neither accepting nor loving, but rather what has been described as "overprotection." This attitude is potentially very damaging to a child.

Now to the specific quotations from my article to which Dr. May takes exception. He claims that my statement "[Joey] wanted to be rid of his unbearable humanity" cannot be proved. If Joey's own repeated statements that he did not want to be a human being, that he did not want to have anything to do with humans because human experiences are much too painful, are purely interpretive and cannot be proved, I should like to know what constitutes proof to Dr. May. The same goes for the statement that "In his papoose fantasies lay the wish to be entirely reborn in a womb." It, too, is based on Joey's repeated declarations.

That the schizophrenic process had begun even before Joey's birth cannot be proven, but I do not believe the meaning of this remark can be misunderstood when it is read in the context in which it is made. I say in the same sentence that this knowledge was acquired through interviews with the parents, and later I directly quote the mother as to the degree to which she had excluded the fact of pregnancy from her consciousness. Since I believe that extreme negative parental attitudes are a necessary—though in and by themselves not a sufficient—cause of childhood schizophrenia, I think it is permissible to say that this causative factor, according to the mother, was at work even before Joey was born.

Another statement to which Dr. May takes exception is that "It is unlikely that Joey's calamity could befall a child in any time and culture but our own." It is beyond me how Dr. May could not recognize that this did not refer to childhood schizophrenia as a disease, but to the specific form which it took in Joey's case. The interesting thing about Joey was that he not only believed he was a machine, but that he also created this impression in others. In the third

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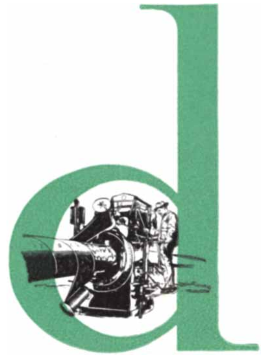

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paragraph I made the point that his case seems to me of great relevance because, while in any age individuals create their delusional world, they "usually fashion it from bits and pieces of the world at hand." To my knowledge children who believed that they were machines run by electric currents and by remote control have not been described. Therefore I felt that Joey's case was of importance because his "emotional development in a machine age" suggests the forms delusions may assume in the future.

I stated that in our world of plenty a child like Joey "suffered no physical deprivation; he starved for human contact." The point is that in more primitive cultures such children usually also suffered from severe physical deprivation and, given their low vitality and the lack of adequate medical care, they were not likely to survive for very long; it is my conviction they usually died in infancy or childhood. It is only in our age of plenty and excellent medical care that more and more of these children survive. I cannot see how this is made invalid by the report of the Direction of Medical Services of Ceylon.

As for the statement that "Joey entered the human condition" with which I ended, it, too, is to be viewed in the context of what was said earlier, that he wanted to be a machine and did not want to be a human being.

Dr. May rightly says that my report is not satisfactory for evaluating a therapeutic procedure. In the third paragraph of my article, however, I said: "This time I shall concentrate on the illness, rather than the treatment." An author is helpless against the accusation that he should have written a different article than he wrote.

I am glad to report that Joey, who came to us unable to maintain any contact with reality, is presently in high school, working at the grade level appropriate to his age. Since society does not expect much more of high-school-age youngsters than to function as such and to stay out of trouble, I think Joey is functioning at the level which society expects of a boy of his age. I do not claim that he is "cured," not knowing what test of cure Dr. May has in mind in cases of infantile autism. Suffice it to say that the improvement of Joey is felt to be remarkable by all those who have known him over the years.

BRUNO BETTELHEIM

Sonia Shankman Orthogenic School
University of Chicago
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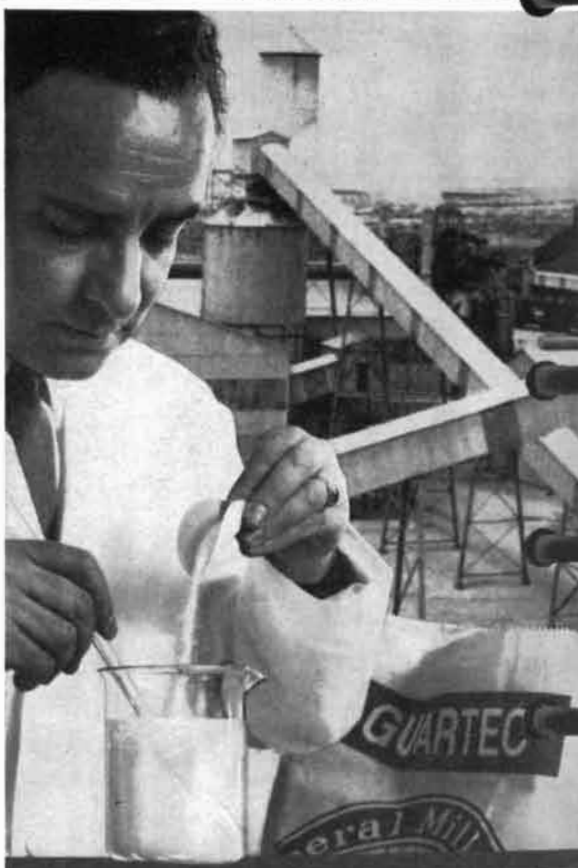

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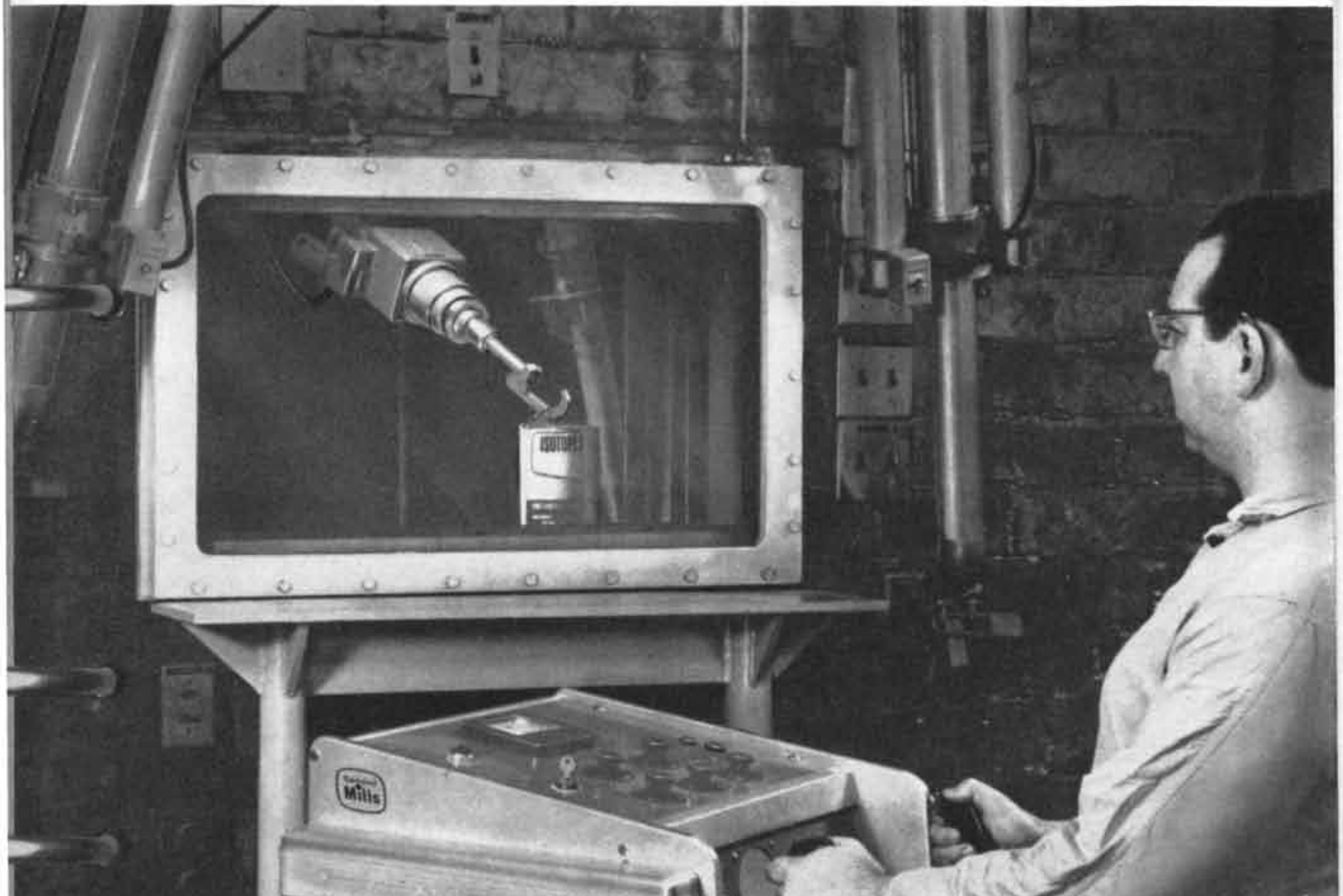

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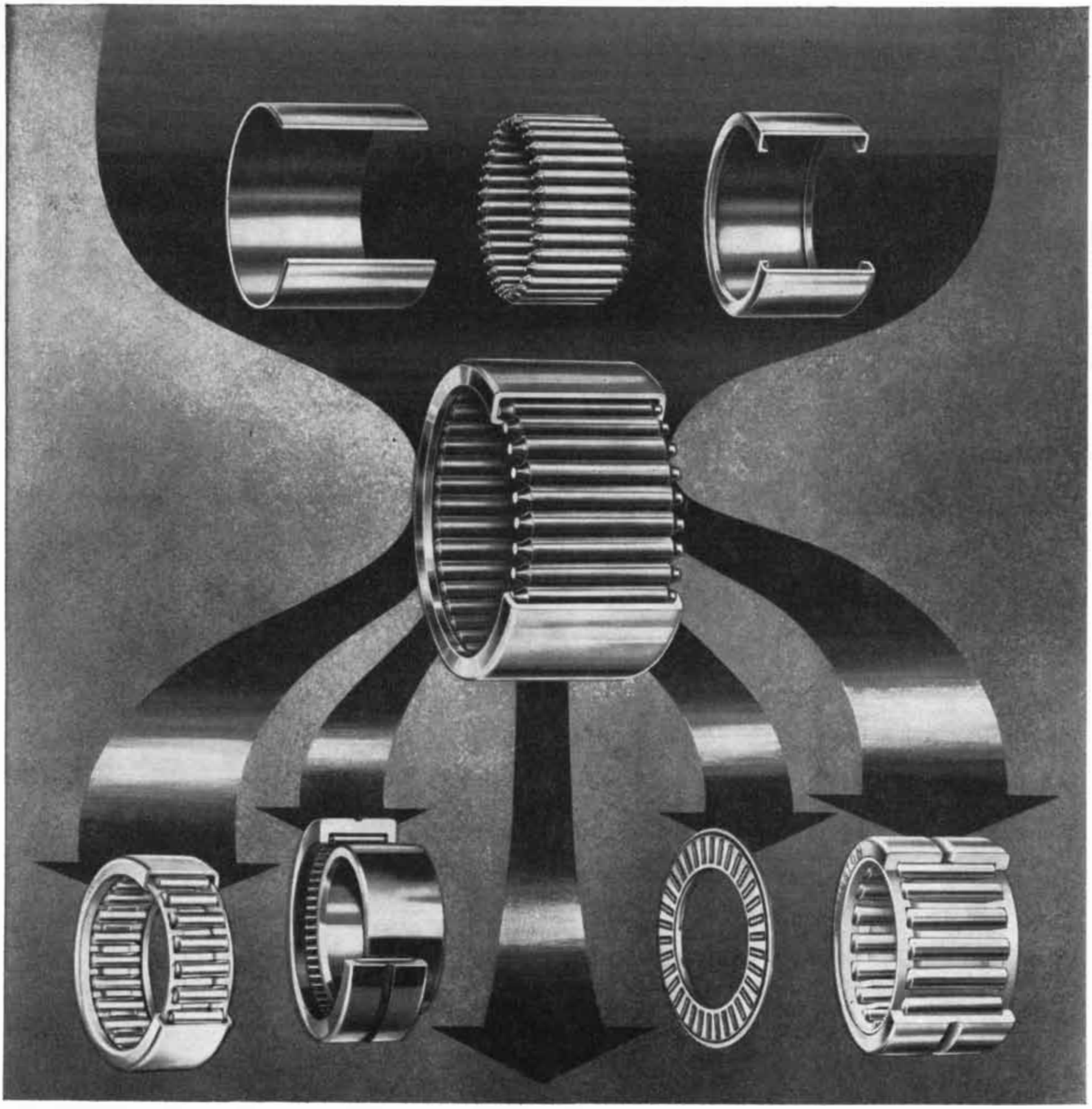

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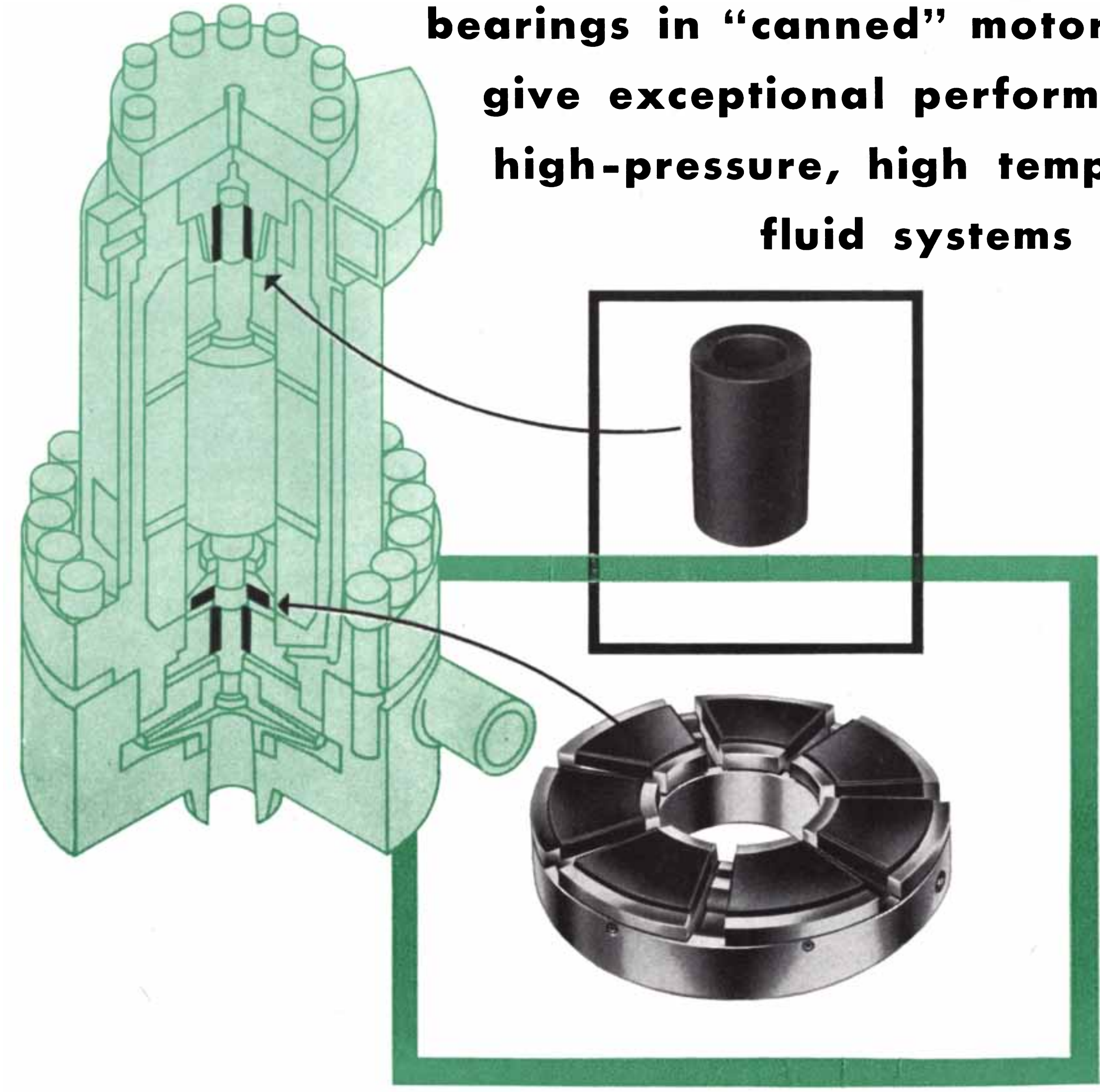

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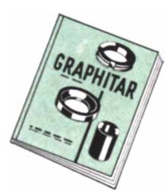

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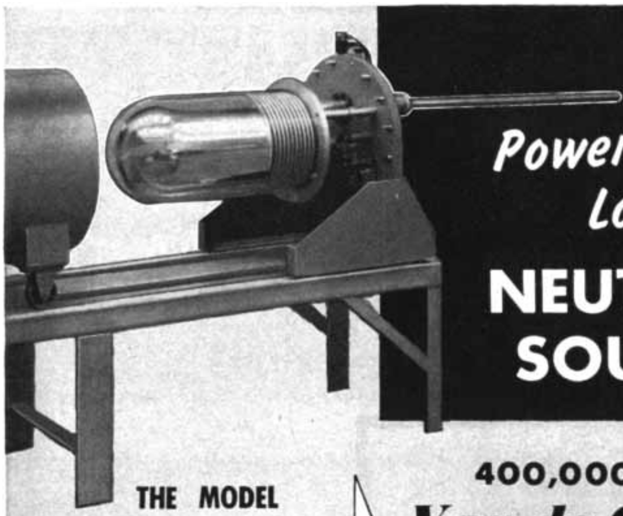

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Which speaker is making the sound? In echoless chamber at Bell Labs, Robert Hanson measures test subject's ability to localize sounds — observes how two ears operate in partnership. This and other tests may point the way to better telephone instruments.

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Our hearing performs feats that no electronic system can yet duplicate. How? Laboratories scientists believe the secret lies in the way our two ears function in partnership and in the way our neural network connects them with our brain. *The problem:* to discover what functions the network performs and to see whether electronic duplication might enhance understanding.

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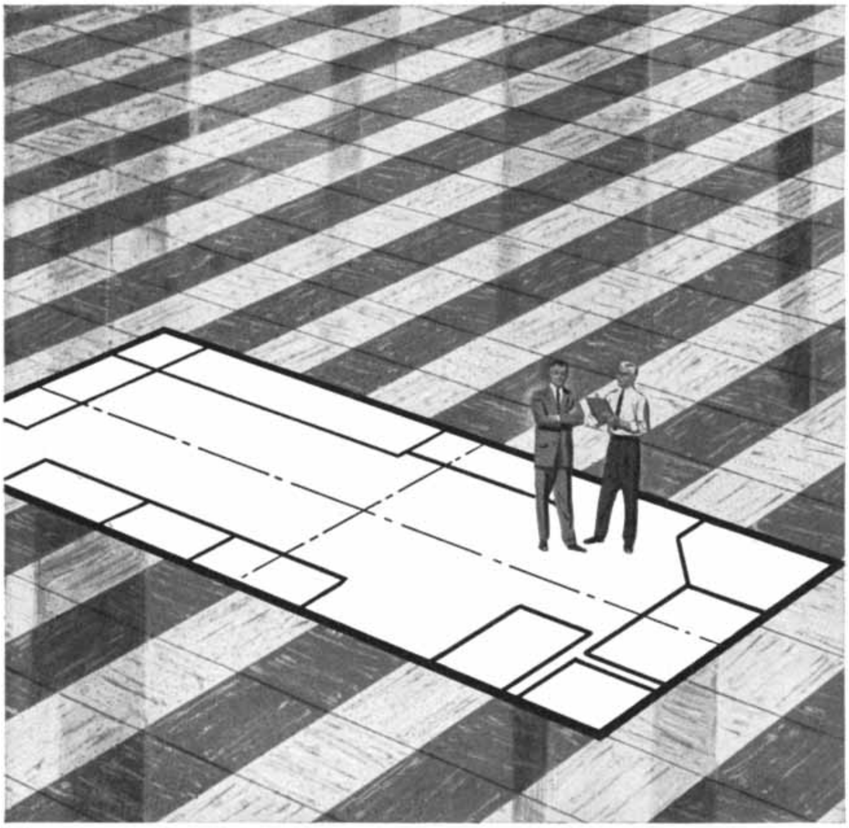
SYLVANIA SYSTEMS... **IN COMPUTERS**



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ELECTRONICS FOR INDUSTRY AND NATIONAL DEFENSE

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A DIVISION OF SYLVANIA ELECTRIC PRODUCTS INC.

63 Second Avenue, Waltham, Mass.

patient investigation that the moon myth has absolutely not an atom of scientific foundation on which to stand. The agricultural experiment stations all over the country have been defying this superstition for several years and have been raising just as good crops when the moon was one way as when it was the other. All of this may not seem very serious investigation for a great government to undertake, but if the scientists have succeeded in weaning a few from the old superstitions about planting potatoes, they have been well paid for their work."

"On May 1st the Delaware, Lackawanna and Western Railroad installed in its through trains a system of supplying water to passengers which must commend itself to those who have the public health at heart. In every car a slot machine is installed, which supplies paraffin drinking cups for 1 cent apiece. The passenger uses this vessel and throws it away after use. The principle of the scheme is so good, and its advantages so obvious, that they need not be dilated upon."

"Starting last September with the first public exhibitions in France and America by Wilbur and Orville Wright, the career of the brothers has been practically a continuous ovation. Wilbur Wright especially has been lauded in the highest terms, first at Le Mans, where on December 31st he made an unparalleled flight of nearly 100 miles in 2 hours and 20 minutes; later at Pau and Rome, where he taught several pupils how to operate the aeroplane in a dozen 15-minute lessons each. The idea of selling aeroplanes to governments, which these two inventors had in mind when they went abroad, seems to have succeeded almost beyond expectations. Italy, Germany, Russia and England have either purchased or negotiated for aeroplanes."

"Reports from Washington regarding the lengthy cruise recently completed by the United States steamer *Cheyenne*, in which oil was used as fuel, are to the effect that the vessel was able to steam faster than with coal, and that her steaming radius of 1,500 miles, which was her limit when burning coal, has been increased by the use of oil to 2,300 miles."

"The whole of the site of the sacred inclosure of Delphi has now been uncovered by the excavations which have been carried on by the French School of Athens, under the direction of the eminent archeologist M. Théophile Homolle. It was far from easy. The site was

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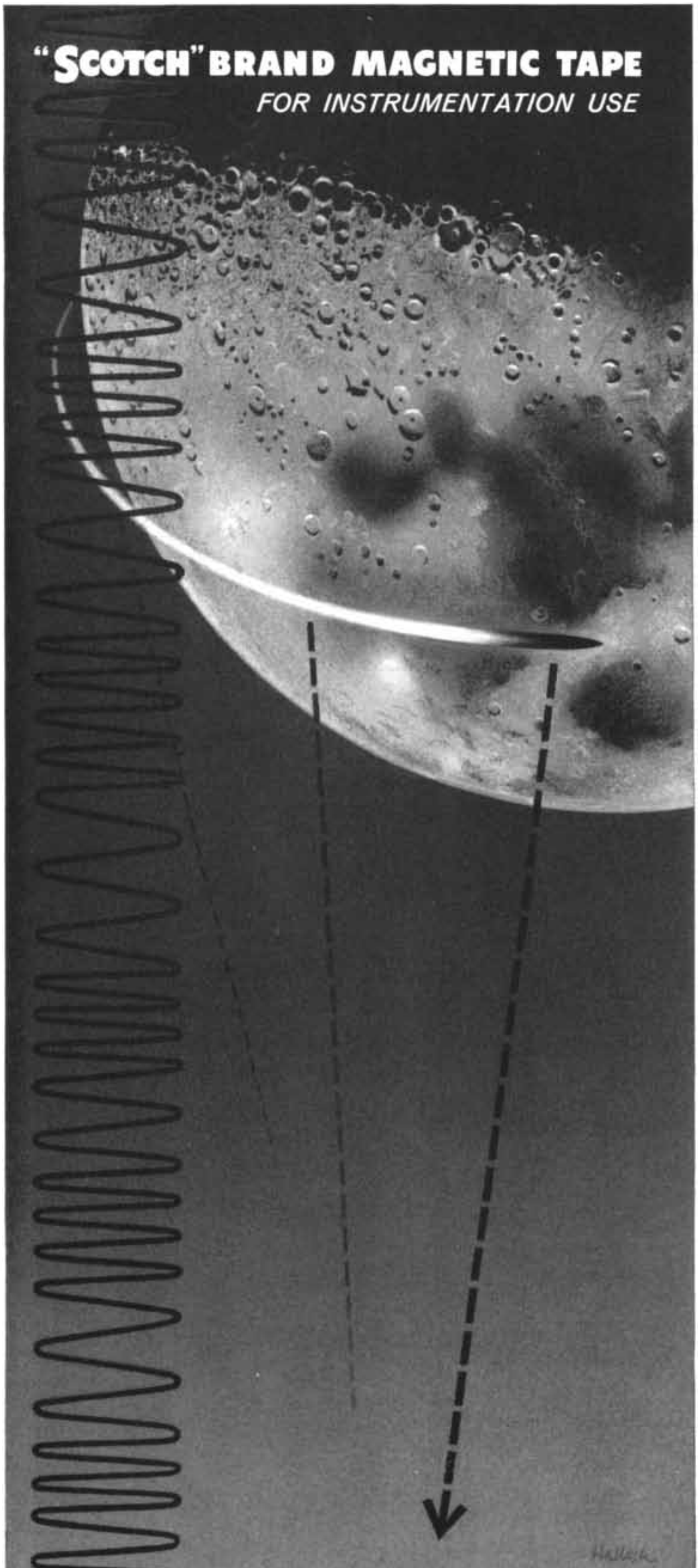

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Velocity. Altitude! Stress! Strain! Air pressure. Trajectory. Heat and cold. Shooting the moon or downrange, the missile man must record these—and more—when he sends his voyager out in the silent sea of space. For this sensitive task of simultaneously recording up to 16 channels of vital readings on the flight performance of a missile, "SCOTCH" BRAND Magnetic Tape has proven reliability.

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. . . WHERE RESEARCH IS THE KEY TO TOMORROW

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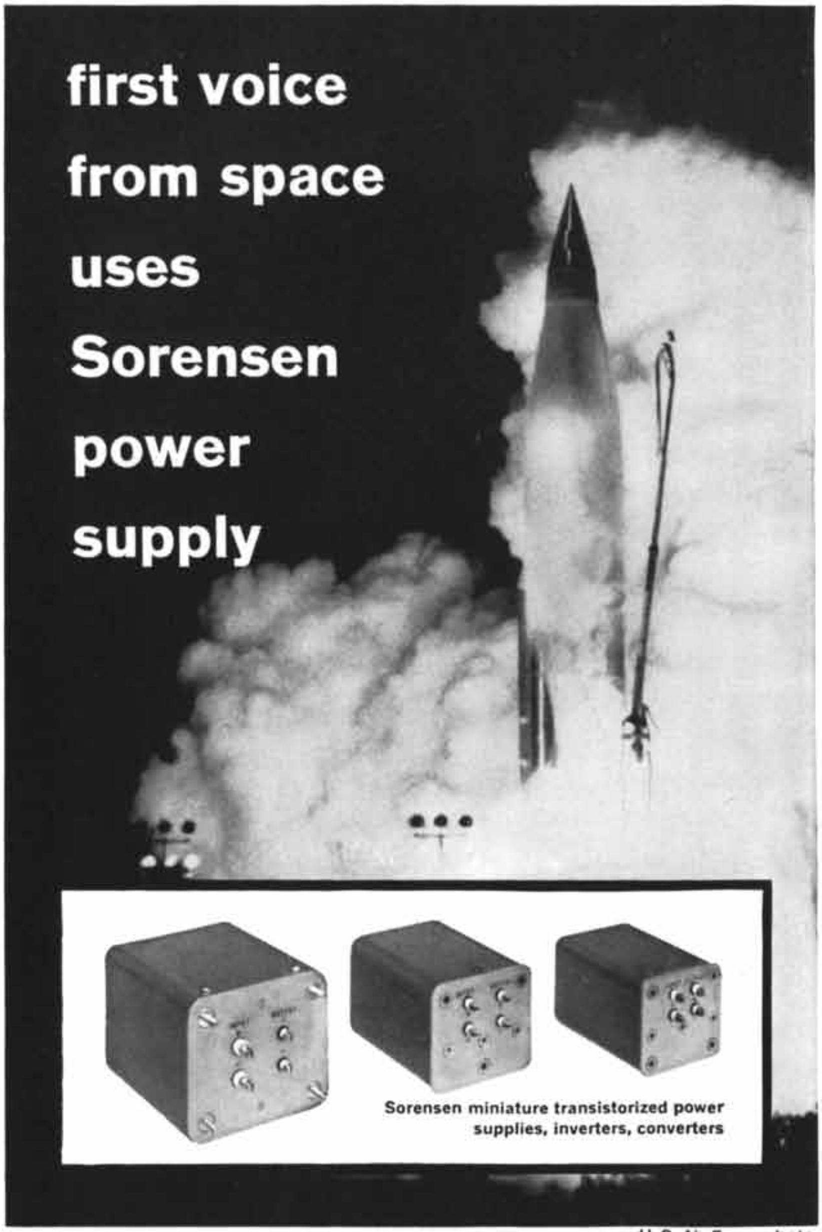

U. S. Air Force photo.

Last December, a Christmas message from outer space heralded a new era in radio communications.

Coming from an orbiting, 80-foot-long U. S. Air Force **Atlas** missile, the voice was broadcast over U. S. Army Signal Corps designed communications equipment. We at Sorensen, are proud indeed that a miniature Sorensen transistorized power supply was selected as part of this communications equipment.

Transistorized supplies for every purpose. Sorensen manufactures a complete line of miniature transistorized power equipment including: highly regulated a-c powered d-c supplies, dc-to-dc converters and dc-to-ac inverters. They are rugged, compact and as simple to incorporate into your equipment as an ordinary transformer or other "potted" component. They are available in an extremely wide variety of input-output voltage combinations and current capacities. Write for complete data.

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covered by the village of Castri, a community of about a thousand inhabitants. Before any excavation could be commenced, measures had to be taken for removing the whole village. As to the scope of the excavations, this work bears upon the entire sacred inclosure containing the temple of Apollo and the theater, as well as all the portions which depended upon it, including the stadium, the gymnasium, the celebrated spring of Cassotis and various edifices. Bronze and marble groups were in abundance all around the sacred inclosure."

"A new type of wrecking vessel has been built at Wyvenhoe, England, from the plans of Mr. Simon Lake, for the recovery of certain sunken treasure. On the night of October 9th, 1799, the British man-of-war *Lutine* sank off the entrance to the Zuyder Zee, while she was transporting some $5,872,000 worth of bullion and specie to Hamburg. The King of England ceded the rights to the treasure to Lloyds. During over a century the company has succeeded in recovering bars and coins to the value of about $541,228. The sand, however, continually drifted in on the wreck and ultimately forced them to suspend operations. The new wrecking vessel consists of a large light-draft surface vessel provided with a submarine tube hinged within the hull. Centrifugal sand pumps are carried by the surface vessel and in connection with the submarine tube, and the sand-pumping capacity of the plant is over 40,000 tons per 24 hours."

"The perfection which has been reached in the manufacture and adjustment of automobiles is well shown by the exhaustive examination, in the laboratory of the Massachusetts Institute of Technology, of the Maxwell car, which has recently completed a 10,000-mile nonstop run. After the engine had been officially stopped at the end of 25 days' continuous running, the car was driven for 10 miles, starting and stopping on the steepest grades in the neighborhood, and showing perfect control by both brake and clutch. The engine was then taken apart and all the workings and other parts were examined. Even on the gear teeth, wear was hardly noticeable."

"A conference was held at Brussels for repressing the use of saccharine in food products or drink. While the drug has 400 times the sweetening power of sugar, it is dangerous to health and it is desired to prevent the fraudulent use of the product. In many countries of

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Sentry that spans a continent

The pre-eminence of Radio Engineering Laboratories, Inc., in specialized radio communications is again underscored by the selection of its equipment for the gigantic tropospheric scatter network being constructed by NATO.

This network, with more than a continental span, will stretch from Norway to Turkey. It is larger by far than any other tropo communications complex yet conceived. REL has designed and is constructing one hundred fifty-three transmitter modulators, one hundred nine 10-kilowatt amplifiers, and seventy-seven quadruple diversity receivers with combiners.

With millions of lives at stake, only supremely reliable equipment could be considered. REL, which has developed and manufactured more tropo scatter radio apparatus than all other companies combined, was awarded the contract after international competitive bidding in accordance with NATO infra-structure procedure.

The imagination and facilities which have won REL world leadership in military and civil tropo scatter can help solve *your* specialized radio problems.

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The electron micrograph behind the young lady shows why millions of Americans can become expert painters, and can afford to paint more often. It shows the spherical configuration and uniform size of resin particles in Velsicol's W-617 emulsion paint base. W-617 is a water emulsion of light colored thermoplastic hydrocarbon resin. The average diameter of W-617 resin particles is .125/micron. Natural rubber latex particles have an average diameter of .600/micron. Latices and emulsions of small particle size have more binding power. They will take higher pigment or filler loadings without losing film strength. Penetrating characteristics are improved. The uniform size of the dispersed resin particles increases film smoothness. W-617 is one of many new products of Velsicol research that is now in commercial production. For more news about this product, and other developments of Velsicol research, please mail the coupon.

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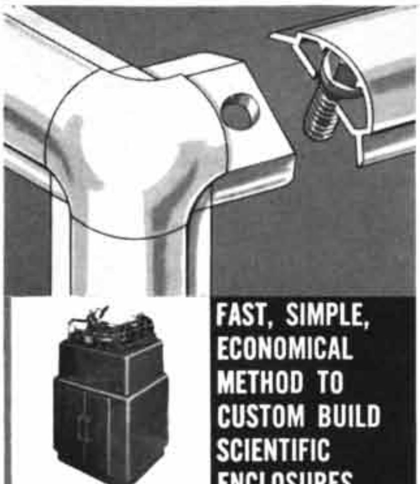

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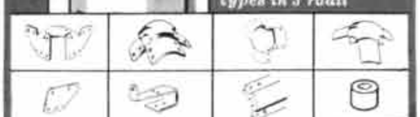

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Europe it is brought in by contraband; in one case a vessel in the Russian port of Riga was found to have a ton of saccharine, which would replace 400 tons of sugar."

MAY, 1859: "Dr. Faraday recently lectured in the Royal Institution, London. The professor made an eloquent appeal for experimental science, stating that it exerts an immediate and powerful influence on the progress of society. It has been fashionable for persons of all classes to consider the devotees of experimental science as a class who feel no interest in, and have no care for, the practical arts and industries of life. But this shallow and fanciful habit is heartily denounced by Professor Faraday, a man who has the best right to speak upon it. It is not alone, he tells us, for educational benefits which arise from the study of physical phenomena and laws that he and others pursue their scientific inquiries. These benefits are undoubtedly valued, and are of themselves worth far more labor than is bestowed on their acquisition. But in addition to these, the experimentalist looks with pride upon those practical fruits which his devotion has fostered, and with confidence anticipates like harvest for the future."

"Canadian cents, which have been lately thrown off at the British Mint, possess a remarkable peculiarity. These are not only tokens of value, but also standards of weight and measure. One hundred cents weigh exactly one pound, and one cent measures one inch."

"News was received in Chicago, 15 years ago, in 40 days from Europe and 240 hours from New York; now London advices reach that city in 10 days, and news from New York is received in five minutes."

"It has been proposed that a by-wash should be built at every dam on our rivers and creeks once frequented by salmon, for the purpose of allowing them to pass up to old spawning grounds. With the artificial cultivation of young salmon, and dams formed with shutes up which the salmon might run to spawn, we have no doubt but the Merrimack, Connecticut and Hudson rivers would once more abound with these delicious fish."

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10 TO 15 NEW JOBS a week, each a different application, require a continuous program of evaluating the properties of metals and fabricating costs at Robertshaw-Bridgeport.

In making bellows (left) and temperature sensors (above) to meet ever-changing needs of control, appliance, and industrial equipment manufacturers, Bridgeport Thermostat Div., Robertshaw-Fulton Controls Co., Milford, Conn., averages 10 to 15 new problems a week. Specifications vary widely in dimensions and physical characteristics. Dependable performance over long periods of uninterrupted service is vital—yet costs must be rigidly controlled.

So for quality with maximum economy in fabrication, materials must be matched precisely to the needs of each job. And in this, Robertshaw-Bridgeport looks to its suppliers for creative technical services. For many years, The American Brass Company specialists have been helping to select the correct alloys in phosphor bronze or brass and to meet fabrication problems in the making of bellows—to apply economically precision-made capillary tubing and other small-diameter copper tube in sensor assemblies. Through such services, The American Brass Company is constantly helping metal fabricators across the nation control quality while keeping costs down.

ARE you caught between cost reduction and quality control? Find out if you are buying metal properties you don't need. An Anaconda specialist may be able to suggest a lower cost alloy that fits the requirements of your job more closely. Or he may find that an adjustment of temper or a change in your fabrication methods can cut your costs. The services of Anaconda specialists are available through your American Brass representative. Call him in today, or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5857

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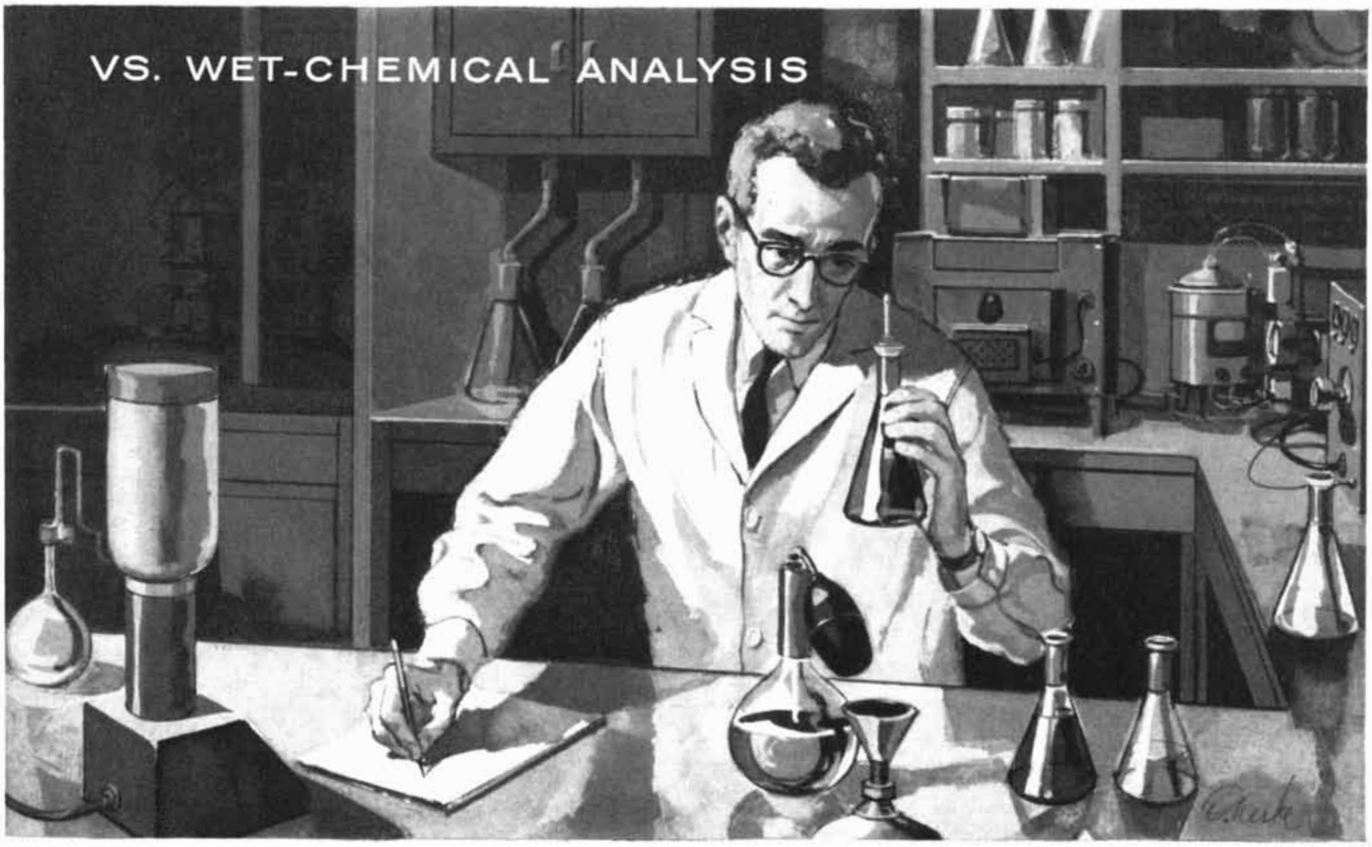
against costs!



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This concept of man's attempt to harness bird power in an attempt to fly first appeared in "The Man in the Moon"—published in Paris in 1648. In 1659, the same mode of air travel was depicted in another book, "The Flying Wanderer" Here, Brussel-Smith, noted graphic artist, has interpreted the original drawing through the medium of wood engraving.

IMAGINATION IN SPACE

Since Creation, man has looked out on space. At first, unknowing and incurious; then with the beginnings of understanding; now free and able to explore. Yet to move in space calls for wholly new concepts of energy.

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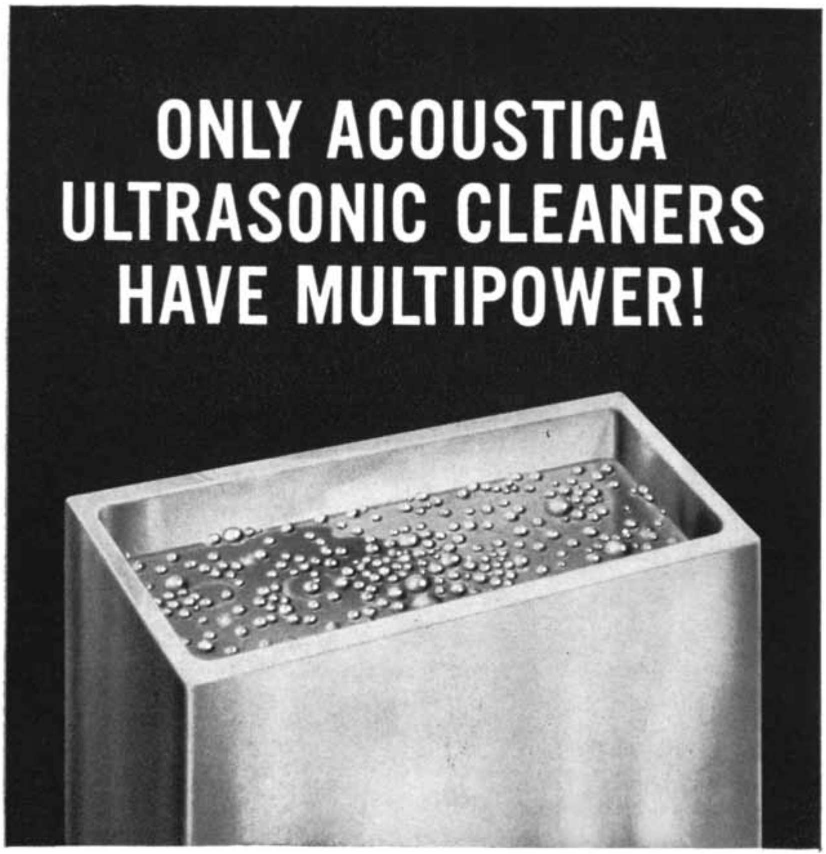
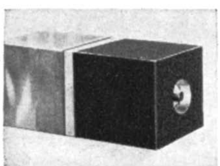


MAJOR BREAKTHROUGH IN ULTRASONIC TECHNOLOGY!



In determining which ultrasonic cleaner to buy, remember that all ultrasonic cleaners are not alike. There is variation in uniformity of cavitation. There is variation in the transducer — and the transducer is the heart of an ultrasonic cleaner. The Multipower transducer developed by Acoustica research, multiplies the power and efficiency of ultrasonic action. Cleaning is faster, labor costs are lower.

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THE AUTHORS

JOHN J. NEWGARD and MYRON LEVOY ("Nuclear Rockets") both work for the Reaction Motors Division of the Thiokol Chemical Corporation. Newgard, a senior project engineer, studied at Columbia University and has specialized in rockets and nuclear reactors for 10 years. Before coming to Reaction Motors he worked on the design of submarine reactors for the Westinghouse Electric Corporation and on manned-aircraft reactors for the Pratt & Whitney Company. Levoy studied chemical engineering at the College of the City of New York and at Purdue University and, like Newgard, worked on aircraft reactors for Pratt & Whitney.

MARTIN and BARBARA SCHWARZSCHILD ("Balloon Astronomy") are, respectively, Eugene Higgins Professor of Astronomy at Princeton University and a Princeton housewife. Martin Schwarzschild treads in the footsteps of his father, Karl Schwarzschild, astrophysicist and director of the Potsdam Observatory in Germany. The younger Schwarzschild received his doctorate from the University of Göttingen in 1935, then held a Nansen fellowship at the University of Oslo and a Littauer fellowship at Harvard University. He taught astronomy at Columbia University for two years, then entered the U. S. Army as a private. In the Army he developed certain still-classified techniques that won him the Legion of Merit and the Bronze Star. In 1945 he married the co-author of the present article, a Radcliffe College graduate and, at that time, staff member of the Radiation Laboratory of the Massachusetts Institute of Technology.

C. D. DARLINGTON ("The Origin of Darwinism") is Sherardian Professor of Botany at the University of Oxford and Keeper of the Oxford Botanic Garden. He received his undergraduate training at Wye College, the agricultural school of the University of London. "The curriculum included law, veterinary science and about 20 other subjects," he says, "but it allowed me to read T. H. Morgan's *The Physical Basis of Heredity*. I was struck by the combination of breeding and chromosome studies and the vigorous method of argument. So much so that on graduating in 1923 I asked for a job at the only place in England where one could pursue such

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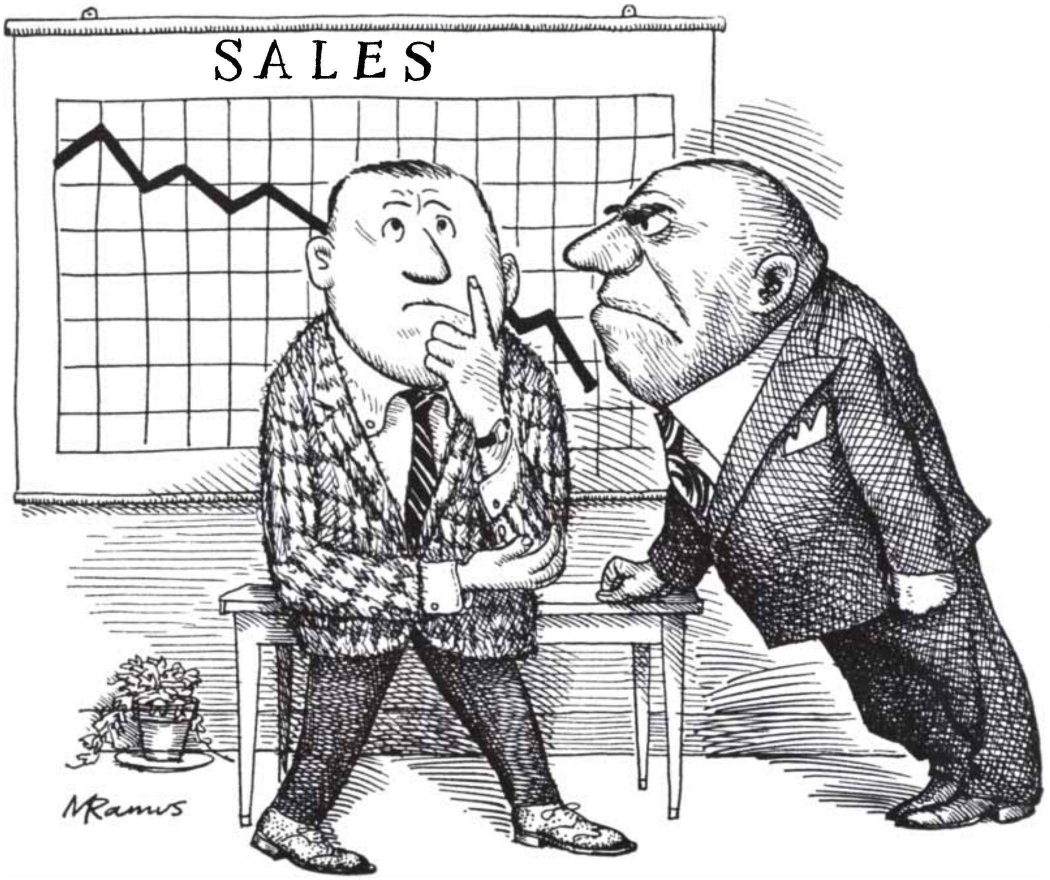

The Perfect Solution

(nutritionally speaking)

"Cut out the brainstorming," roared the harassed sales manager to ivy league adman. "*Ruffage* breakfast cereal needs a *real* sales hypo."

Ivy league shrugged. "Okay, no dancing girls . . . *wait!* I've got a new wave length. Have you read about Pfizer *Lysine?* Terrific! It's something called an amino acid. Gives cereal products the high protein quality of meat or eggs. That kind of health bonus could really get *Ruffage* off the launching pad!"

The manager squints. "Boy, I think you may have it. Get Pfizer on the phone."

* * * * * * * * * * * * *

If you are considering amino acid or vitamin fortification of a food product (or, for that matter, if you need a food acidulant, antioxidant or preservative) get in touch with the Pfizer Chemical Sales Division. *For any problem which might be solved by a high quality organic chemical, think of Pfizer first.* Chas. Pfizer & Co., Inc., Chemical Sales Division, 630 Flushing Ave., Brooklyn 6, N. Y.

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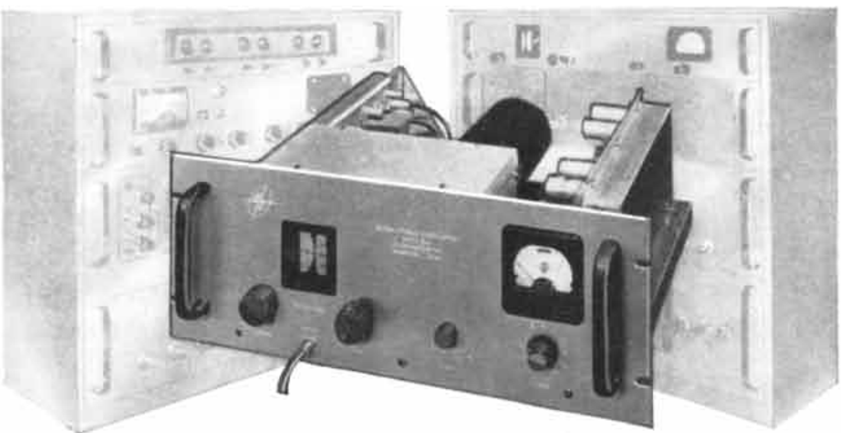
TIMING SYSTEM . . . 1759

This is a view of the works of John Harrison's marine chronometer with which he won a £20,000 prize from the British Government. Using this historic timepiece, navigators were able to determine a ship's longitude to within half a degree after six weeks at sea.

AN INTEGRATED SYSTEM FOR TODAY'S TIMING NEEDS



In the Hycon Eastern Integrated Timing System, solar or sidereal time is displayed visually and is available for both input to automatic computers and as an index to data being recorded on magnetic tape, oscillograms, strip charts, etc.

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work: the John Innes Horticultural Institution in Wimbledon, headed by William Bateson, who invented the word 'genetics.'" Later Darlington botanized in Iran, India, Japan and the U.S.S.R. and, as a Rockefeller Fellow, studied with Morgan at the California Institute of Technology. Darlington's travels led him to think about the genetics of man. In 1953 he published a book entitled *The Facts of Life*, incorporating his ideas on how men cooperate. Since then he has pondered Darwin's observations on the same subject and has studied the prehistory as well as the consequences of Darwinism. His latest book is *Darwin's Place in History*. Darlington is a Fellow and Royal Medalist of the Royal Society and a founder and editor of the journal *Heredity*. In 1953 he left the directorship of the Innes Institution to take up his present appointments at Oxford.

EDWIN H. LAND ("Experiments in Color Vision") is president, chairman of the board and director of research of the Polaroid Corporation, a manufacturing concern that he founded in 1937. To the general public Land's name is best known in association with the popular camera that presents the photographer with a finished positive print within seconds after the shutter is clicked. Before he developed the Land camera he had devoted most of his time to "Polaroid" polarizing filters, on which he had begun to work while he was still an undergraduate at Harvard University.

JOHN S. NIEDERHAUSER and WILLIAM C. COBB ("The Late Blight of Potatoes") work for the Rockefeller Foundation: Niederhauser as a plant pathologist in Mexico, Cobb as head of the Foundation's Office of Publications in New York. Niederhauser comes from Seattle, Wash., graduated from Cornell University and took his doctorate there under the late Donald Reddick. In 1947 he left an associate professorship at Cornell to join the Office of Special Studies in Mexico's Ministry of Agriculture and Animal Industry. The Office of Special Studies is a joint project of the Mexican Government and the Rockefeller Foundation. Cobb, who collaborated with Niederhauser in writing the article, is a Tennessean and a graduate of Vanderbilt University.

PETER M. WORSLEY ("Cargo Cults") is a lecturer in sociology at the University of Hull in England. He received his training at the universities of Cambridge and Manchester and at the

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Photo: Courtesy Electric Boat, Div. General Dynamics Corp.

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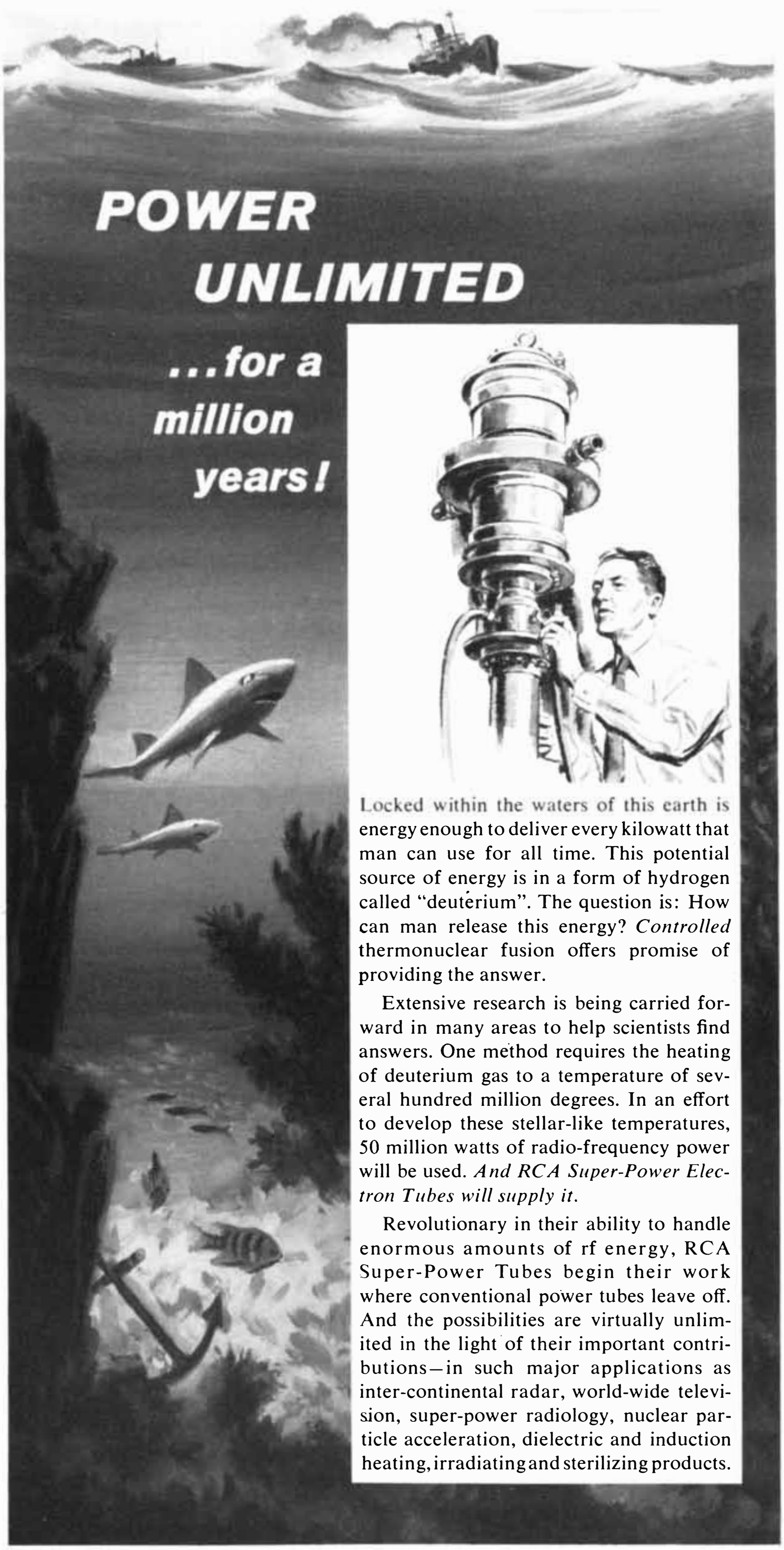

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Australian National University; for his doctoral dissertation at the latter institution he wrote a study of the Groote Eylandt aborigines of Australia's Northern Territory. During World War II he saw service in East Africa and southeast Asia. Later he helped plan the public-education system of Tanganyika. He is the author of a book entitled *The Trumpet Shall Sound*, concerning cargo cults and other strange religious manifestations in the South Pacific of today.

A. A. MOSCONA ("Tissues from Dissociated Cells") teaches zoology at the University of Chicago. An Israeli, he graduated from the Hebrew University in Jerusalem and in 1950 joined the Strangeways Research Laboratory, a well-known center of studies in cellular biology at the University of Cambridge. Before joining the Chicago faculty he held a fellowship at the Rockefeller Institute in New York.

V. L. GINZBURG ("Artificial Satellites and the Theory of Relativity") is a theoretical physicist on the staff of the Academy of Sciences of the U.S.S.R. He is also professor of physics at the University of Gorky. He was born in 1916 in Moscow. His father was an engineer, his mother a physician. Ginzburg studied physics at the University of Moscow, from which he graduated in 1938. Two years later he acquired his Candidate of Science degree with a dissertation on questions in quantum electrodynamics developed from the theory of Cerenkov radiation. After another two years he successfully defended his doctoral dissertation. "Like many other theoretical physicists," he remarks, "I like to occupy myself with a wide variety of problems. In recent years I have been concerned with the phenomenological theory of superconductivity and superfluidity, Cerenkov radiation, the propagation of electromagnetic waves in plasmas, radio astronomy and the origin of cosmic rays."

STEPHEN E. TOULMIN, who reviews Karl R. Popper's *The Logic of Scientific Discovery* in this issue, is professor of philosophy at the University of Leeds and, at present, visiting professor of philosophy at New York University. He is a graduate of King's College at the University of Cambridge, which he left for three wartime years of radar research in Britain's Ministry of Aircraft Production, followed by a Cambridge doctorate, a fellowship at King's College, and a University of Oxford lectureship in the philosophy of science. Toulmin has taught at Leeds since 1955.

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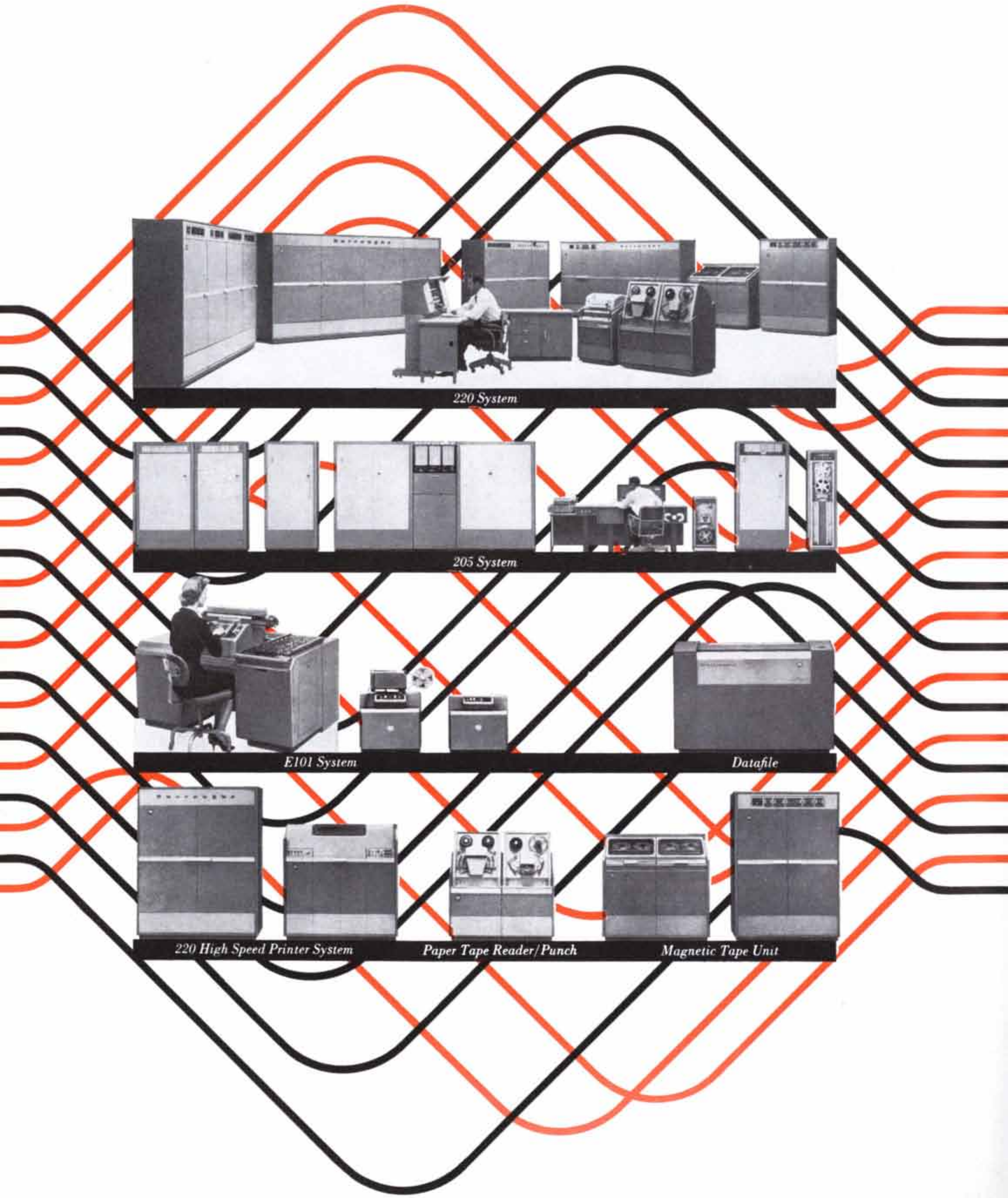

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Sir Isaac Newton...on the first cause

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—*Opticks, 1704*

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Nuclear Rockets

Chemical rockets are already approaching their theoretical limits. Various ways of utilizing nuclear reactions for rocket propulsion have been suggested, some of which are in the experimental stage

by John J. Newgard and Myron Levoy

The rocket, after a remarkably brief period of intensive development, has broken the restraint of earth's gravity upon the aspiration and the deeds of man. But the roar and flames of chemical combustion that now propel the rocket may not carry man far into the realm of outer space where his imagination already soars. The most impatient astronaut must be given pause by the dimensions of the 3,000- to 7,500-ton vehicle that would be required to lift a modest space ship of 50 tons—the weight of a DC-6—from the earth. If the space ship had to depend upon chemical reactions to power its further travels, its fuel supply would leave little weight to spare for a payload of men and instruments. Plainly the rocket propelled by combustion must yield to the rocket that obtains its energy either directly or indirectly from nuclear reactions.

An exotic family of novel propulsion systems is coming into view, so diverse in concept that the name rocket seems in some cases almost misleading. For example, in the frictionless vacuum of space a flashlight or a plate coated with radium may constitute a perfectly good rocket engine, at least in theory. Given enough time, a comparatively feeble beam of light quanta, gamma rays or nuclear particles can accelerate a space ship to extreme velocities.

The first generation of nuclear rockets is in the preliminary stages of design and test. If the nuclear engines are intended to enable a vehicle to escape from the earth, they will still generate the pyrotechnics we associate with rocket launchings. It is the nuclear rocket that we shall discuss first, since of all the new systems it is perhaps the closest to realization.

In the U. S. work on the nuclear rocket has been conducted until recently under the auspices of the Air Force and the Atomic Energy Commission at installations such as the Los Alamos Scientific Laboratory. However, nuclear-rocket propulsion has now been set up as a joint venture of the A.E.C. and the National Aeronautics and Space Administration. The transfer is symbolic of a perhaps surprising aspect of this new technology: it has practically no application to military purposes. As far as weight and cost are concerned, the nuclear rocket is practically noncompetitive with long-range missiles already in existence or in prospect.

Chemical rockets intended for parochial missions inside the earth's gravitational field have begun to press hard on the limits of combustion. A rocket is a heat engine that employs the simple device of a nozzle to convert heat energy into the kinetic energy of a moving gas. The nozzle first converges and then diverges in the path of the outrushing gases; as the gases expand, their velocity increases sharply. The rocket's performance depends essentially upon the velocity of its propellant gases; the performance improves at higher exhaust velocities. The two most important factors determining gas velocity are the initial temperature and the molecular weight of the gases. The higher the temperature, the higher the ultimate velocity. The highest temperature to which the gases can be heated by combustion is 8,000 degrees Fahrenheit; chemical rockets operating at 5,000 degrees F. already approach this inherent ceiling. At a given temperature the velocity of the gases can be increased by lowering their average molecular weight. The unit of molecular weight is the weight of the hydrogen atom; the average molecular weight of the combustion gases of the best present fuels is 19, and the lowest weight attainable without too great a reduction in temperature appears to be about nine. At the optimum combination of temperature and molecular weight the highest exhaust-velocity that can be developed with chemical fuels is about 13,000 feet per second. This is an exhaust-velocity only a little higher than that which put *Lunik* and *Pioneer IV* into orbit around the sun.

Theoretically nuclear physics should free rocket propulsion from both of the limitations imposed by chemistry. Nuclear reactions can furnish heat at unlimited temperatures; either hydrogen or helium may be used as the propellant gas without regard to their chemical characteristics, simply because they are the lightest elements of all. Consider first the work-horse rocket which would be employed to carry a space ship clear of the earth's gravitational field. We may visualize it as a vehicle equipped with a conventional but compact solid-core nuclear reactor instead of a combustion chamber, and with a supply of hydrogen instead of fuel in its tanks. Stored in liquid form at minus 420 degrees F., the hydrogen

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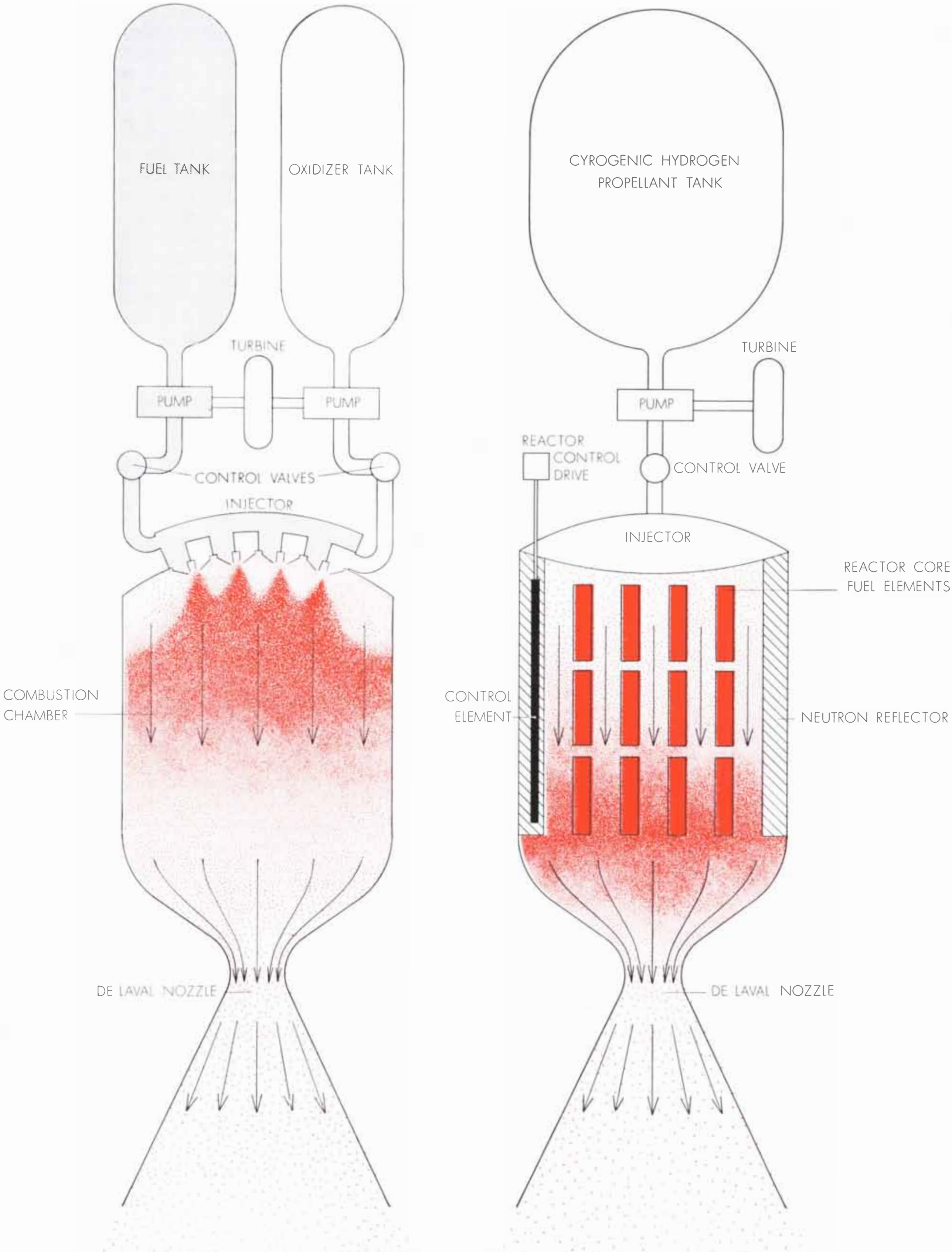

CHEMICAL AND NUCLEAR ROCKET-MOTORS are contrasted in these schematic diagrams. Chemical motor (*left*) burns fuel with an oxidizer to produce a jet of hot combustion gases which propels the rocket. Nuclear motor (*right*) "burns" fissionable uranium or plutonium in a lattice of fuel elements. These heat hydrogen gas which serves as the propelling fluid. The nuclear motor can exert more thrust than the chemical motor because the low molecular weight of hydrogen makes possible higher nozzle velocities.

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would be pumped to the high pressure of 1,000 pounds per square inch, forced between the fuel elements of the reactor, heated there to as high a temperature as the reactor could stand and then ejected through the rocket nozzle [*see illustration on preceding page*]. The choice of propellant gas alone would give such a system an immediate advantage over the most advanced chemical rocket. At a temperature of only 4,000 degrees F. the hydrogen would attain a velocity of 25,000 feet per second. This constitutes a 100-per-cent improvement on the theoretical maximum velocity of the chemical rocket.

On the other hand, as we approach the design of the first nuclear rocket-engine, the temperature of 4,000 degrees F. looms as a formidable objective. A chemical combustion-chamber can be made to contain even higher temperatures because the heat can be confined to the combustion gases, the shell of the chamber being cooled on its outer surface by the inflowing fuel, which acts as a heat-exchange medium. We face a very different situation in adapting the nuclear reactor to serve as a rocket engine. The reactor generates its heat in the solid structure of its core by the fissioning of the uranium incorporated into its fuel plates. Since heat must always flow from a higher to a lower temperature-potential, the fuel plates will be at a considerably higher temperature than the gas. Moreover, the transfer of heat to the gas is hampered by the "boundary layer" of stagnant hydrogen which clings to the surface of the fuel plates. To achieve a gas temperature of 4,000 degrees F., the temperature in the central plane of the fuel plate must be 4,800 degrees F. Few materials that are usable in a reactor can withstand such temperatures. Consequently the choice of materials sets a limit on the gas temperatures we can hope to attain. A promising material is graphite impregnated with uranium. But even though graphite retains its strength at 4,800 degrees F., this strength is rather low. Erosion and corrosion by the flowing hydrogen promise to create additional problems.

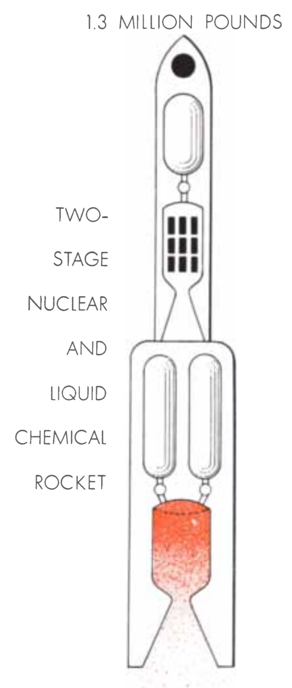
The design of this relatively feasible rocket engine confronts the designer with a host of additional stringent requirements. In the first place, the size and weight of the reactor must be held to a minimum. Calculation shows that a reactor of compact size must generate as much as 10 kilowatts of power per cubic centimeter of uranium-bearing graphite. This is about 10,000 times the equivalent output of the British power reactor at Calder Hall, the first gas-cooled graphite-moderated power reactor. Fortunately the fuel elements may need to remain integral for only a few minutes, since this kind of engine may be jettisoned when its work is done.

The transfer of such huge quantities of heat to the propellant gas requires a relatively large number of thin fuel-plates. The greater surface area between the fuel plate and the gas reduces the amount of heat that must pass through a unit of area in a given time. As a result the peak temperature at the central plane of the plates and the stresses created by thermal gradients within the plates may be kept within permissible bounds. But the solution of the heat problem creates some new ones. The greater surface area causes a larger drop in the pressure of the propellant gas as it flows between the plates. In a typical design, with 1,000 pounds of gas per second flowing through a 10,000-pound core, the frictional drag of the gas on the plates adds up to a total force on the reactor of as much as 300,000 pounds! Since useful thrusts in nuclear-booster rockets require high propellant flow-rates, this drag is not easily reduced. Fewer and thicker plates would crack or warp.

To aggravate the problem, the rocket may have an acceleration of 10 g—that is, an acceleration 10 times that of a body falling at the surface of the earth—by the time it nears the end of its powered flight. This means that in effect the reactor will be 10 times heavier than when it started; the 10,000-pound engine will "weigh" 100,000 pounds. With the increased weight added to the frictional drag, the reactor will exert a total force of 400,000 pounds or more on the rocket structure. Yet the support members that bear this load must occupy a minimum of space, stand up under a temperature of 4,000 degrees F. and contain little or no metal. Since metals that are resistant to high temperatures interfere with the nuclear reaction, graphite again may have to be used for the structural beams or columns. But graphite is difficult to join together; the cabinetmaker's slots and dovetails may have to be employed.

The start-up and control of the nuclear-rocket reactor present another whole family of problems. To avoid a tremendous loss of hydrogen, the reactor must heat up rapidly to operating temperature. But rapid heating creates heavy thermal and mechanical stresses in both the fuel elements and structure of the reactor. Though the danger of a "runaway" that would melt the system is slight, it cannot be ignored. For example, a large increase in hydrogen density arising from accidental blockage of the flow channels could result in melting. We cannot foresee all of the difficulties; they must be uncovered by operating experience with prototype reactors in ground test-beds.

Radiation is another hazard that calls for ingenuity in the design of the rocket and the management of the launching. The erosion of as little as 1 per cent of the fuel-element surface in a typical nuclear rocket-engine might liberate a quantity of fission products equal to 3 per cent of that produced by a 20-kiloton atomic bomb. Launchings will of



FOUR ROCKETS of different types are compared in these drawings. Each represents the estimated weight of a rocket pow-

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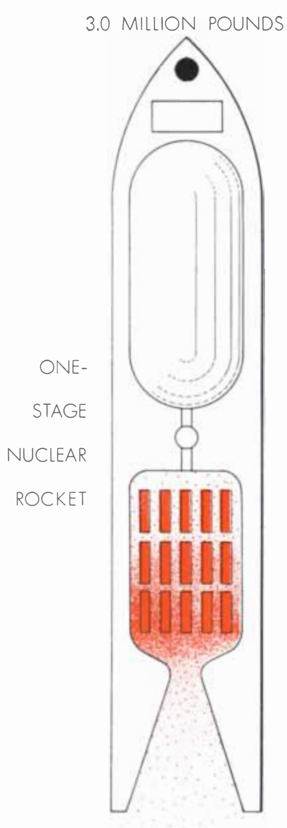
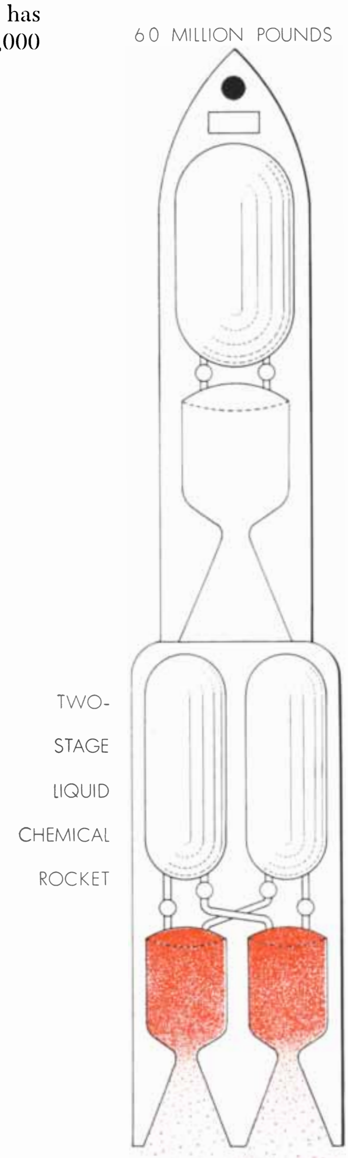
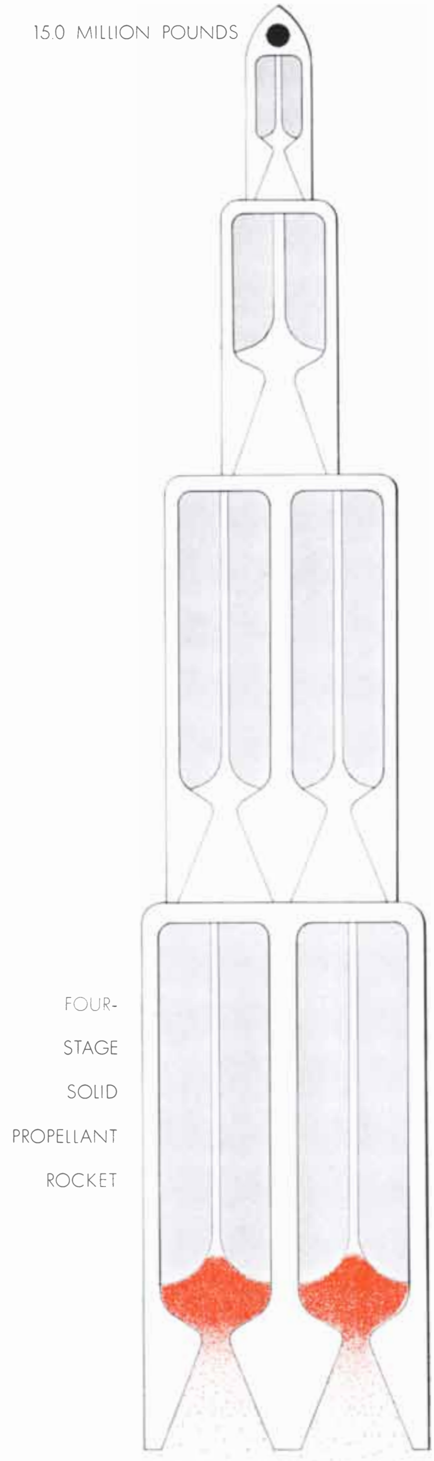
course have to be conducted at remote sites.

The temperature limitation inherent in the solid-core nuclear reactor has inspired a number of alternative systems. One of these is the gas-phase nuclear reactor. Such a reactor would have a gaseous core, with uranium present in the gas phase of a compound such as uranium hexafluoride. It could be operated at temperatures up to 10,000 degrees F. because, as in the chemical rocket, the walls of the reactor chamber would be kept cool by preheating the inflowing propellant. However, no one has figured out how to transfer the heat from the reactor gas to the propellant gas without losing the uranium hexafluoride in the exhaust stream. It has been shown that the ejection of 1,000 pounds of hydrogen per second would sweep out at least 350 pounds of uranium hexafluoride per second. In the three to five minutes it would take the rocket to escape from the earth, as much as 100,000 pounds of uranium hexafluoride would be lost. At the present cost of $10,000 per pound, the launching of such a rocket would use up $1 billion worth of enriched uranium hexafluoride. In addition, the efflux of uranium-hexafluoride molecules would raise the average molecular weight of the ejected gases and thus offset the improvement in rocket performance that the higher gas-temperature was supposed to give. It has been proposed that the heavier uranium gas might be retained in the outer periphery of the chamber by a kind of centrifuging arrangement, with the lighter propellant rushing through the







erful enough to launch a 100,000-pound payload (*symbolized by black spheres*) into space; the drawings do not attempt to show sizes in accurate proportion. The two-stage nuclear-chemical rocket at far left appears more efficient than the single-stage nuclear vehicle next to it. However, the problem of separating the two stages in flight would probably make the single-stage rocket more reliable.

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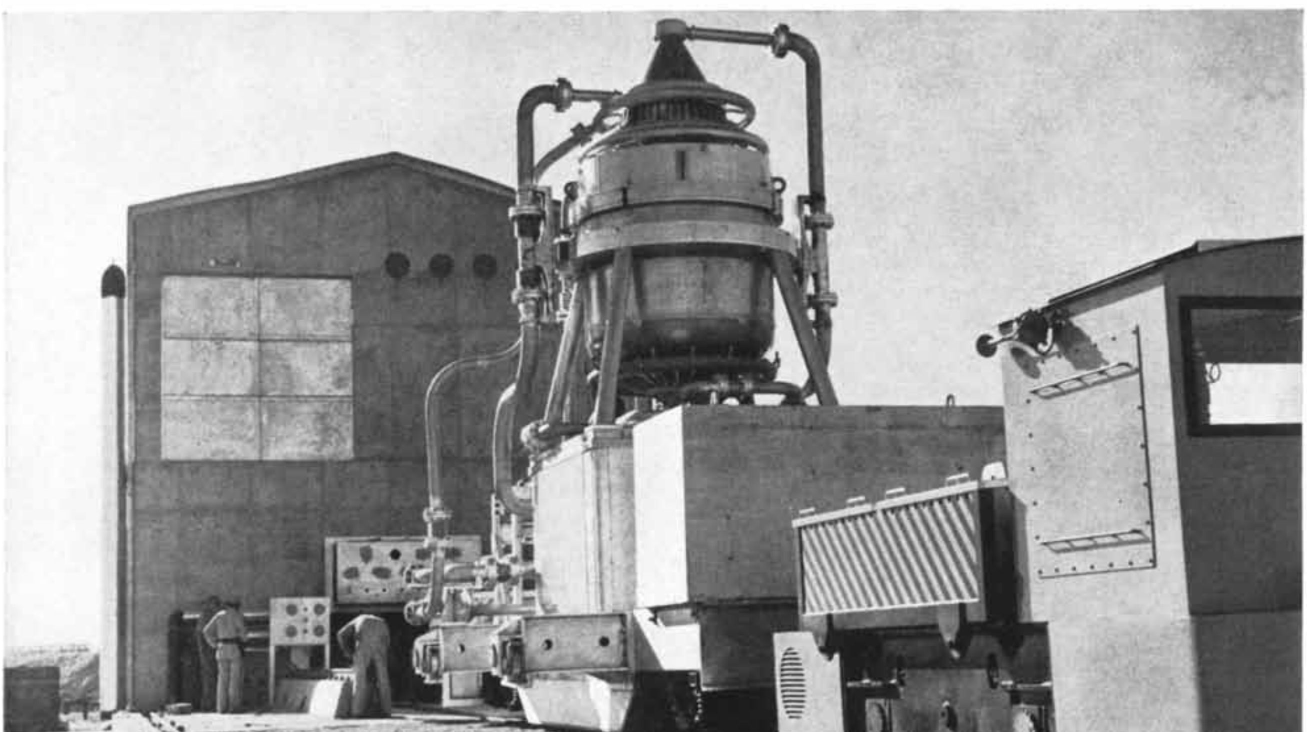
center. Alternatively, porous barriers might be used to "strain" the larger uranium-hexafluoride molecules out of the exhaust stream. Each such suggestion, however, raises more problems than it solves.

Yet temperature limitation is so critical that the gas-phase reactor is receiving further attention, along with other equally radical ideas. According to a recent announcement by the A.E.C., an even more radical idea is being studied. In essence this scheme would utilize sequenced and controlled nuclear explosions to propel a rocket into space. Here again the cost of a single mission might be very high; the technical problems are also formidable.

In view of all this, the solid fuel-element system represents the most probable first-generation nuclear rocket. Judging from the literature, effort along these lines is being pursued in the U.S.S.R. as well as in the U. S. The solid-core nuclear rocket clearly excels the standard chemical systems when the payload of the rocket becomes high or when the mission requires escape from the earth's gravitational field. For launching huge satellites or space craft, of say 50 tons as compared to the 2,000- to 3,000-pound weight of the Sputniks or the 40-pound weight of the Explorers, the nuclear rocket comes into its own. Chemical rockets would require many stages and enormous take-off weights to achieve such launchings. The nuclear vehicle can do it with a single stage, a lower total weight and much higher reliability. If we want to reckon with the possibility of space vehicles designed for voyages of long duration, then we must provide them with nuclear boosters to carry them free of the earth's gravitational pull.

The space vehicle, on the other hand, has quite different energy requirements. Since it is essentially weightless, quite small forces can be utilized to propel it, and it may call upon a wide selection of new and strange propulsion techniques. It might again use a nuclear reactor, but a reactor with low gas-flow and low thrust. However, for space missions of long duration (on the order of a year) a nuclear reactor that directly heats the propellant is not so effective as some of the more exotic systems. One of the more feasible of these systems, first proposed by the Austrian rocket pioneer Hermann Oberth, is ion propulsion. The nuclear reactor that powers an ion-propelled space ship will be markedly different from the engine that gets it off the ground. This reactor will not heat up and accelerate the propellant ions directly but must generate electrical energy for that purpose and others over a long period of time. It will, therefore, more closely resemble an earth-bound nuclear-power plant. Electrical energy from the reactor will first of all vaporize liquid cesium and ionize the free atoms. An electrostatic field of several thousand volts will then accelerate the positive cesium ions to high velocity, while an auxiliary electrostatic accelerator (or perhaps simply a pointed rod in the stream of ejected ions) will bleed the orphaned electrons off into space [*see illustration on opposite page*]. Such an arrangement can impart an exhaust velocity to the ions as high as 200,000 feet per second. The thrust of the ion beam is low; it is on the order of .1 to 10 pounds, or a ten thousandth the weight of the rocket, as compared to the high ratio of thrust to weight required in the launching vehicle. Yet the small thrust is sufficient to propel the space vehicle and, given sufficient time, to accelerate it to extremely high velocities. Since many space missions may take more than a year, the time needed for acceleration is not of great consequence.

It is the intrinsically large mass of the ion-propulsion system that dictates the 50-ton weight of the space vehicle that has been projected in this discussion. The nuclear reactor would be coupled, by means of a helium working-fluid, with



FIRST EXPERIMENTAL ROCKET REACTOR will shortly be ground-tested at Jackass Flats in Nevada. The device, named *Kiwi-A* after the flightless bird of New Zealand, is a gas-cooled solid-fuel reactor that resembles the one diagrammed on page 47.

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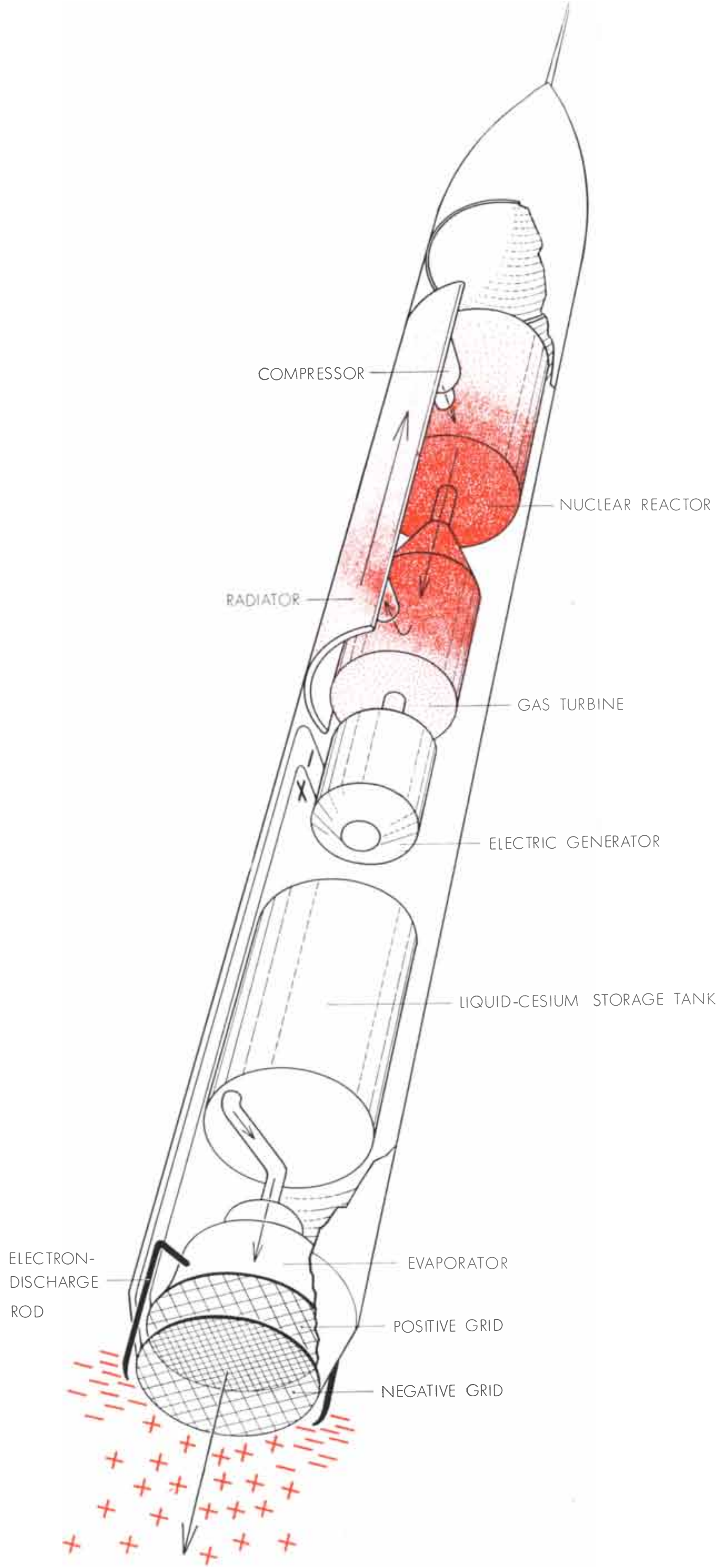
ION ROCKET shown at right is a still-hypothetical device for space travel. Helium (*colored area at top*) heated in a reactor drives a gas turbo-generator; exhaust helium is cooled in a radiator and returned to the reactor. Current from the generator vaporizes liquid cesium, ionizes it and ejects the ions (*plus signs*) at velocities up to 200,000 feet per second. Electrons (*minus signs*) stripped from cesium atoms are bled into space from discharge rods. Ion rockets would exert a weak thrust for long periods, and would require the help of more conventional booster rockets to escape from earth.



a turbine. The turbine would drive an electrical generator, and the spent helium would be compressed and sent back through the reactor. All of these machines contribute to the weight of the rocket. In addition, the low-temperature waste heat of the reactor must be radiated away from the rocket; the size and weight of the required radiator are considerable. As a result of its great weight of equipment, the rocket accelerates slowly and cannot escape from strong gravitational fields without the help of its complementary twin: the high-thrust nuclear booster.

Still another possible means of nuclear-rocket propulsion is the fusion rocket. As regular readers of this magazine are well aware, several laboratories are at work on ways to contain a plasma of electrically charged particles in a magnetic field and to raise the temperatures of the plasma to the point at which its nuclei enter into a fusion reaction. If such a thermonuclear reactor can be made, it should be possible to adapt it to the purposes of a rocket engine. This would be done by ejecting the plasma from the reactor, thus providing thrust.

The prospects of space propulsion abound in such strange systems of energy transformation. The direct conversion of nuclear-fission, or thermonuclear-fusion, heat to electricity would reduce the weight of auxiliary equipment in the ion rocket and lead to improved performance. Propulsion by the ejection of plasmas via internally generated electrostatic and electromagnetic fields and by the ejection of photons are presently under study. Providing man succeeds in surmounting his own menace to his continued existence on earth, he may soon be venturing into space, not unlike the first prehistoric fish that flopped awkwardly out of the sea into thin air on dry land.

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Balloon Astronomy

Some remarkably sharp photographs of the sun made with a telescope lifted 82,000 feet are an example of how astronomy can be advanced by means of observations from balloons, rockets and artificial satellites

by Martin and Barbara Schwarzschild

On a quiet September morning in 1957 a huge, transparent balloon, brilliantly lighted by the sun, floated across the sky 15 miles above the fields of Minnesota. Following its course in automobiles on the ground a group of anxious astronomers wondered whether the telescope and camera they had hung beneath the bright bubble were working. Like all astronomers, they were used to the fact that the objects they were studying were hopelessly out of reach. But to have their viewing equipment also inaccessible was a new experience. Fortunately this time their fears were unnecessary; the instruments did quite nicely on their own, obtaining pictures of the sun's surface sharper than any made previously.

Soon there will be other and more elaborate balloon experiments. We may expect that in the not-too-distant future telescopes will be mounted on satellites revolving hundreds of miles above the earth's surface. Why this effort to get a mere few miles closer to celestial objects? The answer is of course that this short distance takes us above the earth's atmosphere, which hangs like a distorting and dimming veil between our telescopes and the stars. The air is heated unevenly, particularly near the ground and in the region at about 40,000 feet called the tropopause. The resulting turbulence distorts light rays passing through the air, smearing points of light into irregularly varying spots. Anyone who has seen the stars twinkle has observed this effect, which astronomers call "bad seeing." Making each point of light look bigger than it actually is, the effect limits our ability to distinguish separate stars when they are close together, and to make out fine detail on a larger object like the sun.

To help overcome the effects of bad seeing, many observatories are located on carefully selected mountaintops, where the lower air is quietest. But even on mountaintops there is still much local turbulence, and the problem of the tropopause is completely unsolved. In 1956 a telescope was taken aloft in a manned balloon by D. E. Blackwell and D. W. Dewhirst of the University of Cambridge and A. Dollfus of the Meudon Observatory in France; however, the ceiling of their flight was below the tropopause, so they eliminated only one of the two sources of bad seeing.

In addition to causing bad seeing, the atmosphere handicaps astronomers in another way: it absorbs all the ultraviolet and much of the infrared radiation of the sun and stars. Balloon altitudes may suffice to overcome the infrared absorption. But for investigations in the ultraviolet—potentially extremely important—the much higher altitudes of rockets and satellites are needed. Indeed, rockets have already carried ultraviolet spectrographs up 40 miles or more. However, there are many astronomical problems affected by bad seeing but not by absorption; for them stratospheric balloons are a very effective tool.

At the Princeton University Observatory we have long been interested in off-the-ground astronomy, largely because of the enthusiasm of Lyman Spitzer, Jr., director of the Observatory. For the first venture into the field our group chose a comparatively easy yet important problem: a study of the sun. Because of its nearness and brightness the sun is often a good starting point in astronomical research. It is the only star that appears to us as anything more than a point of light. By studying its visible features we can learn not only about conditions of its surface, but also something about its interior. This information helps illuminate many other problems, such as how the stars evolve.

The bright surface of the sun, known as the photosphere, has a finely mottled appearance when it is viewed through a telescope. On it there are bright spots, or "granules," separated by darker regions. The bright spots are columns of hot gas rising from the interior, while the dark areas are cooler gas that is sinking back again. The whole surface of the sun is covered by this ever shifting convective pattern. From the details of the pattern—the size, brightness and duration of the individual granules—we get information about the mechanism by which heat is transported outward from the depths of the star.

Through the years astronomers have taken innumerable photographs of the sun's granulation. For more than half a century—such is the importance of seeing—the prize plate remained one that was made at an unusually favorable moment in 1885 by the French astronomer Jules Janssen. In recent years techniques have improved; photographs of high resolution have been obtained not only during the 1956 manned-balloon flight but also from the ground by Jurgen Rösch of the Pic du Midi Observatory in France, Robert B. Leighton of the California Institute of Technology and G. Thiessen of the Bergedorf Observatory in Germany. However, an accumulation of indirect evidence indicated that there must be finer details in the granulation pattern than were revealed on any of the plates.

To see these details there seemed no alternative but to get a telescope above the tropopause. When James A. Van Allen of Iowa State University encouraged us to use balloons, our group at Princeton began planning. We turned

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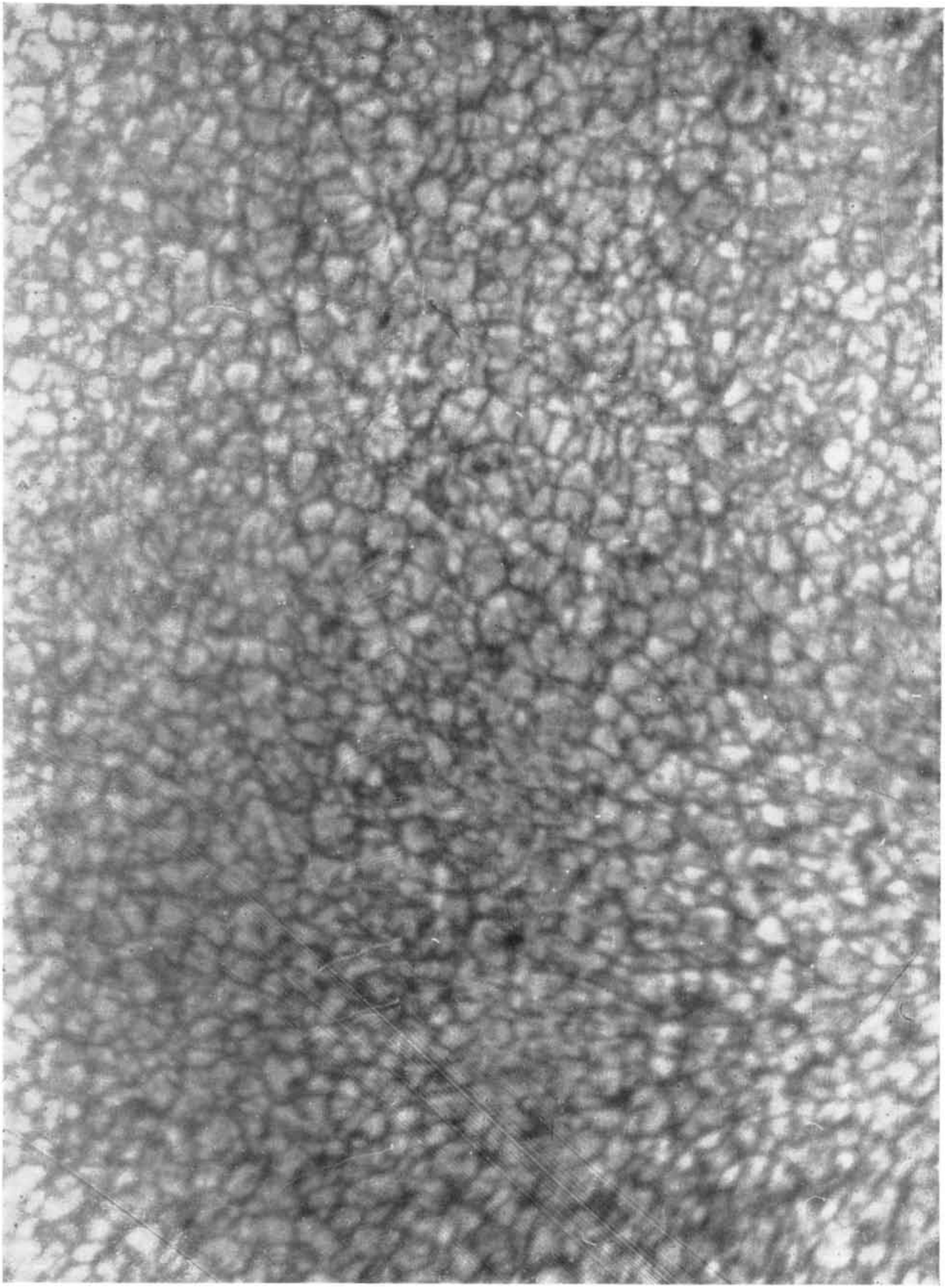

SURFACE OF THE SUN was photographed by the balloon-borne 12-inch reflector of the Flying Telescope Project. This picture covers an area on the sun 43,000 miles by 31,000 miles. The lighter spots in the photograph are rising columns of incandescent gas; the darker areas, sinking masses of gas. The dark spot about an inch from the right at the top is a "pore," resembling a tiny sunspot.

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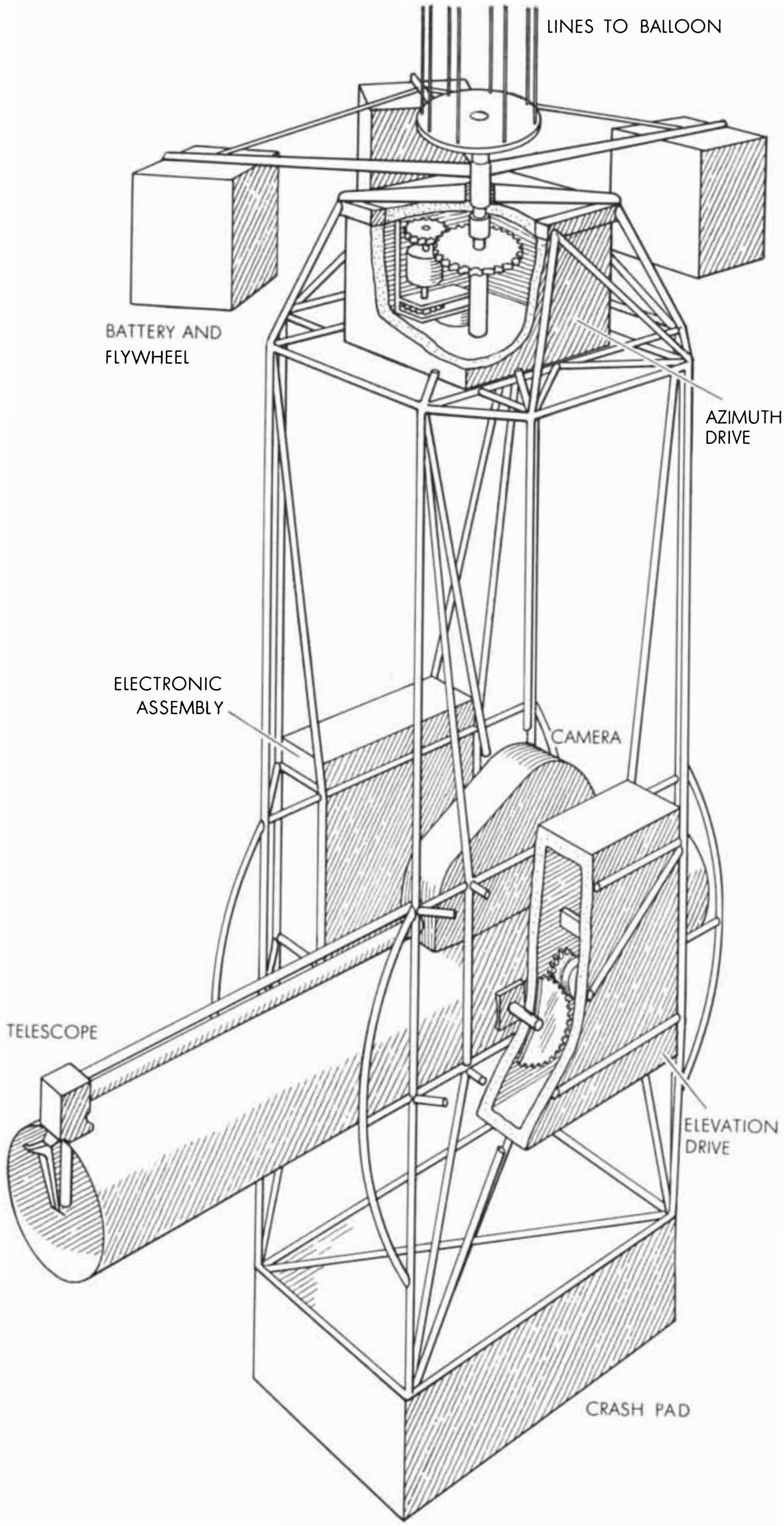

MOUNTING OF THE TELESCOPE is depicted in this simplified drawing. The telescope is shown in its observing position. As it is borne aloft it is stowed within the mounting.

for advice to several experts: John W. Evans of the Sacramento Peak Observatory in New Mexico, the Navy balloonist Malcolm Ross and cosmic-ray physicists at the University of Minnesota. The resulting plans received financial support from the Office of Naval Research, from the Air Force Geophysical Directorate and more recently from the National Science Foundation.

For the 1957 flights the telescope was designed and constructed by the Perkin-Elmer Corporation; the pointing control, by the Research Service Laboratories of the University of Colorado. The balloons were made and the flights conducted by General Mills, Inc. The capability, enthusiasm and spirit of cooperation of these firms have played a decisive role throughout the project.

A good deal of ingenuity went into building a system that would operate automatically in the lonely reaches of the stratosphere. Perhaps the best way to get an idea of the difficulties involved is to look briefly at the apparatus designed to overcome them.

The telescope itself has an eight-foot tube, at one end of which is a parabolic quartz mirror 12 inches in diameter. At the other end of the tube are a plane mirror and a prism that reflect the light gathered by the parabolic mirror back along a path above the tube of the telescope into a 35-millimeter motion-picture camera [*see diagram on opposite page*]. A lens in the light path enlarges the image presented by the primary mirror to the size of an image that would be produced by a 200-foot telescope. At this magnification each frame of the 35-millimeter film covers a rectangle about 50,000 by 35,000 miles on the surface of the sun. Exposures are made at the rate of one per second, each lasting a thousandth of a second.

To find the sun, and to remain pointed at it, the telescope must be free to turn both horizontally and vertically. It is mounted in a metal frame in which it can swing vertically, and the frame itself turns in the horizontal plane [*see illustration at left*]. A pair of motors, guided by light-sensitive semiconductor "eyes," drives the apparatus in the two directions. This guiding mechanism must hold the telescope very steadily centered on the sun; during exposures the rate of motion cannot exceed one rotation of the telescope per hour. The system did its duty well, as we confirmed in advance by ground tests. We suspended the assembly and allowed it to follow the sun; it pointed at the sun's center accurately and steadily. If some-

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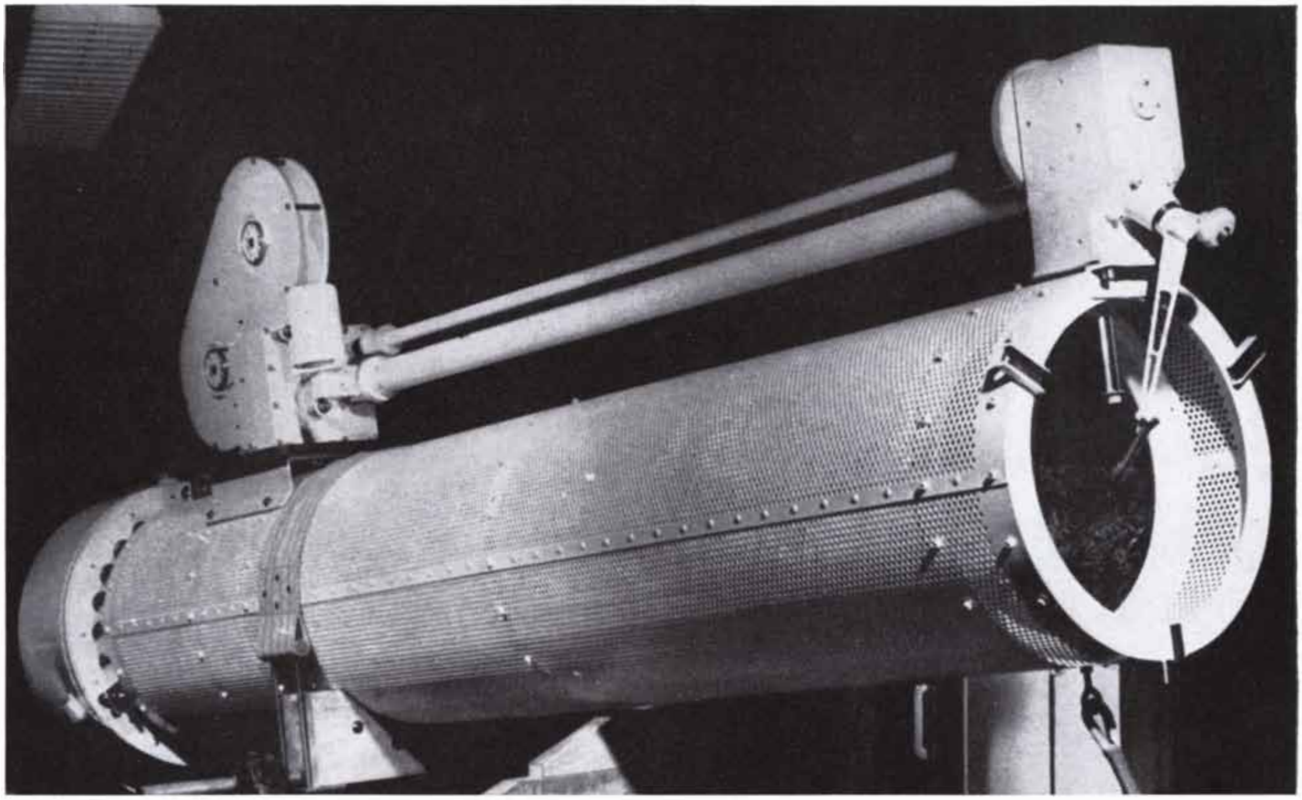
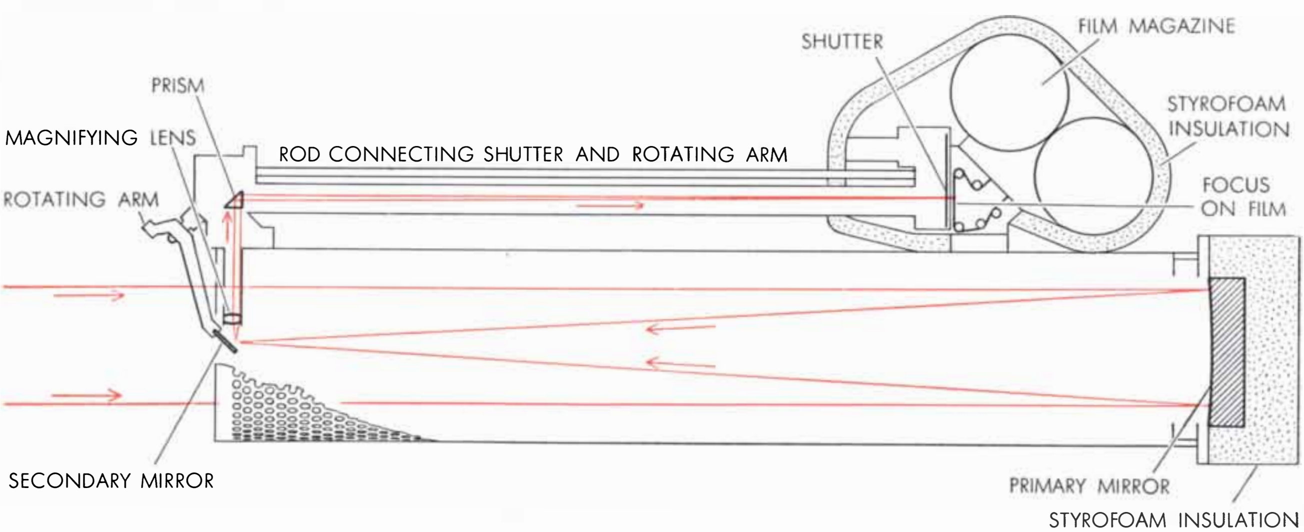
one tried to push the telescope away from its proper position, it would push sturdily back, uttering a low growl. During a preliminary test flight the pointing mechanism passed its final examination.

In flight the apparatus is hung from a parachute that is in turn attached to the balloon. After the film is exhausted a preset timer stows the telescope vertically within the frame and cuts the parachute away from the balloon. In addition to serving as a mounting, the frame protects the telescope when it hits the ground. A Styrofoam crash pad on the bottom cushions the fall, and a large wheel at the top, which carries the batteries that drive the motors, takes up the impact when the frame topples over on its side.

Aside from the fundamental questions of optical design and guidance, the major problems that had to be faced concerned heating. Starting at a temperature of, say, 60 degrees Fahrenheit on the ground, the telescope was exposed to air at about 70 below zero in the stra-



TELESCOPE ITSELF is shown separate from its mounting. Its 12-inch primary mirror is inside the left end of the tube; its secondary mirror is mounted on the arm which projects into the open right end of the tube. The tube is perforated to cool it.



OPTICAL SYSTEM of the telescope is shown in cross section. The arm on which the secondary mirror is mounted is rotated once a second to prevent the mirror from overheating. The magnifying lens increases the size of the image and projects it on the film.

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tosphere while being simultaneously subjected to the full heat of the sun. To minimize distortions the quartz primary mirror was heavily insulated at the back and sides so that practically all the heat was absorbed and radiated at the front face. While the arrangement could not prevent changes in the focal length of the mirror, it did enable the mirror to maintain a nearly perfect surface.

Since the focus of the mirror would necessarily vary, and by an unknown amount, the focal image could not always be expected to fall sharply on the film. We therefore adopted the stratagem of moving the magnifying lens between the mirror and the camera, driving it steadily back and forth over the full range of anticipated variation every 20 seconds. Thus 19 out of every 20 pictures would be blurred, but one was sure to be in focus.

The flat secondary mirror also presented a heating problem, located as it is at the hot primary image of the sun. To ensure its proper functioning it was mounted on an arm that rotated once a second, placing the mirror in the light beam for only a 30th of a second on each cycle. The shutter of the camera was of course synchronized with the motion of the mirror.

By September 16, 1957, all the apparatus had been assembled and tested at an airport near Minneapolis, the headquarters of General Mills. From there it was to be launched. But though we were ready, the stratosphere was not. Overhead was the jet stream, blowing violently toward the north woods. Eight days passed before the winds became favorable. Then we were alerted for a flight at dawn.

Starting at 1:30 a.m. we completed the final check-out, and the launching crew went into action. Using a fork-lift truck, they moved the delicate, top-heavy equipment from the tent where it was stored to the launching truck, hanging it from a pair of hooks on a tall rack. The parachute shrouds were attached to the top of the frame and stretched over the launching truck to the canopy of the parachute, which was laid out in a line. The top of the parachute was attached to the bottom of the balloon, which had been unrolled from its box. The balloon, made of polyethylene two thousandths of an inch thick and reinforced with Fiberglas tapes, would be 130 feet in diameter when it was fully inflated. Now about two thirds of it lay stretched in a thin line beyond the parachute. At the two-thirds point it was held under a roller on a small auxiliary truck. The remaining third was inflated from the top with helium.

As we all tensely awaited sunrise, the quietest time for launching, the inflated portion of the balloon towered above us. It caught the first light of day

BALLOON IS PREPARED FOR LAUNCHING at dawn September 25, 1957, nine days after the flight described in detail by the text. The scene is an airport outside of Minneapolis. The mounting of the telescope is suspended from a rack on the back of the truck at right. Attached to the lines extending from the top of the mounting is a large parachute, which in turn is attached to the balloon.

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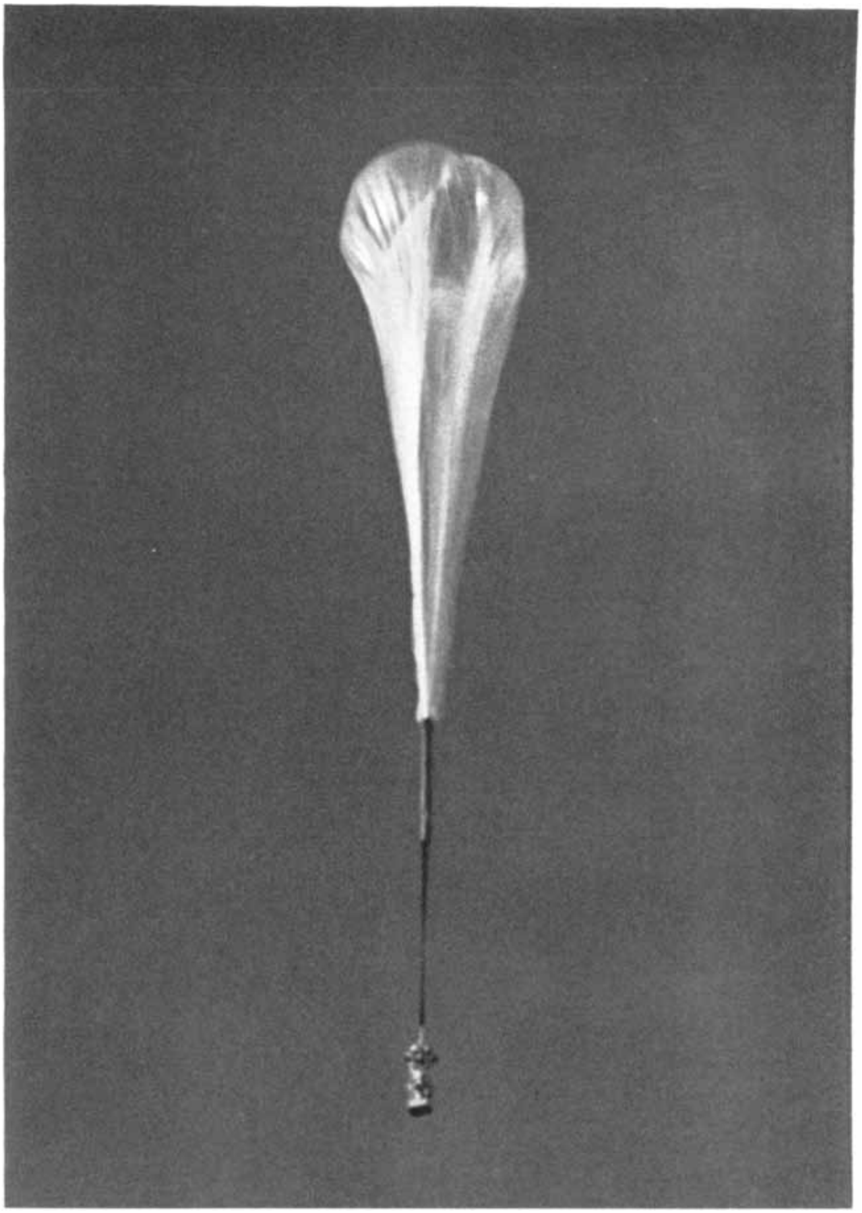
on its smooth and shining sides, and as the sun brightened it gleamed with a rosy sheen. At last the launching chief gave the signal. The roller holding down the balloon was released and the small truck was driven quickly out of the way. The whole bag rose free, with loud snapping noises, pulling downwind and drawing the parachute up after it. As soon as the shrouds were taut, the launching truck started forward. At the instant it came directly under the balloon a powder squib was fired, cutting a cord that tied the parachute to the truck and allowing the balloon to lift the load. After all the bustle and excitement, the quiet calm as the telescope floated noiselessly away came as a striking contrast.

It was just 7:15 a.m. when the launching was completed and the chase began. The posse included a small plane and a truck (both equipped to receive radio signals from the balloon and thus to track it in case of clouds), a van for carrying back the equipment, and several personnel cars.

By nine o'clock the balloon had reached altitude (about 82,000 feet, or above 96 per cent of the atmosphere), and the master timer turned on the electronic equipment. At 9:15 the pointing motors centered the telescope on the sun. An hour later, when the temperature had settled down, the camera was turned on. A thousand feet of film, containing 8,000 frames, was fully exposed by 12:30. At 12:45 the timer gave the signal to restow the telescope in its vertical position. A little later a powder squib cut the parachute free. Those of us who were watching through binoculars saw the balloon shatter into a thousand pieces, and the red- and white-striped parachute open, its load swinging wildly underneath. The shreds of balloon spread out and followed like the silvery tail of a comet.

The parachute landed its cargo in a field about 150 miles east of Minneapolis. Guided by the plane we arrived at the site 15 minutes after impact. We examined the equipment, which had suffered little damage, stowed it in the van after removing the camera with the exposed film and left for home. Arriving at midnight, we had 24 hours of astronomical ballooning behind us. We were so tired we had to go to bed leaving unanswered the burning question of whether the experiment had been successful.

Next morning, when we had rested enough to do reliable work in the darkroom, we started to develop the film. The first 100 feet proved that it was not blank, as we had seen it in our nightmares. The apparatus had functioned well, and we had some photographs of unprecedented quality.



TELESCOPE SOARS ALOFT after the balloon is released. It reaches altitude in about two hours and operates for about four more. Then the telescope parachutes back to earth.

A second flight a short time later gave us another 1,000 feet of photographs. All told about 10 frames turned out to have the superior resolution for which we had hoped. These 10 frames exceeded the minimum goal of the entire undertaking, and contained a wealth of new information. Many other frames contained excellent portions. That there were not more of top quality was the fault of vibration from the motors and other rotating parts. There was no evidence at all that bad seeing interfered in any of the frames.

Three main characteristics stand out on the photographs. First, the granules come in widely assorted sizes. Many of them are only 180 miles in diameter, far too small to have been recognized on photographs taken from the ground. From this size they range up to diameters of about 1,000 miles. Second, most of the granules have the complicated shapes of irregular polygons. Third, the dark areas differ sharply from the bright ones; they tend to form a connected net of narrow lanes separating the more substantial bright spots.

This pattern came as a complete surprise. It represents one of the types of motion that may be set up when a

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TELESCOPE CAME TO EARTH in a cornfield near Scarville, Iowa, 230 miles east of the point at which it had been launched on its second flight. In the foreground is the bottom of the mounting. It is protected against the impact of landing by a crash pad.

fluid is heated evenly from below, as the gas in the sun is. But it is not the type we expected to see.

The behavior of such a fluid depends on its depth and on the rate at which it is heated. If it is shallow and the heating is gentle, the rising columns of gas or liquid form a series of neatly defined polygons of uniform size. This condition is known as stationary convection. Increasing the depth or the rate of heating causes the stationary cells to break up into a shifting array of irregular polygons of varying sizes. The surface now presents an ever changing appearance, from which comes the term nonstationary convection.

The sun's outer layer is exceedingly deep, and heat flows through it at an enormous rate. Because of these extreme conditions we had expected the granulation pattern to be still more chaotic than for nonstationary convection. Instead the new photographs show unmistakably that the pattern of the solar granulation is that of nonstationary convection. This unexpected result corrects our picture of conditions in the solar atmosphere. It contributes to our knowledge of how the heat produced at the center is carried outwards. It therefore provides new information about conditions in the interior of the sun, and is bound to help us in understanding the evolution of stars in general.

Readers who would like to get a vivid picture of conditions on the sun's surface can do so in the following home experiment: Pour molten paraffin to a depth of about an eighth of an inch into a flat-bottomed Pyrex dish at least six inches across. Add a little powdered aluminum and lampblack to make the convection patterns visible. Place the dish on an electric plate and heat it evenly over the entire bottom just enough to keep the paraffin liquid. Soon the surface will divide into uniform, well-defined polygons: the pattern of stationary convection [*see top photograph on opposite page*]. Now add enough paraffin to bring the depth to half an inch. The stationary cells will break up into the typical nonstationary pattern—irregular polygons of assorted sizes separated by lanes, just as in the solar granulation [*see bottom photograph*].

Although granulation studies were the primary aim of the first balloon experiment, the sharp pictures that were obtained throw new light on several other problems. One of them concerns certain small, dark spots known as pores. Photographs taken from the ground were rarely sharp enough to show up the pores clearly, so it was impossible to follow their development. An analysis by J. D. Bahng of the balloon pictures has now demonstrated that the pores have much longer lifetimes than the granules. This substantiates the earlier hypothesis that granules are nothing but small sunspots. In another investigation John B. Rogerson is using the new photographs to measure the sharpness of the edge of the sun. This will give information on the temperature in the outer layers of the solar atmosphere.

Now that it is under way, high-altitude astronomy will develop rapidly. At Princeton our Flying Telescope Project, headed by Lyman Spitzer, is planning both balloon and satellite experiments. In our next venture with the stratoscope (as the balloon telescope has been named) we shall attempt to point and focus the instrument by remote control.

A new television system being developed by V. K. Zworykin's section at the Radio Corporation of America Laboratories will present to ground observers the same picture that is falling on the photographic film. As they watch the television screen, they will adjust the focus of the telescope by radio and keep it sharp. Thus practically every frame

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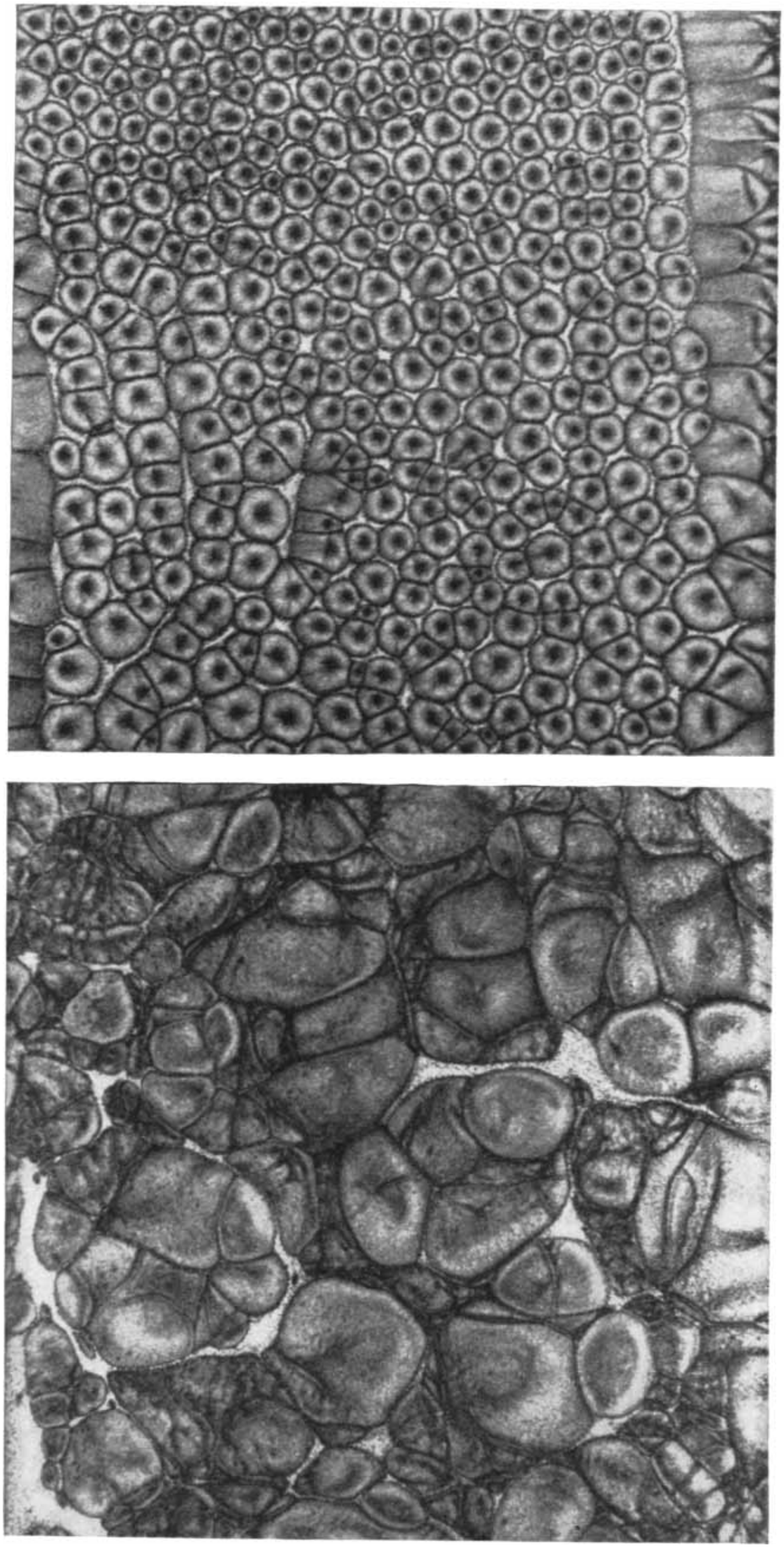
should be in focus, rather than every 20th one. A major effort is also being made to eliminate from the system the mechanical vibrations that gave the chief trouble in 1957.

In the coming flights we plan to observe the granules continuously over an extended period to see how they develop and how long they persist. We also aim to study sunspots and the granulation at their periphery. Here the gas is subject to strong magnetic fields. Do the fields stabilize it sufficiently to set up stationary convection in these areas? This is one of the fascinating questions in the field of plasma physics, a field growing in importance for thermonuclear reactors and astrophysics alike.

Beyond these solar investigations are much broader opportunities for balloon astronomy. The very best night pictures taken from the ground have a resolution of about a third of a second of arc, which is the theoretical resolving power of a 12-inch mirror. With a 36-inch mirror the theoretical limit is a 10th of a second of arc, and above the atmosphere one might attain it. Planning for a 36-inch stratoscope has already begun, but the requirements are formidable. The mirror must be ground to unprecedented accuracy. The telescope must be guided steadily within a 10th of a second of arc for minutes at a time; in the first flights guiding to a third of a second of arc during a thousandth of a second sufficed. However great the difficulties, the potential rewards for solving them are dazzling.

Better resolution is the only answer to many basic astronomical problems. With the help of the 36-inch stratoscope we should be able to understand better the changes in the atmospheres of Venus and Jupiter, analyze the division in Saturn's rings and measure the diameter of Pluto. Farther out in space we could study the Great Nebula in Orion, where new stars seem to be forming in dense interstellar clouds. At the other end of the evolutionary scale we could investigate in detail whether the gigantic shells of gas known as planetary nebulae represent the dying phases of stars. Then there are the galaxies outside our own, whose mysterious dense nuclei may contain clues to their past history.

All these problems and many more can be tackled if a 36-inch telescope can be put into the black and unwavering heights of the stratosphere. And at the same time invaluable experience can be gained for the next phase of astronomy with telescopes on artificial satellites.



EXPERIMENT WITH PARAFFIN heated in a flat dish recreates the pattern of the surface of the sun. At top is the pattern of "stationary" convection in paraffin an eighth of an inch deep; at bottom, the pattern of "nonstationary" convection in paraffin half an inch deep. The nonstationary pattern resembles that observed in photographs of the sun's surface.

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The Origin of Darwinism

Who were the pioneers of the modern concept of evolution? Charles Darwin did not give them the credit they deserved, but his failure to do so ironically paved the way for the acceptance of the concept

by C. D. Darlington

In November, 1859, there appeared a book which within a few days convinced quite a large number of those who read it that the ideas they had cherished of the origin and nature of man were false. The book—Charles Darwin's *Origin of Species*—was an unpretentious account of all aspects of life, which could be understood by educated laymen. It attempted to show that all living things were derived by descent and gradual transformation from common origins many millions of years ago. Hence, to the dismay of serious Christians, the Biblical story of Creation seemed in danger of falling to the ground.

The partisans of Creation, both professors and bishops, counterattacked with vigor, and a bitter struggle ensued. In about 10 years' time, however, the educated world was effectively converted to Darwin's view of what had come to be called evolution and was now called Darwinism. The defeated party retired to lick its wounds in quiet places.

Not all the wounds, however, were suffered on one side. Two shafts of criticism struck Darwin more directly than the outside world was allowed to know. They touched his particular theory that evolution took place by natural selection, a process analogous to the artificial selection which plant and animal breeders were practicing with such great success at that time. The first criticism asserted that Darwin's thesis was not true; the second, that it was not new. Such criticisms are raised against all revolutionary hypotheses, but both of these were serious and well informed.

As to the second criticism, it is often said that it matters little whether the theory was truly Darwin's invention. We owe it to him that the world was brought to believe in evolution; we ought to be duly grateful and leave it at that. If a centenary is an occasion merely for acknowledging a debt, the matter could be allowed to stand. But I think it is an occasion for a more useful exercise. Here is a theory that released thinking men from the spell of a superstition, one of the most overpowering that has ever enslaved mankind. We should have no superstition about how such a spell came to be broken.

The assertion that natural selection was not true, or rather would not work, came from several sources. It came most cogently from one Fleeming Jenkin, professor of engineering at Edinburgh University. In 1867 Jenkin pointed out that if all hereditary differences blended on crossing, as Darwin assumed, then any variation that arose would diminish in importance in each succeeding generation and no new variation could persist long enough to be selected by the process that Darwin proposed. Now this was not a criticism of natural selection. It was a criticism of Darwin's notions of heredity. And it was a perfectly sound one for, as Gregor Mendel showed, differences do not blend on crossing. They remain intact and reappear in full strength in later generations. Yet Darwin took it as a criticism of natural selection. Accordingly, in succeeding editions of the *Origin of Species*, he shifted his ground. He began to suggest that direct adaptation of the organism to its environment brought changes in heredity, and that this direct action played a part, along with natural selection, in the transformation of species.

This shift of ground was noticed by Darwin's critics. Darwin responded by calling their attention to something they had overlooked. In the first edition of the *Origin of Species* he had mentioned twice that the effects of the "external conditions of life"—both the direct effects of climate and food and such indirect effects as the use and disuse of organs—were perhaps in some extremely small degree inherited. Change was partly directed before it took place as well as partly selected after it took place. In other words, Darwin had prepared a line of retreat against the possibility that natural selection might be found untenable. He now prudently took this line.

As time went on Darwin relied more and more on a double or mixed theory of evolution: selection plus direction. When he came to write *The Descent of Man* 10 years after the appearance of the *Origin of Species*, the full advantages of this mixed hypothesis began to be felt.

The critical question in *The Descent of Man* was that of the evolution of man's moral, spiritual or religious character. By this time there was nothing in man's physical or intellectual character that could not follow the principles of animal evolution. But on the moral question Darwin had to weigh a risk. The memory of Joseph Priestley's experience was still fresh. Priestley had made incautious statements on religion, and in 1794 his library had been burned and he had been forced to emigrate to the U. S. Darwin also had to consider the feelings of his wife, a doubly devoted woman, who took her religion quite as seriously as she took his work. He was saved by his mixed theory of evolution.

On the one hand, Darwin argued, any intelligent animal with social instincts could by selection come to develop a moral sense, a feeling of duty, a conscience. Selection by itself is enough to produce the moral sense. A dog, he points out, can be bred and trained so that it has a feeling of guilt

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when it fails to do what it "ought" to have done. So much for the dog. But when Darwin sums up his views and comes to man, he hedges. "Social qualities," he suggests, "were no doubt acquired by the progenitors of man . . . through natural selection aided by inherited habit." And later: "It is not improbable that virtuous tendencies may through long practice be inherited." Finally he concludes that social instincts, which afford the basis for the development of the moral sense, may be "safely attributed" to natural selection. But "the moral qualities are advanced either directly or indirectly, much more through the effects of habit, the reasoning powers, religion, etc."

Here we see the most dangerous passage in all of Darwin's works. For at first glance it seems to mean so much. But when you have read it two or three times you see that it means just what you want it to mean. If you are a rationalist, you will suppose that the blind forces of nature—even an element of chance—working through natural selection produced the moral qualities of man. And if you are devout, you will suppose that man has acquired his spiritual gifts under divine guidance, inspired teachers having instructed him in the principles of religion most pleasing to his Creator. Was it an accident that Darwin's conclusion meant just what every reader wanted it to mean? I think not. Darwin used the same ambiguity in his private letters.

Darwinism, therefore, began as a theory that evolution could be explained by natural selection. It ended as a theory that evolution could be explained just as you would like it to be explained. This brings us back again to the second criticism: that Darwin's theory was not new; that it was not even his own.

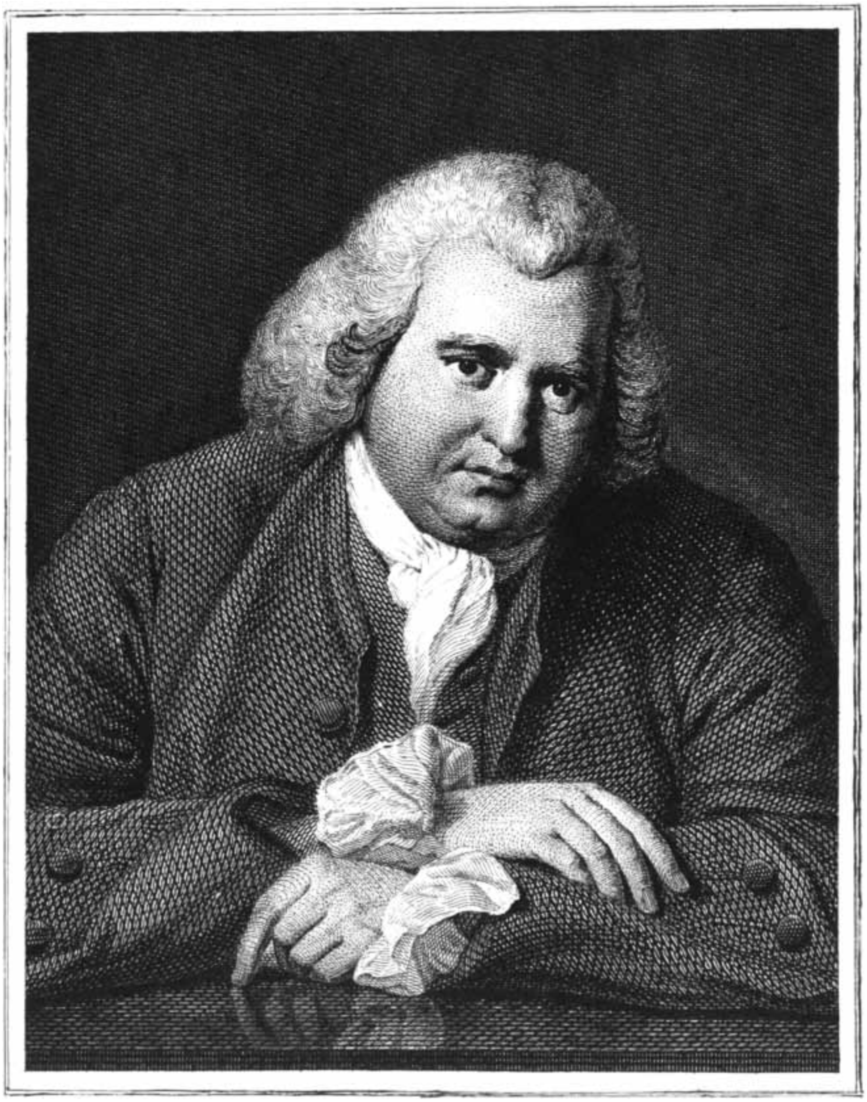
The story of the slow growth of evolutionary theory has been told often. The best account that is friendly to Darwin was written by Henry Fairfield Osborn of the American Museum of Natural History in *From the Greeks to Darwin*, published in many editions beginning in 1894. The best unfriendly account was written by Samuel Butler, the author of *Erewhon*, in four books published between 1877 and 1885. The most unreliable account that ever will be written is undoubtedly the "Historical Sketch" which Darwin himself wrote and appended to the third edition of the *Origin of Species* in response to the appeals of his friends and the challenge of his enemies. This reads like the confession of an unhappy man, written under fearful stress. The story of the origin of Darwinism has not been written in the 20th century. It has not yet been written in the cooler, clearer light of what genetics has taught us and of what each evolutionist in turn has said and done. When the evidence is reviewed in this light, it takes on a living continuity that has not been noticed before.

Much of the story must remain in dispute. But the important steps, as they now appear, can be briefly made out.

During the 18th century a cleavage of opinion developed between those who held to the Biblical story of Creation and those who assumed some kind of evolution. In general the idea of evolution was familiar to students of what was already called natural history, but the evolutionary point of view had to be expressed with caution. Governments almost everywhere wished to maintain the religious beliefs of the uneducated masses. This was particularly true outside France after 1789. But it was possible for Benjamin Franklin in the U. S. to refer to man as "a tool-making animal," and it was possible for Lord Monboddo at the same time in Scotland to suppose that man had formerly walked on all fours and was to be reckoned as belonging to the same species as the orangutan.

It was in these circumstances, between 1789 and 1803, that Erasmus Darwin wrote a series of works, in prose and verse, in which he included statements of his view of evolution. These statements attempt to answer the two obvious questions. First, are all living things in truth descended by transformation from a single ancestor? Second, how could they have been transformed?

In favor of the evolution of animals



ERASMUS DARWIN, grandfather of Charles, originated many central ideas in evolutionary theory. Of him Charles said merely: "He anticipated the erroneous ideas of Lamarck."

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from "one living filament" Erasmus Darwin assembled the evidence of embryology, comparative anatomy, systematics, geographical distribution and, so far as man is concerned, the facts of history and of medicine. He particularly noted the difference between the fauna of the Old World and the New, which was to become an increasingly prominent debating point in the future. These arguments about the fact of transformation were all of them already familiar. As to the means of transformation, however, Erasmus Darwin originated almost every important idea that has since appeared in evolutionary theory. He supposed that competition and selection were means of change; that overpopulation was a continual agent in enhancing competition; that this was true in plants as well as in animals; that in animals another important kind of selection arose from competition between males in pursuit of the female; that fertility and susceptibility to disease, being hereditary, were fields of selection. He took the Comte de Buffon's notion of the inheritance of acquired characteristics and suggested that this inheritance might be not only direct but also indirect; that the effects of use and disuse might be inherited.

Erasmus Darwin, physician, philosopher and poet, was one of the most celebrated personalities in the England of his time. His writings on evolution enjoyed enormous popularity. Two years after his death the word "Darwinian" was first attached to his ideas. This was five years before the birth of his grandson Charles. His *Zoonomia* was translated into French, German and Italian. Four years after it appeared Thomas Malthus developed one of its ideas into his *Essay on Population.* Nine years later the Chevalier de Lamarck expounded a theory of evolution based on the Darwinian inheritance of the effects of use and disuse. Seventy years later Charles Darwin wrote a book on sexual selection. At the same time another of Erasmus Darwin's grandsons, Francis Galton, began to develop his ideas on human breeding and invented the study of eugenics.

Not one of these works acknowledges their undoubted precursor. But it is not the multiplicity of Erasmus Darwin's intellectual heirs that concerns us here. More important is the fact that his influence upon the immediately ensuing history of evolutionary thought was largely negative. This came about through Lamarck's elaboration upon Erasmus Darwin's idea of the inheritance of acquired characteristics. By making the notion explicit and giving examples, Lamarck unintentionally revealed its absurdity. After reading about how the race of giraffes had grown a longer neck simply by stretching for the higher branches, the whole world laughed. It seemed, indeed, to have laughed not only Lamarck but the whole idea of evolution off the stage.

Something more than laughter, however, followed from Lamarck's work. In England three Fellows of the Royal Society seem to have been moved independently to retort to Lamarck and to add an appendix to Erasmus Darwin. I say "seem" because, following the custom of the time and of the subject, they did not mention either Darwin or Lamarck. But they all repudiated the inheritance of acquired characteristics. The three men were William C. Wells, James C. Prichard and William Lawrence. Their views, announced at the same time in 1813, were emphatic and almost identical; since they were all physicians they dealt chiefly with man. As Prichard said: "All acquired conditions of the body end with the life of the individual in whom they are produced. But for this salutary law the universe would be filled with monstrous shapes." All three men advanced explicitly and in detail the alternative theory of natural selection foreshadowed by Erasmus Darwin. These three communications were the first clear statements of such an idea—in opposition to notions of evolution guided by design and purpose—since classical times.

What happened to these three men, these precursors of Charles Darwin? Wells died before his essay was published. Prichard lived many years to publish revised editions of his work. And as he revised them he did exactly what Darwin did later: He mixed his theory to include directed variation. The reason why Prichard, and also Darwin, retreated from their positions is revealed by the case of the third man, William Lawrence.

Lawrence's book bore as its subtitle the significant phrase: "Natural History of Man." His argument was that physical, medical, intellectual and moral differences among the races of man and among individuals were hereditary. The races had arisen by such distinct and identifiable mutations as are observed among members of the same litter of kittens or of rabbits. This is perhaps the first time the idea of genetic segregation and recombination appears in modern times. The characteristics that distinguish the races of men are maintained by barriers against their interbreeding like those that maintain the distinguishing characteristics of species of animals and plants. "Selections and exclusions" are the basis of all adaptation. Differences, either physical or intellectual, between races of men can never be related to the direct action of food, climate or government. Men could be improved or ruined by selection in breeding just as domesticated animals may be improved or ruined. Drawing a political moral, Lawrence noted that the European royal families and aristocracies had mostly followed the second course. Zoology, he concluded—the study of man as an animal—is the only proper approach to the study of either medicine or morals, politics or social science.

Lawrence's book on the natural history of man had the same position in England after the war of 1815 that Marie Stopes's works on sexual relations and birth control had after the war of 1918. It was outspoken and revolutionary. It released personal, sexual, religious and political inhibitions. Lawrence's suggestion that a corrupt and mentally deficient aristocracy and monarchy might be replaced by applying the proper processes of stockbreeding to man was shocking but also extremely readable. His discussion of the orangutan theory of the origin of man was learned but intelligible, and it was relieved by vivid references to the buttocks of Hottentot women and what he called "the rites of Venus."

The clergy read it, enjoyed it and denounced it. The laity read it and enjoyed it. From Lawrence they learned about the principle of sexual selection and the

SKULLS appear in William Lawrence's ***Lectures on Physiology, Zoology, and the***

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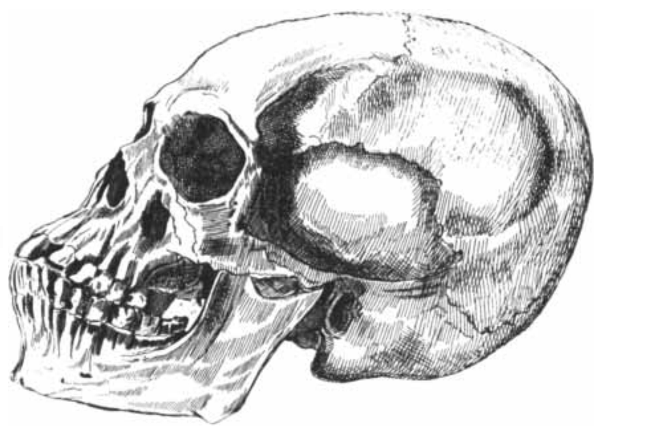

Natural History of Man, **published in 1822. In this work Lawrence advanced the idea that men evolved by natural selection, and rejected the inheritance of acquired characteristics. At left is the skull of a Kalmuck; in center, of a Negro; at right, of a Carib.**

analogy with animal breeding that Charles Darwin was later to expound as his own; about the action of mutation and segregation which Darwin was to dismiss; about the comparative study of skulls, to be improved on by Thomas H. Huxley; and about the idea of eugenics, later invented by Galton. All these things were expounded in 500 pages by Lawrence.

Now in those days no one could study or teach at either Oxford or Cambridge who was not approved by the Church of England. Almost all of the teachers had to be ordained ministers of religion. Through the universities the intellectual life of the country was controlled by the Church. The Church itself and the government were both controlled by the landed aristocracy. The whole country, however, was seething with political discontent, and the government faced the imminent danger of revolution. Lawrence's book made it clear that the theory of evolution was bound up with ideas that would destroy both the Church and the governing class.

The government's reaction was inevitable. The book was examined by the Lord Chancellor, who pronounced it contrary to Scripture and refused it copyright. Meanwhile pamphlets, mostly by anonymous Oxford dons, were denouncing the folly and wickedness of "Surgeon Lawrence." His name was linked to that of "Infidel Paine," that is, Thomas Paine. Lawrence, now 36 years of age, had to decide whether to abandon his profession and to become a martyr to science or to enjoy the lawful fruits of his profession and renounce his scientific opinions. He took the second course. He suppressed his book and made his career. Twice he became president of the Royal College of Surgeons. Later he was appointed Sergeant Surgeon to Queen Victoria, from whom, after more than one offer, he accepted a baronetcy.

So much for Lawrence. His book had a different career. One publisher after another took the risk of reprinting it illicitly. Nine editions had appeared in 1848. Its fame or infamy was enormous. It continued to be extolled by radicals and denounced by tories. Everybody who wrote about evolution in England referred to it. Darwin, Huxley and Alfred Russel Wallace all mentioned it, but not one of them noted its general significance. In their hasty glances at this disfavored book, they had found in it only what they wanted to find: facts but not theories.

Nevertheless, through all these years, evolution was very much alive, even though Charles Darwin, working and waiting at Down, thought that it was dead. Young naturalists were eagerly studying Lawrence and Prichard as well as Erasmus Darwin. Among these were Patrick Mathew, whose priority was later acknowledged by Charles Darwin, and Edward Blyth, whose importance in developing the idea of natural selection has only recently been fully revealed by Loren Eiseley of the University of Pennsylvania. Poets like Browning and Tennyson were well aware of the growing theory, and they could phrase their ideas in such a way as to inform the educated reader without shocking a larger audience.

At almost the same time, on a more scientific level, Charles Naudin in Paris advanced the view that evolution had taken place by a process of natural selection analogous to what man had done in improving his domesticated crops and stock. Naudin had a good reason for reaching this conclusion because he had for some years been engaged in experiments on the crossing of horticultural plants. These experiments had led him to the conclusion that first-generation crosses are uniform in character but exhibit the characteristics of both progenitors. The dissimilar "essences" derived from the parent strains disjoin in the second generation to give different germ cells and hence a wide range of types of plant. This was the same conclusion that Mendel reached independently at about the same time. Naudin's argument was less well reasoned than Mendel's and his experiments less well designed. His conclusion, however, provided a more defensible explanation of the mutations that heredity supplied to the process of selection than Darwin was ever able to devise. It is therefore significant that Darwin dismissed Naudin and his experiments on heredity as unsound.

Having thrown open the shutters in these forgotten attics, we can see in a clearer light the problem that Darwin faced in 1844 when he put aside his first essay on natural selection and proceeded to devote eight years to the description of barnacles. The idea of evolution, popular as it was with the uneducated masses, was far from respectable in academic circles. It was contrary to the prevailing belief of naturalists, who liked to think that their species were fixed for all time. It was identified with the absurdities of Lamarck or with rubbishy works that adapted Lamarckism to the idea of Cre-

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ZOONOMIA;

OR

THE LAWS

OF

ORGANIC LIFE.

VOL. I.

By ERASMUS DARWIN, *M.D. F.R.S.*
AUTHOR OF THE BOTANIC GARDEN.

Principio cœlum, ac terras, camposque liquentes,
Lucentemque globum lunæ, titaniaque astra,
Spiritus intùs alit, totamque infusa per artus
Mens agitat molem, et magno se corpore miscet.
VIRG. Æn. vi.

Earth, on whose lap a thousand nations tread,
And Ocean, brooding his prolific bed,
Night's changeful orb, blue pole, and silvery zones,
Where other worlds encircle other suns,
One Mind inhabits, one diffusive Soul
Wields the large limbs, and mingles with the whole.

NEW-YORK:
Printed by T. & J. SWORDS, Printers to the Faculty of Physic of Columbia College, No. 99 Pearl-Street.
—1796.—

AN

ESSAY

ON THE

PRINCIPLE OF POPULATION,

AS IT AFFECTS

THE FUTURE IMPROVEMENT OF SOCIETY.

WITH REMARKS

ON THE SPECULATIONS OF MR. GODWIN,

M. CONDORCET,

AND OTHER WRITERS.

LONDON:

PRINTED FOR J. JOHNSON, IN ST. PAUL'S CHURCH-YARD.

1798.

TITLE PAGES of four early evolutionary works are reproduced. At left is the title page of an edition of Erasmus Darwin's *Zoonomia* published in New York. Second from left is the title page of Thomas Malthus's famous *Essay*, which developed one of Erasmus

ation and the phrases of piety. Worse yet, it was associated with revolutionary propaganda such as that in Lawrence's book. In Darwin's own family the idea of evolution was associated with a grandfather whose 18th-century views and conduct were judged to be immoral. In his "Historical Sketch" Charles Darwin refers to the works of Erasmus Darwin as merely having "anticipated the erroneous opinions of Lamarck." Evidently, although he had been allowed to read them when he was young, he had been warned not to believe them. He never returned later to study them and to take them into proper account.

Darwin's attitude toward his precursors now becomes clear. It also explains to us something we otherwise have great difficulty in understanding: the secret of his success in converting the world to evolution.

No doubt Darwin was able to cut himself off so completely from his historical forerunners because he succeeded so well in separating science from history in his own mind. The science of evolution was real; the history of the idea of evolution was unreal. The kindest interpretation we can put on his attitude is that he was looking forward all of the time, wrapped up in his own ideas and his own inquiries. He could not spare the time to look back. Deep in his unconscious he must have known that the past contained the origins of his ideas and that his predecessors were not quite so cheap as he made them out to be. But he wanted to think out his ideas for himself.

This is the kindest interpretation. But we have to record that Samuel Butler advanced a less kind interpretation. He pointed out that the first edition of the *Origin of Species* contained 45 references to "my theory." But no one could quite tell what "my theory" might be. Was it the theory that evolution had taken place? Was it the theory of natural selection? Or was it the shifting combination of selection and direction? The British geologist Charles Lyell and the German zoologist Ernst Haeckel made it quite clear that in their opinion justice had not been done to Lamarck by the man who was adopting his theory. Consequently (this is Butler's argument) Darwin gradually cut out the references to "my theory" in successive editions of the *Origin of Species.* Gradually it became "the theory." But by that time the public all over the world had begun to think of it as Darwin's theory.

Whatever the cause, the effect served Darwin splendidly. That he appeared to come suddenly out of nothing, without herald or harbinger, was one of the factors that contributed principally to his

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HISTOIRE NATURELLE

DES

ANIMAUX SANS VERTÈBRES,

PRÉSENTANT

LES CARACTÈRES GÉNÉRAUX ET PARTICULIERS DE CES ANIMAUX, LEUR DISTRIBUTION, LEURS CLASSES, LEURS FAMILLES, LEURS GENRES, ET LA CITATION DES PRINCIPALES ESPÈCES QUI S'Y RAPPORTENT;

PRÉCÉDÉE

D'UNE INTRODUCTION offrant la Détermination des caractères essentiels de l'Animal, sa distinction du végétal et des autres corps naturels, enfin, l'Exposition des Principes fondamentaux de la Zoologie.

PAR M. LE CHEVALIER DE LAMARCK,

Membre de l'Institut Royal de France, de la Légion d'Honneur, et de plusieurs Sociétés savantes de l'Europe; Professeur de Zoologie au Muséum d'Histoire naturelle.

Nihil extrà naturam observatione notum.

TOME PREMIER.

PARIS,

VERDIERE, LIBRAIRE, QUAI DES AUGUSTINS, N.° 27.

Mars. — 1815.

LECTURES

ON

PHYSIOLOGY, ZOOLOGY,

AND THE

Natural History of Man,

DELIVERED AT

THE ROYAL COLLEGE OF SURGEONS,

BY

W. LAWRENCE, F.R.S.

PROFESSOR OF ANATOMY AND SURGERY TO THE COLLEGE, ASSISTANT SURGEON TO ST. BARTHOLOMEW'S HOSPITAL, SURGEON TO BRIDEWELL AND BETHLEM HOSPITALS, AND TO THE LONDON INFIRMARY FOR DISEASES OF THE EYE.

WITH TWELVE ENGRAVINGS.

LONDON:

BENBOW, PRINTER AND PUBLISHER, AT THE BYRON'S HEAD, CASTLE STREET, LEICESTER SQUARE.

1822.

Darwin's ideas. Third from left is the title page of one of the volumes in which the Chevalier de Lamarck advanced his concept of the inheritance of acquired characteristics. At right is the title page of Lawrence's book. Lawrence announced his ideas in 1813.

success. The enemies of evolution liked to believe that Darwin represented a form of infidelity entirely novel in its folly and wickedness, one that no decent Christian could entertain or ever had entertained. On the other hand, the friends of evolution were delighted to discover that Darwin had put it on entirely new grounds, quite unlike those of Lamarck which they had found unacceptable; natural selection now justified a belief in evolution.

It was not without reason, therefore, that Huxley and Wallace and Galton unobtrusively failed to follow Darwin in his retreat from natural selection. Their dislike for Lamarckism was genuine and consistent. It carried them over to the day of their vindication.

The challenge of Lamarckism was taken up at last just a year before Darwin's death. The German zoologist August Weismann asked the question: What is the evidence for the inheritance of acquired characteristics? He showed that there is indeed none but a collection of old wives' tales. Weismann did not know, of course, any more than Darwin knew, that Lawrence and Prichard had made the matter pretty clear 60 years earlier. Nor, indeed, did the Russian agriculturist Trofim Lysenko, a recent proponent of Lamarckism, realize that the question had been settled long ago.

Another, and equally important, explanation for Darwin's success as the propounder of evolution is to be found in his equivocation on the central issue of selection versus direction. The issue had long been recognized as cardinal in any theory. Those who had taken either side unequivocally, whether that of Lamarck or of his opponents, had failed, though their failure was political. But Darwin confused the alternatives on all possible occasions. The confusion helped greatly in dealing with untrained opponents who did not notice the blurring of the issue. Darwin's success makes his choice in this dilemma seem deliberate and disingenuous. But it was no doubt unconscious, like most of his more important reasonings.

Thus in his 1858 publication he refers to "changes of external conditions," and once merely to "external conditions," as causing variation. But in 1859 these conditions, through the effects of use and disuse, were already directing variation, and cooperating with natural selection in directing it. The directive component in the theory grew stronger year by year. But his contemptuous references to the authors of the idea—Erasmus Darwin and Lamarck—were sealed off in the prefatory "Historical Sketch," away from the main line of discussion.

A third ground for Darwin's success

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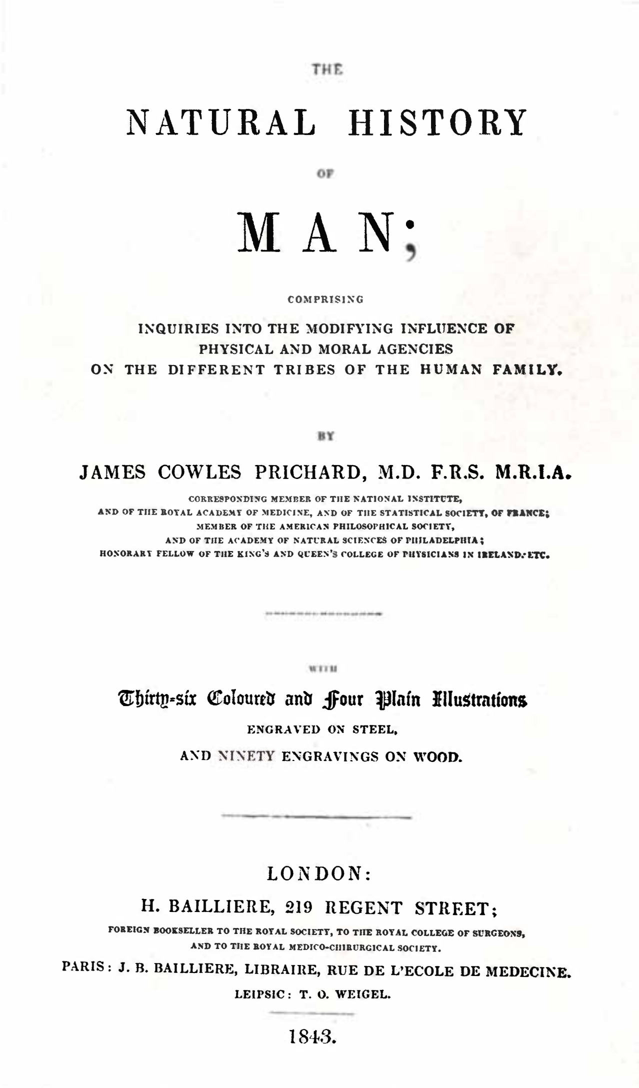

THE

NATURAL HISTORY

OF

MAN;

COMPRISING

INQUIRIES INTO THE MODIFYING INFLUENCE OF
PHYSICAL AND MORAL AGENCIES
ON THE DIFFERENT TRIBES OF THE HUMAN FAMILY.

BY

JAMES COWLES PRICHARD, M.D. F.R.S. M.R.I.A.

CORRESPONDING MEMBER OF THE NATIONAL INSTITUTE,
AND OF THE ROYAL ACADEMY OF MEDICINE, AND OF THE STATISTICAL SOCIETY, OF FRANCE;
MEMBER OF THE AMERICAN PHILOSOPHICAL SOCIETY,
AND OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA;
HONORARY FELLOW OF THE KING'S AND QUEEN'S COLLEGE OF PHYSICIANS IN IRELAND, ETC.

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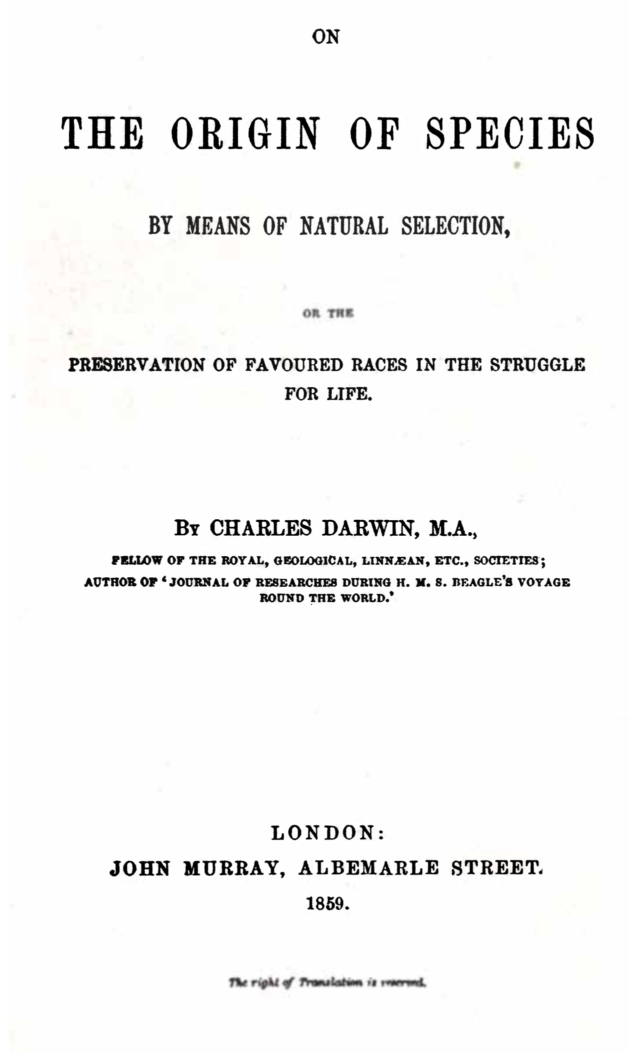
PARIS: J. B. BAILLIERE, LIBRAIRE, RUE DE L'ECOLE DE MEDECINE.

LEIPSIC: T. O. WEIGEL.

1843.



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE
FOR LIFE.

BY CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE
ROUND THE WORLD.'

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1859.

The right of Translation is reserved.

LATER WORKS are an 1843 edition of James C. Prichard's *The Natural History of Man*, in which he modified some of his earlier ideas on evolution by means of natural selection. At right is the title page of the first edition of Darwin's *Origin of Species*.

is to be found in a perfectly conscious and acknowledged stratagem. He avoided man's origins and relations, the one problem that every one who read his book was thinking about. Mark the words he uses. In the *Origin of Species* he observed: "Much light will be thrown on the origin of man and his history." He was careful not to enlarge upon this statement until he published *The Descent of Man* a decade later. This was a stroke of genius. It turned the flank of the Church party and made it possible to keep at least a part of the argument on a scientific plane. A year after the publication of the *Origin of Species*, as we know, Bishop Wilberforce brought the question down to his own intellectual level. When he asked Huxley at Oxford whether he was descended from an ape through his grandfather or his grandmother, Wilberforce moved the conflict onto the ground that Darwin had earnestly wished to avoid. But by this time it was already too late. The Church had lost its battle.

In short, it is clear that Darwin's success was due to several common vices as well as to several uncommon virtues. His gifts as an observer in all fields concerned with the needs of a theory of evolution were extraordinary. His industry and patience in collecting and editing his own observations as well as other people's were hardly less remarkable. On the other hand, his ideas were not, as he imagined, unusually original. He was able to put his ideas across not so much because of his scientific integrity, but because of his opportunism, his equivocation and his lack of historical sense. Though his admirers will not like to believe it, he accomplished his revolution by personal weakness and strategic talent more than by scientific virtue.

We owe to the *Origin of Species* the overthrow of the myth of Creation, especially the dramatic character of that overthrow. Yet the overthrow itself has led to the growth of a smaller myth with lesser danger of its own: the myth of Darwinism, which obscures what happened. It is important for us to know as clearly as possible what happened, to understand its small deceptions and its larger paradoxes, to grasp how much of the struggle takes place within the mind of the discoverer. We must realize that a man who liberates the whole world may never quite succeed in liberating himself.

These things show that scientific discovery is not purely a matter of science. It is not a purely intellectual process. This is a lesson that we shall need to bear in mind when Darwinian ideas—the ideas he foreshadowed but did not venture to develop—come to be applied to man and society.

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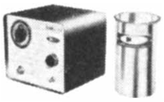

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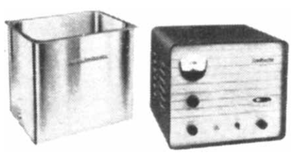

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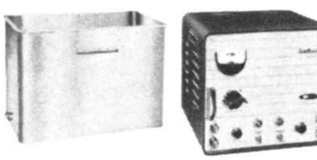

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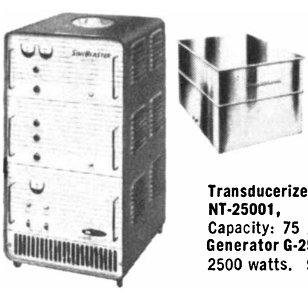

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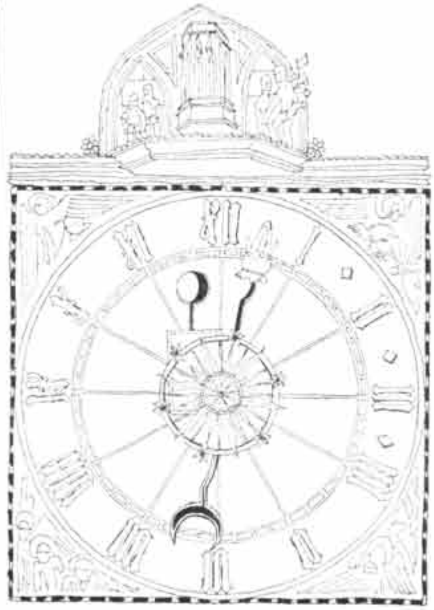

SCIENCE AND

Radiation and Public Health

Whether "to continue the assignment of primary authority over the public-health aspects of atomic energy in the same agency [the Atomic Energy Commission] that has a prime interest in the promotional aspects of the field" or to transfer that authority to "an independent agency . . . with a special interest in public health, *i.e.*, the U. S. Public Health Service": this is a topic of debate that is assuming the dimensions of a major controversy in the Administration and in Congress.

The issue was thus defined by a scientific advisory committee empaneled by the Surgeon General. That group, under the chairmanship of Russell H. Morgan, radiologist of Johns Hopkins University, recommended that the transfer of authority be made immediately. Legislation to this effect is before Congress, and provides a focal point for the series of major hearings scheduled early this month by the Joint Committee on Atomic Energy. Meanwhile the A.E.C., the National Academy of Sciences and the White House have opened or reopened parallel investigations of the scientific and administrative aspects of the public-health hazards of ionizing radiation.

With international negotiations for the suspension of nuclear-weapons tests stalled in Geneva, the public has been disquieted by reports of intense local concentrations of fallout radiation in various parts of the U. S. The A.E.C. announced that the build-up of strontium 90 in the soil of the New York City area since 1954 now totals 53,310 microcuries per square mile; that Richmond, Calif., in a single two-week period in 1958, received 4,470 microcuries per square mile; and that Westwood, N.J. sustained the heaviest 12-month fallout of strontium 90 in 1958, totaling 15,030 microcuries per square mile. From the Public Health Service came reports of new record levels of strontium-90 concentration in milk, with highs of 20.1 units in Saint Louis and 32.7 units in Mandan, N. D., compared to a maximum permissible concentration of 80 units. In Minneapolis it was revealed that the strontium-90 concentration in wheat, as measured by the A.E.C., exceeded the maximum tolerable level by 50 per cent.

Charging that the Department of Defense and the A.E.C. had been "gagging the Joint Committee on making public important data on fallout from weapons tests," Senator Clinton P. Anderson, chairman of the Committee, released an exchange of letters with those two agencies which indicates that radioactive debris falls out of the stratosphere at a much higher rate than previously estimated by the A.E.C. According to Herbert B. Loper, atomic-energy assistant to the Secretary of Defense, the calculated "residence half-life" of strontium 90 and other fission products in the stratosphere must be reduced to two years. Willard F. Libby, retiring commissioner of the A.E.C. agreed that his earlier estimates of seven years should be reduced, perhaps to four years. On the basis of these calculations the A.E.C. predicted that the fallout will double or triple, reaching a peak by 1970, if no further tests are made. The Department of Defense studies also showed that, in consequence of the briefer residence half-life, the atomic debris is not as thoroughly dispersed in the upper atmosphere as previously assumed, and that in both the Northern and Southern hemispheres "there is a latitude band of maximum drip-out" between 35 and 50 degrees north and south of the Equator. In the U. S. "the concentration of strontium 90 on the surface of the earth [is] greater than in any other area of the world."

According to Libby, the Northern Hemisphere fallout will be considerably amplified during the next 12 months as the result of Soviet weapons tests in the Arctic last October. This test series, apparently involving very "dirty" explo-

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sives, has increased the amount of radiation debris in the stratosphere by 50 per cent. With fallout proceeding at an even higher rate from these high-latitude explosions, U. S. Naval Research Laboratory observers have reported a 300-per-cent increase in the concentration of radioactivity in the air at points along the eastern U. S. seaboard.

In defense of the A.E.C. stewardship of public health in its area of technology, A.E.C. Chairman John A. McCone released figures showing that the A.E.C. has been spending $60 million on biomedical research during the current fiscal year, that it employs "the equivalent of 800 scientists . . . in this work" and maintains 100 stations in 37 different countries to monitor fallout. "However," he declared, "we have no desire to preempt this area of activity."

The principal hazard from ionizing radiation, according to the Morgan committee's report to the Surgeon General, has arisen "from X-ray machines employed by the health professions." In the future "the rapid anticipated growth of devices and products which produce ionizing radiation urgently points to the nation's need for a comprehensive program governing the public-health aspects of this radiation." Arguing that "controls may be best exercised where the authority responsible for control is not far removed from the group or groups being protected," the committee's report urged that enforcement functions of the radiation control program be assumed by state and local as well as federal agencies, under the over-all responsibility of the Public Health Service. As a precedent for this assignment of responsibility, the committee observed that "the record of public-health authorities in the field of sanitation is difficult to surpass."

Project Argus

It was described as "the greatest scientific experiment ever conducted." Certainly it was one of the most ambitious: it required a far-flung array of advanced devices and the coordinated effort of thousands of men. But the results of the experiment were not yet announced.

Actually it was not one experiment but three. On August 27 of last year a

Stokes high vacuum oven installed in dry box at Raytheon's Semiconductor Division. Vacuum gages are on top of dry box.

AT RAYTHEON

Transistor reliability improved with Stokes High Vacuum Ovens

Stokes High Vacuum Ovens are featured in an entirely new method of baking and processing transistors at the Semiconductor Division, Raytheon Manufacturing Co. at Newton, Mass. Chosen because they met the rigid requirements set by Raytheon engineers, these ovens assure improved transistor quality and uniformity, more stable electrical parameters and increased production.

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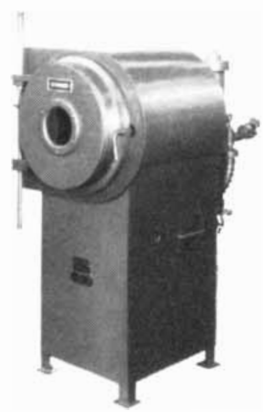
If high vacuum is an important aspect of your present or planned process, Stokes' long experience in vacuum techniques, and in designing and manufacturing high vacuum equipment, can be of valuable aid. Your inquiry is invited.



The Stokes Model 236 Vacuum Baking Oven includes fully automatic instrumentation.

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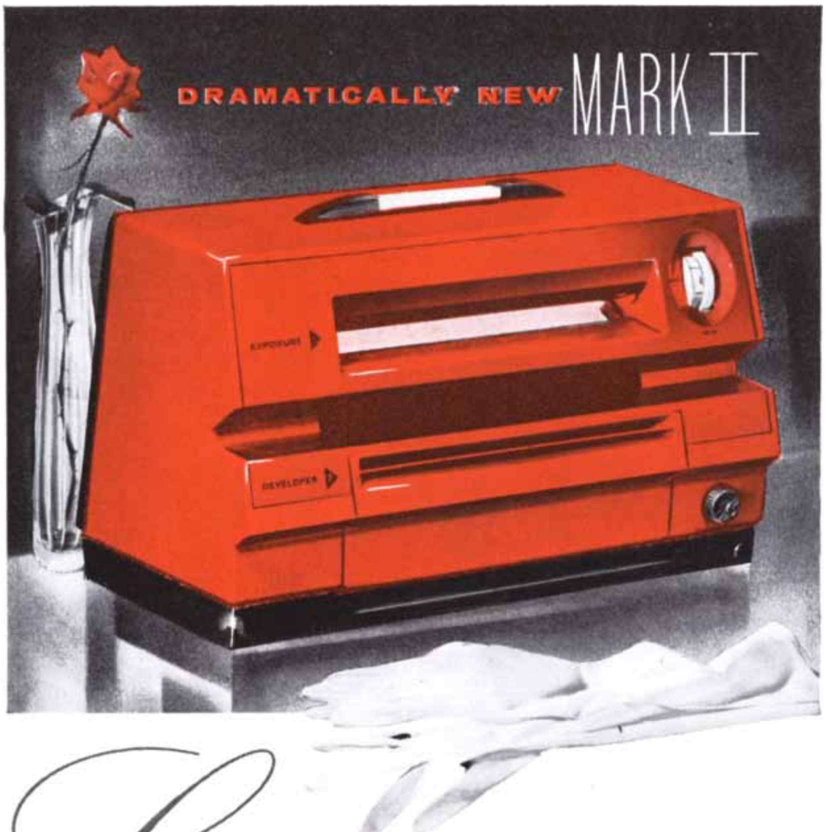

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small nuclear bomb was exploded 300 miles above the South Atlantic off the tip of South America. The performance was repeated on August 30 and September 6. The bombs were carried aloft from the *U.S.S. Norton Sound* by three-stage rockets.

As each bomb exploded in the near-vacuum at 300 miles, it shot out a blast of (among other radiations) high-energy electrons. Unimpeded by the denser gases of the atmosphere below, the electrons flashed on helical orbits along the arching lines of force in the earth's magnetic field. Some of the electrons followed the lines of force back into the denser atmosphere, where, it was said, they caused one aurora south of the *Norton Sound* and another 8,000 miles away in the North Atlantic. Other electrons reversed their direction before they came so low and oscillated back and forth between the Northern and Southern hemispheres. Over a period of time these "trapped" electrons drifted eastward, girdling the earth with a layer of man-made particles.

The Argus electron layer was analogous to the two recently discovered natural belts of charged particles which encircle the earth [see "Radiation Belts around the Earth," by James A. Van Allen; SCIENTIFIC AMERICAN, March]. Indeed, one of the most important scientific results of the Argus experiments seems to relate to the origin of the natural belts. One of the main questions about the natural belts is: Where do their particles come from? The outer natural belt, which is most intense at an altitude of some 10,000 miles, consists predominantly of relatively low-energy particles; a recent study of records from the U. S. solar rocket *Pioneer IV* leaves little doubt that the particles in this belt come from the sun. The inner natural belt, which is most intense at an altitude of about 2,000 miles, contains a higher proportion of high-energy particles; where the particles in this belt originate is not clear.

Two possible origins have been advanced. One, espoused by Thomas Gold of the Harvard College Observatory, is that particles are somehow transferred to the inner belt from the outer one. The other, favored by Nicholas C. Christofilos of the University of California, is that the particles in the inner belt originate with high-energy cosmic rays. According to this idea, when cosmic-ray particles disrupt the nuclei of atoms in the earth's atmosphere, some of the neutrons that result from these collisions splash upward and decay radioactively into a belt of protons and electrons. At

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a press conference in Washington, Christofilos, who had originally proposed the Argus experiment, suggested that the experiment had lent credence to the cosmic-ray hypothesis. He said that the Argus electron belt had been about 100 miles deep, that it had maintained its depth within 10 or 20 miles for several weeks and that this stability argued against the flow of particles from the outer belt.

Donald A. Quarles, Deputy Secretary of Defense, indicated that at least some of the scientific results of Argus would be released. Indeed, the U. S. is committed to an agreement under which all information gathered by International Geophysical Year satellites must be published by September. And much valuable information about the Argus experiment was obtained by the satellite *Explorer IV*.

Quarles also said that the Argus experiment had produced information of interest to the national defense. There was much speculation as to what effects might be useful in this connection. On August 1 and August 12 of last year two large nuclear bombs had been set off between 50 and 100 miles above Johnston Island in the Pacific; these explosions had apparently interfered with radio communication on some wavelengths (and incidentally had caused an aurora 2,000 miles to the south). Could artificially created curtains of particles at higher altitudes interfere with radio and radar, and could the curtains somehow be used to set off or "poison" rocket-borne nuclear bombs? The consensus of informed comment was that such curtains would have no real military significance.

The Perfect Curve

No sports fan doubts that a golf ball or a tennis ball can curve laterally in flight. Some, however, question whether the same is true of a thrown baseball, or at least whether a thrown baseball curves as much as baseball players and sports writers commonly claim. To such skeptics a baseball seems too heavy, and its flight too slow, to account for such an effect. Now some persuasive experimental evidence indicates that the skeptics are wrong.

After a series of experiments, Lyman J. Briggs, Director Emeritus of the National Bureau of Standards, concludes that it is within the capacity of a pitcher to make a baseball curve as much as 17.5 inches in the 60 feet between the pitcher's mound and home plate. This "perfect curve" travels about 100 feet

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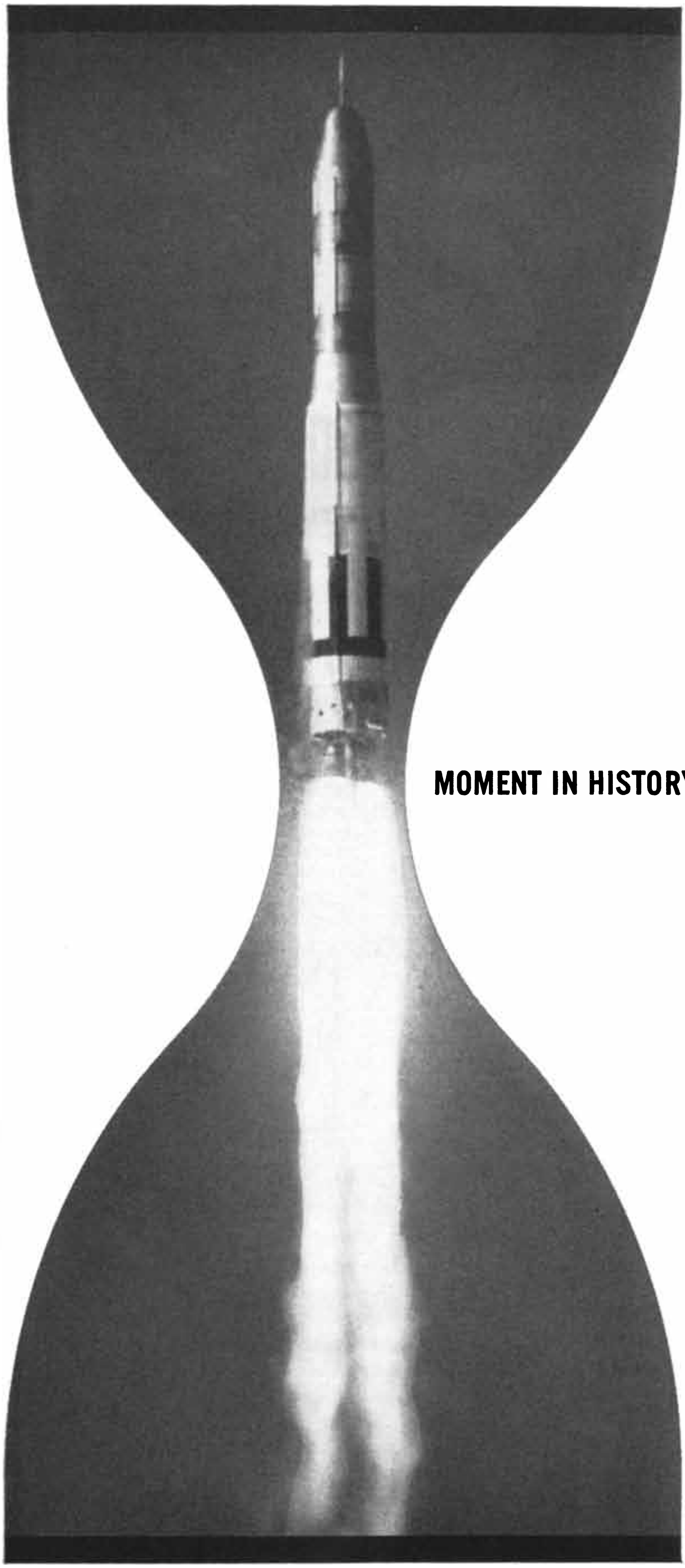

MOMENT IN HISTORY

THIS IS THE "FIRST FLIGHT" of the new Air Force TITAN, America's most powerful weapon and our No. 1 challenger in the big-missile field. Time: 2/6/59—4:22 p.m. EST. The most important thing about this moment in history is not visible here—and it is this: Three years to the day from the breaking of ground at Martin-Denver, TITAN No. 1 roared into the sky. Those 36 months saw the creation of the free world's most advanced ballistic missile facility—and the development, production, testing, delivery and launching of the first of an entirely new generation of ballistic missile weapon systems, forerunner of the Global Ballistic Missile. TITAN is the result of an advanced engineering concept—developed by Martin under the direction of the Air Force's Ballistic Missile Division of the Air Research and Development Command—which provides the most extensive pre-flight testing of components, subassemblies and full scale missiles ever undertaken. This method in the TITAN development, and in the generations of space systems to follow, may well be one of the most important single factors in speeding America's bid for space supremacy.

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per second and spins around a vertical axis at 1,800 revolutions per minute.

Briggs attributes the curve of a baseball to the Magnus effect, named for a 19th-century German engineer who sought to explain the curve of cannon balls. According to Magnus, a spinning ball flying through the air is surrounded by a vortex of air. On one side of the ball the air in the vortex moves in the same direction as the air through which the ball is traveling; on the other side of the ball the air in the vortex moves in the opposite direction. Thus the air pressure on the first side is lowered, and the pressure on the second side is increased. This differential in pressure makes the ball curve in the direction of spin.

To measure the effect it is necessary to know the speed of the ball and the speed of spin. The speed of a thrown baseball is indicated by a well-known measurement of a pitch thrown by Bob Feller of the Cleveland Indians: 144 feet per second. Presumably any competent pitcher can throw a baseball at 100 feet per second. To determine the spin of a putatively curving baseball Briggs enlisted the aid of Pedro Ramos and Camilo Pascual of the Washington Senators. He attached one end of a flat tape to the ball as the pitchers threw curves; by counting the number of twists in the tape he determined that the ball spun 7 to 16 times on its way to the plate. Assuming that the balls were traveling at 100 feet per second, this corresponds to a spin of between 700 and 1,600 r.p.m.

Briggs conducted other investigations in the laboratory. At first he tried to relate speed, spin and curve by photographing from above a baseball that was spun on a rubber tee and then projected forward by a wooden projectile fired from a gun. This attempt was abandoned because the spin of the ball could not be measured in flight. He then turned to a wind tunnel. When he dropped a ball spinning at known speed into a horizontal stream of air moving at known speed, he was able to determine how much the ball was deflected at right angles to its axis of spin. In this way he found that the maximum deflection, equivalent to 17.5 inches in 60 feet, occurred when the air was moving at 100 feet per second and the ball was spinning at 1,800 r.p.m.

Briggs's experiments left unanswered one question that troubles the devotee of baseball physics. Can a baseball be made to "break," that is, to curve more sharply at the end of its trajectory than at the beginning? If someone can dem-

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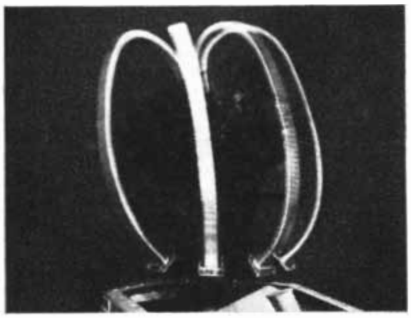
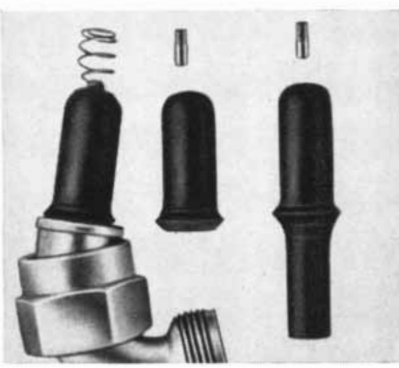
Tubexperience in action

Specials are Superior's Specialty

Superior is equipped to supply the unusual—its facilities and experience enable it to produce tubing in many analyses and shapes for such diversified applications as waveguides for solid-state masers or bushings for high-temperature spark plug terminals. Typical of the products incorporating Superior tubing are those shown here.



Flexible waveguides of beryllium copper are used to conduct microwaves along desired path in radar systems. Customer selected Superior tubing because it met grain size and temper specifications, it was fabricated to the close tolerances required, had the ability to withstand repeated flexures when hardened, could be convoluted in the annealed state, and could be precipitation hardened after forming.



Cable bushings in silicone spark plug terminals that are not adversely affected by heat or electrolysis, yet are both machinable and workable. Type 304 stainless steel tubing, as supplied by Superior, was selected. This resulted in a completely reliable terminal that stands up under elevated temperature application without corroding. Machinability and workability were achieved by drawing the tubing to a special ¼ hard temper.

Solid-State masers. Power is coupled in and out of the cavities by stainless steel coaxial lines or waveguides. The Superior tubing, fabricated into close tolerance rectangular waveguides, helped minimize the problem of heat transfer in units using liquid helium.

Superior has long been one of the outstanding suppliers of tubing for unusual applications. And only Superior can offer more than 120 analyses, in a range of ID, OD and wall thicknesses, and thus meet almost every requirement for small tubing—in standard forms or in a wide variety of shapes. The analyses available and the characteristics of each, with production sizes and recommended applications, are given in Bulletin 41. Write for your copy today. Superior Tube Company, 2052 Germantown Ave., Norristown, Pa.

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onstrate that it does not, then at last those who are skeptical of curve-ball folklore will have their innings.

Geologic Punctuation Mark

The discovery of an immense bed of volcanic ash that may help define the time-scale of recent geologic history in many parts of the world has been announced by workers at Columbia University's Lamont Geological Observatory. Last fall echo-recordings made from the oceanographic research vessel *Vema*, cruising from Panama to Peru, showed a curious double signal. Cylindrical samples, or cores, raised from the bottom showed that the second echo came from a "false bottom" of white, glassy ash underlying the top sediment. As far as has been determined, the ash layer varies from two inches to a foot in thickness, extends from 750 miles north of the Equator to 825 miles south and stretches as far as 300 miles from east to west. The finding is reported in the March issue of *Proceedings of the National Academy of Sciences* by J. Lamar Worzel, who was aboard *Vema*. Its significance is analyzed in a companion article by Maurice Ewing, Bruce C. Heezen and David B. Ericson.

The ash layer in the Pacific, they write, may correspond to similar false-bottom soundings made in the South Atlantic and in the Indian Ocean. The ashes would have spread widely if they were ever ejected high into the air, for they consist mainly of curved, fluted or crumpled films of glass that would have drifted with the wind and settled slowly. If indeed they are distributed throughout the world, they would serve as a unique marker of some historic cataclysm.

There is little doubt that the ashes were deposited in fairly recent geologic time, for the sediment overlying them represents the accumulation of no more than 100,000 years. As to the origin of the ash, the authors can only speculate. It probably did not come from the most obvious source, the Andes, because most of the Andean volcanoes were extinct long before the ash was deposited. But the ash may have come from one gigantic volcanic explosion, the simultaneous explosion of several volcanoes, or conceivably from an astronomical catastrophe that rained debris upon the earth.

Calling Venus

The first two-way radio contact with another planet has been made by workers of the Massachusetts Institute of

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AT RAYTHEON

Scientific imagination focuses on MISSILE GUIDANCE

The guidance system in an anti-aircraft missile continuously senses missile-to-target geometry and translates it into corrective maneuvers until interception. In most missiles the sensing element is radar.

Radar, however, is limited in that it normally cannot differentiate between low-altitude targets and the ground's reflection of radar energy. Now a unique radar conceived by Raytheon scientists overcomes this problem by discriminating between moving and stationary objects. As applied in the Army Hawk and Navy Sparrow III missiles—both of which are Raytheon prime contracts—this radar system makes possible the interception of aircraft literally at tree-top height.

Advanced missile guidance is one of the fields in which Raytheon scientists and engineers, typified by such men as Mike W. Fossier, Chief Engineer of the Bedford Laboratory, Missile Systems Division, are contributing to basic knowledge.

Excellence in Electronics RAYTHEON

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Technology's Lincoln Laboratory, who bounced radar signals off Venus. The experiment took place a year ago last February, two weeks after Venus had approached to within 28 million miles of the earth. So indistinct were the return signals that it took a year to unscramble a record of them with the aid of a high-speed computer. Yet the signals have yielded measurements of interplanetary distances more than 100 times as accurate as those made by conventional astronomical methods. The project was headed by Robert Price and Paul E. Green, Jr.

Realizing that the return signals would be extremely faint and would be obscured by "noise," the Lincoln workers put the outgoing signals in the form of a coded message. For about 4½ minutes they transmitted a distinctive pattern of pulses. Then, before the first of the pulses had completed its round trip, they switched from transmitting to receiving. Everything they received they recorded on magnetic tape. Next came the task of winnowing from the noise the pulse pattern of the original signal.

On the basis that the radio signals traversed interplanetary space at the speed of light, the Lincoln group has calculated the distance between Venus and Earth with a probable error of only 100 miles. Astronomers using light-gathering telescopes must settle for a probable error of 50,000 miles, because the accuracy of their observation depends on the length of the terrestrial base line by which they triangulate, and the length of the base line cannot be measured as precisely as the time of a radio echo. Relative distances established by conventional astronomical methods, however, are far more accurate. Thus the radio observation can be used to refine other interplanetary measurements. Preliminary calculations based on the Lincoln data indicate that distances in the solar system may be .0013 per cent shorter than heretofore supposed.

Oriented Corn

The orientation of a corn plant's leaves is determined by the way the seed is put into the ground. Agricultural investigators have now taken advantage of this fact to develop a better way of growing corn. They insert each seed kernel point-down with its flat sides parallel to the row of plants. As the corn grows, the first pair of leaves emerges at right angles to the row, and each subsequent pair is turned slightly counter-

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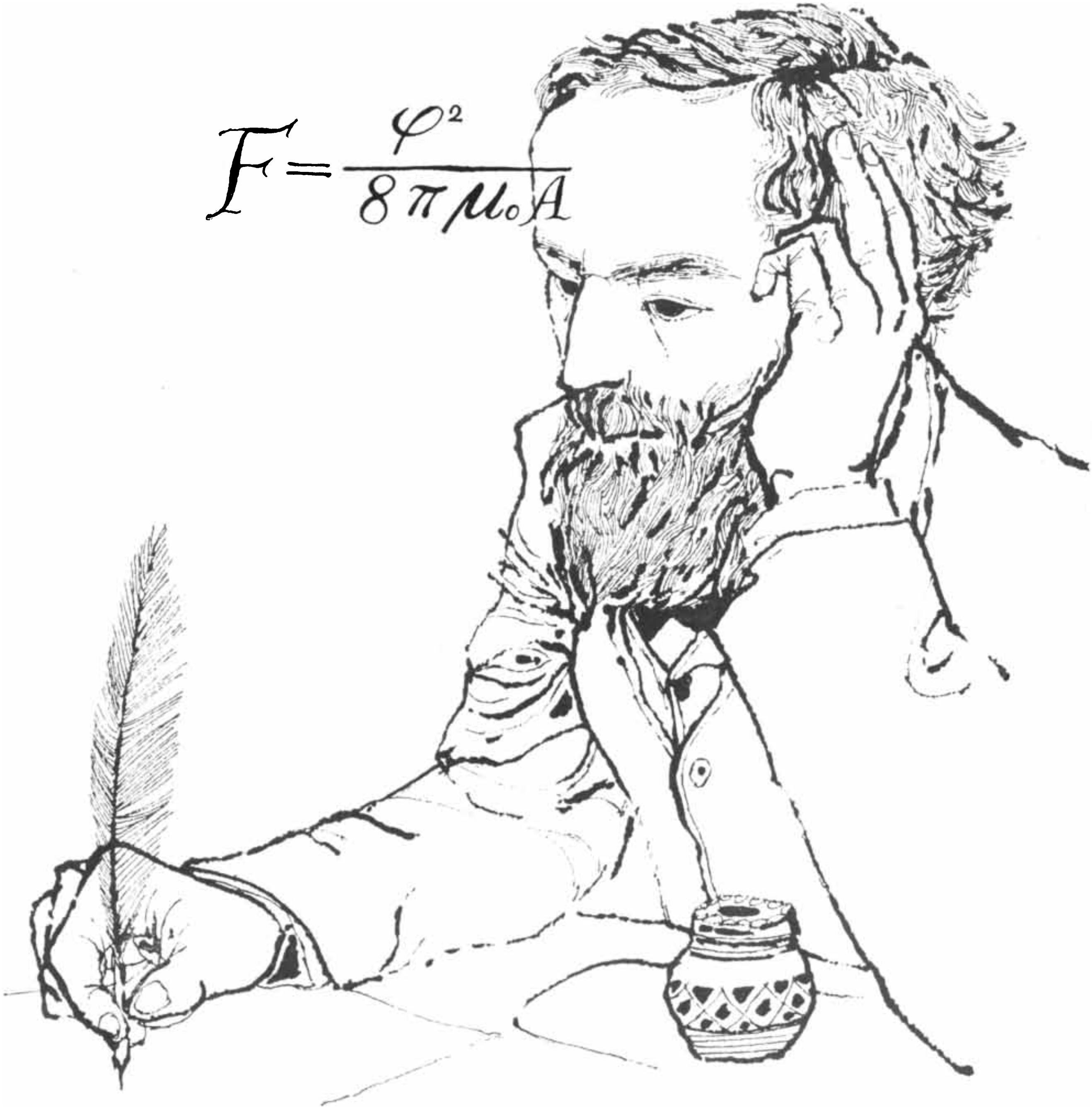

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clockwise with respect to the pair below. As a result of the regular pattern, the leaves more effectively shade the ground and thus reduce evaporation of soil moisture.

Oriented planting increased yield per acre by as much as 22 per cent in tests conducted by D. B. Peters and J. T. Woolley of the U. S. Agricultural Research Service in cooperation with the Illinois Agricultural Experiment Station. In addition, fewer weeds grew in the evenly shaded soil.

The agricultural workers believe that oriented planting can be made practical for large-scale farming. Commercial planting machines could be adapted to position the kernels properly. Or the kernels might be attached to a tape, which could then be buried in long strips.

Peters and Woolley plan to follow up their research by planting oriented corn in rows parallel to or at right angles to prevailing winds to see whether they can increase yields still further. They reported their work in the U. S. Department of Agriculture journal *Agricultural Research*.

The Sick Hospital

The sterilization of hospital interiors with a new series of germicides promises to reduce the number of hospital-acquired bacterial infections. The more serious of these infections are caused by organisms that have become resistant to antibiotics. Because the hospital itself is the breeding ground for these bacteria, Perry B. Hudson of the Columbia College of Physicians and Surgeons, the developer of the germicides, believes that to prevent infections physicians should treat the hospital, not the patient.

He explains why in *Medical Annals of the District of Columbia*. Widespread antibiotic therapy has produced resistant strains of bacteria almost as fast as research can produce new drugs to kill them. Hospital outbreaks of rashes, abscesses, blood poisoning and pneumonia caused by these bacteria have again focused medical attention on the importance of aseptic and antiseptic techniques in hospitals [see "The Staphylococcus Problem," by Stuart Mudd; SCIENTIFIC AMERICAN, January].

Because most hospital antiseptics are effective germ-killers for only a short time, their ability to control bacteria is sharply limited. With this in mind, Hudson and his co-workers substituted a group of long-lasting, broad-spectrum

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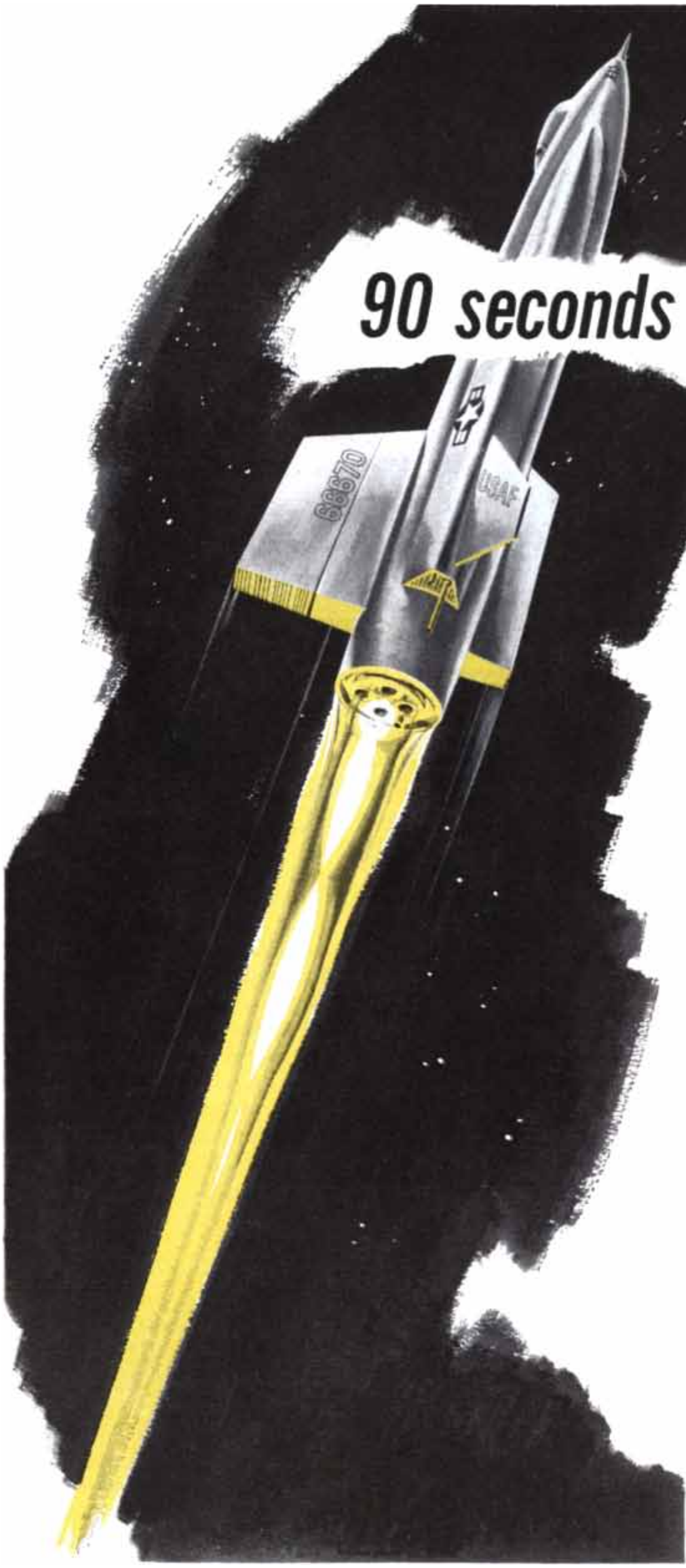

90 seconds of inferno

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germicides for the disinfectants generally used in hospital housekeeping. The new germicides contained such compounds as bis (n-tributyl) tin oxide, dialkyl dimethyl ammonium chloride and silver nitrate. In a five-week trial at Columbia's Francis Delafield Hospital the new germicides were sprayed on walls, mixed with floor wax, bound into air filters and added to laundry and mop water. Mattresses were sprayed, then covered with germicide-impregnated plastic bags; food trays, book carts, bedside tables and patients' personal belongings were similarly treated.

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Gold innards are not the only unusual feature of LAPRE II; another is the reactor's circulatory system, which relies on convection currents instead of the usual pumps to transport hot fuel solution to a heat exchanger.

The heat output of the reactor is almost self-regulating because the fuel solution expands at high temperatures, forcing the reacting uranium atoms farther apart and thus reducing their reactivity. Conversely, when cold water in the heat-exchanger coils withdraws heat from the reactor, the fuel solution contracts slightly, bringing the uranium atoms closer together. This increases the reactivity and hence the temperature of the solution until it reaches a new equilibrium.

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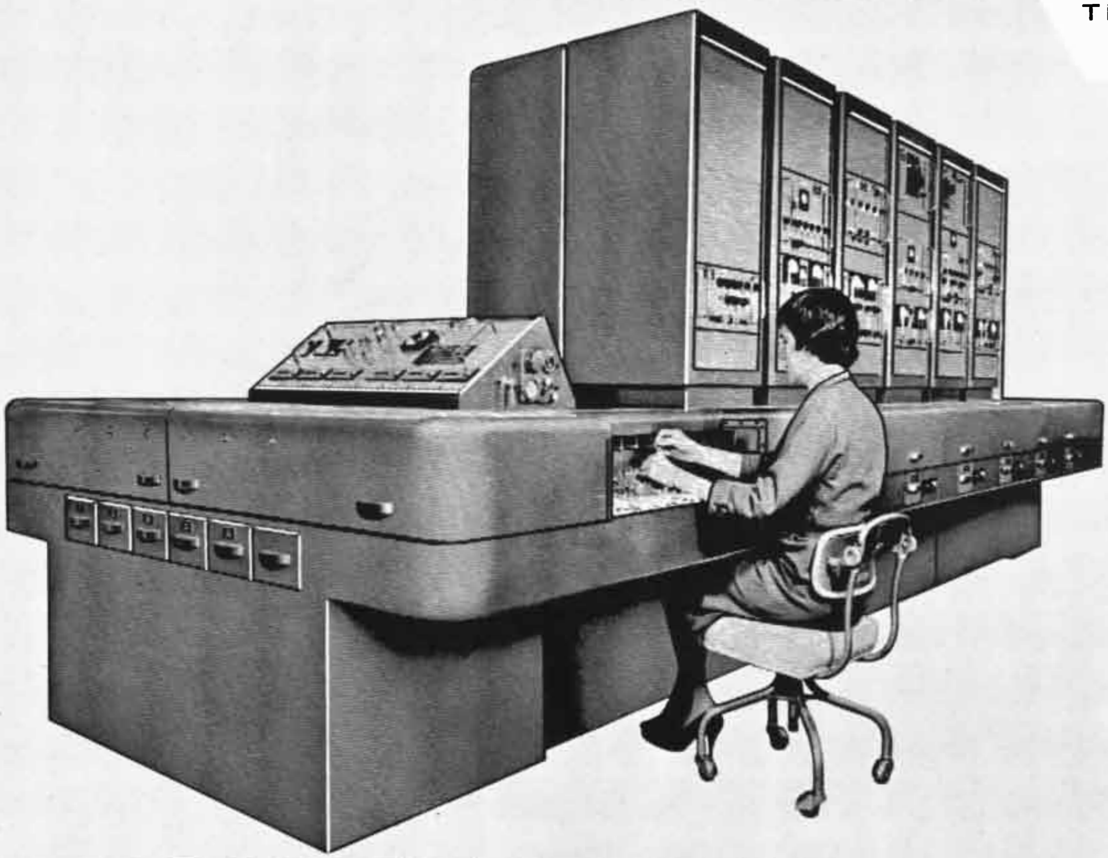

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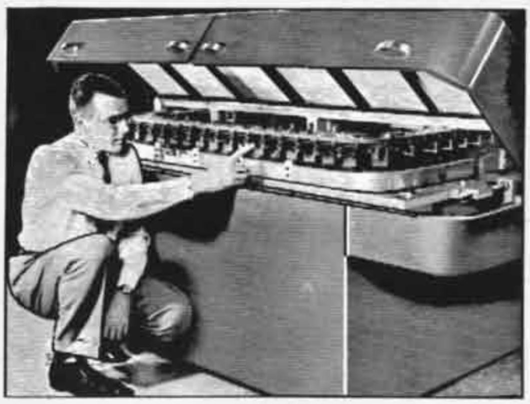

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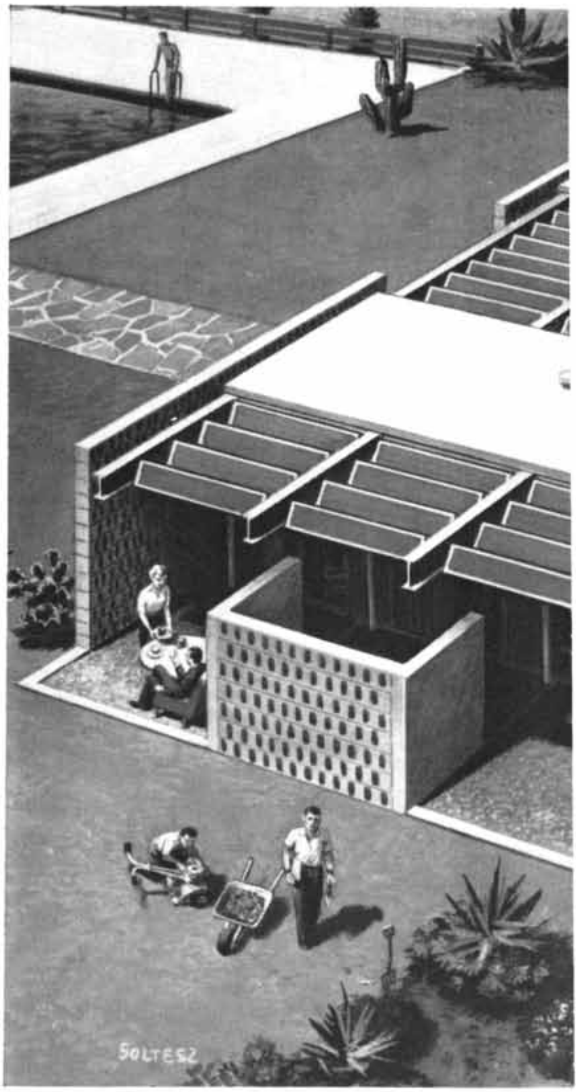

FUN FOR THE FAMILY and the elimination of a storage problem are sure to make this inflatable runabout popular. The seven-tube construction of this unsinkable boat is made possible by neoprene-coated nylon fabric. This lightweight, strong material brings the boat's weight down to 40 pounds. Nylon fiber is not weakened by salt water, gasoline, lubricants. It is resilient . . . can take shock. Portable boat has nylon lifeline and case.

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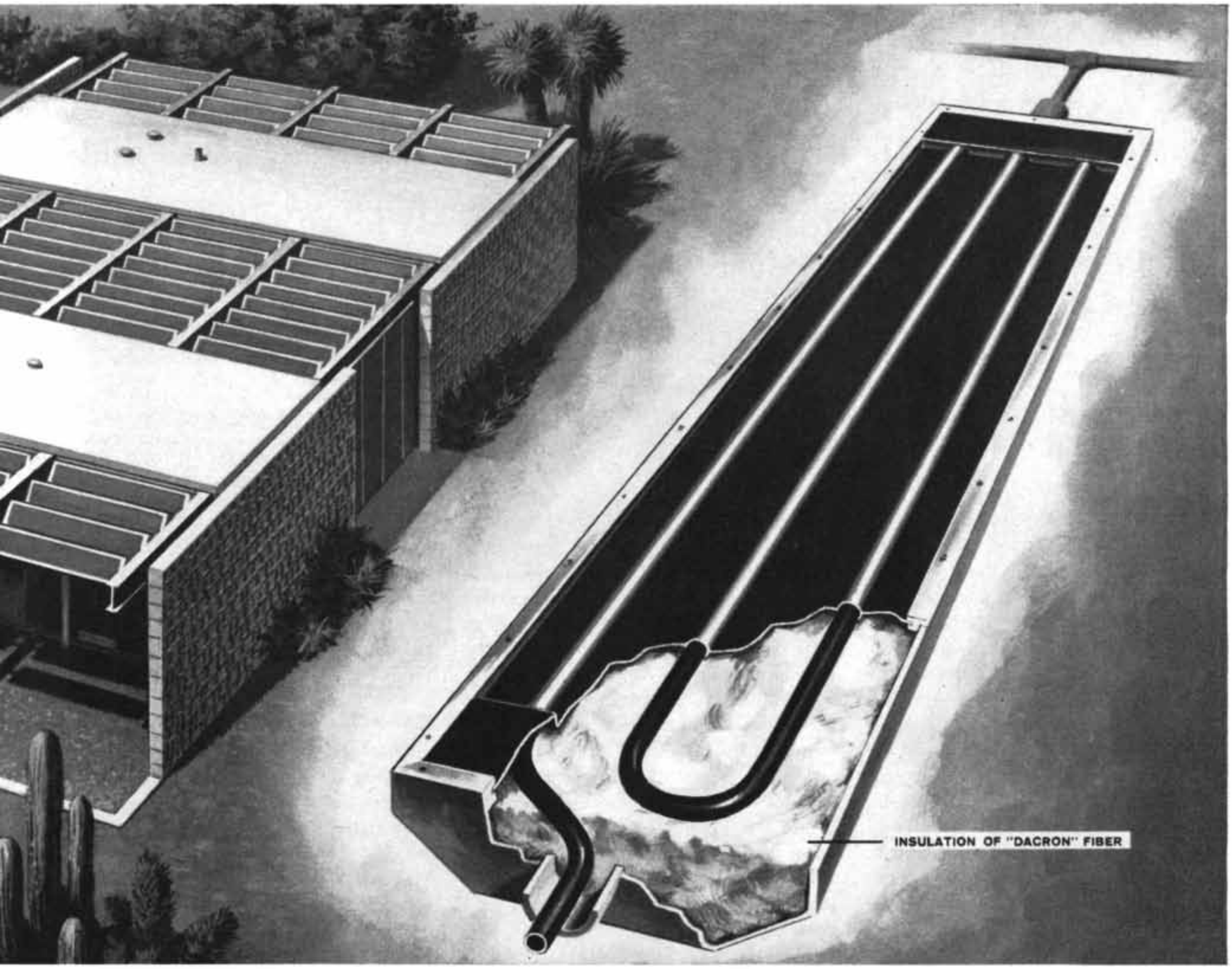

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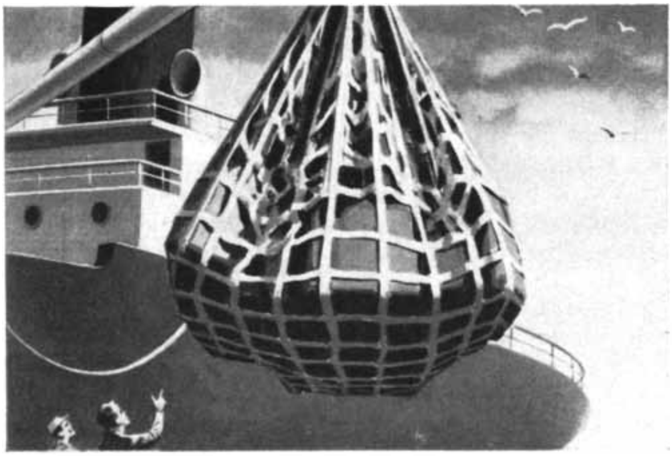

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EXPERIMENTS IN COLOR VISION

The eye has recently been found to be an instrument of wonderful and unsuspected versatility. It can perceive full color in images which, according to classical theories, should be monochromatic

by Edwin H. Land

From childhood onward we enjoy the richness of color in the world around us, fascinated by the questions: "How do we see color? How do you know you see the same color I do? Why do colors sometimes mix to give quite different colors?" Since 1660, when Isaac Newton discovered the properties of the visible spectrum, we have slowly been learning the answers; and we are finding that the beauty of the outer world is fully matched by the technical beauty of the mechanisms whereby the eye sees color.

No student of color vision can fail to be awed by the sensitive discernment with which the eye responds to the variety of stimuli it receives. Recently my colleagues and I have learned that this mechanism is far more wonderful than had been thought. The eye makes distinctions of amazing subtlety. It does not need nearly so much information as actually flows to it from the everyday world. It can build colored worlds of its own out of informative materials that have always been supposed to be inherently drab and colorless.

Perhaps the best way to begin the story is to consider two sets of experiments. The first is the great original work of Newton, which set the stage for virtually all research in color vision since that time. The second is an apparently trivial modification that reverses some of his basic conclusions.

As is so often the case with truly revolutionary insights, the simplicity of Newton's discovery causes one to wonder why no one before him had made it. He passed a narrow beam of sunlight through a prism and found that it fanned out into the band of colors we know as the visible spectrum: red, orange, yellow, green, blue, indigo and violet. When he reversed the process, gathering the beam together with a second prism, the colors vanished and white light reappeared. Next he tried recombining only parts of the spectrum, inserting a slotted board to cut off all but certain selected bands [*see diagram on page 88*]. When he combined two such bands of color, letting the rays mix on a screen, a third color appeared, generally one matching a color lying between the bands in the spectrum.

Let us repeat this last experiment, placing the openings in the board just inside the ends of the narrow yellow band in the spectrum. When these two yellow beams strike the screen, they combine, as Newton observed, to produce yellow.

Now for our modification. In front of the slits we place a pair of black-and-white photographic transparencies. Each shows the same scene: a collection of variously colored objects. There is, of course, no color in the photographs. There are simply lighter and darker areas, formed by black silver grains on transparent celluloid. A glance at the two shows that they are not absolutely identical. Some of the objects in the scene are represented by areas which are lighter in the first photograph than in the second. Others are darker in the first and lighter in the second. But all that either photograph can do is to pass more or less of the light falling on its different regions.

The yellow beams pass through these transparencies and fall on the screen. But now they are not yellow! Somehow, when they are combined in an image, they are no longer restricted to producing their spectral color. On the screen we see a group of objects whose colors, though pale and unsaturated, are distinctly red, gray, yellow, orange, green, blue, black, brown and white [*see bottom photograph on page 86*]. In this experiment we are forced to the astonishing conclusion that the rays are not in themselves color-making. Rather they are bearers of information that the eye uses to assign appropriate colors to various objects in an image.

The Old Theory

This conclusion is diametrically opposed to the main line of development of color theory, which flows from Newton's experiments. He and his successors, notably Thomas Young, James Clerk Maxwell and Hermann von Helmholtz, were fascinated by the problem of simple colors and the sensations that could be produced by compounding them. Newton himself developed quite good rules for predicting the colors that would be seen when various spectral rays were mixed to form a spot of light on a screen. These rules can be summarized in geometrical diagrams, one of the oldest of which is the color triangle [*see diagram at top of page 96*]. On modern versions of it we can read off the result of com-

COLORED OBJECTS in the top picture on the opposite page were photographed with the special dual camera which appears at left. Here the two ground-glass screens of the camera are left uncovered to show that one image is photographed through a green filter and the other through a red filter. The images are photographed on ordinary black-and-white film; then black-and-white positive transparencies are made from the negatives. In the bottom photograph the "red" transparency is projected through a red filter and the "green" without a filter. When the two images are superimposed on the screen at right, they reproduce the objects in a full range of color.

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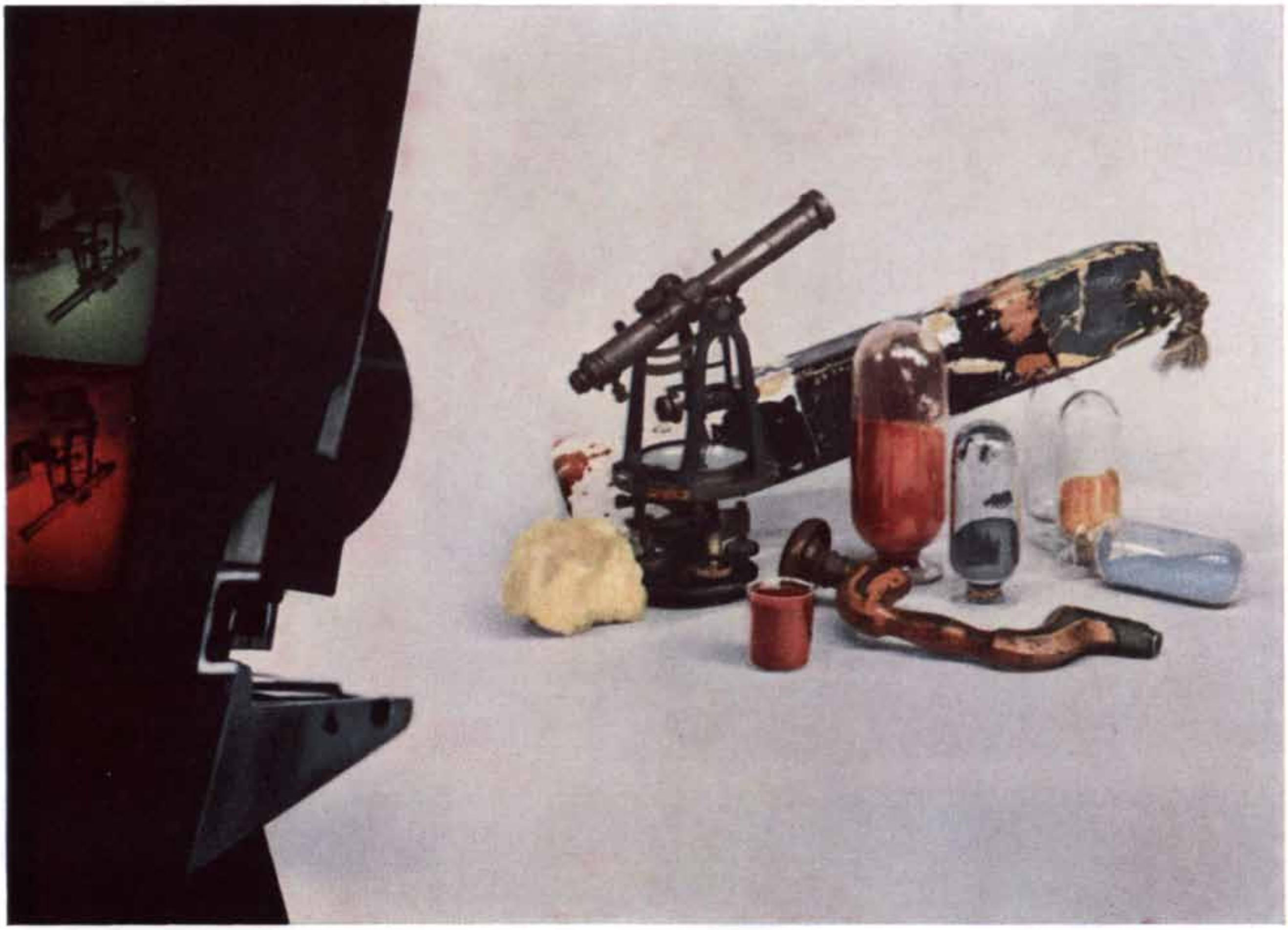

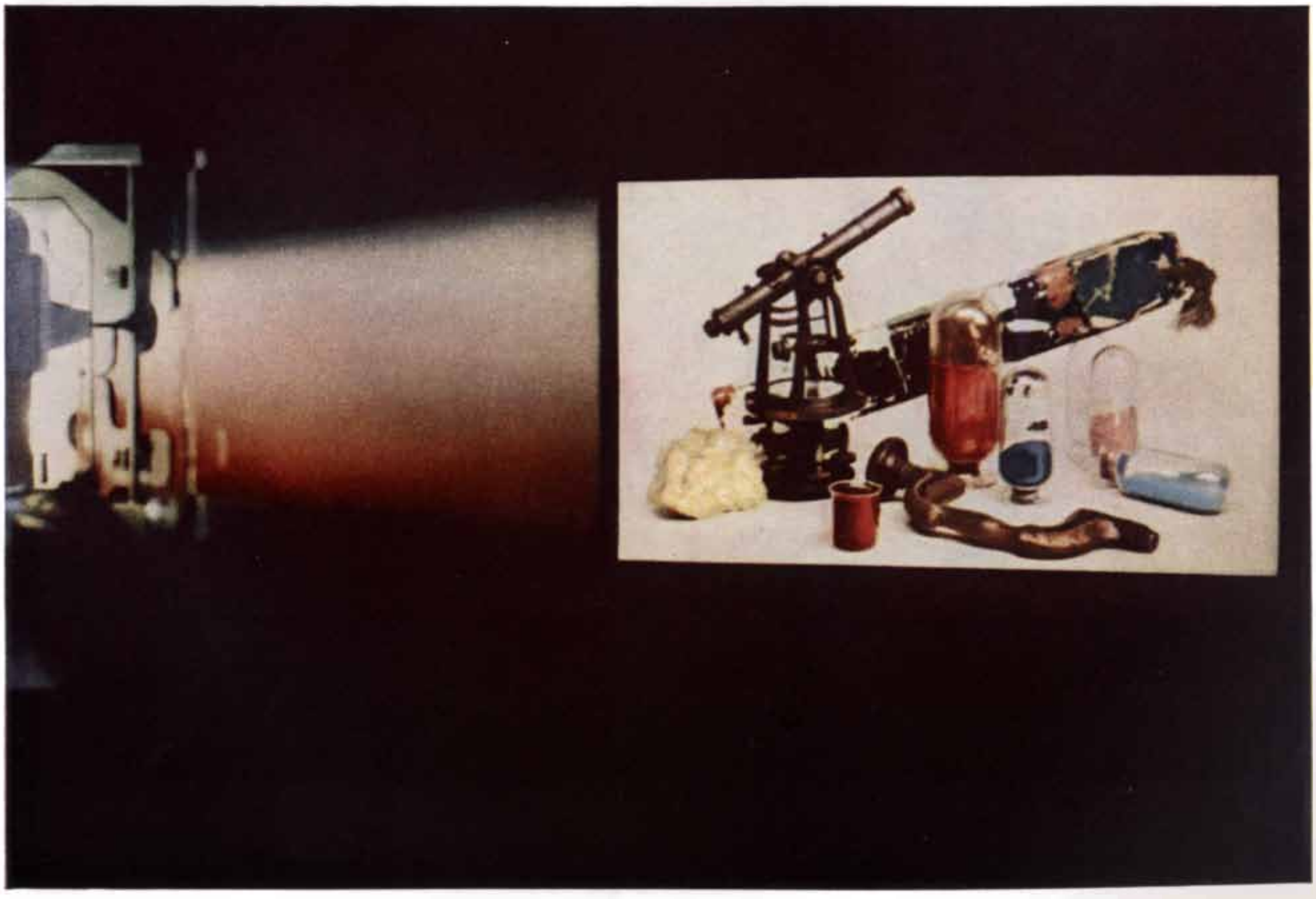

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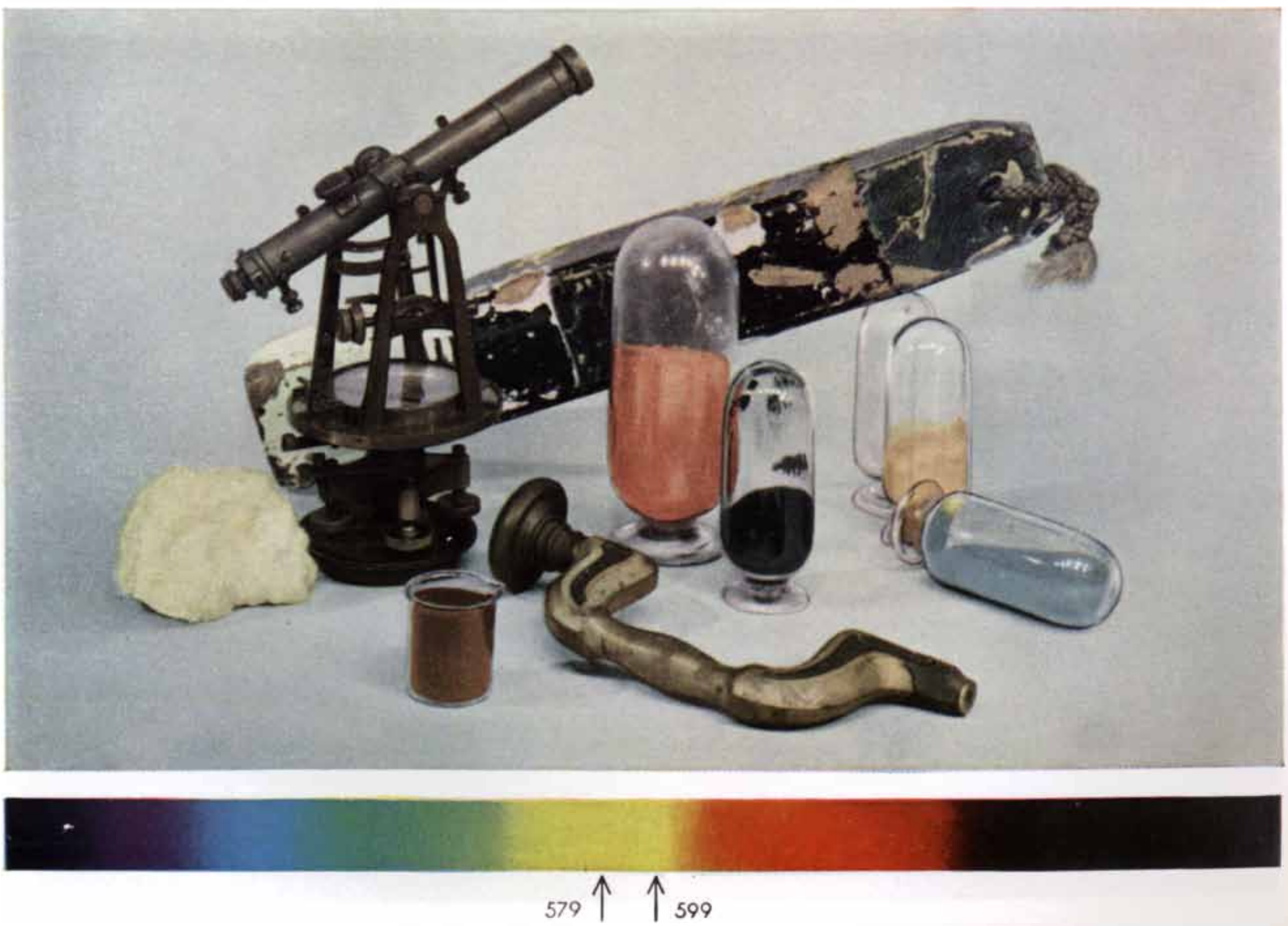

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bining so many parts of color A with so many of color B.

Once it was discovered that light is a wave motion, the classical investigations of color acquired a deeply satisfying logical basis. The order of colors in the spectrum follows wavelength, the longest visible wavelength falling at the red end of the spectrum and the shortest at the violet end. A pure color would be a single wavelength; compound colors would be mixtures of pure colors.

In trying to match colors by mixing spectral stimuli Maxwell and Helmholtz found that three different wavelengths were enough to effect all matches, and that those wavelengths had to be chosen from the red, green and blue bands of the spectrum. Accordingly red, green and blue came to be called the primary colors. On the basis of this evidence they proposed a three-color theory of color vision. We need not go into the details here. The central idea is that the eye responds to three different kinds of vibration, and that all color sensation is the result of stimulating the three responses in varying degrees of strength. Thus it has become an article of faith in standard theory that the color seen at any point in a field of view depends on what wavelengths are issuing from that point and upon their relative strengths or intensities.

Now, as we have seen in our modification of Newton's experiment, the light at any point on the screen was composed of only two "yellow" wavelengths, yet the image was fully colored. And, as we shall see later, the colors in images will be remarkably stable even when the over-all relative strengths or intensities of the two wavelengths are varied.

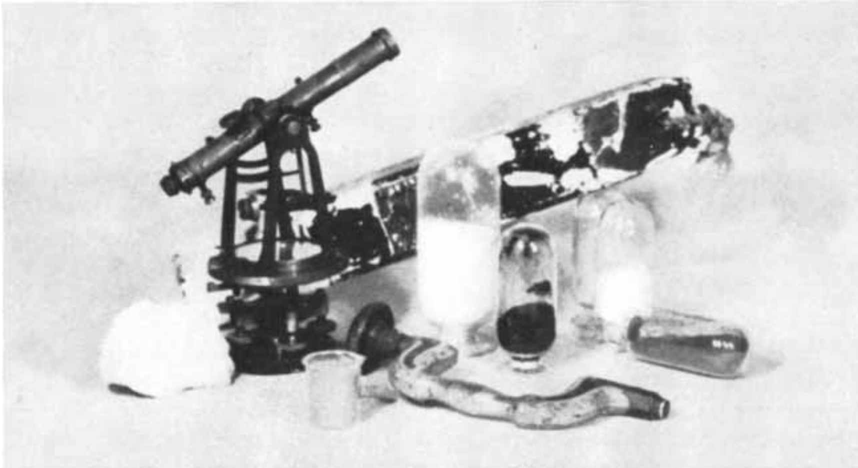
Natural Images

Is something "wrong" with classical theory? This long line of great investigators cannot have been mistaken. The answer is that their work had very little to do with color as we normally see it. They dealt with spots of light, and particularly with pairs of spots, trying to match one to another. The conclusions they reached were then tacitly assumed to apply to all of color sensation. This assumption runs very deep, and has permeated all our teaching, except for that of a few investigators like E. Hering, C. Hess and the contemporary workers Dorothea Jameson and Leo M. Hurvich (who have studied the effect produced on a colored spot by a colored surround).

The study of color vision under natural conditions in complete images (as opposed to spots in surrounds) is thus an unexplored territory. We have been working in this territory—the natural-image situation, as we call it—for the past five years. In the rest of this article I shall describe some of the surprises we have encountered.

To form the image in our modification of Newton's experiment we needed two sets of elements: a pair of different photographs of the same scene, and a pair of different wavelengths for illuminating them. It is possible to make the pictures different by tinkering in the laboratory, arbitrarily varying the darkness of their different areas. But, as every photographer will have recognized at this point, a simple way to produce the two pictures is to make "color separations", that is, to photograph the scene through two filters that pass different bands of wavelengths. In this way the film is systematically exposed to longer wavelengths coming from the scene in one case, and to shorter wavelengths in the other. In our investigations we usually use a red filter for the longer wavelengths and a green filter for the shorter.

Now when we illuminate the transparencies with practically any pair of wavelengths and superimpose the images, we obtain a colored image. If we send the longer of the two through the long-wave photograph and the shorter through the short-wave photograph, we



LONG AND SHORT RECORDS are provided by transparencies of these black-and-white photographs made through a red filter (*top*) and a green filter (*bottom*). In projection the long record (*top*) is illuminated by the longer of two wavelengths or bands of wavelengths, and the short record is illuminated by the shorter wavelength or band of wavelengths.

COLORS SEEN when long and short records are illuminated by closely spaced narrow bands of wavelengths are reproduced in these "Flexichrome" photographs. The illuminating wavelengths are indicated by arrows on the spectrum under each photograph. These images could not be photographed directly; the response of color film to the limited range of wavelengths used here is very different from that of the eye. SCIENTIFIC AMERICAN has artificially reproduced the colors seen by the eye by adjusting the color in a Flexichrome print.

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obtain most or all of the colors in the original scene and in their proper places. If we reverse the process, the colors reverse, reds showing up as blue-greens and so on.

Long Wavelengths *v.* Short

It appears, therefore, that colors in images arise not from the choice of wavelength but from the interplay of longer and shorter wavelengths over the entire scene. Let us now test this preliminary hypothesis by some further experiments.

There are several more convenient ways to combine images than in the arrangement of Newton's experiment. One of the simplest is to place the transparencies in two ordinary projectors, using filters to determine the illuminating wavelengths. The color photographs on the cover and at the bottom of page 85 show images formed in this way.

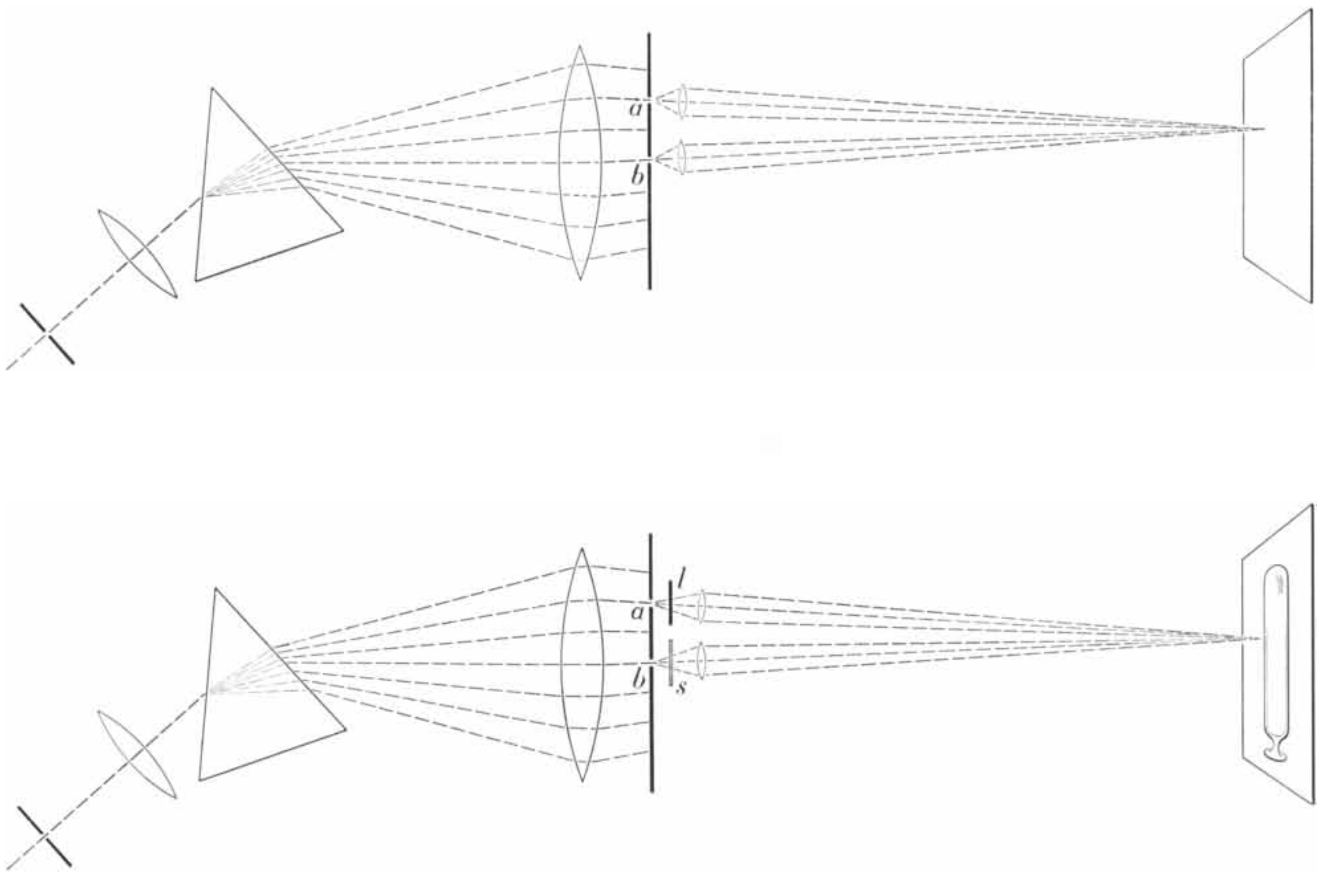
When we work with filters, we are not using single wavelengths, but rather bands of wavelengths; the bands have more or less width depending on the characteristics of each filter. It turns out that the width of the band makes little difference. The only requirement is that the long-wavelength photograph, or, as we call it, the "long record," should be illuminated by the longer band and the "short record" by the shorter band. Indeed, one of the bands may be as wide as the entire visible spectrum. In other words, it may be white light. The photograph on the cover, and the lower photograph on page 85, show the result of using a red filter for the long record and no filter (that is, white light) for the short record.

One advantage of this arrangement is that an observer can test the truth of our hypothesis in a simple and dramatic way. According to classical theory the combination of red and white can result in nothing but pink. With no photograph in either projector, and with a red filter held in front of one of them, the screen is indeed pink. Now the transparencies are dropped into place and the view changes instantly to one of full, vivid color. If the red filter is taken away, the color disappears and we see a black-and-white picture. When the filter is put back, the colors spring forth again.

An incidental advantage in using red for the long record and white for the short lies in the fact that the colors produced look about the same to color film as they do to the eye. Thus the image can be photographed directly. With more restricted bands of wavelengths the film, which does not have the newfound versatility of the eye, cannot respond as the eye does, and reproductions must be prepared artificially [*see photographs on page 86*].

The projectors afford a simple way of testing another variable: brightness. By placing polarizing filters in front of the projector's lenses we can vary the amount of light reaching the screen from each source. With no transparencies in the projector, but with the red filter still over one lens, the screen displays a full range of pinks, from red to white, as the strengths of the two beams are changed. When the photographs are in place, the colors of the image on the screen hold fast over a very considerable range of relative intensities.

Let us pause for a moment to consider the implications of this last demonstration. Remember that the photographs



NEWTON'S EXPERIMENT in mixing spectral colors is shown schematically at top; the author's modification of the experiment, in which a pair of black-and-white transparencies is inserted in the beams, is diagrammed at bottom. When slits *a* and *b* are both in the yellow band of the spectrum, Newton's arrangement produces a spot of yellow on the screen. The image at bottom contains a gamut of color. The letters *l* and *s* in this diagram and others in this article refer, respectively, to the long record and the short record.

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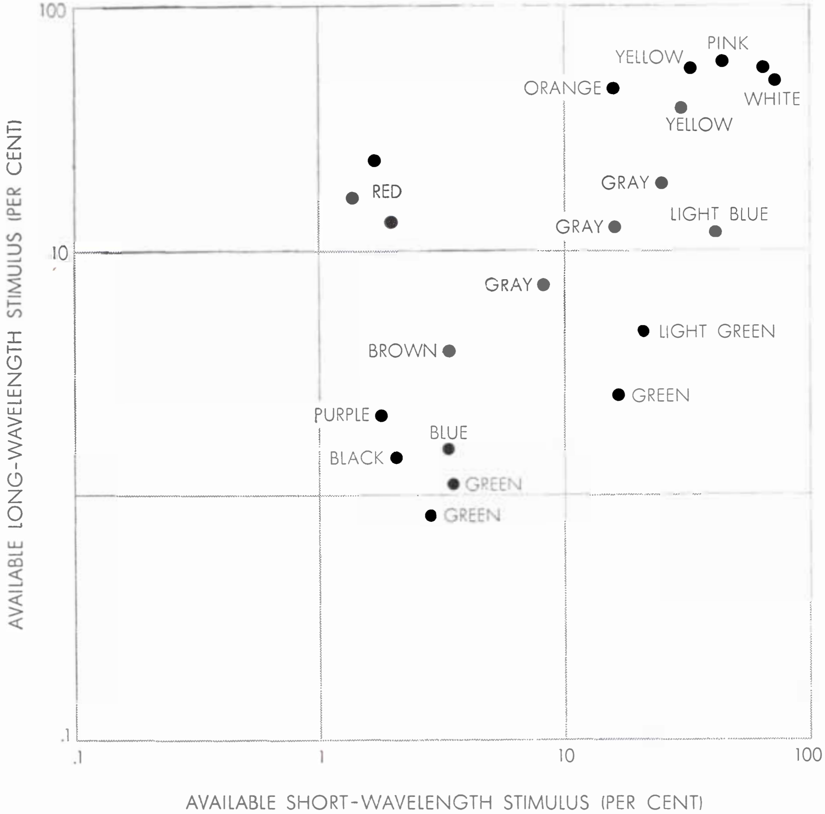
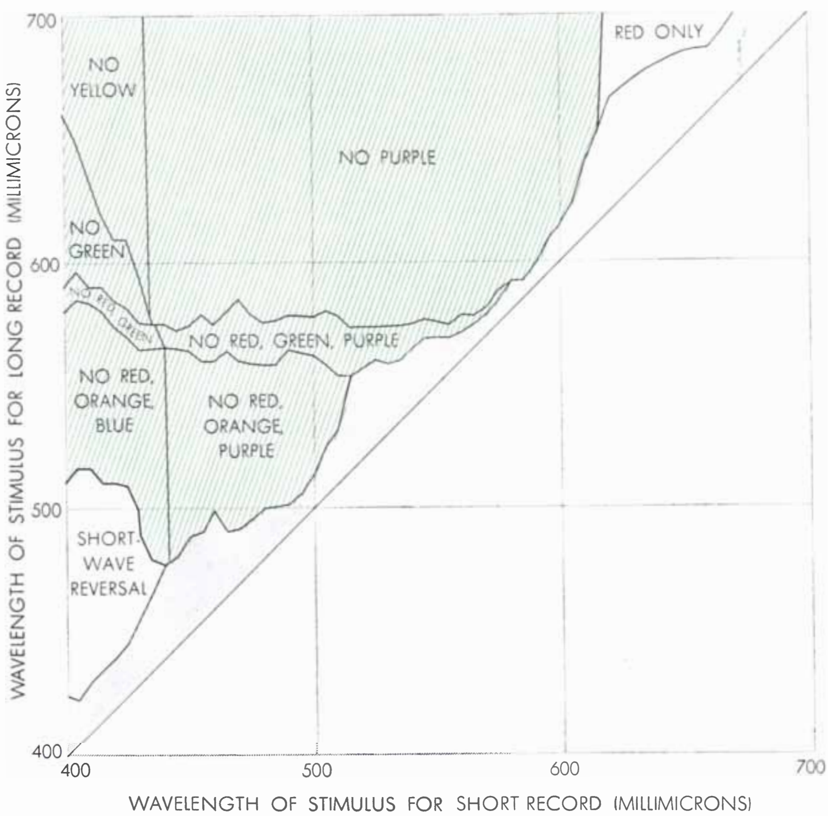
are nothing but pieces of celluloid treated to pass more light in some places than in others. All they can do to the red and white beams is to change relative intensities from point to point. In doing so they stimulate a complete gamut of color. Yet when we vary the relative intensities of the beams over the whole field of view, the colors stay constant. Evidently, even though the eye needs different brightness ratios, distributed over various parts of the image, to perceive color, the ratios that the eye is interested in are not simple arithmetic ones. Somehow they involve the entire field of view. Just how they involve it we shall see a little later.

The dual-projector system is convenient, but it is not a precision instrument. The wavelengths it can provide are limited by the characteristics of available filters. Narrow band-width filters may be used, but they seriously restrict the quantity of light. My colleague David Grey has therefore designed for me a dual image-illuminating monochromator [*see illustration on page 94*]. This instrument contains a pair of spectroscopes which allow us to light our transparencies with bands as narrow as we choose and of precisely known wavelength. By blocking off the spectroscopes and using filters, we can also obtain white light or broad bands. The two images are combined by means of a small, semitransparent mirror; light from one record passes through the mirror, and light from the other is reflected from its top surface. The intensity of each light source can be closely controlled.

With the dual monochromator we have confirmed our broad hypothesis: Color in natural images depends on a varying balance between longer and shorter wavelengths over the visual field. We have also been able to mark out the limits within which color vision operates. It turns out that there must be a certain minimum separation between the long-record wavelength and the short. This minimum is different for different parts of the spectrum. Any pair of wavelengths that are far enough apart (and the minimum distance is astonishingly small) will produce grays and white, as well as a gamut of colors extending well beyond that expected classically from the stimulating wavelengths. Many combinations of wavelengths produce the full gamut of spectral colors, plus the nonspectral color sensations such as brown and purple. All this information has been summarized in a color map showing the limitations on the sensations produced by different pairs of wave-



COORDINATE SYSTEM predicts colors in natural images. Axes are dimensionless, each measuring illumination at every point as a percentage of the maximum that could be there.



COLOR MAP shows limits on color obtainable with different pairs of wavelengths. The gray area is an achromatic region in which wavelengths are too close together to produce any kind of color. In the region marked "short-wave reversal" the colors are normal, but the short wavelengths act as the stimulus for the long record and the long wavelengths as the stimulus for the short record. The blank area below the diagonal is a region of reversed color obtained by illuminating the short record with long wavelengths and *vice versa*.

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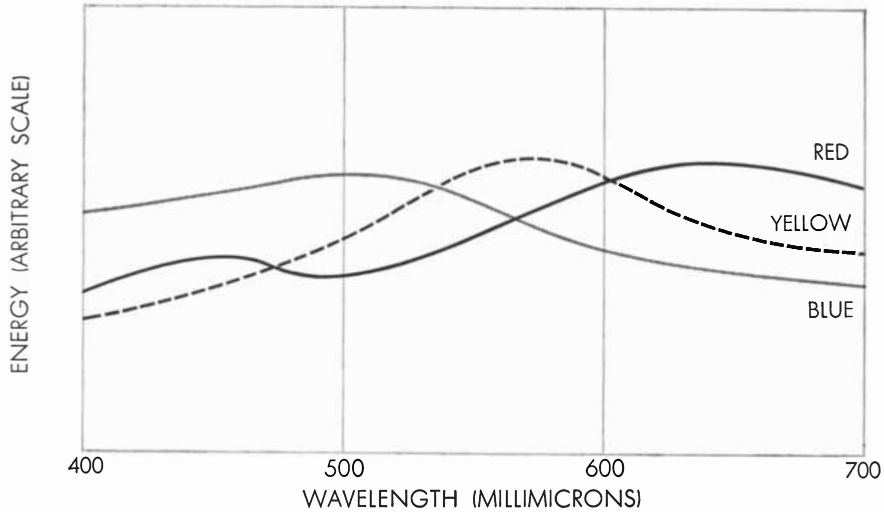
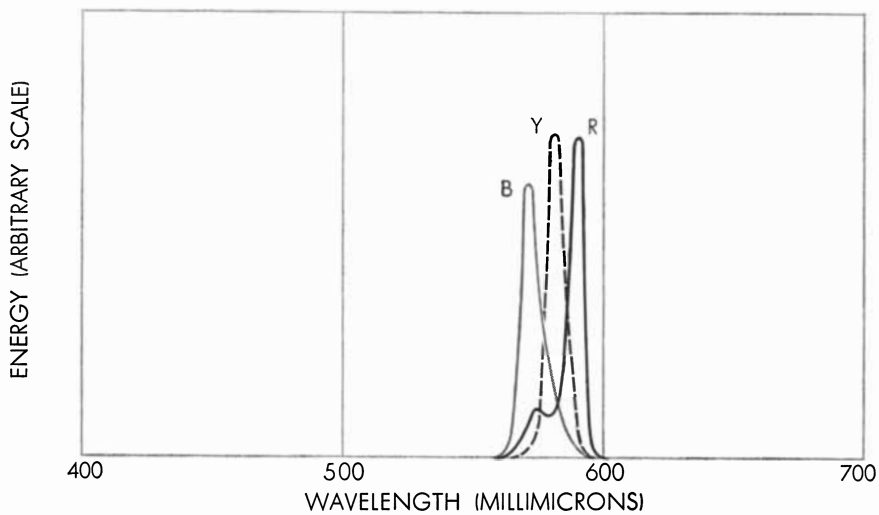
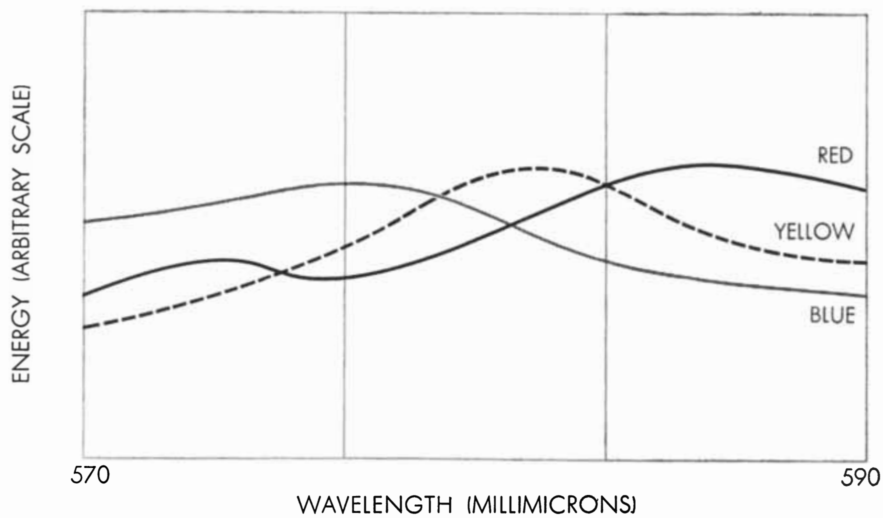


PIGMENTS IN OUR WORLD have broad reflection characteristics. Each pigment reflects some energy from wavelengths across the visible spectrum (400 to 700 millimicrons).





PIGMENTS IN AN IMAGINARY WORLD, whose available light is limited to a band of wavelengths extending only from about 570 millimicrons to 590 millimicrons, would have to be much more sharply selective. Upper curves show reflection curves of pigments which would give full color in such a world. Lower curves represent the same curves stretched out so that the 570-590 band covers the same width as the 400-700 band of the visible spectrum.

lengths [*see illustration at bottom of preceding page*]. We have also investigated the limits on relative brightness. With some pairs the colors are maintained over enormous ranges of brightness; with others they begin to break down with smaller changes. Again, the result depends on the wavelengths we are using. A table showing the stability of various colors for a sample pair of wavelengths appears on page 99.

A New Coordinate System

The color map tells us what we will *not* see when we combine a pair of images at various wavelengths. Can we now make a positive prediction? Given a pair of records of the same scene, and a pair of wave bands with which to illuminate them, what color will appear at each specific point on the combined image? In other words, we want a set of rules that will do for images what the color triangle does for color-matching experiments (and what most of us have mistakenly supposed it does for images as well).

We have formed a new coordinate system that does for the first time predict the colors that will be seen in natural images. Perhaps the best way to approach it is through an actual experiment. Let us set up the dual projector (or the monochromator) for any pair of "long" and "short" bands, say red and white, that can produce full color. We know that local variations in the relative brightness of the two records must somehow give rise to the color. Yet we have also found that changing all the brightness ratios in a systematic way, for example by cutting down the total light from the red projector, has no effect. Therefore we look for a way of describing the brightness in terms that are independent of the total light available in either image.

This can be done as follows: We turn on the "long" projector alone, setting its brightness at any level. Now we find the spot on the red image corresponding to the point at which the long black-and-white record lets through the most light. We measure the intensity at that point and call it 100 per cent. It tells us the maximum available energy for the long waves. Next we measure the intensity of the light all over the rest of the red image, marking down for each point the red intensity as a per cent of the maximum available. Then we turn off the "long" projector, turn on the "short" one and follow the same procedure for the short wavelengths (in this case the full

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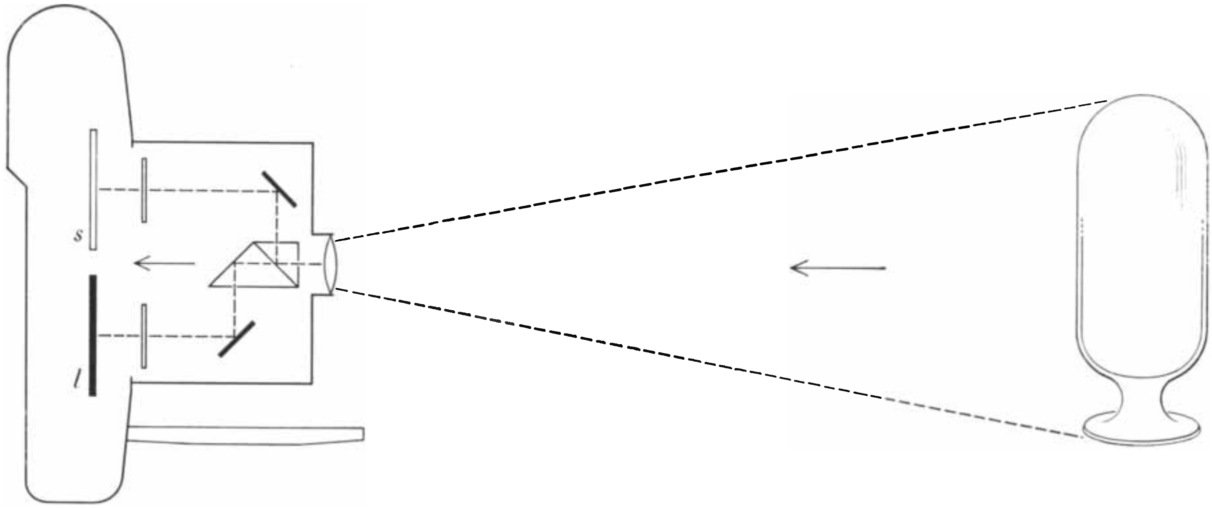

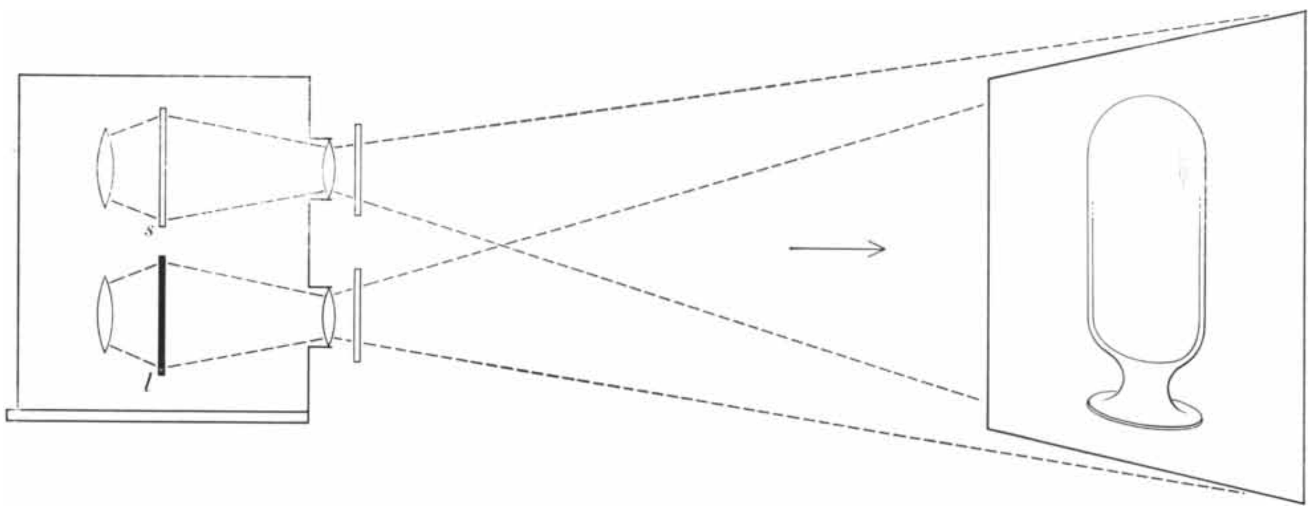

LONG AND SHORT RECORDS are prepared by photographing a scene with the dual camera diagrammed at top. Small open rectangles represent colored filters; the filter in front of the long record is red and the one in front of the short record is green. A composite image is formed by superimposing long and short records (*labeled l and s*) on a screen by means of a dual projector (*bottom*).

spectral band). Now we draw up a two-dimensional graph [*top of page 89*], plotting the percentage of available long wavelengths on one axis and the percentage of available short wavelengths on the other. Every point on the image can be located somewhere on this graph. Each time we plot a point, we note next to it the color it had on the image.

What emerges is a map of points, each associated with a color. When it is finished, we can see that the map is divided into two sections by the 45-degree line running from lower left to upper right. This is the line of gray points. If we had put the same transparency in each projector, all the points would fall on the gray line, since the percentage of available light would be the same at every point on the image for both projectors. The other colors arrange themselves in a systematic way about the 45-degree line. Warm colors are above it; cool colors are below. Thus it seems that the important visual scale is not the Newtonian spectrum. For all its beauty the spectrum is simply the accidental consequence of arranging stimuli in order of wavelength. The significant scale for images runs from warm colors through neutral colors to cool colors.

Repeating our experiment with different illuminating wavelengths or bands, we find that for every pair that produces full color the position of the colors on the coordinate graph remains the same. Thus we have the rule we were looking for, a rule that tells us in advance what color we shall find at any point in an image. We can take any pair of transparencies and measure their percentage of transmission in various regions of the picture. Then, before projecting them, we can predict the colors these areas will have. We will be right provided that the illuminating wavelengths are capable of stimulating all the colors. In cases where they are not, we must change the coordinate map accordingly. Thus the full set of rules consists of a group of coordinate color plots, one for each section of the color map at the bottom of page 89.

Note that each coordinate system is

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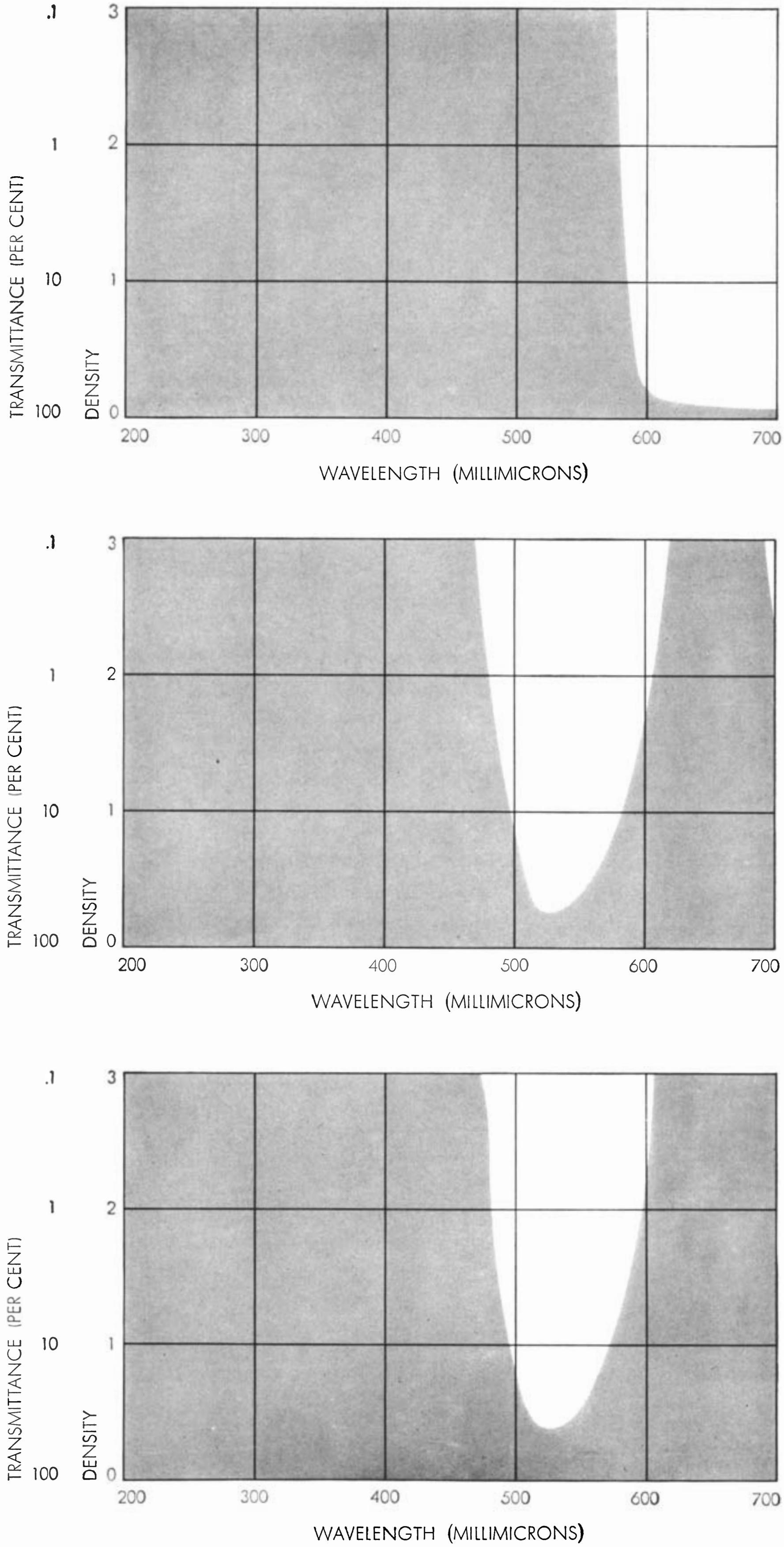

WAVELENGTHS PASSED BY FILTERS used in various experiments described by the author are shown in these curves. At top is the transmittance curve for the red filter used in photographing long record; below it is transmittance curve of green filter for preparing short record. At bottom is curve for the green filter used in the sodium-viewer experiment.

itself dimensionless. The axes do not measure wavelength, brightness or any other physical unit. They express a ratio of intensities at a single wavelength or for a broad band of wavelengths. The axes have another interesting property: they are stretchable. Suppose we superimpose two identical long-wavelength photographs in the slide holder of the "long" projector and leave a single short-wavelength photograph in the holder of the "short" projector. We find that this combination still does not alter the colors on the screen. What sort of change have we made? Every point in the long record that transmitted 1/2 of the available light now transmits 1/4, points that transmitted 1/5 now transmit 1/25 and so on. On the logarithmic scale of our graph this corresponds to stretching the long-record axis to twice its former length. The 45-degree line now shifts to a new direction, but all the color points shift with it, maintaining their relative positions [*see diagram on opposite page*].

Randomness

Our studies of the coordinate graph have uncovered another interesting and subtle relationship. As we plotted graphs for various experiments we began to suspect that any arrangement which yielded points falling on a straight line, or even on a simple smooth curve, would be colorless. To test this idea we tried putting a negative photograph in one projector and a positive of that negative in the other. Such a pair of images will plot as a straight line running at right angles to the 45-degree gray line. The image is indeed virtually colorless, showing only the two "colors" of the stimuli involved in projection and a trace of their Newtonian mixture.

If an image is to be fully colored, its coordinate graph must contain points distributed two-dimensionally over a considerable area. But even this is not enough. The points must fall on the graph in a somewhat random manner, as they do in the plot of any natural scene. This requirement can be demonstrated in a very striking experiment. Suppose we put a "wedge" filter in the slide holder of the red projector. The effect of the filter is to change the intensity of the beam continuously from left to right. That is, when the red projector is on and the white projector off, the left side of the screen is red and the right side is dark, with gradations in between. Now we place a similar wedge, but vertically, in the white projector so

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that the top of the screen is white and the bottom is dark. With both projectors turned on we now have an infinite variety of red-to-white ratios on the screen, duplicating all those that could possibly occur in a colored image. However, they are arranged in a strictly ordered progression. There is no randomness. And on the screen there is no color —only a graded pink wash.

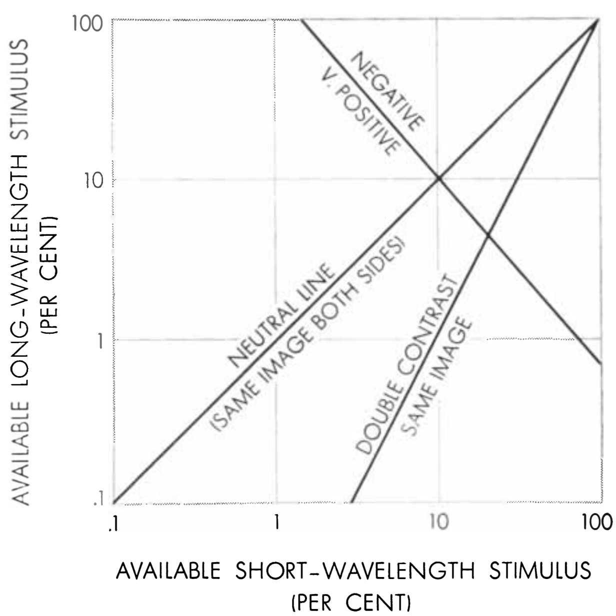
To repeat, then, the colors in a natural image are determined by the relative balance of long and short wavelengths over the entire scene, assuming that the relationship changes in a somewhat random way from point to point. Within broad limits, the actual values of the wavelengths make no difference, nor does the over-all available brightness of each.

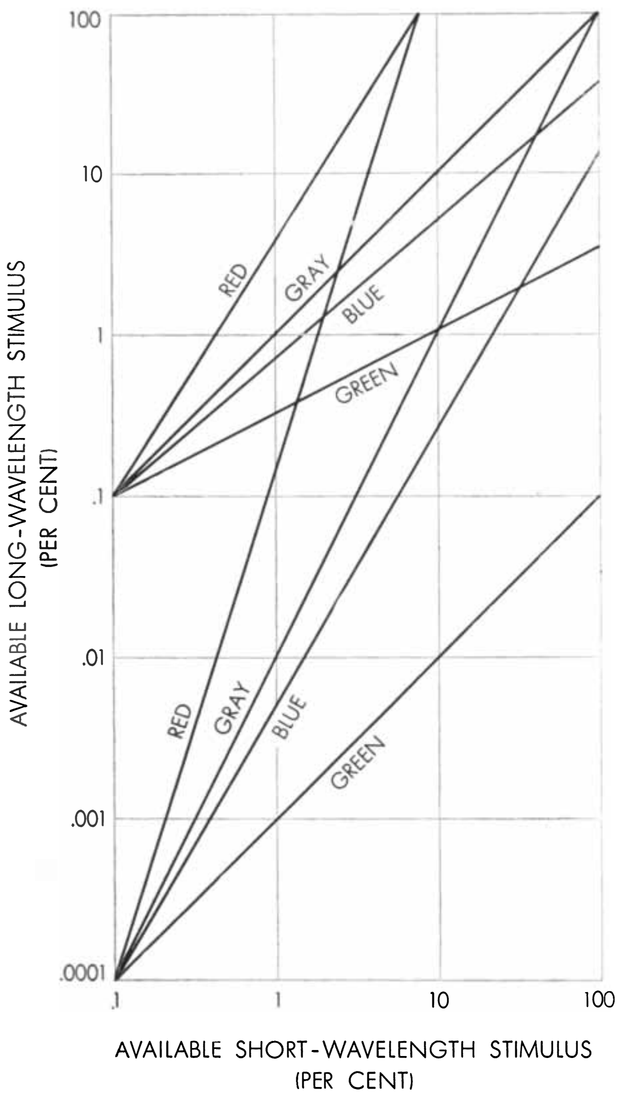
The independence of wavelength and color suggests that the eye is an amazingly versatile instrument. Not only is it adapted to see color in the world of light in which it has actually evolved, but also it can respond with a full range of sensation in much more limited worlds. A dramatic proof of this is provided by another series of experiments.

Color Worlds

In these we use a pair of viewing boxes that superimpose fairly large images by means of semitransparent mirrors [*see diagram at bottom of page 99*]. Each box contains tungsten lamps, which produce white light, to illuminate one record and a sodium lamp to illuminate the other. We turn on one viewer, inserting the long and short transparencies and placing a red filter over the tungsten lamp. The composite image is fully colored, containing greens and blues, although the shortest wavelength coming from the mirror lies in the yellow part of the spectrum. Now we turn on the second viewer, inserting a green filter over the white light-source. Again the image contains a gamut of color, including red. The observer can see the images in both viewers at once—each showing the same range of color, but representing different visual worlds. In the first the sodium light (with a wavelength of 589 millimicrons) serves as the shortest available wavelength and helps to stimulate the green and blue. In the second it is the longest wavelength and stimulates red. If the observer stands back far enough from the viewer, he can also see the "natural" colors in the room around him. Here then is a third world in which yellow is "really" yellow.

Another way to use the green filter in the second sodium viewer is to hold it





PROPERTIES OF COORDINATE SYSTEM are illustrated in these diagrams. At left are the graphs of experimental situations which do not produce a gamut of color in the image. Such situations appear to graph as straight lines. At right the axes are shown to be stretchable. When gray line dividing warm and cool colors is displaced, colors move but maintain their relative positions.

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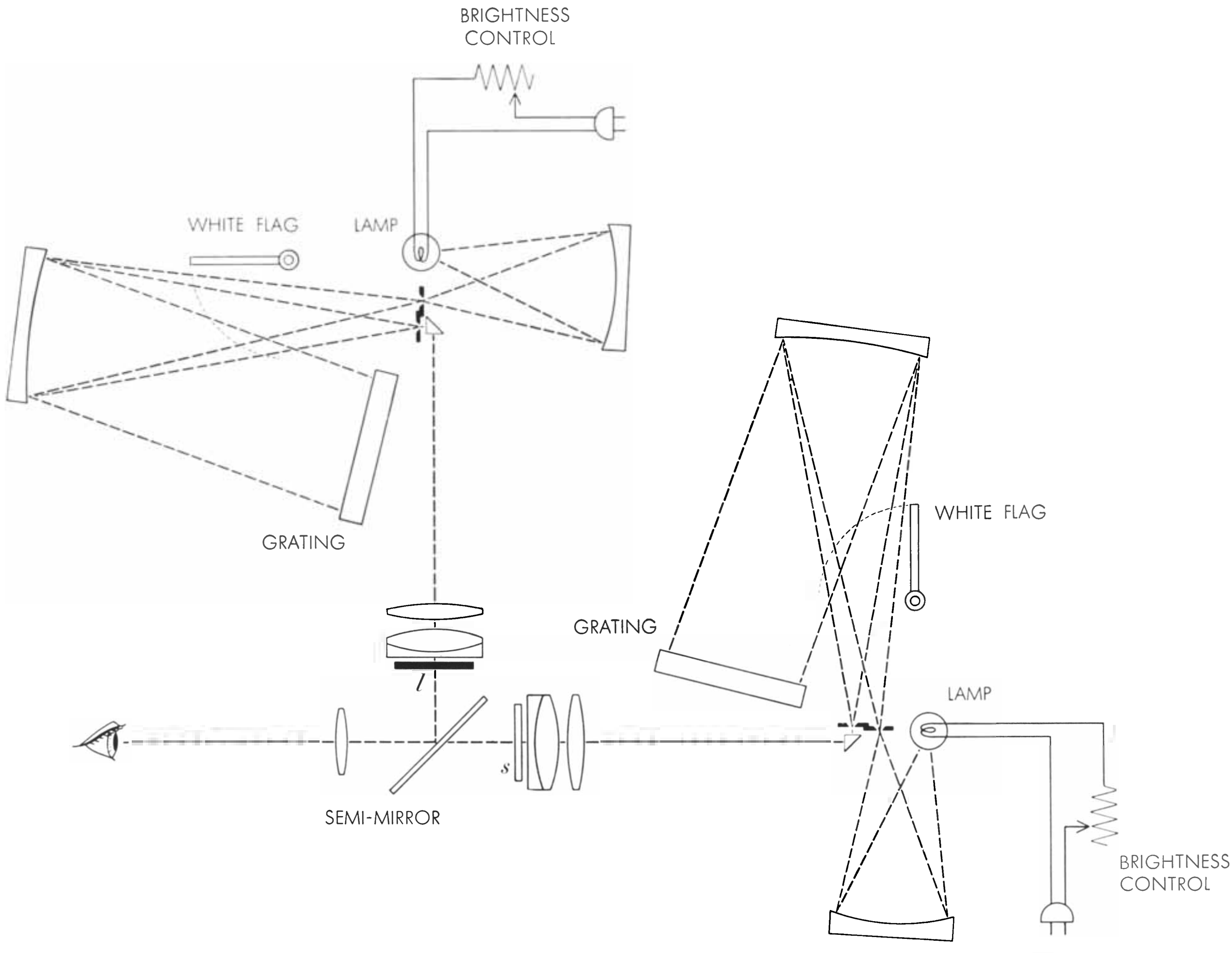
up to the eye instead of placing it in front of the tungsten lamps. This filter passes both the sodium wavelength and the green band [*see bottom graph on page 92*]. When he looks around the room, the observer sees red objects as black and the rest of the colors as washed-out green. But when he looks at the picture in the second viewing box, he sees it quite full of color, including red.

The color worlds of the viewers are produced by pictures. Could we make physical models of these worlds, populating them with real objects which would show the same colors as the images in the viewers under the same conditions of illumination? We could if only we had the proper pigments. The pigments in the world around us are the best we have been able to find that look colored in our lighting: a spectrum of visible wavelengths from 400 to 700 millimicrons. Each of these pigments reflects a broad band of wavelengths, and its peak is not sharp [*see diagram at top of page 90*].

Thus our coloring materials do not distinguish clearly between wavelengths that are fairly close together. If we could find pigments with much narrower response curves, we would suspect that these might provide full color in a more restricted world of light—a world, for example, lighted by the wavelengths that pass through the green filter. In the absence of such coloring materials, we might content ourselves with creating this world photographically, if we could show that this is possible. A moment's study of the diagrams on page 90 will show the exciting fact that a two-color separation photograph in a world of any band-width is the same as a two-color photograph in a world of any other band-width—including our own, provided that we postulate that a correctly proportioned change in the absorption bands of the pigments goes along with a change in the band-width of the world. Therefore we can use our regular long and short pictures, taken through the red and green filters, to transport ourselves into new worlds with their new and appropriately narrow pigments.

The Visual Mechanism

The sodium-viewer demonstration suggests an important consideration that we have not previously mentioned, although it is implicit in what has already been said. If the eye perceives color by comparing longer and shorter wavelengths, it must establish a balance point or fulcrum somewhere in between, so that all wavelengths on one side of it



DUAL MONOCHROMATOR used in experiments described in this article is diagrammed. Very narrow bands of wavelengths from any part of the visible spectrum are produced by the two gratings. White flags can be inserted to give white light. Narrow rectangles marked *l* and *s* represent the black-and-white transparencies that serve as the long record and the short record respectively.

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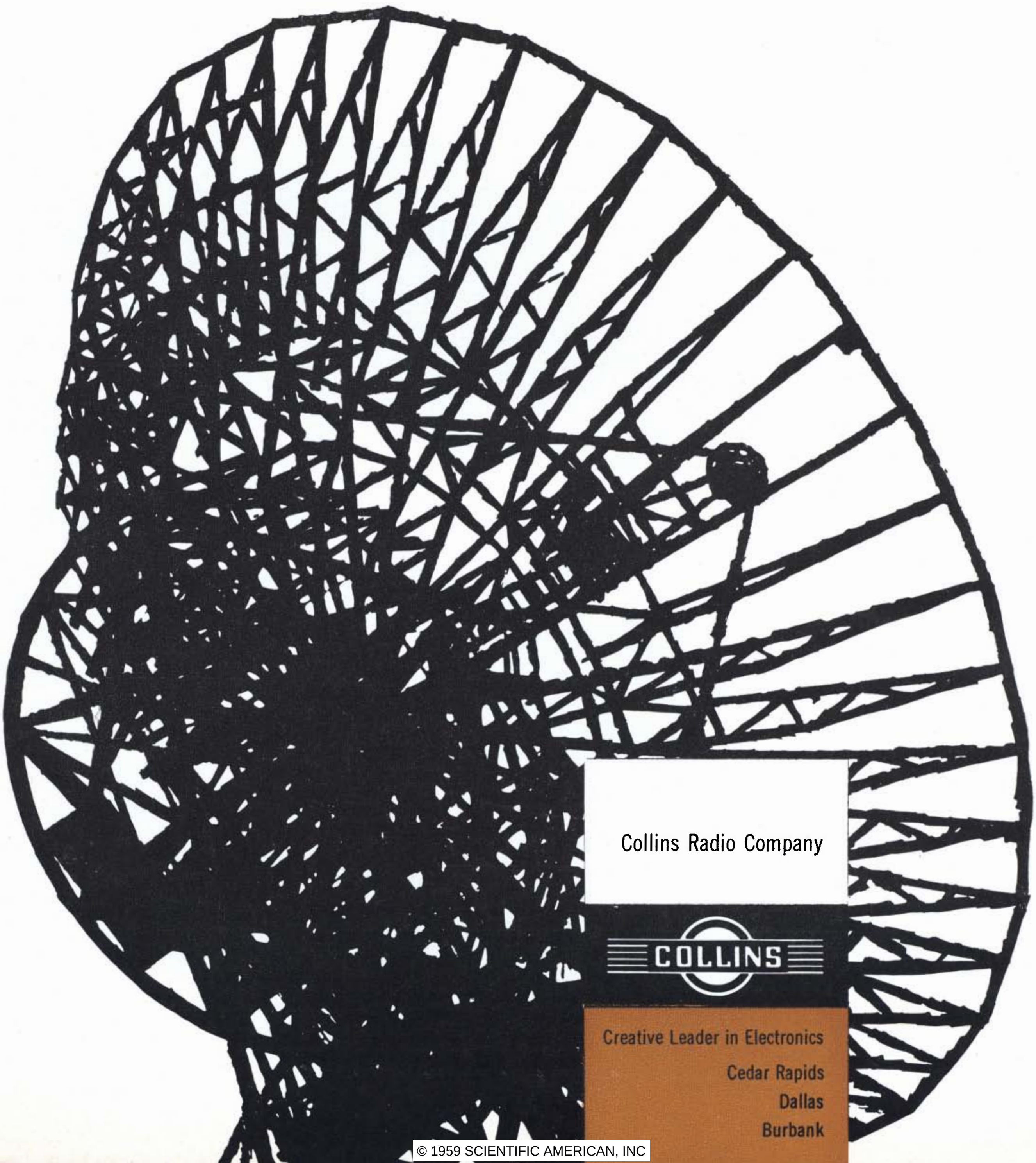

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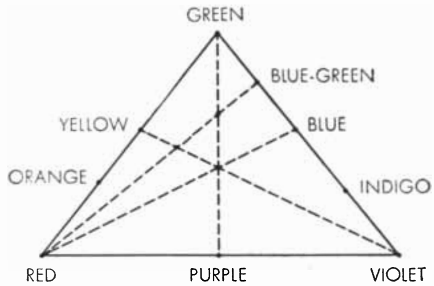


COLOR TRIANGLE of classical theory is shown in an early schematic form. Points of intersection of lines represent colors obtained by mixing spectral wavelengths in amounts proportional to distances from sides of triangle. Central point is equal mixture of primaries and is therefore white.

are taken as long and all on the other side as short. From the evidence of the viewer we can see that the fulcrum must shift, making sodium light long in one case and short in the other.

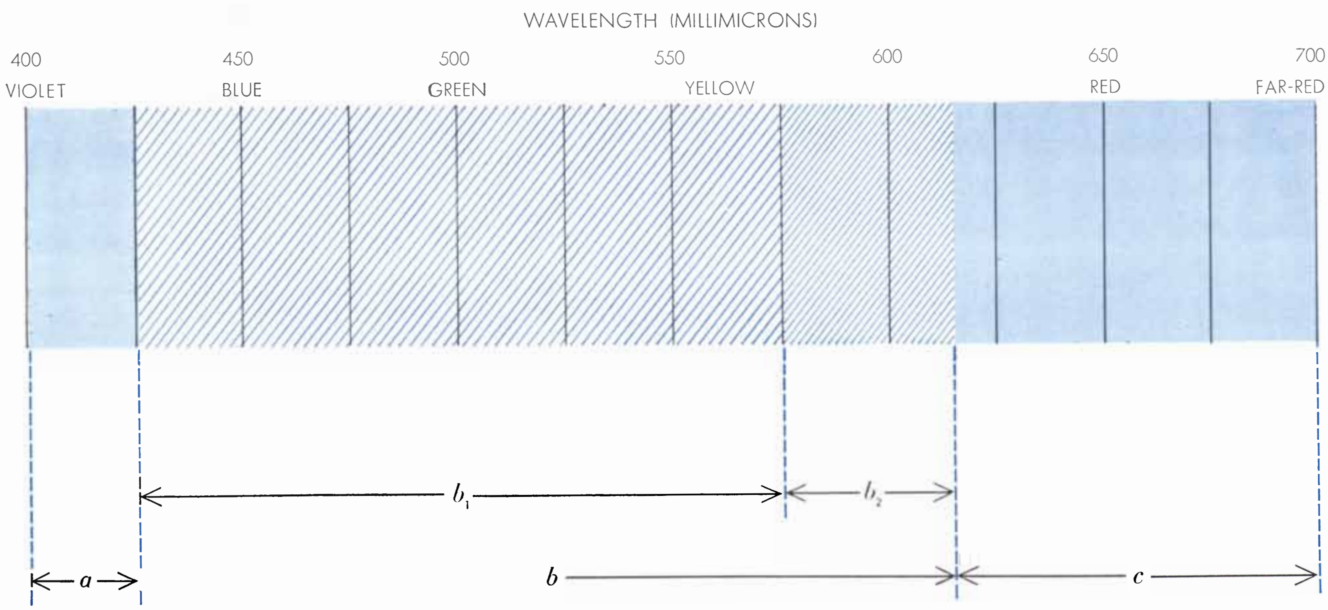
Where is the fulcrum in the ordinary, sunlit world? Experiments on a large number of subjects indicate that it is at a wavelength of 588 millimicrons. When we use this wavelength in one part of the dual monochromator and white light in the other, the image is nearly colorless. With a wavelength shorter than 588 millimicrons, white serves as the longer stimulus in producing color; with a wavelength longer than 588 millimicrons, white becomes the short record.

From the dual-image experiments we learn that what the eye needs to see color is information about the long and short wavelengths in the scene it is viewing. It makes little difference on what particular bands the messages come in. The situation is somewhat similar to that in broadcasting: The same information can be conveyed by any of a number of different stations, using different carrier frequencies. But a radio must be tuned to the right frequency. Our eyes are always ready to receive at any frequency in the visible spectrum. And they have the miraculous ability to distinguish the longer record from the shorter, whatever the frequencies and the band-widths. Somehow they establish a fulcrum and divide the incoming carrier waves into longs and shorts around that point.

In our experiments we provide a single photograph averaging all the long wavelengths and a single photograph averaging all the short. What happens in the real world, where the eyes receive a continuous band of wavelengths? We are speculating about the possibility that these wavelengths register on the retina as a large number of individual color-separation "photographs," far more than the three that Maxwell thought necessary and far more than the two that we have shown can do so well. The eye-brain computer establishes a fulcrum wavelength; then it averages together all the photographs on the long side of the fulcrum and all those on the short side. The two averaged pictures are compared, as real photographic images are compared in accordance with our coordinate system.

Finally I should like to make clear that, although our experiments deal with two photographs and our coordinate system is two-dimensional, we have not been describing a two-color theory of vision. When we use a band of wavelengths for either or both of the records, we have light of many wavelengths coming from each point on the screen. And if classical three-color theory holds, it should describe the color of each of these points. This, as we have seen, it completely fails to do. It is true, however, that our experiments deal with two packages of information. We have demonstrated that the eye can do almost everything it needs to do with these two packages. The significance of what a third package will add is far from obvious. We are building a triple image-illuminating monochromator to find out.

A third picture may provide better information at the photographic level or an additional and useful interaction with the stimuli from two images. However, there is not a very big gap in the sensation scale to be filled by the third picture. In a given image a particular combination of two stimuli might not provide an electrically intense blue or a delicately yellowish green, but it is still likely to provide more than enough for the animal to live with. Nevertheless we



WAVELENGTH AND COLOR are independent of each other, except for the long-short relationship. This diagram shows the roles that various wavelengths can play. Those in the interval *a* can serve only as the short-record stimulus; those in *b* may be either long or short; those in *c* can only be long. If the wavelengths in b_1 are used as short-record stimuli, they will combine with a longer wavelength to produce the full gamut of color. If they are used as long-record stimuli, they will produce a more limited range. Wavelengths in b_2 will produce full color, serving as the stimuli for either the long record or for the short record. When both stimuli come from between 405 and 520 millimicrons, "short-wave reversal" occurs (*see color map on page 89*).

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The Vscope on the front of each equipment is shown here enlarged to improve readability. The Vscope at left shows a vertical disturbance of .187". The Vscope at right reveals no apparent motion due to the high isolation of the Robinson mounting.

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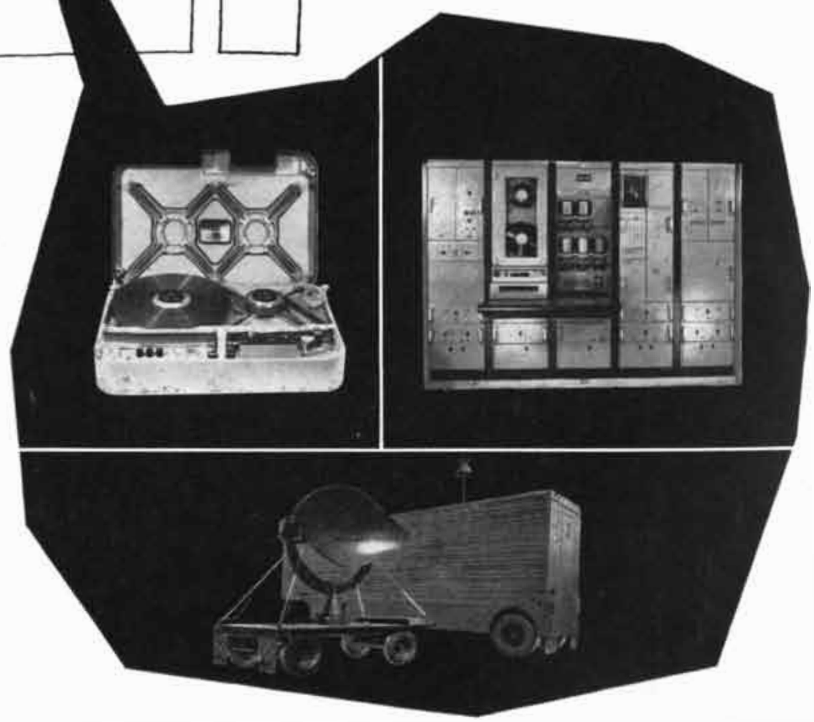

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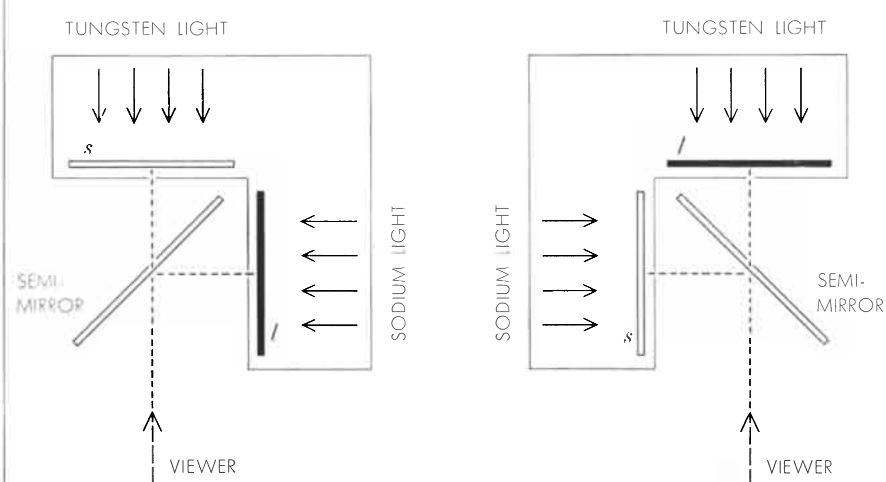
COLORS SEEN	RANGE OVER WHICH SEEN	VARIATION IN COLOR OVER THIS RANGE
GRAY	200 TO 1	LITTLE VARIATION
BROWN	100 TO 1	YELLOW-BROWN TO DARK BROWN
WHITE	100 TO 1	YELLOWISH-WHITE TO BLUISH-WHITE
YELLOW	30 TO 1	YELLOW TO OFF-WHITE
YELLOW-GREEN	30 TO 1	YELLOW-GREEN TO YELLOW ORANGE
BLUE	10 TO 1	BLUE-VIOLET TO BLUE GREEN
GREEN	6 TO 1	BLUE-GREEN TO GRAY-GREEN
RED	5 TO 1	DARK RED TO DARK ORANGE-RED
ORANGE	5 TO 1	YELLOW TO RED-ORANGE

LIMITS OF STABILITY of colors under variation in relative brightness of a sample pair of long and short stimuli are summarized in this typical chart. Second column shows the mechanism ratio (changing the brightness of either or both of the stimuli) for which color at left is recognizable. Pair of stimuli used was 450 millimicrons and 575 millimicrons.

do expect that the richness of many colors will be increased by the interplay of a third stimulus. Whatever we learn by adding a third picture, the visual process will remain an amazing one from the evolutionary point of view. Why has a system that can work so well with two packages of information evolved to work better with three? And who knows whether it will not work better still with four, or five or more?

What does the eye itself do in the everyday world of the full spectrum? Does it make only two averages? Or does it put to better use the new ability we have discovered—the ability to distinguish sharply between images at closely spaced wavelengths? Perhaps it creates many sets of averages instead of just two or three.

Even if more than two information channels are used, we feel that the big jump is obviously from one to two. Most of the capability of our eyes comes into play here. And whatever may be added by more channels, the basic concept will remain. Color in the natural image depends on the random interplay of longer and shorter wavelengths over the total visual field.



SODIUM-VIEWING BOXES are diagrammed schematically. Each of these instruments produces a large composite image by means of the semitransparent mirror. Tungsten light is white, and is restricted to narrower bands of wavelengths by means of colored filters.

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THE LATE BLIGHT OF POTATOES

This devastating disease is now controlled only by repeated spraying. Potato varieties that can withstand it are being produced in central Mexico, the probable home of the blight

by John S. Niederhauser and William C. Cobb

Until quite recently Mexican farmers regarded the lowly potato as a luxury crop to be cultivated either at high altitudes or during the dry season with irrigation. "The potato just won't grow during the summer rainy season," one farmer said. "It is not well adapted here."

It was strange to find such opinion prevailing among the farmers of Mexico. The tropical highlands of Central and South America are the native home of the potato. In the very countryside where farmers found it so difficult to cultivate the plant, dozens of wild species, producing small, largely inedible tubers, grow throughout the rainy season and apparently flourish in the cool, humid climate. From Latin America the potato went forth to become one of the major food crops of the world. It yields more calories per acre than any other crop; it ranks second only to rice in total annual tonnage. Wherever day temperatures are cool and the climate moist, the potato is the food of the poor. In Europe above the 45th parallel, from the U.S.S.R. to Ireland, the potato feeds the populace; in North America, along both sides of the Canadian border, the

MOUNTAIN SLOPES IN CENTRAL MEXICO, like this one near Mexico City, yield half the country's small potato crop. The potato fields in the foreground are nearly 10,000 feet above sea level. Though the cool climate at this altitude retards the spread of late blight, the crop is often partly destroyed. At lower altitudes potatoes are grown only during the dry season in irrigated fields.

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potato is grown for shipment and is a vital cash crop. For decades expeditions have come to Mexico to collect wild species of the potato for the genetic improvement of domesticated strains. Yet the farmers of Mexico held that the potato was not adapted for cultivation in their country!

Such was the status of the potato in Mexican agriculture when one of us (Niederhauser) in 1947 joined the staff of the Office of Special Studies, a joint research enterprise of the Rockefeller Foundation and the Government of Mexico which is devoted to the improvement of the country's plant and animal stocks and agricultural methods. Though it is usually wise to listen to the opinion of good farmers, I arranged for the planting of small plots of potatoes at two of our experiment stations at the beginning of the next rainy season. The plants got off to a grand start and looked fine until about the middle of July. Then it became clear why the Mexican farmers had so little faith in the potato. After a series of daily rains, dark lesions appeared on the leaves and stems; within a week the luxuriant green foliage was reduced to blackened stalks. The "late-blight" disease had struck.

With the black stem rust of wheat the late blight of potatoes shares the notoriety of being the world's most destructive plant disease. These blights are caused by fungi: pale microscopic plants that lack chlorophyll and are obliged to live parasitically on plants that are capable of photosynthesis. *Phytophthora infestans*, the fungus that causes the late potato blight, entered the pages of history in the 1840s, when it twice destroyed the potato crop of Ireland. In the ensuing famine more than a million of the island's eight million people perished, and more than 1.5 million emigrated to other lands [see "The Social Influence of the Potato," by Redcliffe N. Salaman; SCIENTIFIC AMERICAN, December, 1952]. The potato farmer figuratively cultivates his fields with a hoe in one hand and a spray can in the other. The late blight levies its heaviest tax in labor and the cost of chemical sprays on the small subsistence farmers who can least afford to pay it. In extensive regions of the world where the climate is excellent for potatoes, including the highlands of India as well as those of Mexico, people who most need this energy-rich food have had to forego it.

The sudden and devastating appearance of a plant disease provokes in a plant pathologist more than scientific in-

CULTIVATED POTATO (*Solanum tuberosum*) originated in the Andes, but wild species are dispersed throughout Latin America. As a crop plant, the potato is reproduced vegetatively, new plants arising from the "eyes" of its tubers. The seeds of its small, tomato-like fruits are of value primarily to plant breeders seeking to develop new varieties from crosses.

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terest. I determined to do something about it. One of my professors at Cornell University, the late Donald Reddick, had developed blight-resistant varieties. I was confident that these would take care of the situation in Mexico. In the spring of 1949 I planted a series of experimental plots in the Toluca Valley near Mexico City. Surely the local farmers would be astonished to see unsprayed potatoes growing nicely during the rainy season!

But in July, when the rains began, I was the one who was astonished. Without exception all of the resistant varieties were blighted and killed, several being destroyed almost as they emerged from the ground. The puzzled farmers shook their heads and wondered why I should try to prove something that they already knew.

I could be forgiven for my optimism. The "resistant" potatoes I had planted were crosses of *Solanum tuberosum*, the familiar Irish potato, and the wild species *Solanum demissum*, which is indigenous to Central America. Reddick and others had found that the wild species was immune to all cultures of the blight fungus available to them, and they had incorporated the genes responsible for this immunity into new varieties.

How then explain the outcome of my experiment? Reddick had surmised years before that the Toluca region was the endemic home of the late-blight fungus as well as of *Solanum demissum*. In nature the contest between host and parasite is rarely won by either side. Few epidemics among plants or animals are ever 100-per-cent fatal. Natural selection provides for the survival of those individuals that have genes endowing them with the biochemical constitution to defeat infection by a particular pathogen. In a parallel selection process, strains of the parasite evolve on the resistant remnants of the host population. In the Toluca Valley, as a result of this centuries-long struggle for survival, a biological balance had been reached between the resistant species of wild potato and the virulent races of the fungus prevalent there.

Clearly the fungus in these Mexican highlands presented a fine subject for basic research on the disease. It was equally apparent that the experiment station at Toluca would provide an excellent proving ground to test the resistance of new strains of potatoes. Perhaps it would be possible to combine the hard-won resistance of the wild species with the commercial characteristics of the Irish potato in a new Mexican hybrid variety that would produce big edible tubers and stand off the ravages of blight.

Since the Office of Special Studies had projects of higher priority (concerned with the improvement of corn and beans, the staples of the Mexican diet) it was several years before the active work on the potato could begin. Then in 1952, on the model of our experience with these other plants, we undertook the first phase of our effort to increase the importance of the potato in the agriculture of the country. This called for the testing of thousands of varieties each year from the U. S. and from every other potato-growing nation in the world. Most of them come to us

LATE-BLIGHT DISEASE can destroy a potato field in a few days. Blight-resistant (*left*) and susceptible (*right*) seedlings, both grown without spraying, are the same age. The photograph was made in the Toluca Valley, an international center of potato research.

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Roy E. Marquardt, *President*

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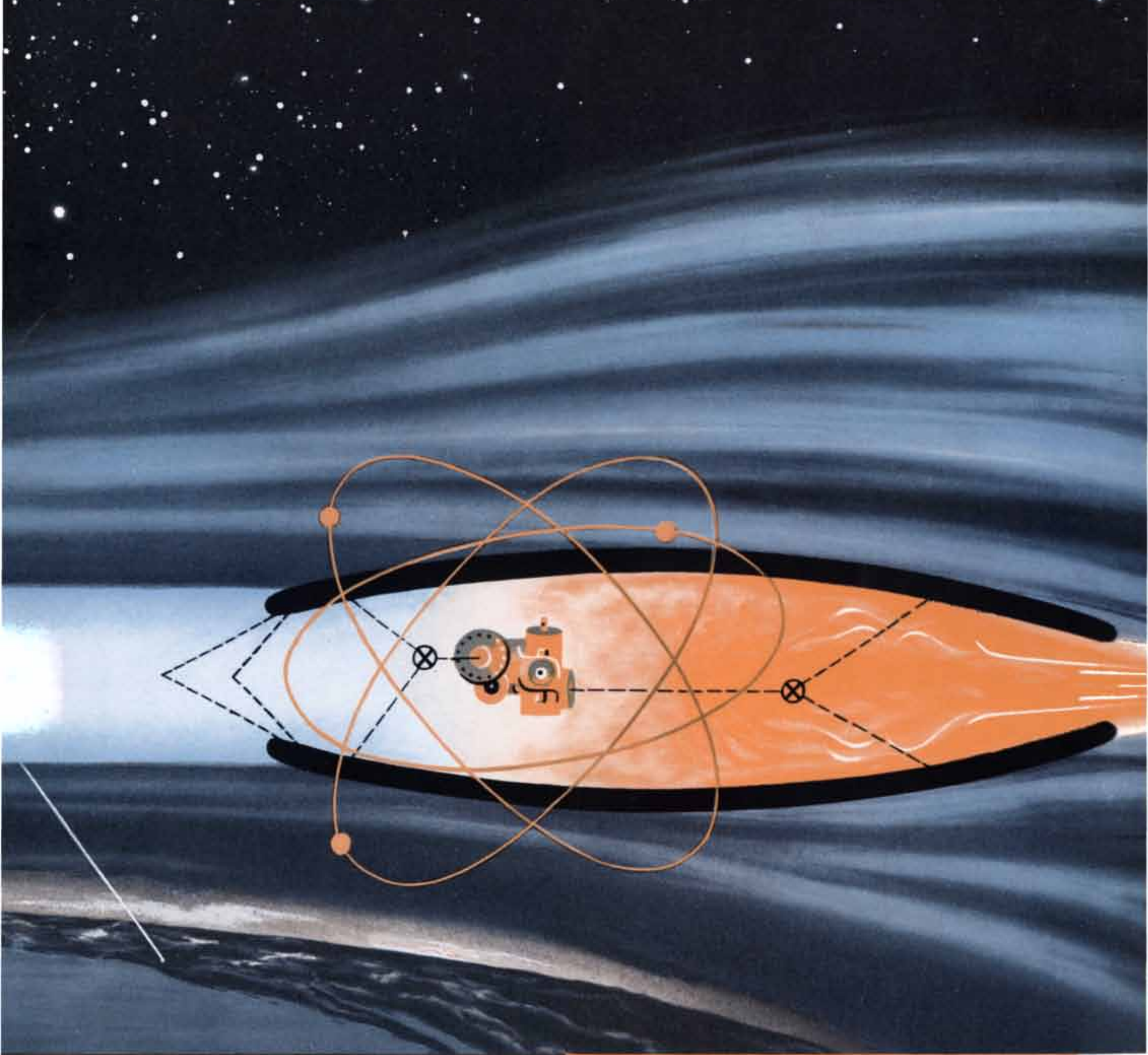

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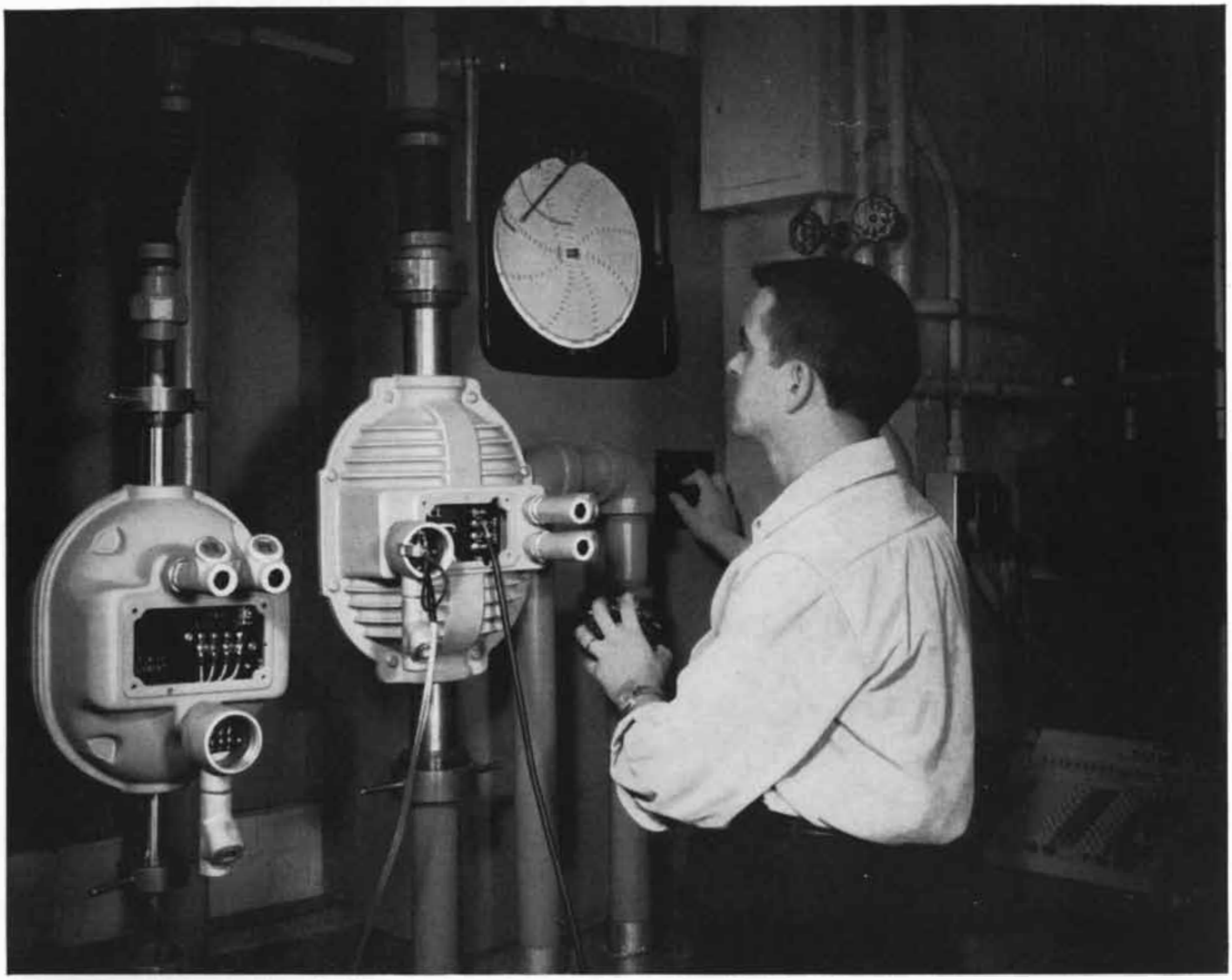

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rated as "immune" to the blight on the basis of their resistance to the races available in their country of origin. But few of them have survived the withering exposure to the races of fungus that abound in the Mexican countryside. To date only 250 blight-resistant selections have survived the field test in Toluca Valley.

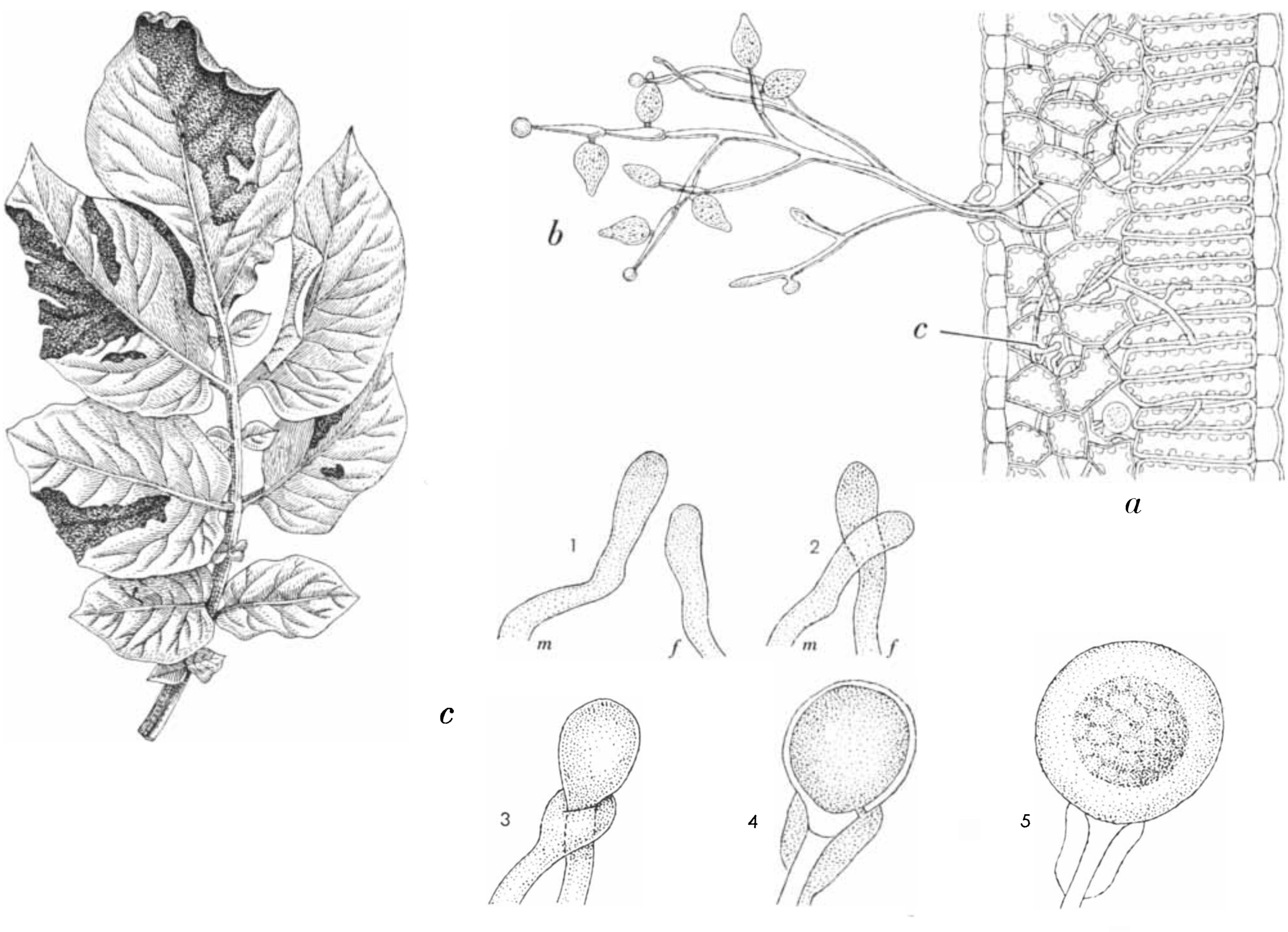
Of course blight resistance is not the only criterion of this "varietal selection" program. A useful variety of potato must also yield a rewarding crop of well-shaped tubers, free of cracks and discolorations. Moreover, in a country like Mexico potatoes must be good "sleepers"—slow to sprout even in warm weather—so that the farmer can keep his seed potatoes from one season to the next. On the basis of these additional criteria three "elite" varieties have been selected from the 250-odd resistant strains. Their yield is moderately good, and their shape and eating qualities are acceptable for the Mexican market. Regional tests over a four-year period indicate that they will grow without spraying in all parts of Mexico where the climate is suitable. The rural people are now beginning to add the potato to their basic diet.

The eager acceptance of the potato on the part of average Mexican farmers has been demonstrated by our experience in a remote and mountainous part of the state of Michoacán. Three seasons ago 100 pounds of seed tubers of one of the elite varieties were given free to each of about 20 farmers in four neighboring villages. The only stipulation was that from his first harvest each farmer would in turn give 100 pounds of seed to some other farmer. Though the region is almost without roads, and travel is by burro and foot, by last summer this strain was under cultivation as far as 75 miles from the original villages.

Three fourths of the Mexican population lives on a great central plateau at elevations of 4,500 feet or more. In this cool climate, with fairly reliable summer rains, the potato can grow very well. The new blight-resistant varieties make it possible for a subsistence farmer to put in a small plot of potatoes or for his wife to plant a few hills in her dooryard garden. Mexico now has a new food source that, at very low cost, will vary and augment its traditional diet of corn and beans.

The screening program has evolved into the International Cooperative Project for Late-Blight Research. Potato breeders all over the world now send their experimental varieties to Toluca for testing. The battery of indigenous blight races eliminates most of the plants at once and enables the breeder to concentrate his attention on the relatively few survivors. Since 1956 we have also been sending certain selections to other countries for further testing. Uniform sets of 10 elite strains have gone out to collaborators in 29 different countries on five continents. Reports on the resistance, adaptation and yield of each variety indicate that the Toluca-screened potatoes grow at least as well in every other country as they do in Mexico. Most of them appear to be immune to the blight races established in those countries.

With progress toward immediate practical objectives under way, we were able to turn to the long-range basic study



BLACK LESIONS OF LATE BLIGHT (*left*) are caused by a fungus which grows in the potato leaf as a network of filaments about .001 inch in diameter (*a*). The fungus normally reproduces asexually by producing pear-shaped spore sacs (*b*); this process is shown in more detail on page 112. Under special conditions, two fungi can reproduce sexually (*c*). A female cell grows through a male cell (*1, 2, 3*), which then fertilizes it (*4*). The fertilized female cell then grows into a thick-walled and hardy oöspore (*5*).

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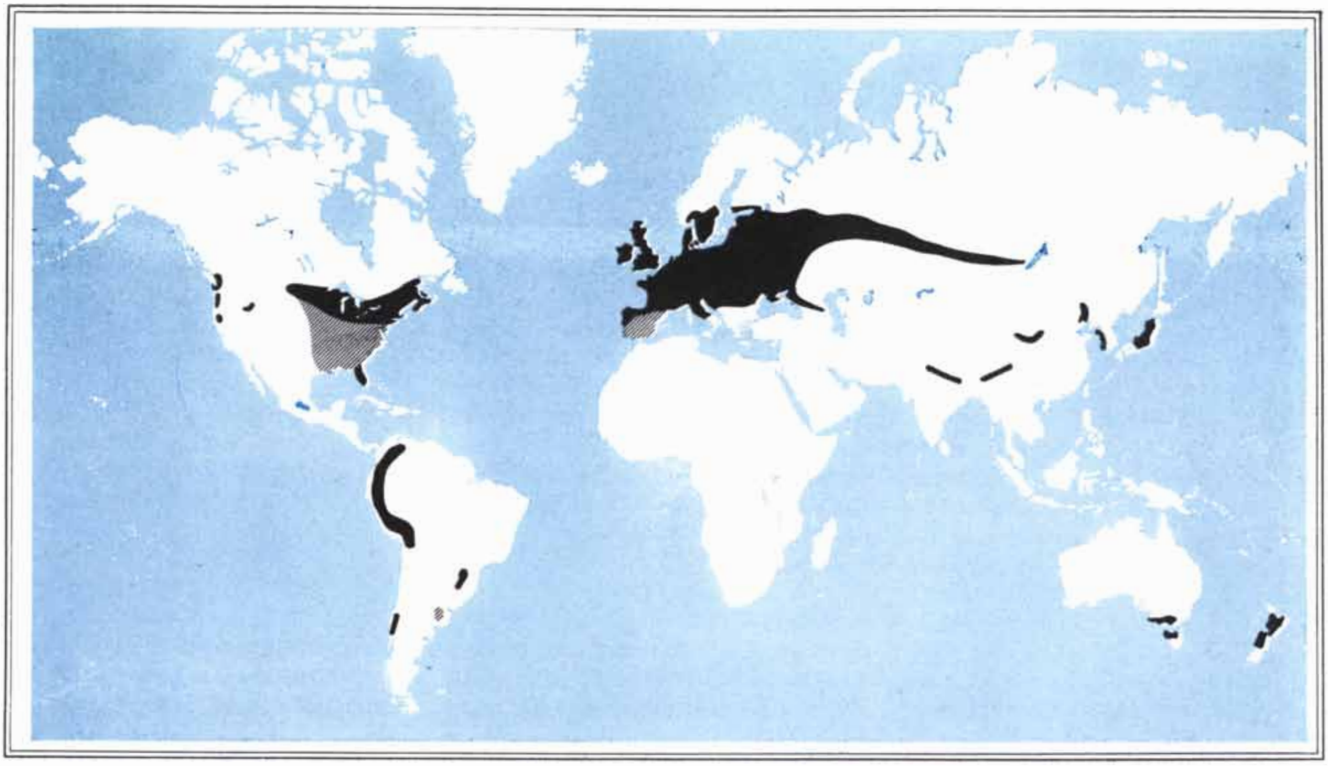
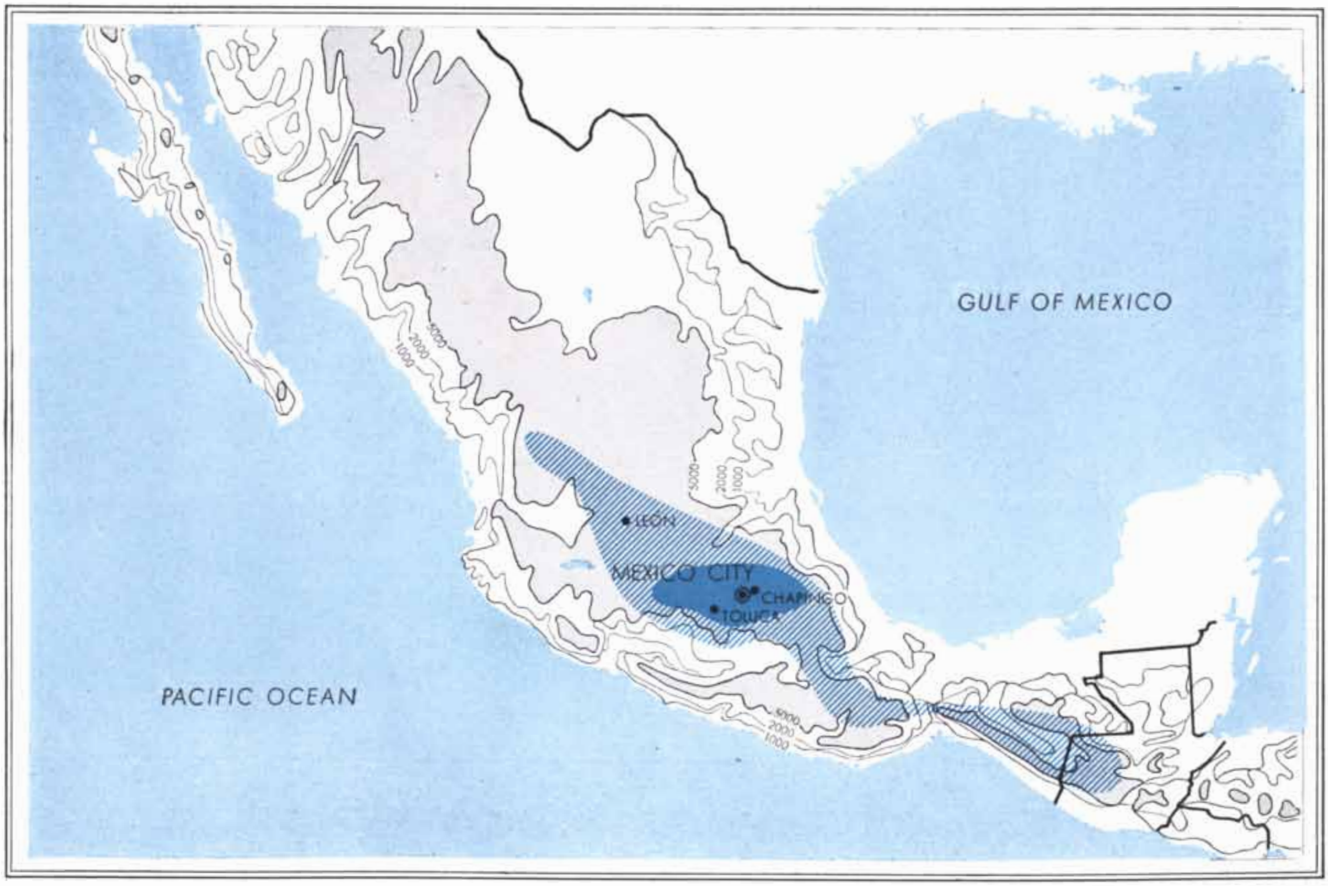


POTATO-GROWING AREAS (*black and hatched*) show the plant's preference for a cool, moist climate; in the tropics it grows only in highland regions. Late blight is a serious problem throughout the black areas, but is only sporadically troublesome in the hatched areas. A small area in central Mexico (*color*) has produced all the wild-potato species used in breeding blight-resistant types.



BLIGHT-RESISTANT WILD POTATOES are found only in Mexico and northern Guatemala (*colored area*). The concentration of resistant species in central Mexico (*dark color*) indicates that the blight probably originated in that region. The intensely virulent strains of the blight fungus in Mexico drastically limit potato culture there, though much of the land above 5,000 feet (*gray*) possesses a suitable climate. Toluca, Chapingo and León are centers of the research discussed in the text of this article.

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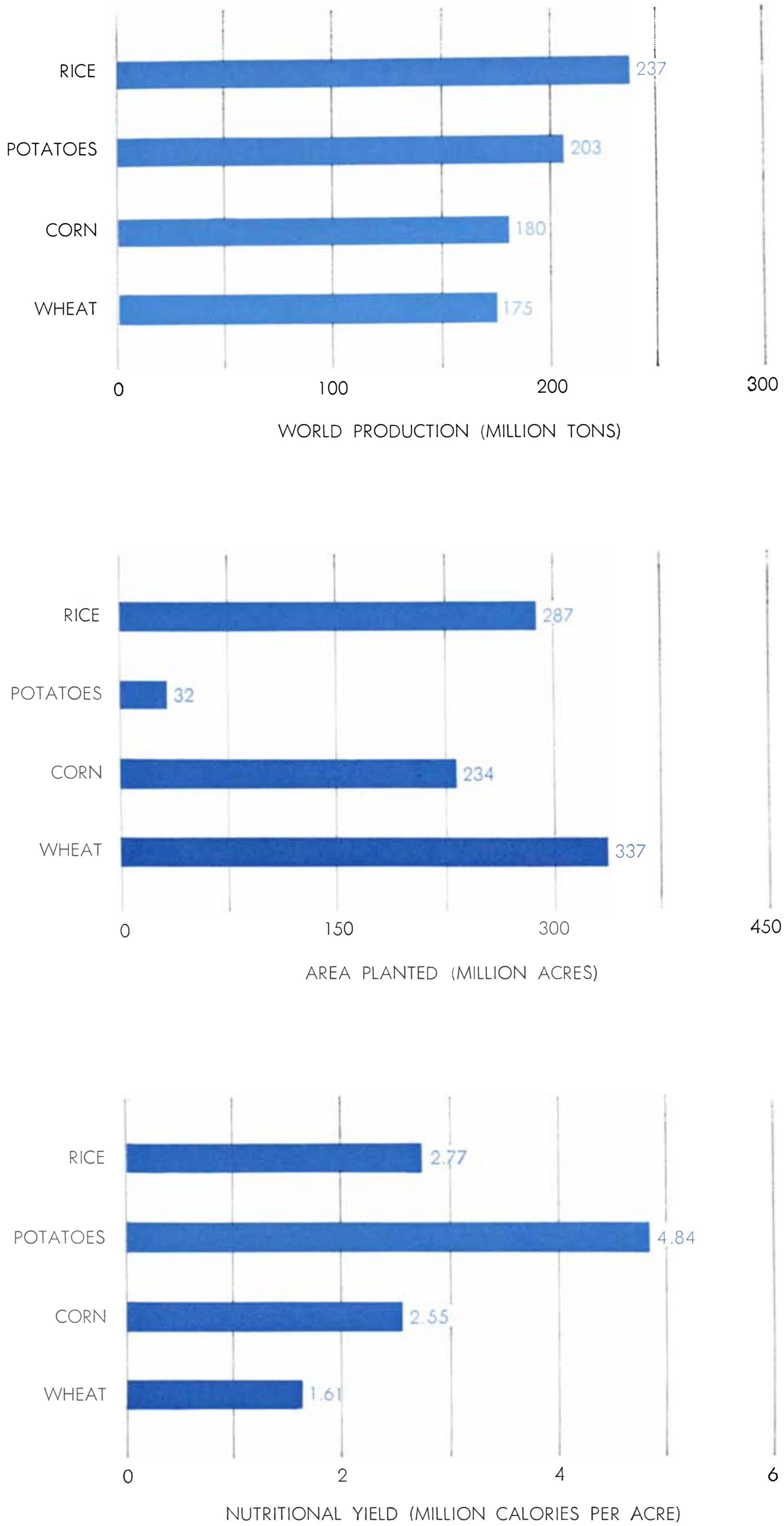
of the blight fungus itself. Such a program would have fundamental value to any effort to breed new resistant strains of potato. Plant pathologists had postulated the existence of 16 races of the fungus. But not more than nine races had been found and identified before 1954. A study of the fungus cultures in the Toluca Valley, however, promptly revealed all 16 races. There are strong reasons for believing that other races exist which cannot be segregated by present methods of identification.

In the wheat rust and many other fungi, new races arise mainly from sexual crosses. The potato-blight fungus, however, has been a scientific puzzle, for it has seemed to be "sexless." It reproduces asexually, "pinching off" some of its cells and setting them adrift, each wrapped in a thin protective membrane, as a "fallout cloud" of infection. Many other fungi reproduce in this manner, but most of them can also produce male or female cells that fuse to form larger and more thickly walled sexual spores. Potato-blight cultures yielded few such spores, and these were invariably sterile.

Thus new races of *Phytophthora infestans* could presumably have originated only through chance mutation or through some other process of adaptation to variation in its host. Such sluggish evolutionary processes would explain why only 16 races of blight had been found, as against some 200 strains of the sexually reproducing wheat rust. But 16 or more races in one small valley bespeaks some more rapid evolutionary process.

In October, 1955, workers at our Chapingo Experiment Station noted that certain cultures of blight fungi from the Toluca Valley were producing large numbers of fertile sexual spores. The spores originated mainly in "mixed" cultures; subcultures started from a single asexual spore rarely produced them. The Chapingo investigators at first suspected that some nutritional element vital to the production of sexual spores had been carried into the original mixed cultures and had been lost when these were broken down into pure subcultures. However, a parallel investigation by John J. Smoot and his associates of the U. S. Department of Agriculture revealed that the Toluca fungi can be separated into two "compatibility groups." Only when both groups are present in a culture can the fungus reproduce sexually. The two groups show no other observable distinction. In fact, Jorge Galindo of the Office of Special Studies has shown that cultures of both groups can produce both male and fe-



IMPORTANCE OF THE POTATO is shown by these charts. Among major food crops the potato is surpassed only by rice in total production (*top*), but requires much less acreage (*center*). Therefore its nutritional yield per acre exceeds that of other staples (*bottom*).

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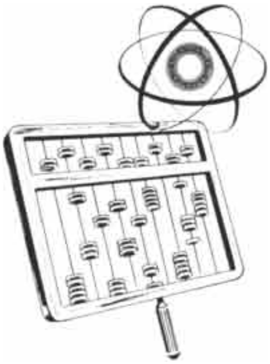

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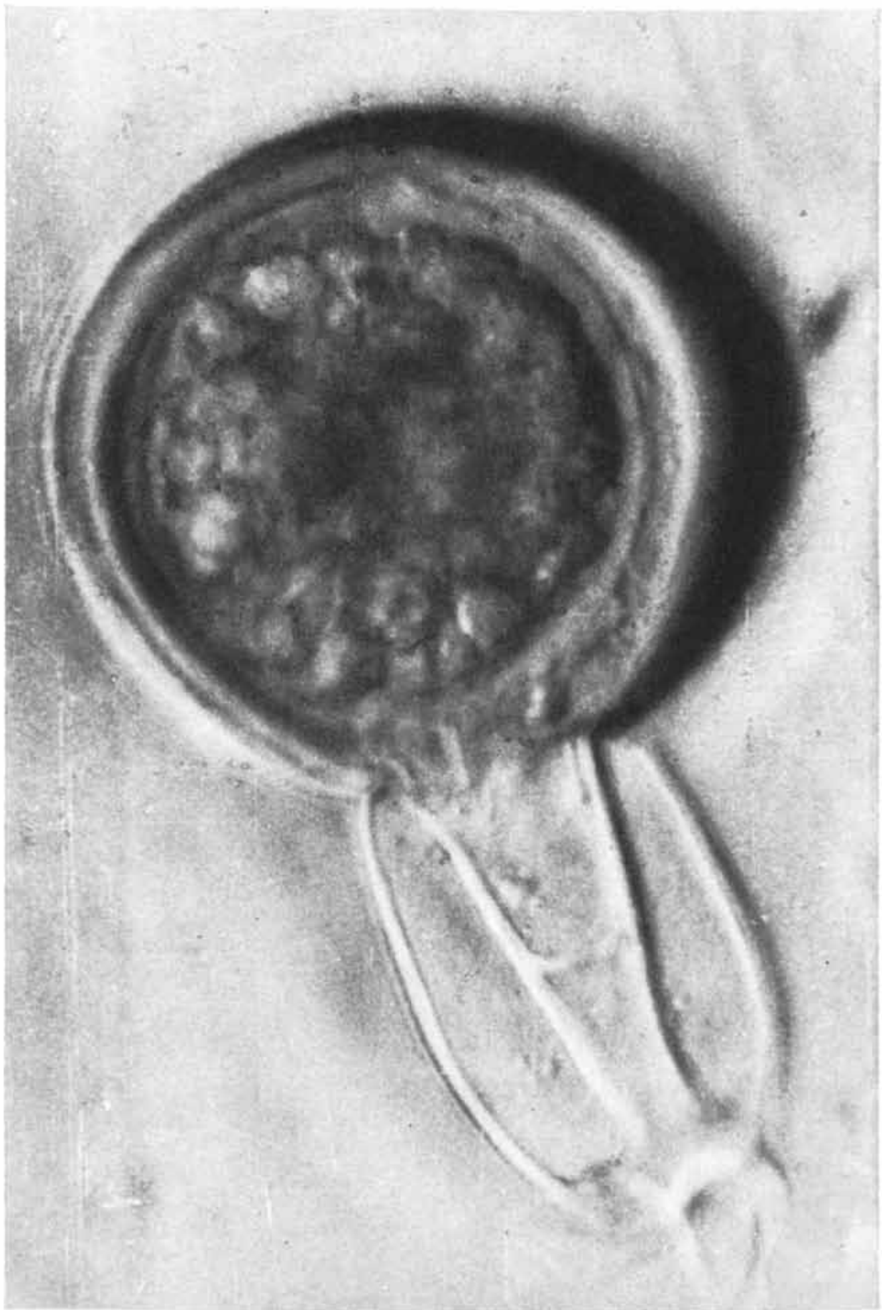
male cells. Nor does race, as identified by the ability to infect given potato varieties, have anything to do with this segregation into compatibility groups; fungi of the same race turn up in both groups. A male cell of one group, however, can fertilize only a female cell from the other group. What physiological mechanism prevents fertilization within a group is still a mystery.

In the Toluca Valley fungi of both compatibility groups are present in approximately equal numbers. Sexual crossing appears to be responsible for the many virulent races which have arisen in this limited area. Elsewhere in the world all cultures of the blight fungi that have been tested belong to a single compatibility group.

This discovery has focused attention on a still-unsolved problem: How does the blight fungus survive the long, cold winters of northern Europe and America? In general, asexual fungus spores



SEXUAL SPORE of the late-blight fungus is shown here magnified about 2,000 times. The membranes at left are the remains of the stem on which the female cell grew and of the male cell which fertilized it. Fertile sexual spores of the fungus are found only in Mexico; sexual crossing probably gave rise to virulent races of blight that are prevalent there.

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cannot survive extremes of temperature or extended periods of dryness. Most fungi, including the downy mildews of which the potato blight is a representative, withstand cold or drought by producing the thicker-walled and far more hardy sexual spores. But no fertile sexual spores of the potato blight have been found outside Mexico. Some investigators believe that the potato blight has survived in northern climates by wintering in tubers left in the ground, but the evidence from different countries is conflicting. A fuller knowledge of how the fungus gets through the winter may reveal a vulnerable point in its life cycle.

With the discovery of the sexual mode of reproduction in the blight fungus, however, we can now begin to study the formation of new races in the laboratory. Better understanding of the genetic mechanism of the fungus will make it possible to plan the breeding of more resistant varieties of potato.

The history of the century-long search in Europe and North America for the blight-resistant potato variety tells of a succession of "resistant" varieties that soon became susceptible. As a rule, the resistance incorporated in these varieties was a narrow one, protecting the plant only from particular races of the fungus. Such resistance appears to be governed by only one or two genes. The blight pathogen found it comparatively easy to overcome this simple resistance; the appearance of a new race of the fungus negated these facile conquests.

The outlook for the future was discouraging until the violent test at Toluca made possible the elimination of all but the most resistant plants. In these varieties resistance appears to be directed not against particular races of the fungus but against the entire species. This "field" resistance seems to be governed by many genes rather than a few. It is this type of resistance that has enabled the wild potato-species to survive centuries of exposure to the wide spectrum of virulent blight races in central Mexico.

Having obtained a limited number of successful varieties from the screening of many thousands and having learned something of the genetic secrets of the blight fungus, we were prepared to begin a breeding program of our own. At first our investigators followed the precedent of earlier breeders and crossed several commercial varieties with the Mexican wild potato, *Solanum demissum.* But this is a tedious and frequently un-

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rewarding procedure. The first-generation hybrids of wild species and commercial varieties invariably produce small and unappetizing potatoes, and must be repeatedly backcrossed to the commercial types before they yield an acceptable product.

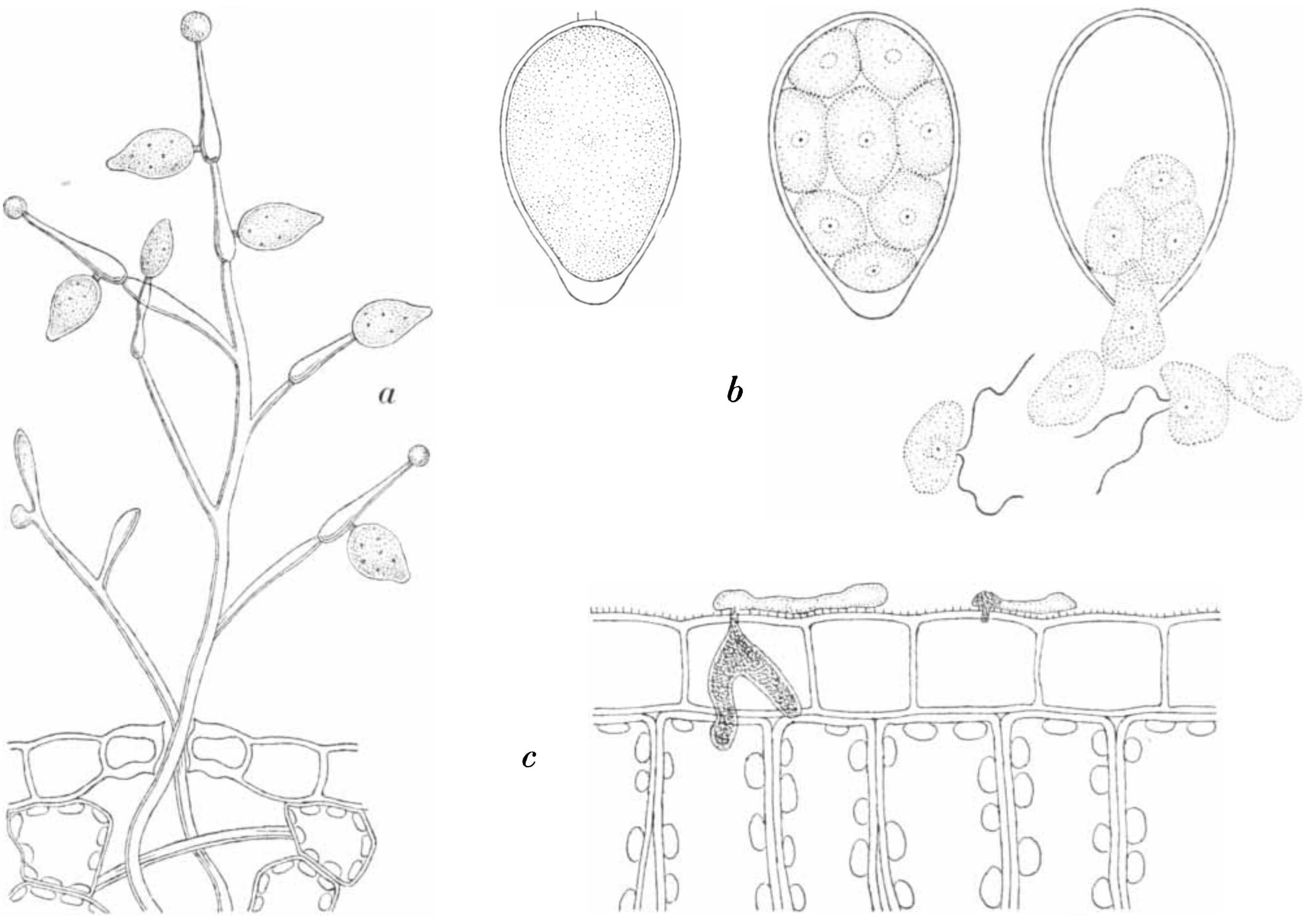
Soon we switched to a more promising and fruitful procedure for obtaining new blight-resistant commercial varieties; we crossed the few varieties that had demonstrated high resistance at Toluca. Within the surprisingly brief period of three years this breeding program has created a number of promising new selections, and dozens more of them are on the way.

The field resistance of the new varieties, though difficult to measure when they are inoculated as seedlings in the greenhouse, is nevertheless of the utmost practical value. On such plants in the field the fungus spreads slowly and produces few spores. The lesions are fewer in number and tend to appear chiefly on the older, lower leaves. But because so many genes are involved we understand only imperfectly how field-resistant plants transmit this characteristic to their progeny.

What assurance have we that a potato variety now resistant to late blight will not one day succumb to new races of the fungus? Wheat breeders constantly face the necessity of producing new strains of wheat to resist new races of stem rust. Occasionally the rust gets the upper hand. Between 1949 and 1951 a new race of stem rust destroyed tens of millions of bushels of wheat in the U. S. before wheat breeders could overtake it. So far, however, the resistance of our Mexican selections has maintained its original level at Toluca. Furthermore, some European varieties have exhibited a constant low level of field resistance for several decades. Many wild species of *Solanum* have maintained their blight resistance for hundreds and perhaps thousands of years of exposure.

Though a number of experiments in other parts of the world have shown the Toluca selections to be "immune" to late blight, we know they are not immune. They only seem so because the blight races in Europe and the U. S., for example, are not yet able to attack them. There is at least a good chance they will remain blight-free for some years. But more important, our experiments at Toluca indicate that even when our selections are attacked by new blight races, their field resistance will still permit the production of a satisfactory crop. Indeed, if we can find ways of incorporating the field resistance of *Solanum demissum* into a commercially acceptable potato, protective spraying against late blight will probably become unnecessary. Even partial field resistance can bring substantial savings to potato growers by enabling them to spray less frequently.

Our existing blight-resistant varieties, though not up to the exacting requirements of farmers and consumers in Europe and the U. S., will soon be contributing substantially to the Mexican diet. In the near future these first fruits of our international potato-research program should bring similar benefits to other calorie-hungry regions in Asia, Africa and Latin America.



ASEXUAL REPRODUCTION of blight fungus begins with the formation of pear-shaped spore sacs (*a*). The contents of each sac divide into several thin-walled zoospores (*b*), which can be carried for miles by moist currents of air. If a zoospore falls on a potato leaf, it sends filaments through the epidermis (*c*) which progressively invade the cells of the leaf, destroying them as they go.

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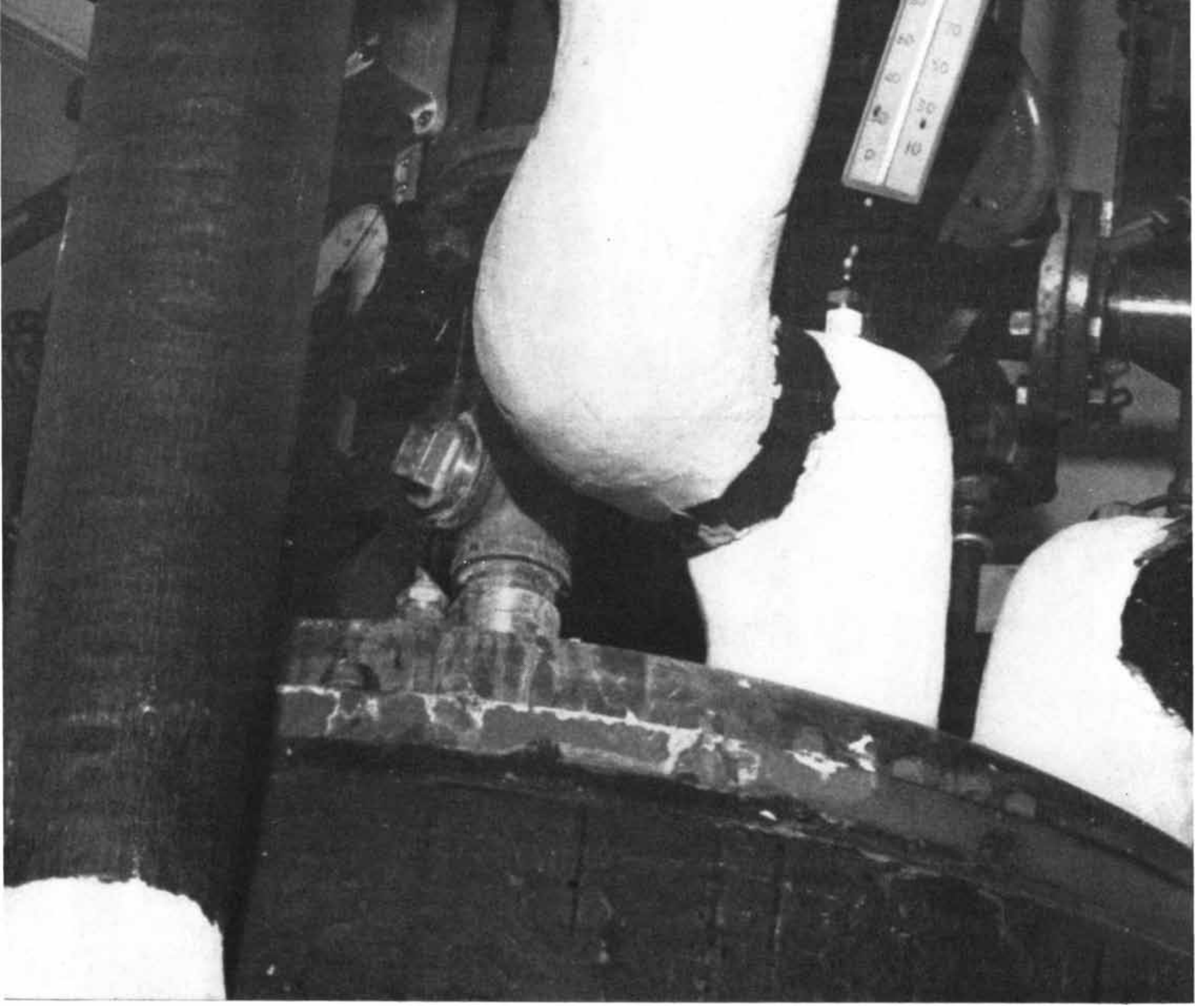

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Throughout Melanesia primitive men await a black Messiah who will bring them a largess of "cargo" (European goods). These cults typify the impact of Christendom on premodern society

by Peter M. Worsley

Patrols of the Australian Government venturing into the "uncontrolled" central highlands of New Guinea in 1946 found the primitive people there swept up in a wave of religious excitement. Prophecy was being fulfilled: The arrival of the Whites was the sign that the end of the world was at hand. The natives proceeded to butcher all of their pigs—animals that were not only a principal source of subsistence but also symbols of social status and ritual preeminence in their culture. They killed these valued animals in expression of the belief that after three days of darkness "Great Pigs" would appear from the sky. Food, firewood and other necessities had to be stock-piled to see the people through to the arrival of the Great Pigs. Mock wireless antennae of bamboo and rope had been erected to receive in advance the news of the millennium. Many believed that with the great event they would exchange their black skins for white ones.

This bizarre episode is by no means the single event of its kind in the murky history of the collision of European civilization with the indigenous cultures of the southwest Pacific. For more than 100 years traders and missionaries have been reporting similar disturbances among the peoples of Melanesia, the group of Negro-inhabited islands (including New Guinea, Fiji, the Solomons and the New Hebrides) lying between Australia and the open Pacific Ocean. Though their technologies were based largely upon stone and wood, these peoples had highly developed cultures, as measured by the standards of maritime and agricultural ingenuity, the complexity of their varied social organizations and the elaboration of religious belief and ritual. They were nonetheless ill prepared for the shock of the encounter with the Whites, a people so radically different from themselves and so infinitely more powerful. The sudden transition from the society of the ceremonial stone ax to the society of sailing ships and now of airplanes has not been easy to make.

After four centuries of Western expansion, the densely populated central highlands of New Guinea remain one of the few regions where the people still carry on their primitive existence in complete independence of the world outside. Yet as the agents of the Australian Government penetrate into ever more remote mountain valleys, they find these backwaters of antiquity already deeply disturbed by contact with the ideas and artifacts of European civilization. For "cargo"—Pidgin English for trade goods—has long flowed along the indigenous channels of communication from the seacoast into the wilderness. With it has traveled the frightening knowledge of the white man's magical power. No small element in the white man's magic is the hopeful message sent abroad by his missionaries: the news that a Messiah will come and that the present order of Creation will end.

The people of the central highlands of New Guinea are only the latest to be gripped in the recurrent religious frenzy of the "cargo cults." However variously embellished with details from native myth and Christian belief, these cults all advance the same central theme: the world is about to end in a terrible cataclysm. Thereafter God, the ancestors or some local culture hero will appear and inaugurate a blissful paradise on earth. Death, old age, illness and evil will be unknown. The riches of the white man will accrue to the Melanesians.

Although the news of such a movement in one area has doubtless often inspired similar movements in other areas, the evidence indicates that these cults have arisen independently in many places as parallel responses to the same enormous social stress and strain. Among the movements best known to students of Melanesia are the "Taro Cult" of New Guinea, the "Vailala Madness" of Papua, the "Naked Cult" of Espiritu Santo, the "John Frum Movement" of the New Hebrides and the "Tuka Cult" of the Fiji Islands.

At times the cults have been so well organized and fanatically persistent that they have brought the work of government to a standstill. The outbreaks have often taken the authorities completely by surprise and have confronted them with mass opposition of an alarming kind. In the 1930s, for example, villagers in the vicinity of Wewak, New Guinea, were stirred by a succession of "Black King" movements. The prophets announced that the Europeans would soon leave the island, abandoning their property to the natives, and urged their followers to cease paying taxes, since the government station was about to disappear into the sea in a great earthquake. To the tiny community of Whites in charge of the region, such talk was dangerous. The authorities jailed four of the prophets and exiled three others. In yet another movement, that sprang up in declared opposition to the local Christian mission, the cult leader took Satan as his god.

Troops on both sides in World War II found their arrival in Melanesia heralded as a sign of the Apocalypse. The G.I.'s who landed in the New Hebrides, moving up for the bloody fighting on Guadalcanal, found the natives furiously at work preparing airfields, roads and docks for the magic ships and planes that they believed were coming from

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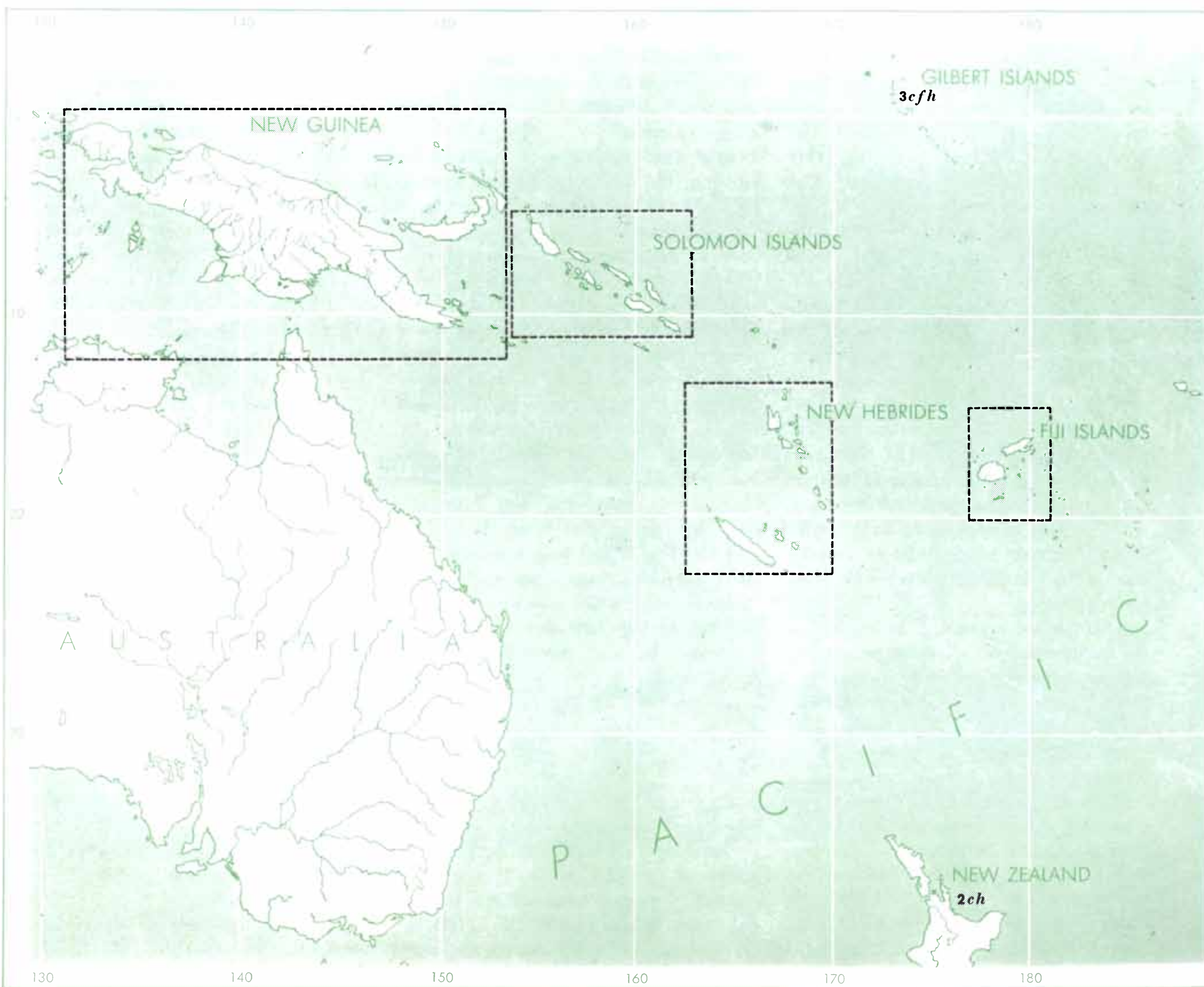
"Rusefel" (Roosevelt), the friendly king of America.

The Japanese also encountered millenarian visionaries during their southward march to Guadalcanal. Indeed, one of the strangest minor military actions of World War II occurred in Dutch New Guinea, when Japanese forces had to be turned against the local Papuan inhabitants of the Geelvink Bay region. The Japanese had at first been received with great joy, not because their "Greater East Asia Co-Prosperity Sphere" propaganda had made any great impact upon the Papuans, but because the natives regarded them as harbingers of the new world that was dawning, the flight of the Dutch having already given the first sign. Mansren, creator of the islands and their peoples, would now return, bringing with him the ancestral dead. All this had been known, the cult leaders declared, to the crafty Dutch, who had torn out the first page of the Bible where these truths were inscribed. When Mansren returned, the existing world order would be entirely overturned. White men would turn black like Papuans, Papuans would become Whites; root crops would grow in trees, and coconuts and fruits would grow like tubers. Some of the islanders now began to draw together into large "towns"; others took Biblical names such as "Jericho" and "Galilee" for their villages. Soon they adopted military uniforms and began drilling. The Japanese, by now highly unpopular, tried to disarm and disperse the Papuans; resistance inevitably developed. The climax of this tragedy came when several canoe-loads of fanatics sailed out to attack Japanese warships, believing themselves to be invulnerable by virtue of the holy water with which they had sprinkled themselves. But the bullets of the Japanese did not turn to water, and the attackers were mowed down by machine-gun fire.

Behind this incident lay a long history. As long ago as 1857 missionaries in the Geelvink Bay region had made note of the story of Mansren. It is typical of many Melanesian myths that became



SOUTH PACIFIC, scene of the religious disturbances known as cargo cults, is shown in this map. Most cargo cults have been in Melanesia, shown here as four regions enclosed in broken rectangles. Each of these regions is shown in a detailed map in the following pages. Also shown on this map are three outlying cargo cults, two of them Polynesian and the third Micronesian. Numbers

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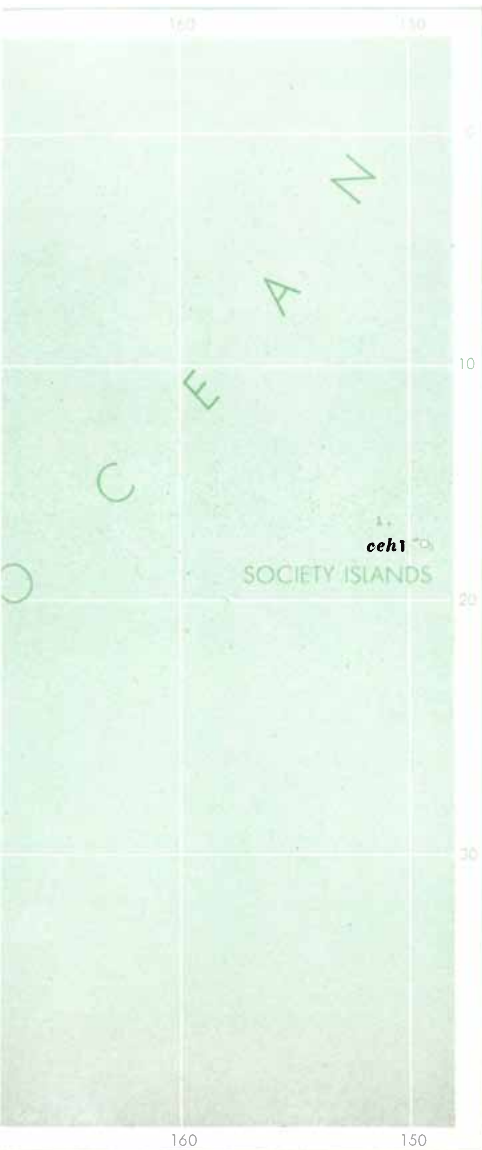
confounded with Christian doctrine to form the ideological basis of the movements. The legend tells how long ago there lived an old man named Manamakeri ("he who itches"), whose body was covered with sores. Manamakeri was extremely fond of palm wine, and used to climb a huge tree every day to tap the liquid from the flowers. He soon found that someone was getting there before him and removing the liquid. Eventually he trapped the thief, who turned out to be none other than the Morning Star. In return for his freedom, the Star gave the old man a wand that would produce as much fish as he liked, a magic tree and a magic staff. If he drew in the sand and stamped his foot, the drawing would become real. Manamakeri, aged as he was, now magically impregnated a young maiden; the child of this union was a miracle-child who spoke as soon as he was born. But the maiden's parents were horrified, and banished her, the child and the old man. The trio sailed off in a canoe created by Mansren ("The Lord"), as the old man now became known. On this journey Mansren rejuvenated himself by stepping into a fire and flaking off his scaly skin, which changed into valuables. He then sailed around Geelvink Bay, creating islands where he stopped, and peopling them with the ancestors of the present-day Papuans.

The Mansren myth is plainly a creation myth full of symbolic ideas relating to fertility and rebirth. Comparative evidence—especially the shedding of his scaly skin—confirms the suspicion that the old man is, in fact, the Snake in another guise. Psychoanalytic writers argue that the snake occupies such a prominent part in mythology the world over because it stands for the penis, another fertility symbol. This may be so, but its symbolic significance is surely more complex than this. It is the "rebirth" of the hero, whether Mansren or the Snake, that exercises such universal fascination over men's minds.

The 19th-century missionaries thought that the Mansren story would make the introduction of Christianity easier, since the concept of "resurrection," not to mention that of the "virgin birth" and the "second coming," was already there. By 1867, however, the first cult organized around the Mansren legend was reported.

Though such myths were widespread in Melanesia, and may have sparked occasional movements even in the pre-White era, they took on a new significance in the late 19th century, once the European powers had finished parceling out the Melanesian region among themselves. In many coastal areas the long history of "blackbirding"—the seizure of islanders for work on the plantations of Australia and Fiji—had built up a reservoir of hostility to Europeans. In other areas, however, the arrival of the Whites was accepted, even welcomed, for it meant access to bully beef and cigarettes, shirts and paraffin lamps, whisky and bicycles. It also meant access to the knowledge behind these material goods, for the Europeans brought missions and schools as well as cargo.



1 MAMAIA MOVEMENT TAHITI 1930-1944
2 HAU-HAU MOVEMENT NEW ZEALAND 1860-1871
3 ONOTOA TROUBLES GILBERT ISLANDS 1932

a MYTH OF THE RETURN OF THE DEAD
b REVIVAL OR MODIFICATION OF PAGANISM
c INTRODUCTION OF CHRISTIAN ELEMENTS
d CARGO MYTH
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g ATTEMPTS TO RESTORE NATIVE POLITICAL AND ECONOMIC CONTROL
h THREATS AND VIOLENCE AGAINST WHITE MEN
i UNION OF TRADITIONALLY SEPARATE AND UNFRIENDLY GROUPS

on these maps indicate individual cults. Letters refer to typical features of cults (*see number and letter keys accompanying each map*).

Practically the only teaching the natives received about European life came from the missions, which emphasized the central significance of religion in European society. The Melanesians already believed that man's activities—whether gardening, sailing canoes or bearing children—needed magical assistance. Ritual without human effort was not enough. But neither was human effort on its own. This outlook was reinforced by mission teaching.

The initial enthusiasm for European rule, however, was speedily dispelled. The rapid growth of the plantation economy removed the bulk of the able-bodied men from the villages, leaving women, children and old men to carry on as best they could. The splendid vision of the equality of all Christians

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began to seem a pious deception in face of the realities of the color bar, the multiplicity of rival Christian missions and the open irreligion of many Whites.

For a long time the natives accepted the European mission as the means by which the "cargo" would eventually be made available to them. But they found that acceptance of Christianity did not bring the cargo any nearer. They grew disillusioned. The story now began to be put about that it was not the Whites who made the cargo, but the dead ancestors. To people completely ignorant of factory production, this made good sense. White men did not work; they merely wrote secret signs on scraps of paper, for which they were given shiploads of goods. On the other hand, the Melanesians labored week after week for pitiful wages. Plainly the goods must be made for Melanesians somewhere, perhaps in the Land of the Dead. The Whites, who possessed the secret of the cargo, were intercepting it and keeping it from the hands of the islanders, to whom it was really consigned. In the Madang district of New Guinea, after some 40 years' experience of the missions, the natives went in a body one day with a petition demanding that the cargo secret should now be revealed to them, for they had been very patient.

So strong is this belief in the existence of a "secret" that the cargo cults gener-

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i UNION OF TRADITIONALLY SEPARATE AND UNFRIENDLY GROUPS

4 KORERI MOVEMENT NUMFOR, DUTCH NEW GUINEA 1911
5 KORERI MOVEMENT BIAK, DUTCH NEW GUINEA 1939
6 KORERI MOVEMENT BIAK, DUTCH NEW GUINEA 1886
7 KORERI MOVEMENT BIAK, GEELVINK BAY, DUTCH NEW GUINEA 1942-1947
8 SIMSON INCIDENT HOLLANDIA, DUTCH NEW GUINEA 1940- ?
9 PAMAI MOVEMENT LAKE SENTANI, DUTCH NEW GUINEA 1928
10 NIMBORAN MOVEMENT LAKE SENTANI, DUTCH NEW GUINEA 1945
11 NINIGO ISLANDS MOVEMENT NINIGO ISLANDS, NEW GUINEA 1945- ?
12 BLACK KINGS MOVEMENT AITAPE, WEWAK, NEW GUINEA 1930
13 GREAT PIGS WEST-CENTRAL NEW GUINEA 1946
14 HINE MOVEMENT WABAG, CENTRAL NEW GUINEA 1945
15 BLACK KINGS MOVEMENT MOUNT HAGEN, NEW GUINEA 1940
16 NATIVE KING KERAM RIVER, CENTRAL NEW GUINEA 1943-1945
17 GHOST WIND KAINANTU, CENTRAL NEW GUINEA 1940-1947
18 TOMMY KABU COOPERATIVE MOVEMENT PURARI DELTA, PAPUA 1945-1947
19 BATAWI INCIDENT WESTERN PAPUA
20 GERMAN WISLIN SAIBAI, TORRES STRAIT 1913-1915
21 VAILALA MADNESS PAPUA 1919-1931
22 FILO INCIDENT MEKEO, PAPUA 1940-1941
23 GOILALA AND GOGODARA CULT PAPUA 1945
24 PIG KILLING KAIRUKU, PAPUA 1937
25 THREE BLACK KINGS WEWAK, NEW GUINEA 1948-1949
26 MAMBU MOVEMENT MADANG, NEW GUINEA 1937-1940
27 TIFU INCIDENT RAMU, MADANG, NEW GUINEA 1951
28 BLACK KING MOVEMENT MADANG, NEW GUINEA 1935
29 KUKUAIK MOVEMENT KARKAR ISLAND, NEW GUINEA 1940- ?
30 CARGO CULT MADANG, NEW GUINEA 1940
31 CARGO CULT MADANG, NEW GUINEA 1934
32 YALI INCIDENT MADANG, NEW GUINEA 1945-1955
33 GARIA MOVEMENT MADANG, NEW GUINEA 1940- ?
34 SECOND COMING OF CHRIST RAI COAST, NEW GUINEA 1936
35 LETUB MOVEMENT MADANG, NEW GUINEA 1939-1940
36 EEMASANG MOVEMENT HUON PENINSULA, NEW GUINEA 1927- ?
37 COMING OF JESUS EASTERN HIGHLANDS, CENTRAL NEW GUINEA 1943-1945
38 TIMO INCIDENT HUON PENINSULA, NEW GUINEA 1922
39 THREE BLACK KINGS FINSCHHAFEN, NEW GUINEA 1945- ?
40 LAZARUS MOVEMENT HUON PENINSULA, NEW GUINEA 1933
41 SOSOM INCIDENT MOUNT GOLDBERG, NEW GUINEA 1936
42 MOROBE MOVEMENT MOROFE, NEW GUINEA 1933-1936
43 MARKHAM VALLEY MOVEMENT MARKHAM VALLEY, NEW GUINEA 1932-1934
44 YERUMOT INCIDENT TOEPFER RIVER, NEW GUINEA 1930- ?
45 SCHWAERMEREI RAWLINSON RANGE, NEW GUINEA 1933
46 MARKHAM VALLEY MOVEMENT MARKHAM VALLEY, NEW GUINEA 1932-1934
47 BAIGONA MOVEMENT MASSIM, NEW GUINEA 1912-1919
48 TARO CULT NORTHEAST NEW GUINEA 1914-1928
49 PIG KILLING NORTH PAPUA 1930
50 PIG KILLING NORTHEAST PAPUA 1930
51 ASSISI CULT NORTHEAST PAPUA 1930-1944
52 MILNE BAY MOVEMENT MASSIM, NEW GUINEA 1893- ?
53 PALIAU MOVEMENT MANUS AND BALUAN, ADMIRALTY ISLANDS 1946-1954
54 THE NOISE RAMBUDJON, ADMIRALTY ISLANDS 1946-1948 (?)
55 BATARI MOVEMENT GALILO, NEW BRITAIN 1940-1946
56 BAINING TROUBLES NEW BRITAIN 1955
57 BAINING MOVEMENT NEW BRITAIN 1929-1930
58 KOKOPO MOVEMENT NEW BRITAIN 1930 (?)
59 NAMATANAI MOVEMENT NEW IRELAND 1939

NEW GUINEA has been a prolific breeder of cargo cults, resulting from the impact of

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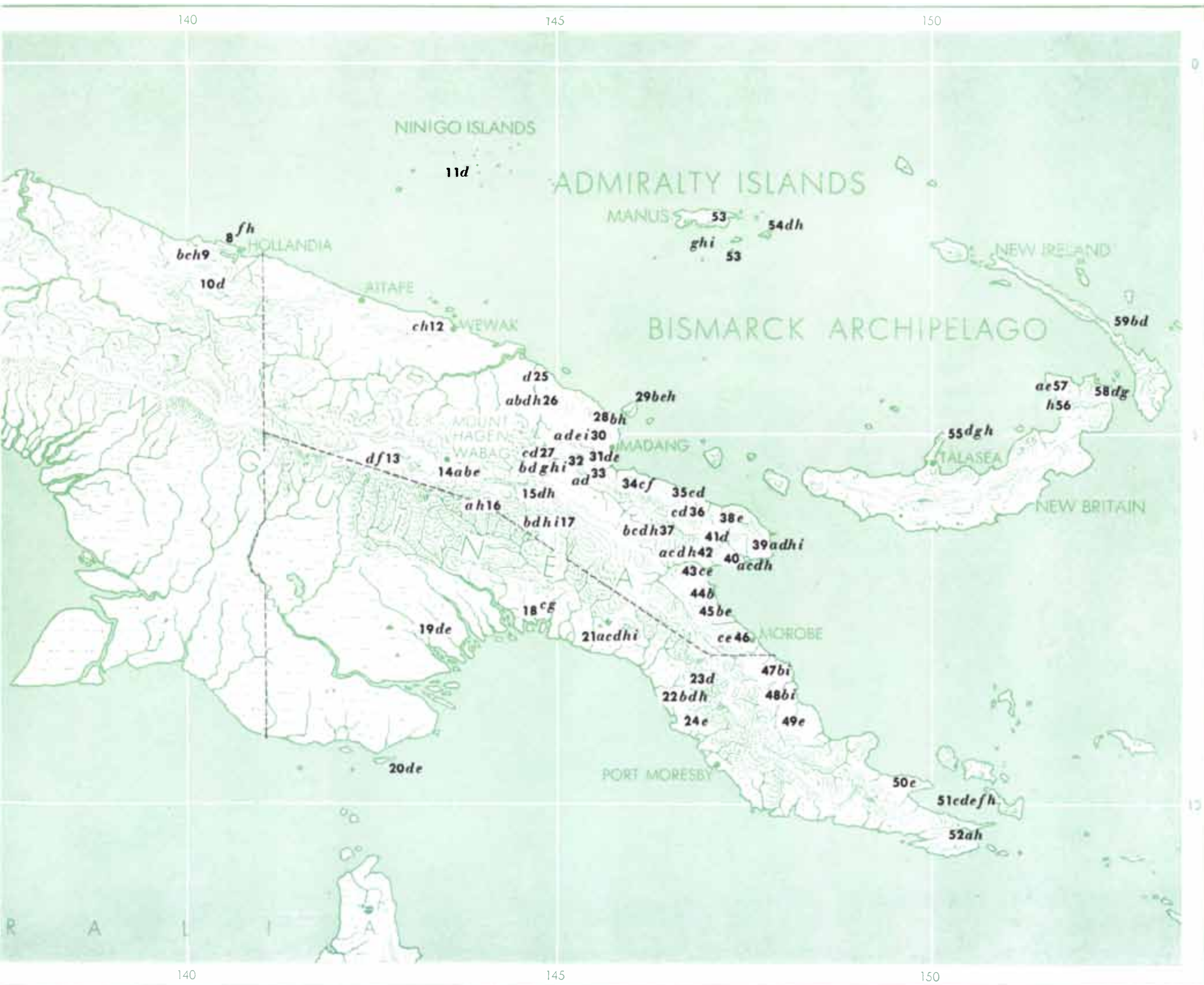
ally contain some ritual in imitation of the mysterious European customs which are held to be the clue to the white man's extraordinary power over goods and men. The believers sit around tables with bottles of flowers in front of them, dressed in European clothes, waiting for the cargo ship or airplane to materialize; other cultists feature magic pieces of paper and cabalistic writing. Many of them deliberately turn their backs on the past by destroying secret ritual objects, or exposing them to the gaze of uninitiated youths and women, for whom formerly even a glimpse of the sacred objects would have meant the severest penalties, even death. The belief that they were the chosen people is further reinforced by their reading of the Bible, for the lives and customs of the people in the Old Testament resemble their own lives rather than those of the Europeans. In the New Testament they find the Apocalypse, with its prophecies of destruction and resurrection, particularly attractive.

Missions that stress the imminence of the Second Coming, like those of the Seventh Day Adventists, are often accused of stimulating millenarian cults among the islanders. In reality, however, the Melanesians themselves rework the doctrines the missionaries teach them, selecting from the Bible what they themselves find particularly congenial in it. Such movements have occurred in areas where missions of quite different types have been dominant, from Roman Catholic to Seventh Day Adventist. The reasons for the emergence of these cults, of course, lie far deeper in the life-experience of the people.

The economy of most of the islands is very backward. Native agriculture produces little for the world market, and even the European plantations and mines export only a few primary products and raw materials: copra, rubber, gold. Melanesians are quite unable to understand why copra, for example, fetches 30 pounds sterling per ton one month and but 5 pounds a few months later. With no notion of the workings of world-commodity markets, the natives see only the sudden closing of plantations, reduced wages and unemploy-



Dutch, German, British and Japanese rule on its Stone Age cultures. At present the western portion is held by the Netherlands but claimed by Indonesia. The southeast (Papua) and northeast (U.N. Trust Territory of New Guinea) are governed by Australia.

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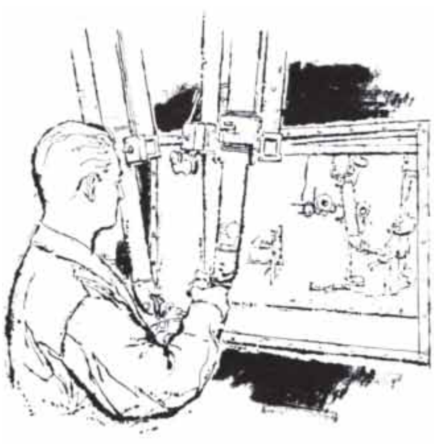

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ment, and are inclined to attribute their insecurity to the whim or evil in the nature of individual planters.

Such shocks have not been confined to the economic order. Governments, too, have come and gone, especially during the two world wars: German, Dutch, British and French administrations melted overnight. Then came the Japanese, only to be ousted in turn largely by the previously unknown Americans. And among these Americans the Melanesians saw Negroes like themselves, living lives of luxury on equal terms with white G.I.'s. The sight of these Negroes seemed like a fulfillment of the old prophecies to many cargo cult leaders. Nor must we forget the sheer scale of this invasion. Around a million U. S. troops passed through the Admiralty Islands, completely swamping the inhabitants. It was a world of meaningless and chaotic changes, in which anything was possible. New ideas were imported and given local twists. Thus in the Loyalty Islands people expected the French Communist Party to bring the millennium. There is no real evidence, however, of any Communist influence in these movements, despite the rather hysterical belief among Solomon Island planters that the name of the local "Masinga Rule" movement was derived from the word "Marxian"! In reality the name comes from a Solomon Island tongue, and means "brotherhood."

Europeans who have witnessed outbreaks inspired by the cargo cults are usually at a loss to understand what they behold. The islanders throw away their

60 BUKA MOVEMENTS NORTHERN SOLOMON ISLANDS 1913-1935
61 BOUGAINVILLE MOVEMENT NORTHERN SOLOMON ISLANDS 1935-1939
62 MAASINA (MARCHING) RULE MALAITA, SOLOMON ISLANDS 1945-1958
63 CHAIR AND RULE CULT MALAITA, SOLOMON ISLANDS 1935

a MYTH OF THE RETURN OF THE DEAD
b REVIVAL OR MODIFICATION OF PAGANISM
c INTRODUCTION OF CHRISTIAN ELEMENTS
d CARGO MYTH
e BELIEF THAT NEGROES WILL BECOME WHITE MEN AND VICE VERSA
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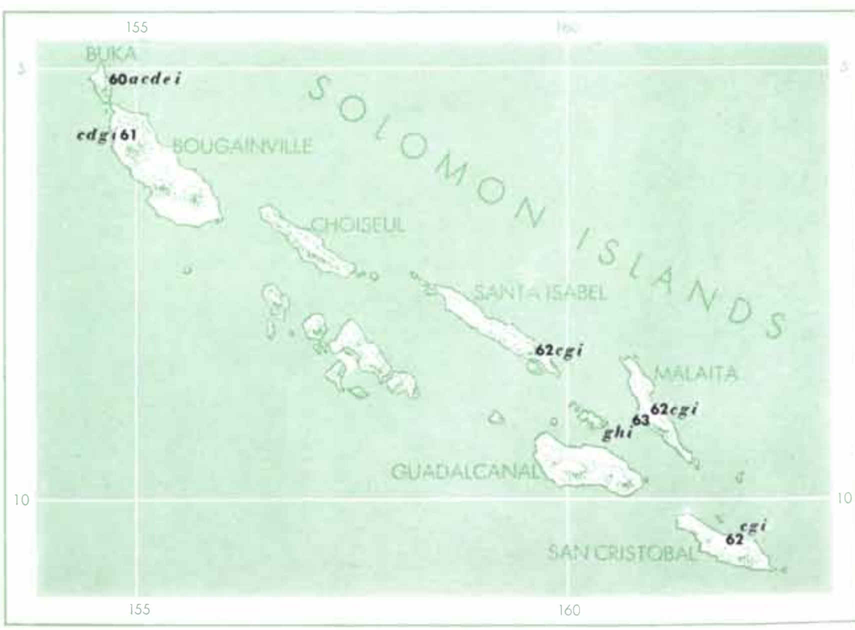

SOLOMON ISLANDS, administered by Australia and Great Britain, are another center of cargo cults, some caused by the cataclysmic impact of World War II. The data contained in these maps and tables, prepared by the author and Jean Guiart of the Ecole des Hautes Etudes in Paris, are not a complete list of cargo cults. Many dates are only approximate.

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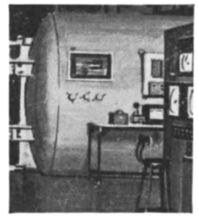

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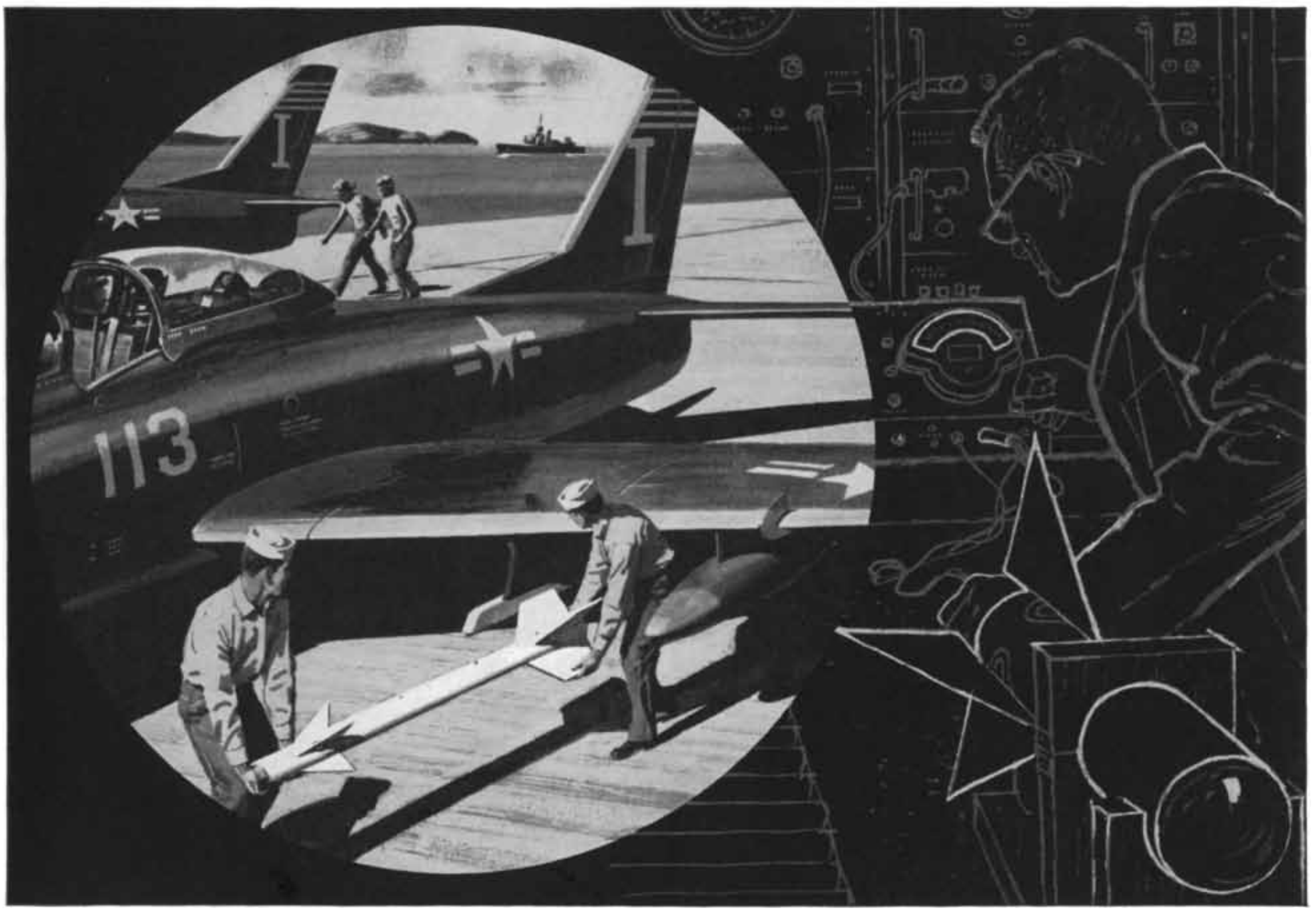

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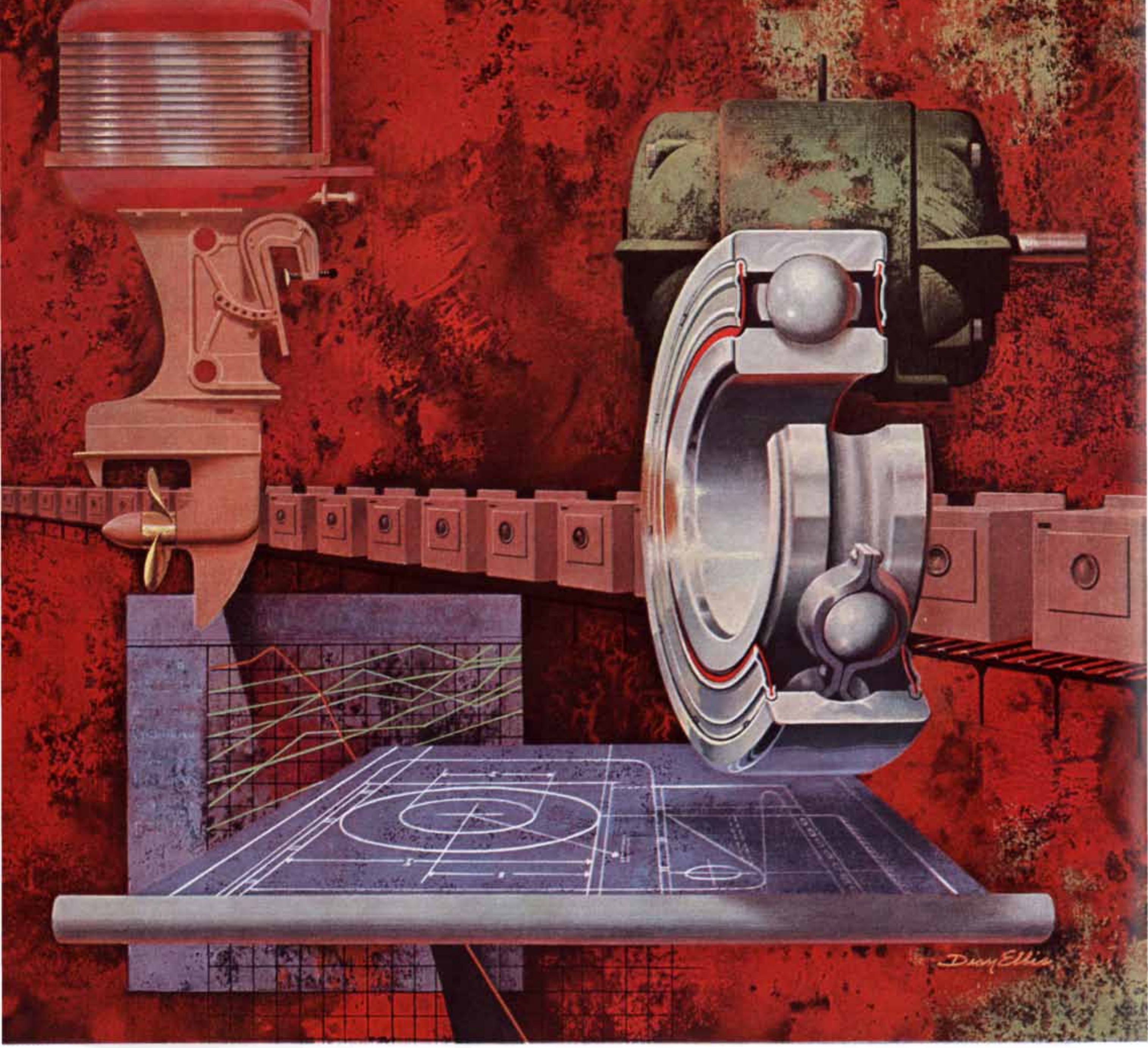

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money, break their most sacred taboos, abandon their gardens and destroy their precious livestock; they indulge in sexual license or, alternatively, rigidly separate men from women in huge communal establishments. Sometimes they spend days sitting gazing at the horizon for a glimpse of the long-awaited ship or airplane; sometimes they dance, pray and sing in mass congregations, becoming possessed and "speaking with tongues."

Observers have not hesitated to use such words as "madness," "mania," and "irrationality" to characterize the cults. But the cults reflect quite logical and

64 MAMARA MOVEMENT (NAKED CULT) WEST-CENTRAL ESPIRITU SANTO, NEW HEBRIDES 1945-1951
65 ATORI INCIDENT SOUTH ESPIRITU SANTO, NEW HEBRIDES 1945
66 RONGOFURO AFFAIR SOUTH ESPIRITU SANTO, NEW HEBRIDES 1914-1923
67 AVA-AVU INCIDENT SOUTH-CENTRAL ESPIRITU SANTO, NEW HEBRIDES 1937
68 MALEKULA NATIVE COMPANY CENTRAL NEW HEBRIDES 1950
69 BULE INCIDENT MELSISI, PENTECOST, NEW HEBRIDES 1947
70 JOHN FRUM MOVEMENT TANNA, NEW HEBRIDES 1938-1958
71 PWAGAC INCIDENT NORTHERN NEW CALEDONIA 1941
72 "COMMUNIST PARTY" LIFU, NEW CALEDONIA 1947

a MYTH OF THE RETURN OF THE DEAD
b REVIVAL OR MODIFICATION OF PAGANISM
c INTRODUCTION OF CHRISTIAN ELEMENTS
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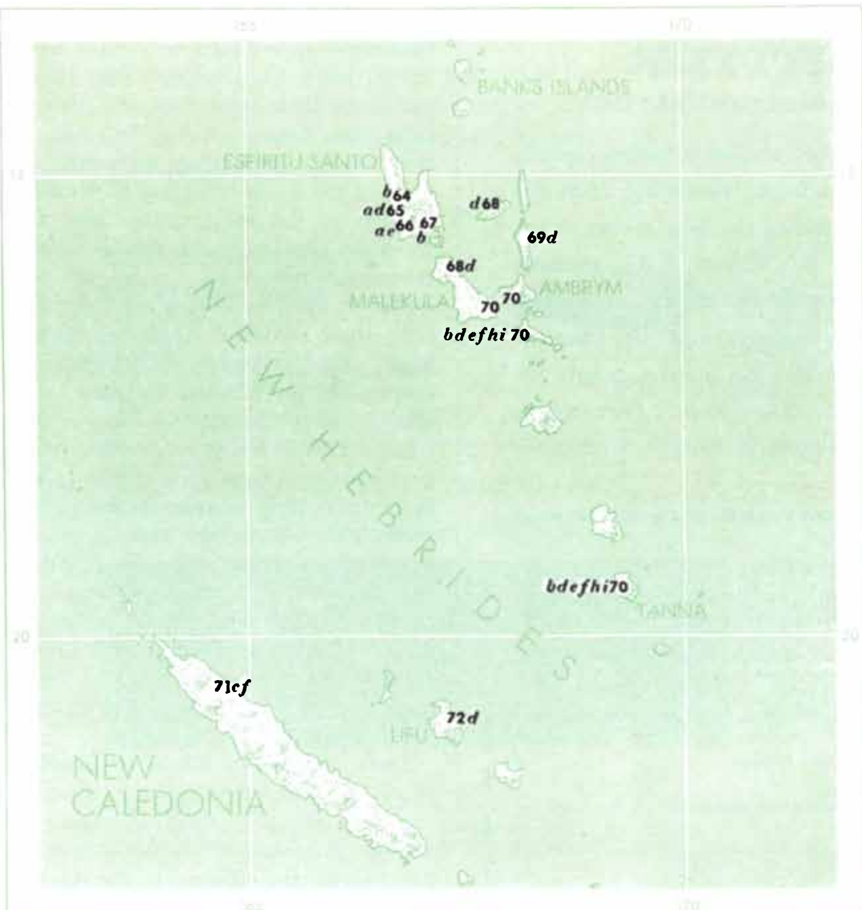
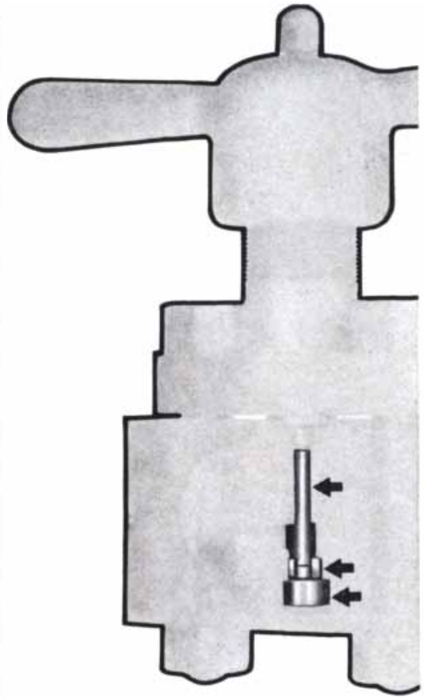


NEW HEBRIDES AND NEW CALEDONIA are, respectively, Anglo-French and French possessions. One New Caledonian cult placed Messianic hopes in the Communist Party.



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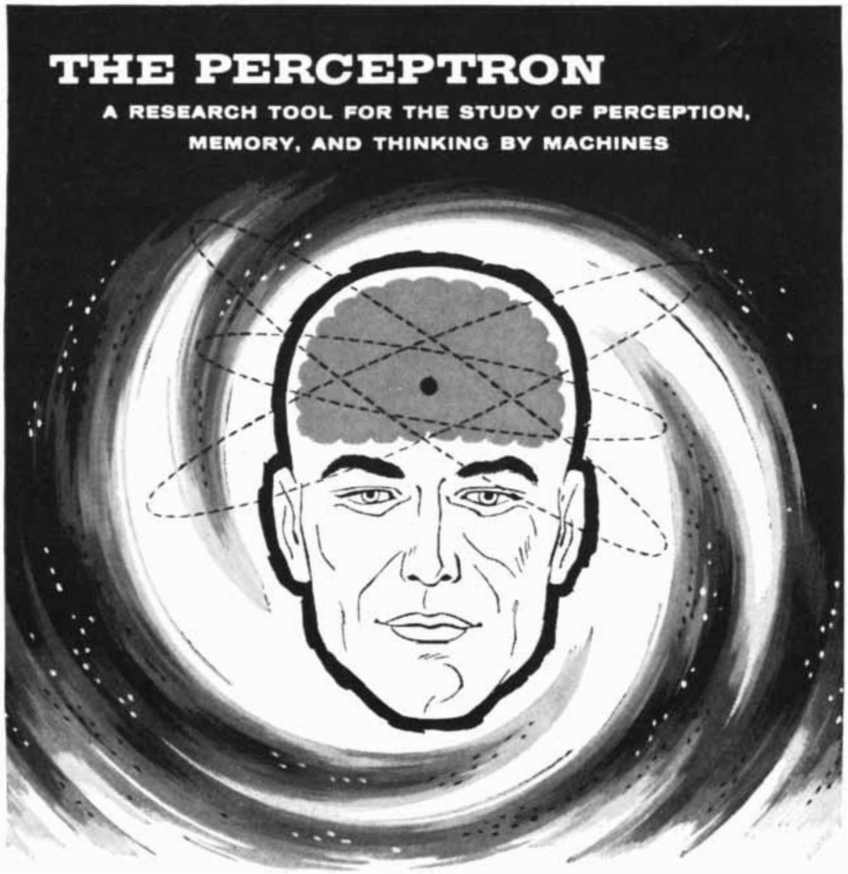

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rational attempts to make sense out of a social order that appears senseless and chaotic. Given the ignorance of the Melanesians about the wider European society, its economic organization and its highly developed technology, their reactions form a consistent and understandable pattern. They wrap up all their yearning and hope in an amalgam that combines the best counsel they can find in Christianity and their native belief. If the world is soon to end, gardening or fishing is unnecessary; everything will be provided. If the Melanesians are to be part of a much wider order, the taboos that prescribe their social conduct must now be lifted or broken in a newly prescribed way.

Of course the cargo never comes. The cults nonetheless live on. If the millennium does not arrive on schedule, then perhaps there is some failure in the magic, some error in the ritual. New breakaway groups organize around "purer" faith and ritual. The cult rarely disappears, so long as the social situation which brings it into being persists.

At this point it should be observed that cults of this general kind are not peculiar to Melanesia. Men who feel themselves oppressed and deceived have always been ready to pour their hopes and fears, their aspirations and frustrations, into dreams of a millennium to come or of a golden age to return. All parts of the world have had their counterparts of the cargo cults, from the American Indian ghost dance to the communist-millenarist "reign of the saints" in Münster during the Reformation, from medieval European apocalyptic cults to African "witch-finding" movements and Chinese Buddhist heresies. In some situations men have been content to wait and pray; in others they have sought to hasten the day by using their strong right arms to do the Lord's work. And always the cults serve to bring together scattered groups, notably the peasants and urban plebeians of agrarian societies and the peoples of "stateless" societies where the cult unites separate (and often hostile) villages, clans and tribes into a wider religio-political unity.

Once the people begin to develop secular political organizations, however, the sects tend to lose their importance as vehicles of protest. They begin to relegate the Second Coming to the distant future or to the next world. In Melanesia ordinary political bodies, trade unions and native councils are becoming the normal media through which the islanders express their aspirations. In recent

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years continued economic prosperity and political stability have taken some of the edge off their despair. It now seems unlikely that any major movement along cargo-cult lines will recur in areas where the transition to secular politics has been made, even if the insecurity of prewar times returned. I would predict that the embryonic nationalism represented by cargo cults is likely in future to take forms familiar in the history of other countries that have moved from subsistence agriculture to participation in the world economy.

73 TUKA MOVEMENT CENTRAL VITI LEVU, FIJI 1873-1920
74 APOLOSI MOVEMENT WEST VITI LEVU, FIJI 1914-1940
75 LUVE-NI-WAI CENTRAL VITI LEVU, FIJI 1880- ?
76 KELEVI SECT KADAVU, FIJI 1945-1947

a MYTH OF THE RETURN OF THE DEAD
b REVIVAL OR MODIFICATION OF PAGANISM
c INTRODUCTION OF CHRISTIAN ELEMENTS
d CARGO MYTH
e BELIEF THAT NEGROES WILL BECOME WHITE MEN AND VICE VERSA
f BELIEF IN A COMING MESSIAH
g ATTEMPTS TO RESTORE NATIVE POLITICAL AND ECONOMIC CONTROL
h THREATS AND VIOLENCE AGAINST WHITE MEN
i UNION OF TRADITIONALLY SEPARATE AND UNFRIENDLY GROUPS

FIJI ISLANDS are a British colony. Although generally Christianized, they have spawned several semi-Christian cargo cults.

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No hiding place?

■ *The problems:* first, to detail consequences of fallout from a large nuclear attack on the northeastern quarter of the United States; second, to measure shielding effectiveness of large buildings as public shelters against fallout.

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WHAT'S MAKING NEWS?

A revolution in industrial thinking has taken place in recent years. The speed of technological progress has made obsolete the old formula for success which demanded only a close guard over company secrets to stay ahead of competition. Today's fast pace of technological developments demands, instead, that the executive remain alert and receptive for every new idea that may be applied profitably to his own business.

You may wish to check certain items in this advertisement and forward to those concerned in your company.

Route to:

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Chemical research . . . good medicine for pharmaceutical progress

Chemists at Dow have had a healthy interest in the pharmaceutical industry for almost 70 years. Since the introduction of the first Dow product, bromine, Dow chemists have helped meet the industry's growing demand for basic chemicals and important intermediates. New "multi-purpose" plant speeds production of experimental chemicals to aid pharmaceutical progress.

When you hand your druggist a prescription, it's more than likely you're also handing him an order for Dow chemicals. For, since Dow produced its first bromine in 1897, Dow chemists have played an increasingly important role as "the men behind the men behind the prescription counter".

Painstaking research at Dow, in cooperation with leading pharmaceutical houses, has led to the development of many of the intermediates needed for the introduction of new and better drugs such as antihistamines, sulfas and antibiotics.

Today, the imposing list of high quality pharmaceutical chemicals supplied by Dow in abundance includes bromine, medicinal salicylates, epsom salt, chloroform, analgesic drugs and elemental iodine. And the research goes on for even newer answers to the age-old fight against pain and disease.

A new multipurpose plant at Dow is playing a front-line role in this fight. This new plant has been built to enable the pharmaceutical industry to more fully utilize the production and research capabilities of The Dow Chemical Company. It is designed to produce semi-commercial quantities of intermediates during the critical period of new product development and market evaluation. Later, these products can be supplied in commercial quantities from regular production facilities.

Other Dow chemicals in the

NEWS SPOTLIGHT

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DOWANOL:

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In flake or pellet form, high grade Dow calcium chloride helps keep highway building on schedule and up to standards . . . and then improves highway maintenance summer and winter. The Highway and Construction Materials Laboratory at Dow aids users in the proper selection and application of Dow calcium chloride for highway construction and maintenance.

Dow calcium chloride speeds highway construction by improving mixing and setting characteristics of concrete.

Today's fast-moving, fast-improving pharmaceutical business depends to a great extent on a ready supply of pharmaceutical raw materials from basic chemical companies like Dow.

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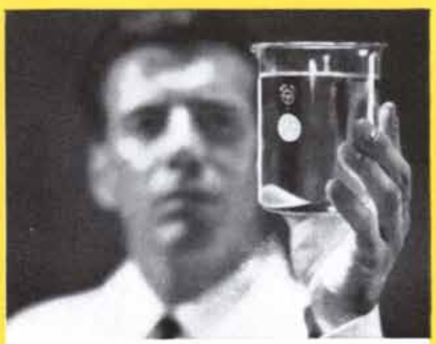

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Tissues from Dissociated Cells

An embryonic tissue can be broken apart into its constituent cells. Then, under appropriate conditions, the separated cells reassemble into a tissue similar to that from which they came

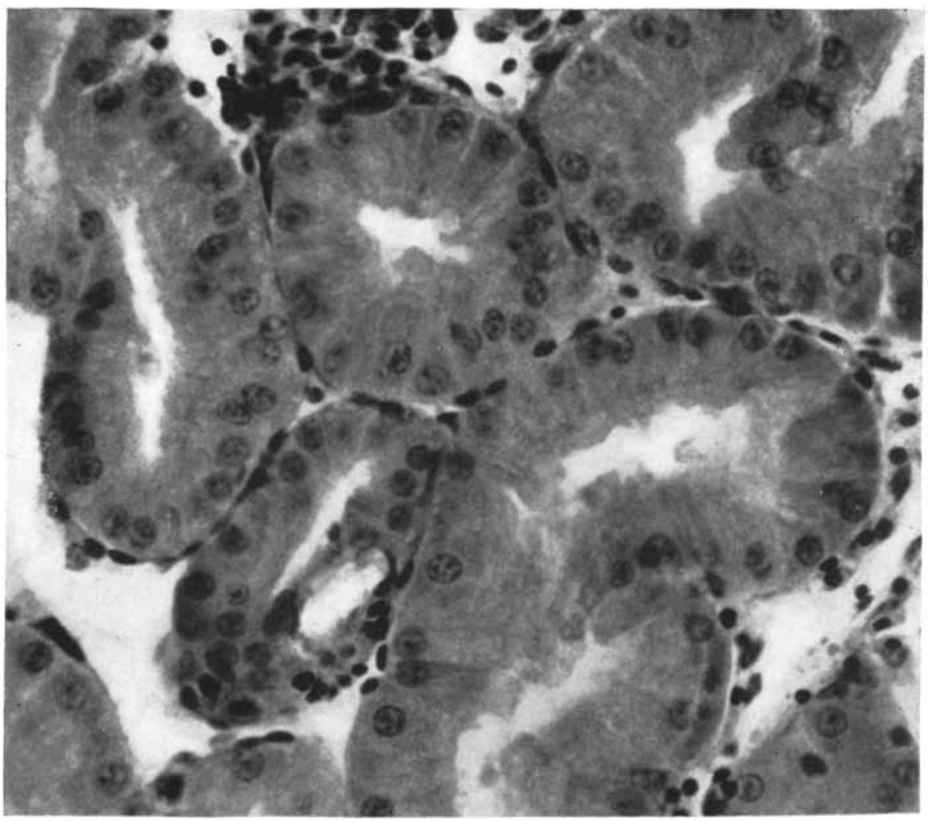
by A. A. Moscona

Usually it is easier to take something apart than to put it back together again. But we must perform both operations successfully if we want to know what makes a thing tick. Thus, by analysis and synthesis, the physical sciences have shown that matter consists of molecules and atoms, and have resolved the laws governing the interactions by which these elementary bodies combine to produce the diversity of substances in the physical world. In the life sciences our understanding is not nearly so far advanced. The cell was long ago established as the basic unit of living forms. But the cell is an immensely complex elementary body; its integration in tissues is as much a matter of behavior as of architecture. Until recently it has not been at all easy to dissociate tissues into cells, much less to attempt the recombination of cells into tissues. Thanks to new experimental techniques, however, the dual process of analysis and synthesis now promises to reveal important information about the laws that govern the bonding and interaction of cells in the development of the tissues of higher organisms.

Though the synthesis of tissue from living cells would seem to be a remotely futuristic project, its feasibility was foreshadowed as early as the turn of the century in the remarkable outcome of an experiment performed by Henry V. Wilson of the University of North Carolina. Wilson was investigating the growth and regeneration of marine sponges. When a sponge is cut up into minute fragments, each fragment grows and develops into a complete individual. He decided to see what would happen in the extreme situation of the dissociation of sponge tissue into its smallest viable fragments: the individual cells. By pressing live sponges through a finely woven cloth into sea water, he obtained a dense suspension of cells. The events that followed turned this simple stratagem into a classic experiment. Like crystals precipitating out of a solution, the cells condensed into clusters that soon organized into tissues and eventually developed into complete sponges!

Unfortunately the implications of this experiment went unexplored for years. It was almost taken for granted that such a drastic procedure would work only with primitive creatures like sponges, which resemble colonies of cells rather than true multicelled organisms. Biologists doubted that the highly integrated and specialized tissues of vertebrates, for example, could be so easily taken apart and reassembled.

Such doubts began to be dispelled in the 1940s, when Johannes Holtfreter of the University of Rochester succeeded in breaking down the tissues of early amphibian embryos into cells by treating them with a mild alkali. When he heaped the cells together in a mass, they co-



KIDNEY TISSUE from a chick embryo consists of several types of cells organized into tubules (*seen in cut section in the first photograph*). Treatment with enzymes breaks the

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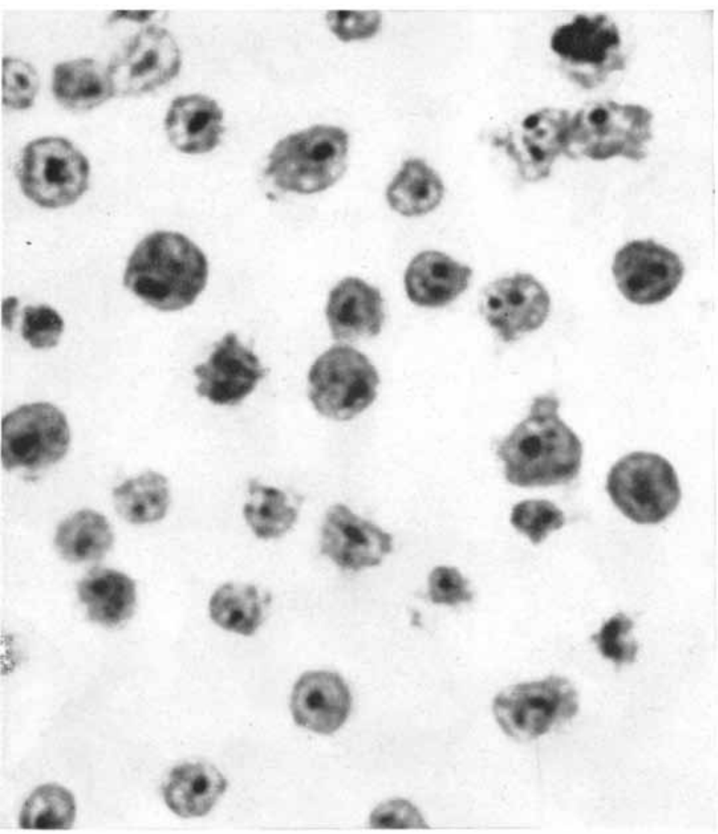
alesced and reconstituted the type of tissue from which they had come. Thus the cells of vertebrates, albeit from lowly members of the order and very young embryos, could be freed of their original affiliations and made to recombine into tissues. The repetition of such experiments with the tissues of higher vertebrates was now only a matter of time.

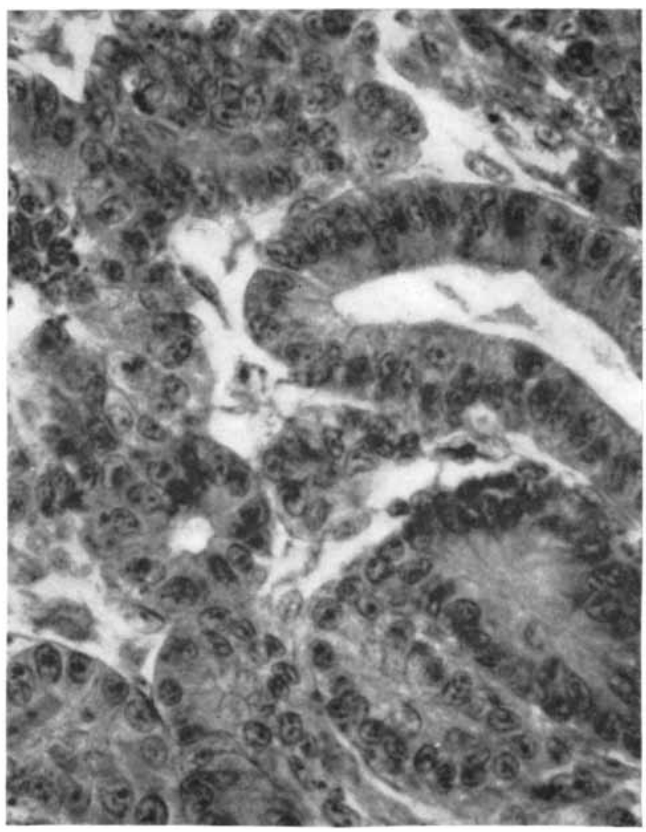
The tissues of a chick, a mouse or a man, however, require much more careful handling than the relatively sturdy and nutritionally quite independent amphibian material. Honor B. Fell of the University of Cambridge had already developed a culture system that made it possible to grow tissues outside the body; this technique seemed adequate for the culturing of dissociated cells. A more difficult objective was the dissociation of the cells. This called for the dissolution of the viscous cement that binds vertebrate cells together in tissue structures. The active ingredients of this cement are sugar-bond mucoproteins which are somehow stabilized by calcium. E. N. Willmer of the University of Cambridge and other investigators had suggested that certain enzymes which digest proteins might dissolve the intercellular cement. Trypsin, an enzyme secreted by the pancreas, is such an enzyme, but in low concentrations it does not digest living cells. Accordingly in 1952 I treated fragments of mouse and chick tissues briefly with a calcium-removing agent and then placed them in a weak solution of trypsin. The enzyme loosened the cement, and the cells fell apart from each other. In the place of a compact, highly organized tissue, there were now scattered, individual living cells.

Not all tissues disintegrate so easily. Some require the use of enzymes other than trypsin, and in some cases a battery of enzymes and other substances must be employed, each affecting a different component of the cement. Some tissues, however, break down simply upon the removal of calcium from the intercellular cement. By such chemical microdissection techniques a variety of tissues and even whole embryonic organs such as liver, kidney, heart and limb buds may be disassembled into living cells.

Can the dispersed cells of a dissociated tissue continue their normal development in the solitary state? The answer depends largely upon the type of cell and the stage of embryonic development at which the tissue is disrupted. Some cells are strong "individualists," and beyond a certain point do not depend upon the cellular community for stimulation and regulation of their growth. Separated muscle-forming cells, for instance, can develop into striated-muscle fibers that contract upon stimulation just as cells do in the intact tissue. Individual nerve cells, able to conduct electric impulses in a typical way, can arise from separated nerve-forming cells. On the other hand, most embryonic cells are unable to proceed with their normal course of development when isolated from each other; they may proliferate, but they lose their characteristic appearance in a short time. The kidney, for example, has a complex tubular structure that gradually arises during embryonic development; the arrangement of the specialized cells that compose each tubular element is the outcome of a highly complicated, closely synchronized series of events. When kidney tissue is dissociated into cells, this organization is disrupted; the processes that set it up are voided. The cells are still kidney cells, but they cannot properly display their characteristics outside the multicellular environment.

If such cells are dissociated, can they reassemble themselves into an organized and functionally effective group? In





tissue apart into individual living cells (*second photograph*). Under appropriate conditions the cells come together in masses within which they become organized into typical kidney structures. The third photograph shows a cut section of one tissue mass.

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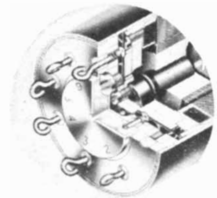
the



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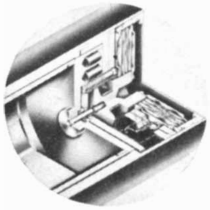

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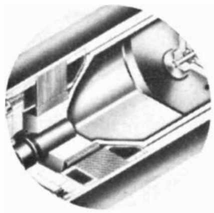

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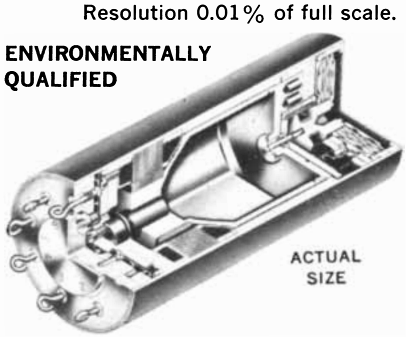

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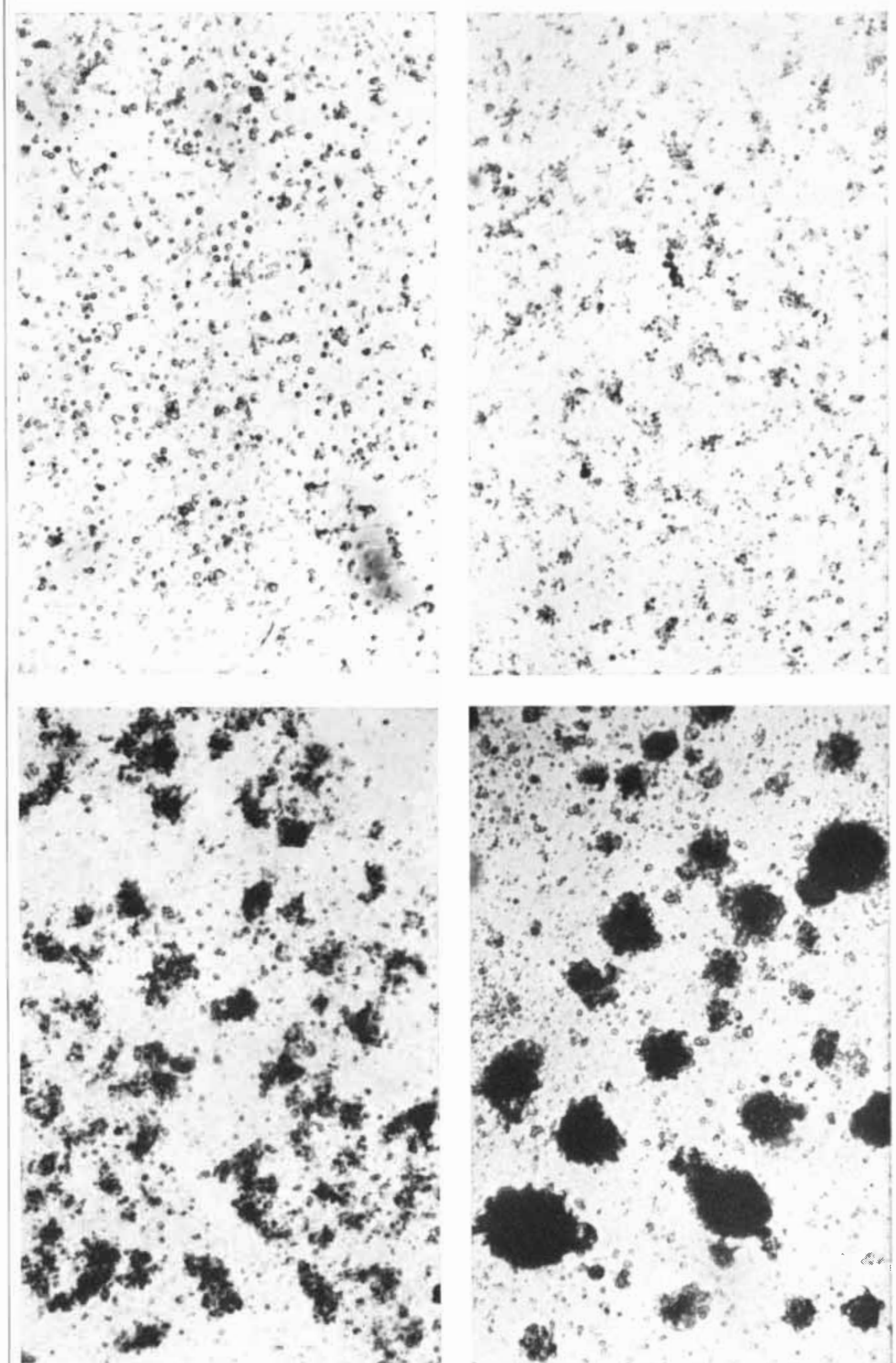
other words, can the progressive development of tissues in the embryo be simulated by a short-cut reconstruction from individual "prefabricated" cells? In many cases it can.

The reconstruction of tissue out of the chaos of the cell suspension proceeds in a characteristic way. When embryonic kidney tissue is dissociated, for example, the cells can be seen actively moving about on the floor of the culture vessel; at the same time they lay down a delicate film composed of a material chemically related to the intercellular cement. The precise role of this film is problematical. It may represent a defensive reaction of the denuded cells to the culture environment. On the other hand, since it provides a loose interconnection between the cells, it may serve to orient their movements. When the cells meet, they may skirt each other; or, if they are of mutually acceptable types, they remain in contact, gradually forming small clusters. Frequently chains of cells con-



DISSOCIATED CELLS settle out of suspension and begin to gather in clusters (*top left and right*). With further aggregation the clusters enlarge into compact rounded masses (*bottom left and right*). The cells shown here were obtained from embryonic kidney tissue.

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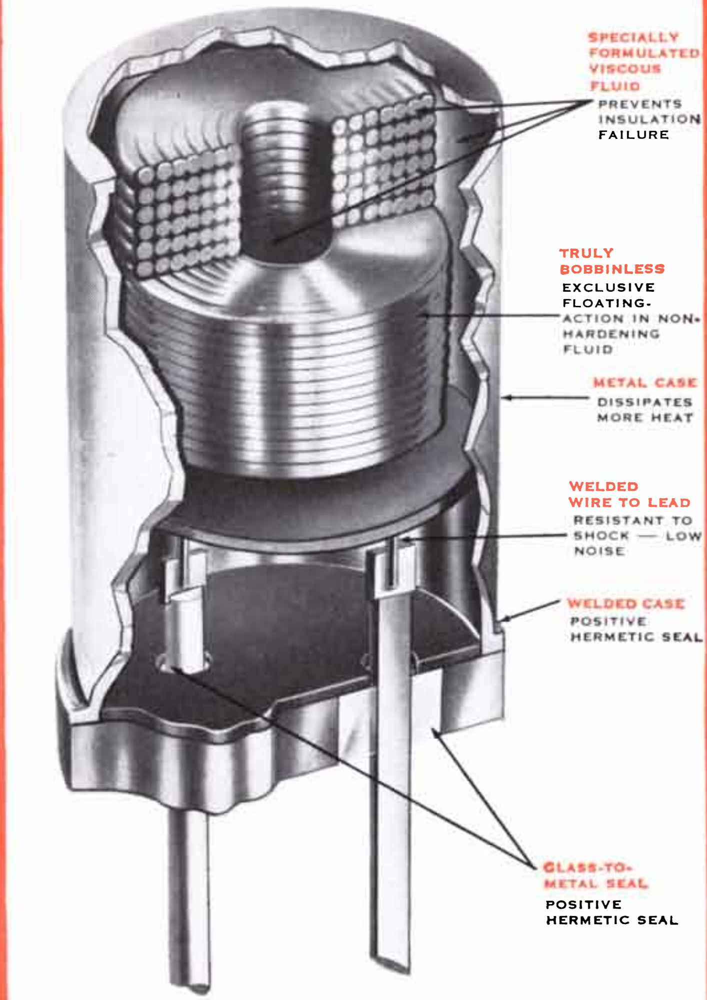

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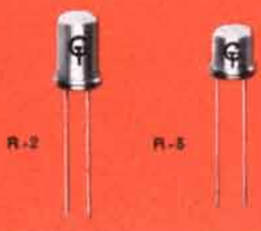

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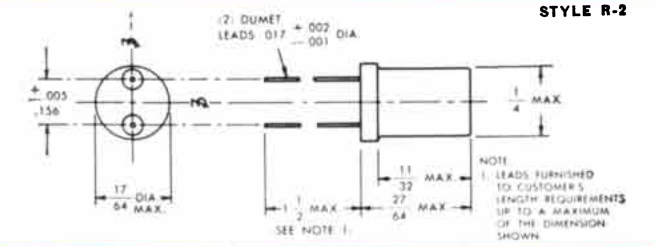

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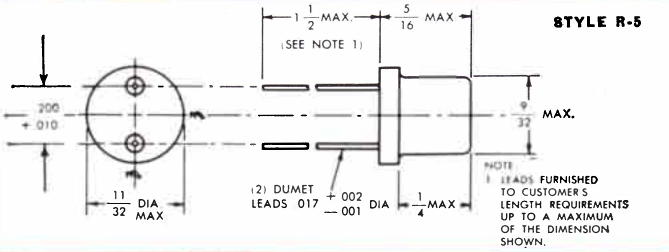

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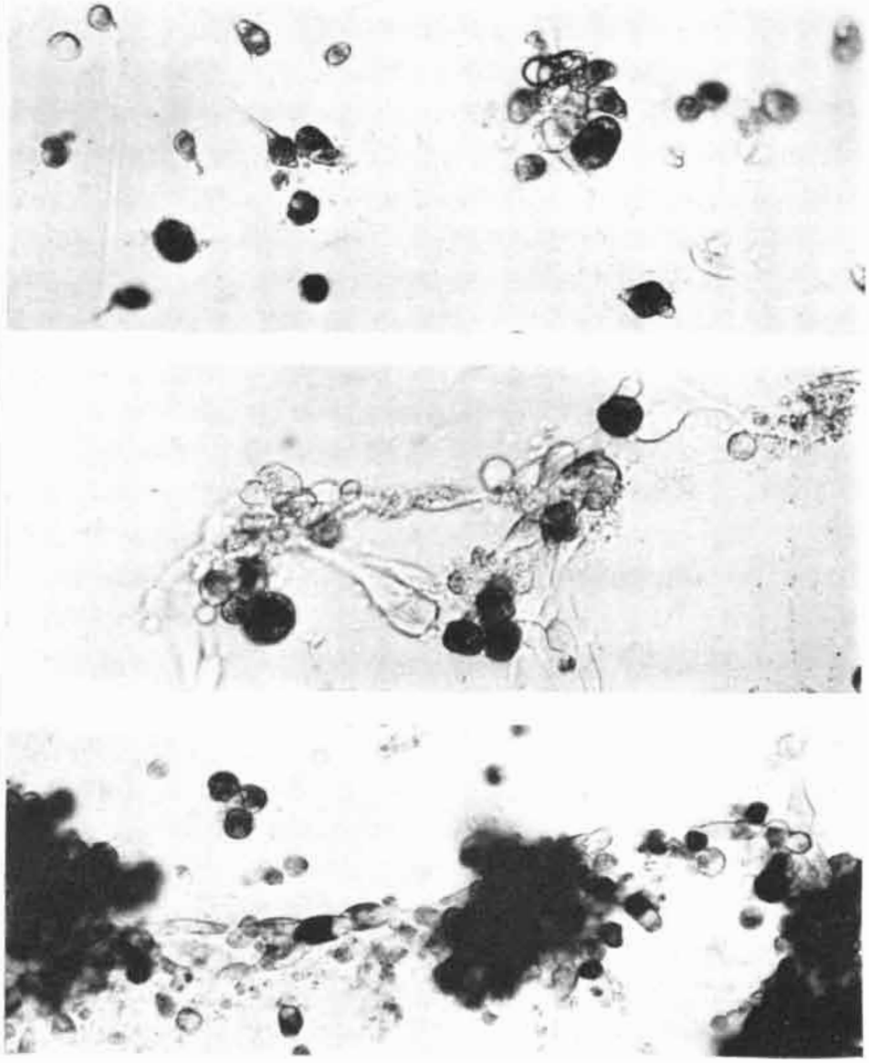
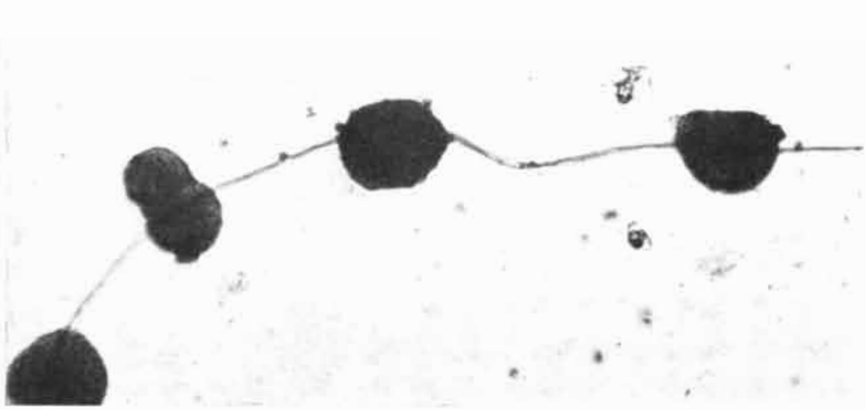
nect the clusters, and free cells colliding with the cellular bridges are directed by them, as if by guiding rails, toward the growing clusters. Later on the bridges may contract and draw the clusters together so that they merge into larger masses. In less than 24 hours a suspension of dispersed cells has formed aggregates visible to the naked eye.

There now begins another phase of activity that is even more puzzling. The cells in the clusters organize themselves into recognizable tissue patterns, each type of cell taking its proper place in



AGGREGATING CELLS are shown at an early stage of clustering at top. Small clusters frequently become interconnected by chains of cells, as in the middle photograph. Loose cells collide with these chains and move along them toward the growing clusters (*bottom*).



A COTTON FIBER placed in a culture of aggregating cells acts as an artificial interconnection between clumps. Like cell chains, it may guide migrating cells toward clumps.

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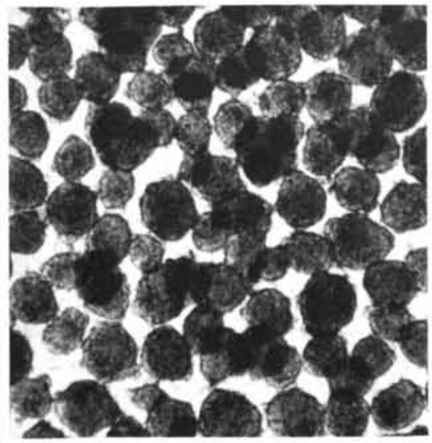
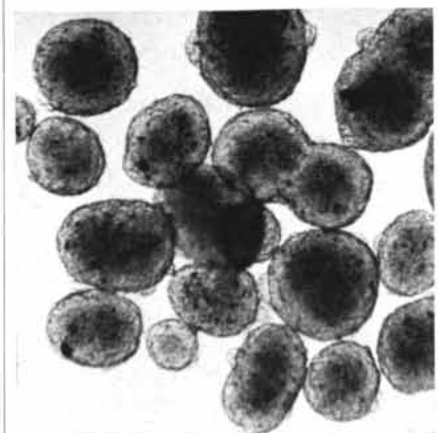
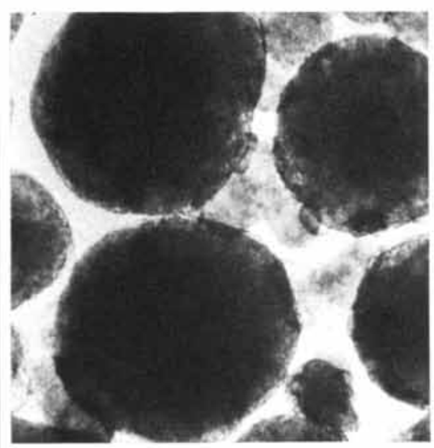
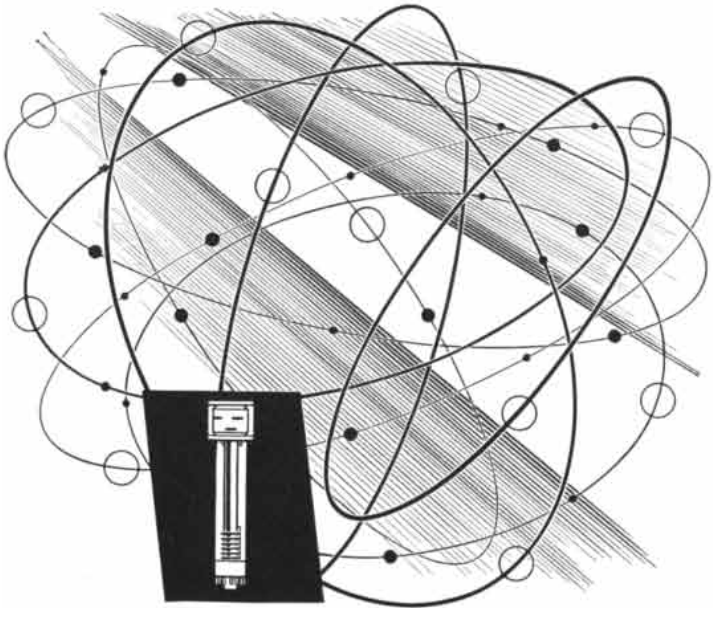
the emerging organization. Aggregated kidney cells form intricate tubules that resemble normal kidney tubules, and soon exhibit secretory activity. Cells from limb buds form lumps of cartilage surrounded by muscle tissue; liver cells reassemble in structures resembling the functional lobules of the intact organ, and begin to accumulate glycogen; dissociated heart cells coalesce into rhythmically contracting tissue. Paul Weiss of







UNIFORMLY SIZED CLUMPS appear when cell suspensions have been spun slowly on a revolving plate. Differences in size in these 24-hour aggregates were induced by slight differences in the suspending fluid. The rate of spinning also controls size.



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To arrange confidential interview, contact: Mr. E. F. Stevens, Manager, Employment, Radio Corporation of America, New Holland Pike, Lancaster, Penna., Attention Dept. **G-13E.** Or phone: EXpress 0-3661.

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Tomorrow is here today at RCA

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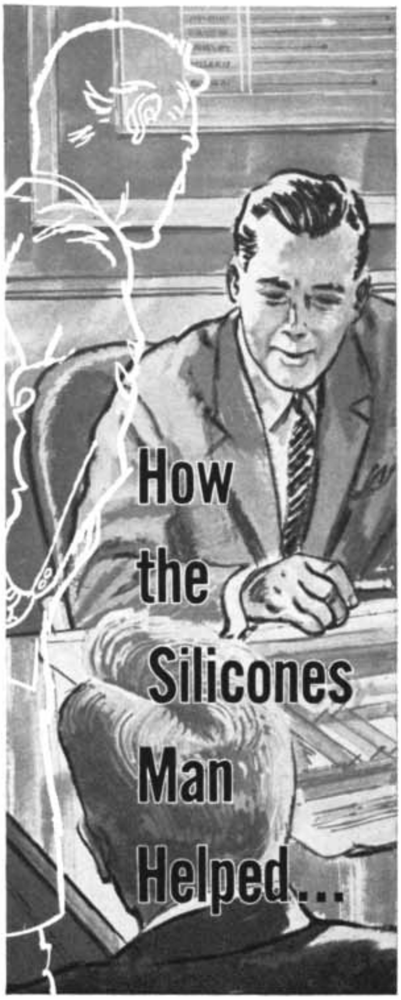
the Rockefeller Institute has described a spectacular case in which clumped cells of embryonic chick skin not only formed skin but also produced the precursor structures of feathers.

An especially remarkable aspect of this process is the way the various types of cell that make up a given organ reestablish their functional relationship to one another. A cell suspension derived from a whole organ contains a variety of cells, each with its specific structure and function. They nonetheless sort themselves out, type by type, and take their assigned places in the reorganized structure. It occurred to us to ask what would happen if we mixed together the several varieties of cell from one organ with the cells from another unrelated tissue. Would they form chaotic conglomerates with no resemblance to any of the original tissues, or would they somehow arrange themselves into recognizable tissue patterns?

We intermingled dissociated cells from kidney-forming tissue and from cartilage-forming tissue in the same suspension. At first the cells coalesced in quite randomly mixed aggregates of cells from both organs, with no sign of internal pattern. Within the clumps, however, the cells moved about actively. In less than a day the clusters had changed remarkably, becoming subdivided into regions having the pattern of cartilage tissue and regions of kidney tissue. Like parts of an animated jigsaw puzzle, the cells appeared to have become reshuffled and sorted out in accord with their original identities, fitting themselves into patterns that replicated the tissues from which they came. We subjected the tissues of other combinations of organs to the same test. In every case the initial random clustering gave way to a selective regrouping of cells according to tissue types, followed by the resumption of characteristic development. It was as if the cells recognized their own kind and remembered their proper arrangement, undistracted by the proximity of other cells that were engaged simultaneously in organizing themselves along different lines.

These observations suggested that certain properties of each cell must serve as cues to others, inducing similar cells to join in association with it and causing dissimilar cells to separate from it. The information at hand was, however, clearly not sufficient to justify such generalization. We needed to design an experiment in which we could trace the activities of various cell types and observe the constancy with which they



RUBBER THAT TAKES A 350 F PINCH

The rubber-covered pinch rolls used in a vinyl sheet laminating machine had to be changed every two weeks. The 350° F. operating temperature and high pressure caused the rubber to crack, become hard and glazed, making frequent regrindings necessary. After a few regrindings the rolls had to be completely resurfaced. Since the press was in operation around the clock, these delays were costly.

The Silicones Man suggested a springy, heat-resistant silicone rubber be used to surface the hard-working rolls. This was done . . . and the rolls are now giving full-time, profitable service. There hasn't been a shutdown for renewal after more than eight months.

The delighted manager of the laminating plant says the silicone rubber resists hardening, cracking, glazing, and oxidation . . . unlike the old type of rubber surfacing. And it's saving his company considerable money, despite the higher cost of the silicone rubber.

NEW WRINKLE IN ANTI-WRINKLE PROCESSING

Chemical treatment of wearing apparel to make it hold creases and resist wrinkling also brought wrinkles to the brows of processors. In many cases, the resins used to make a fabric crush-proof also made the fabric too stiff and harsh feeling. However, many of the softeners available created an additional problem. Crush-proof fabrics so treated tended to pick up soil during laundering.

To help resolve this situation, UNION CARBIDE developed a silicone emulsion softener that works well with stiffeners, giving fabrics a better hand and eliminating the tendency of wet cloth to pick up or retain soil. The silicone emulsion is not harmed by chlorine, doesn't yellow with age, and won't water spot.

Other advantages of the new silicone emulsion lie in its ability to provide fabrics with greater durability and tear strength, better abrasion resistance, and non-scorching properties.

FAST, ACCURATE CONTROL OF FOAMING SYSTEMS

Undesirable foaming can easily be controlled with a new silicone antifoam fluid, now being offered to processors by UNION CARBIDE. Only a few parts per million of the antifoam, called SAG, are needed in many systems to assure complete quiescence. Processing time is considerably reduced, providing fuller utilization of production capacity.

Silicone antifoam fluid can be used full strength, or dispersed with a solvent, or pre-blended with a foaming component. For aqueous solutions, it may be introduced by first mixing with a water-miscible solvent. An example of this application is in reducing the foaming in brackish water used for boiler feed.

Its chemical inertness and oxidation resistance extend the effectiveness of silicone antifoam over long periods. Since it is low in volatility, the antifoam works well at elevated temperatures. It is not irritating to the skin of those who work with it.

The Silicones Man is accustomed to helping solve problems like these . . . and he may be able to help you, too. For background information on these and other applications, write Dept. EF-0902, Silicones Division, Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

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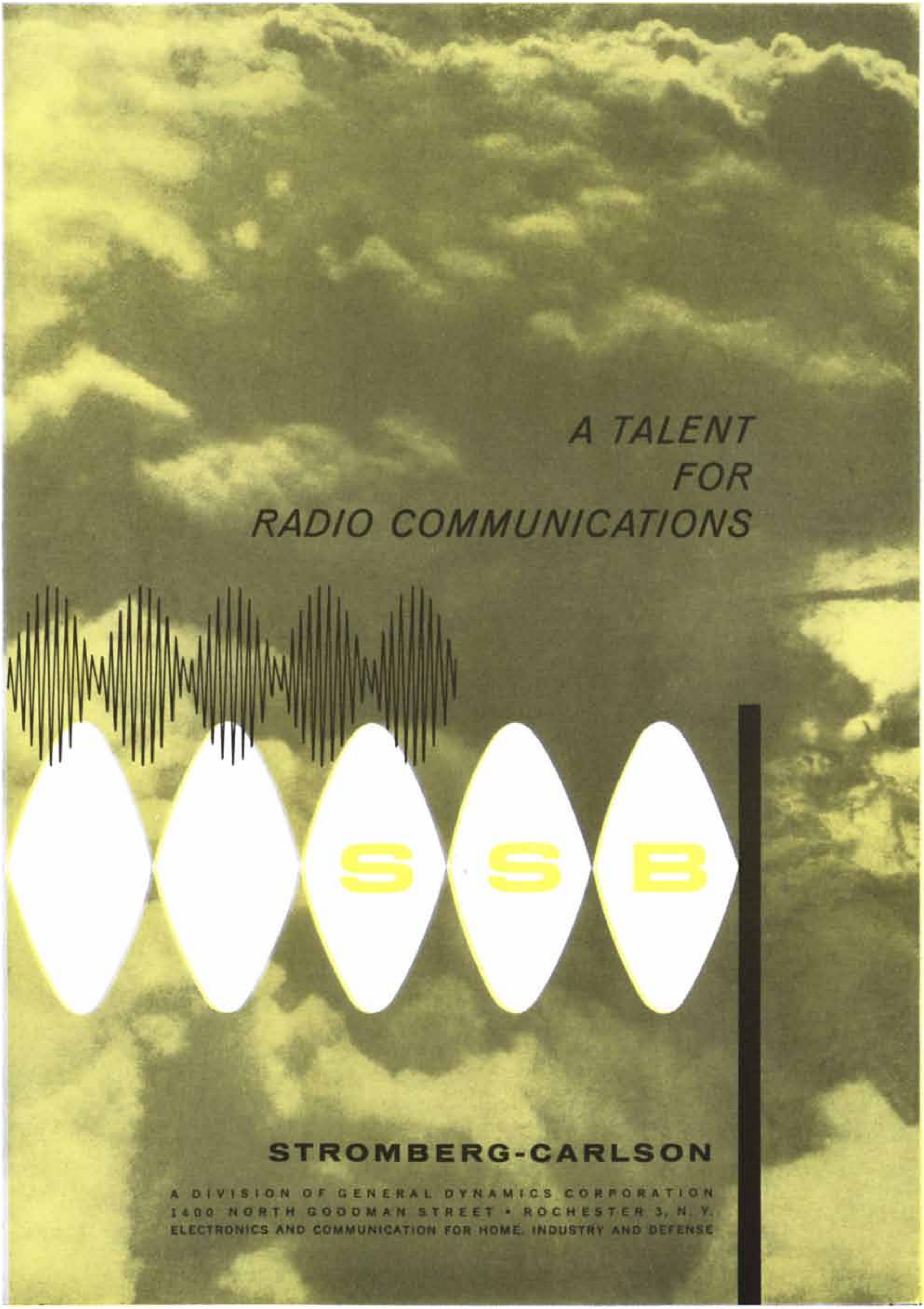

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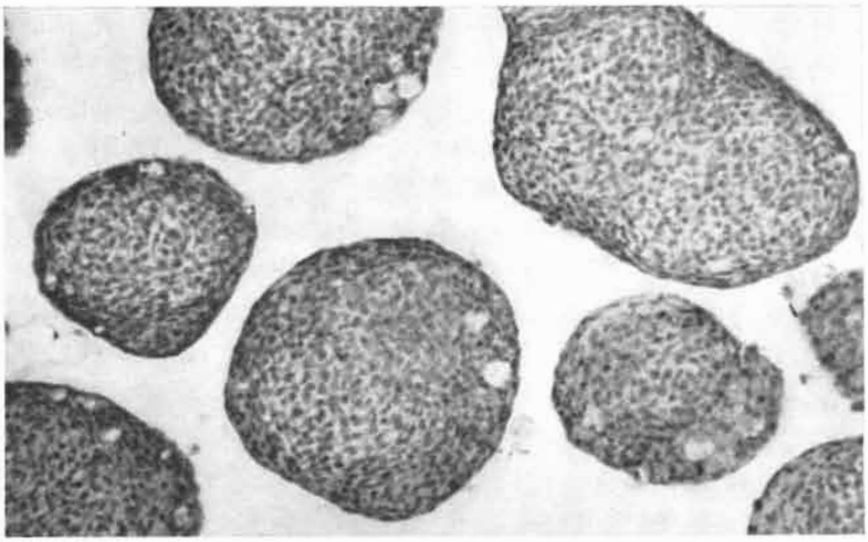
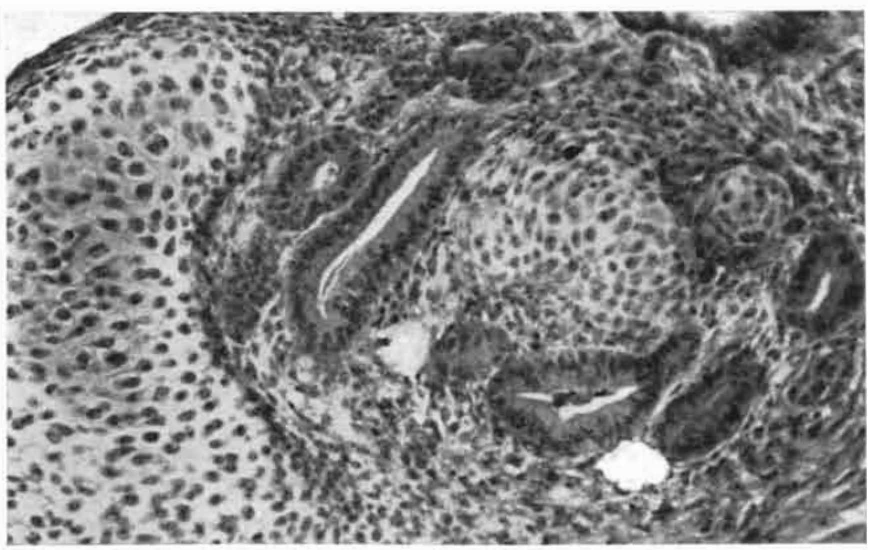
joined others of their kind. To this end we mixed dissociated cells from the same organ but from two different organisms: the embryos of a mouse and of a chick. The cells of these animals differ markedly in size and staining properties, and are therefore easily distinguishable and identifiable. Would the cells associate according to animal or according to organ? The basic assumption was that the "cues" that guide embryonic cells in tissue-forming actions are essentially the same in different, even unrelated, organisms. In other words, chick cartilage-forming cells intermingled with mouse cartilage-forming cells should "recognize" the underlying similarity of their formative destinations and, in spite of their diverse origins, cooperate to form a uniform, bispecific tissue. To our admitted surprise, the first experiment along these lines confirmed the assumption. Intermingled chick and mouse cartilage-forming cells produced a common mosaic cartilage. Within it cells of both species were equally dispersed and closely bound by a common matrix in a manner typical for this tissue. Such "hybrid" tissues also formed from combinations of liver cells and kidney cells from the embryos of chicks and mice.

The next step was to ascertain whether, in line with our previous findings, cells from different organs as well as from different organisms would sort themselves out in accordance with their different formative cues. Mouse cartilage-forming cells were combined with chick kidney-forming cells; it was indeed found that mouse cells grouped together



SMALL MASSES OF CARTILAGE TISSUE have been reconstructed from dissociated cartilage-forming cells which reaggregated. These cells were obtained from a chick embryo.



INTERMINGLED CELLS from kidney-forming tissue and cartilage-forming tissue of chick embryo produced mixed aggregates in which the cells grouped themselves by type. The kidney cells formed tubules (*rings of darker cells*); the others formed cartilage.

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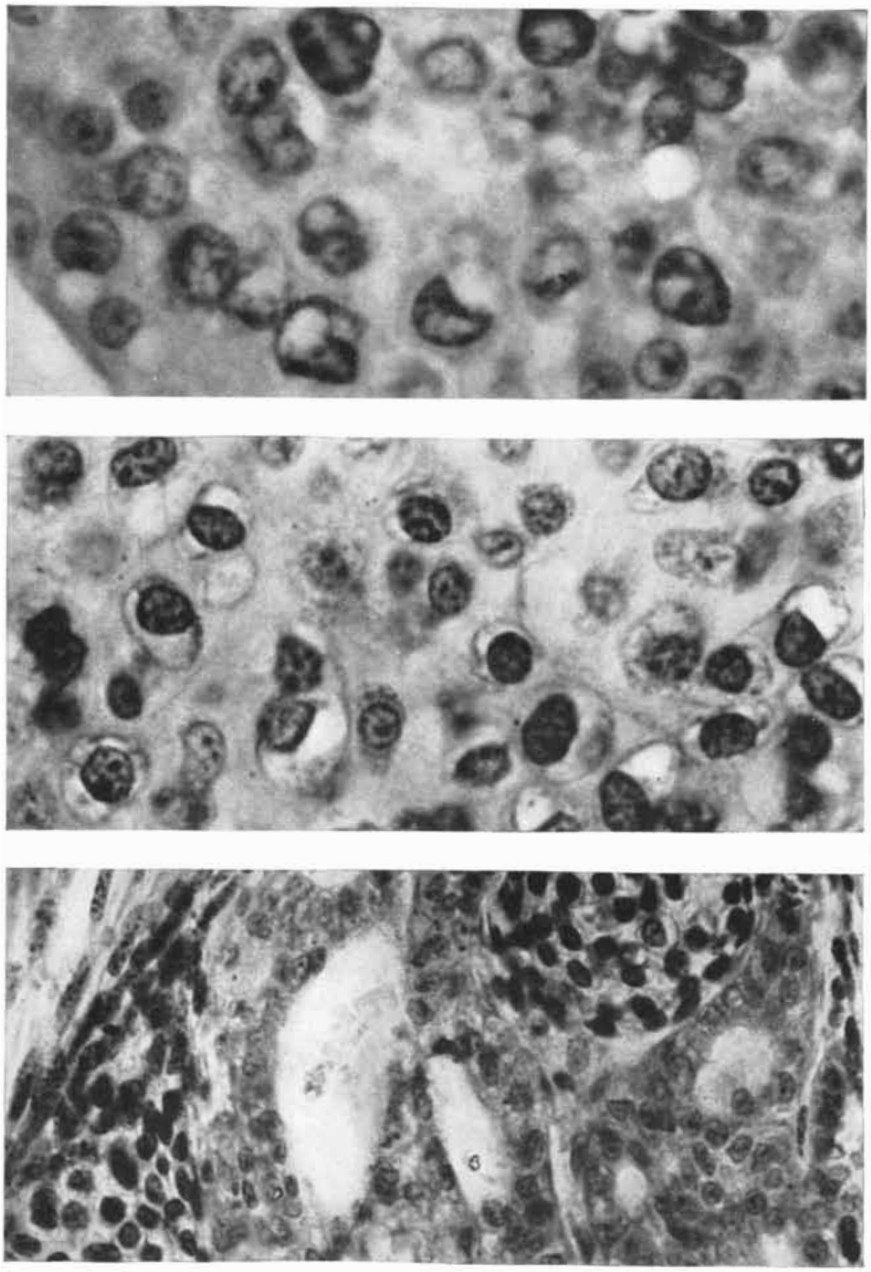
and reconstructed cartilage, while the chick cells became organized in tubules.

Such mixtures of cells from the embryos of two different species are now helping in the study of other knotty problems of growth. Charles E. Wilde, Jr., of the University of Pennsylvania has applied it to the controversial question of muscle formation. Embryologists had long debated whether large muscle fibers having many cell nuclei are formed by the merging of individual muscle-forming cells or by the rapid subdivision of a single cell. Wilde found that muscle fibers which develop in a mixed culture of mouse and chick muscle-forming cells are made up of cells of both species. This indicates that the fibers form from the merger of two or more cells, although it does not exclude the possibility of other mechanisms in muscle formation.

Clifford Grobstein, now at Stanford University, employed interspecific cultures to investigate the formation of the kidney in mouse embryos. He had found in earlier experiments that the very young kidney-forming rudiment of a mouse embryo would not develop if it



MOUSE-CHICK TISSUE in which the cells of both species are freely intermingled results from mixtures of dissociated cells of corresponding organs. At top is mouse-chick liver tissue; in middle, mouse-chick cartilage. Mouse cells have larger, darker-staining nuclei than chick cells. At bottom, less magnified, is an aggregate of mouse-cartilage cells and chick-kidney cells. Coming from dissimilar organs, the cells separated according to type.

FLIGHT DATA and CONTROL ENGINEERS

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Forward resume to:
Mr. G. D. Bradley

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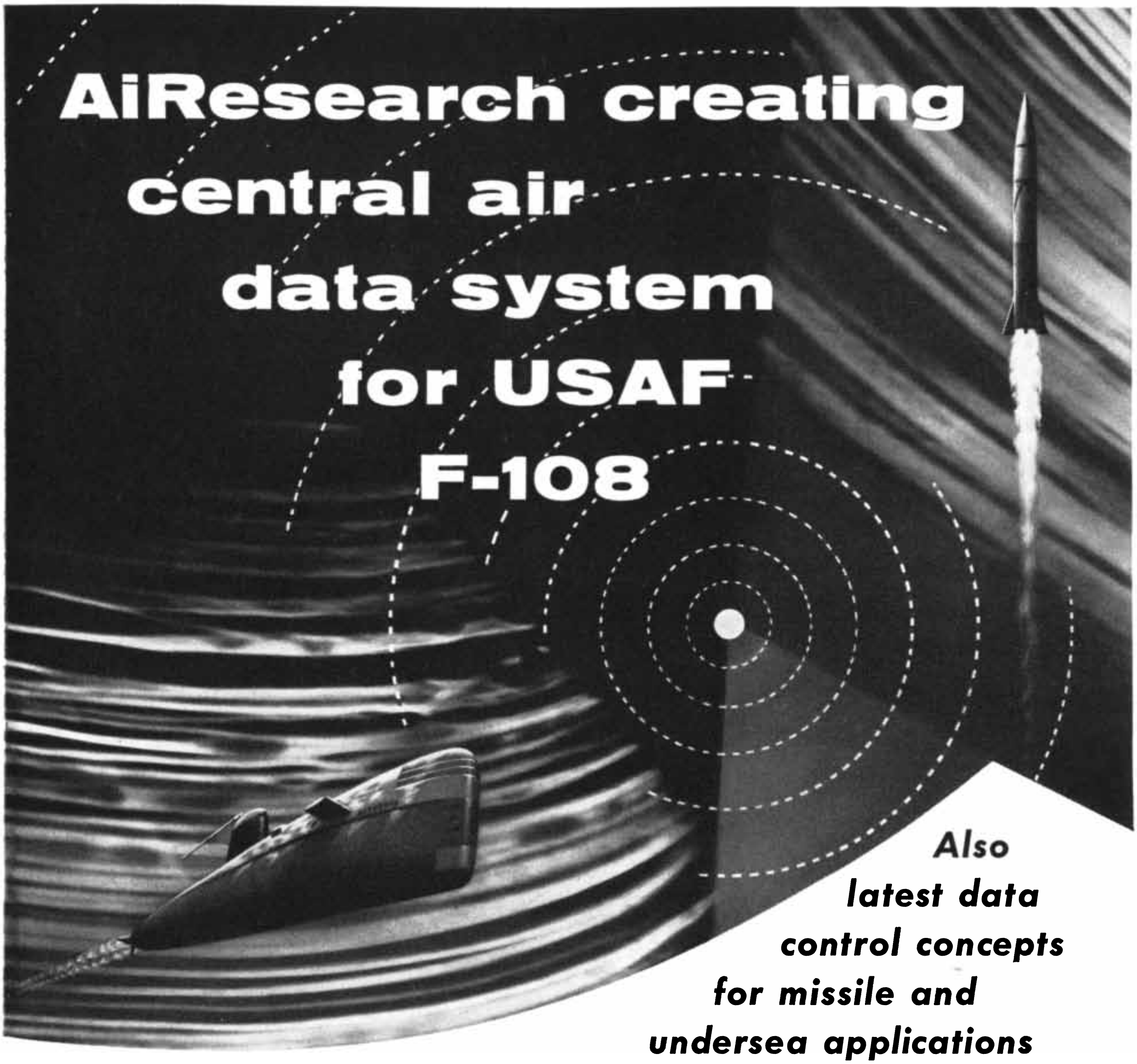

The AiResearch Centralized Air Data Computing System will sense, measure and automatically correct for air parameters affecting flight of the North American-Air Force F-108 Interceptor and will supply simplified air data to the pilot. Eliminating duplication of components, the system will cut down space and weight requirements over decentralized systems by many times.

The centralized combination of transducers, computers and indicators represents an integrated system concept combining electrical, electronic, pneumatic, hydraulic, electro-mechanical and mechanical servo capabilities. Technical experience in each of these fields enables AiResearch to achieve optimized systems covering a wide range of functions while meeting the most rigid specifications. Systems management is an integral part of each Central Air Data program enabling AiResearch to assume the overall responsibility for systems or subsystems.

The first fully optimized central air data system is already operational aboard the Navy's supersonic F4H-1, the first aircraft to fly with such a system. Similar equipment is on the Navy's first weapon system, the A3J "Vigilante." This broad AiResearch systems capability is now being applied in the fields of military aircraft, commercial jet transports, missiles and submarines.

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Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

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was isolated in a tissue culture, but that it could be stimulated to form tubules in the presence of fragments of mouse spinal cord or even bits of spinal cord from a chick. Together with Robert Auerbach, Grobstein prepared cell suspensions in which cells from the kidney-forming rudiments of a mouse embryo were mixed with the dissociated cells of chick spinal-cord tissue. The cells not only sorted themselves out but the chick spinal-cord cells also activated the mouse kidney-forming cells to develop into recognizable tubules.

The capacity of dissociated cells to synthesize complex structures outside the body is furthering our understanding of the processes that regulate the behavior of cells and the development of tissues in the intact organism. Recent experience indicates furthermore that dissociated cells may exhibit their inherent powers of self-recognition and organization in the living organism as well as in culture fluids. In 1952 Weiss and G. Andres injected a suspension of pigment-forming skin cells from one breed of chicken into the bloodstream of chick embryos of an unpigmented breed. Pigmented skin and feathers appearing on these chicks demonstrated that the injected cells had become localized in the skin and resumed their normal development. Thus an organism devoid of a certain type of cells has been "seeded" with them by injection!

Such experiments have given reality to hopes that the loss of cells or tissue in adult organisms may, in certain cases, be restored by injection of a suitable cell suspension. Important progress in this direction has been made in studies of animals exposed to X-rays. Exposure to intense radiation destroys the blood-forming tissue in the bone marrow and causes death. The injection of viable bone-marrow cells greatly increases their chance of survival. The injected cells become lodged in the depleted bone-marrow and reconstruct blood-forming tissue there. It is even possible to replenish destroyed marrow with cells from another species. Bone-marrow cells from rats have been successfully transplanted by injection into irradiated mice. These promising experiments are receiving considerable attention in view of their obvious medical implications.

The idea of tissue synthesis from dissociated cells thus presents ever more challenging possibilities to the biologist and medical investigator. We are greatly indebted to the direct and simple curiosity that prompted Wilson to squeeze sponges through a cloth.

Fellow Engineers and Scientists:

My company has asked me to tell you of the unusual opportunities in operations research at System Development Corporation. These range from positions for engineers and scientists who would like to develop their skills working in a team under an experienced leader to opportunities for those who are looking for positions of leadership. I hope that the following account of our work will lead you to inquire for further information.

Briefly, SDC's business is automated decision-making systems. More fully, we develop large scale, computer-based information processing systems in which the computer is used as an on-line, centralized control element for a system operating in real-time. At this stage of the art these systems are semi-automatic, the man-machine type in which man shares the repetitive control function with the computer. Our work is concept-oriented, rather than hardware-oriented, and deals with problems of over-all system design, data processing development, and man-machine system training.

The most fully developed large-scale semi-automatic system is the SAGE (Semi-Automatic Ground Environment) Air Defense System. We have a major responsibility in the development of SAGE. Our experience and unique team skills have led to diversification of our activities; we now have important contracts for other major military and government systems vital to our country. The demand for our services is reflected in our growth from 70 to more than 2,700 employees since 1955, and the intriguing possibilities of automated decision-making are only beginning to be realized.

In this brief message, I can only suggest the variety of operations research problems at SDC. Perhaps the most important point is that this variety is limited only by the imagination and initiative of our scientists.

Some examples of areas of work are: (1) allocation of decision-making functions between man and machine for optimal system performance; (2) measures of system capacity and system performance; (3) exploration and evaluation of design changes by operational gaming; (4) quality control and testing of operational computer programs; (5) allocation of computer capacity among several system functions; (6) scheduling and costing of production of operational computer programs; (7) optimal assignment of mixed weapons to targets.

SDC recognizes the importance of a well planned research program for the vitality and future of the company, and we are carefully organized to carry out such a program. The following are some areas our operations research people are involved in: (1) simulation and operational gaming techniques in problems of control systems; (2) information retrieval and theory of information processing; (3) medical data processing; (4) universal language for computer programming; (5) logistics. We have unusual facilities for research at SDC—these include one of the largest computer facilities in the world and outstanding simulation laboratories.

We have given considerable thought to organizing the activities at SDC to provide for professional development and self-expression. Operations research professionals are carefully assigned so that their individual talents are matched with company needs. These assignments are reviewed regularly to make sure that developing talents are directed into new company opportunities. We regard the publication of research articles and participation in professional societies as activities important to the company. We encourage new ideas and provide the time and means to explore them.

SDC is one of the leaders in a field which will have a remarkable technological and scientific development. It is a new and vigorous company with a bright future. I encourage you to join us.

Please write Mr. R. W. Frost at the address below if you wish to pursue this invitation.

William Karush

SDC

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William Karush
Assistant Director for Research
Operations and Management Research
System Development Corporation

SYSTEM DEVELOPMENT CORPORATION

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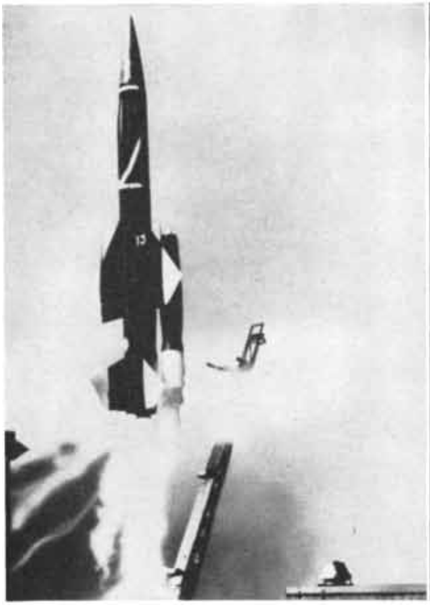
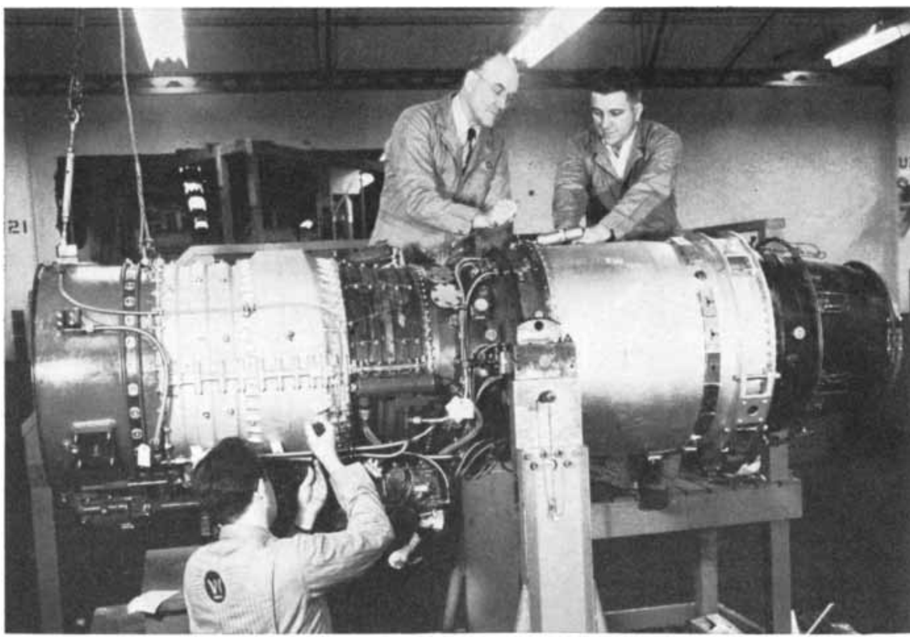
10,904 graduate engineers and scientists with over 133,000 years of experience perform vital tasks at Westinghouse



MISSILE GUIDANCE SYSTEMS. Both ground guidance and terminal guidance systems are designed, developed and produced at Westinghouse. More advanced guidance systems are now being developed to replace those in production and in actual operation. The latest techniques in radar, infrared, and data processing and display are being applied to all phases of missile guidance by Westinghouse engineers with many years of experience in this field. ***Air Arm and Electronics Divisions***

AIRBORNE ELECTRONIC SYSTEMS for weapons control, terrain avoidance, bombing and navigation, antisubmarine warfare, missile guidance, bomber defense and other applications are designed and manufactured by Westinghouse. Aero 13 Armament Control System, shown above, for the Navy's F4D Douglas Skyray fleet interceptor, is a recent example. ***Air Arm Division***



PROPULSION. From the design of America's first turbojet engine in 1941—by 14 pioneering engineers at Westinghouse—to present-day engines for high-speed aircraft, Westinghouse has kept pace with the aviation industry's constant demand for increases in engine power and efficiency. Current applications include the use of new metals and advanced design features to attain maximum thrust-to-weight ratio, higher speed and higher altitude performance. Jet propulsion engineering reached a new high when a recently developed Westinghouse engine met design goals just 11½ months after these goals were set.

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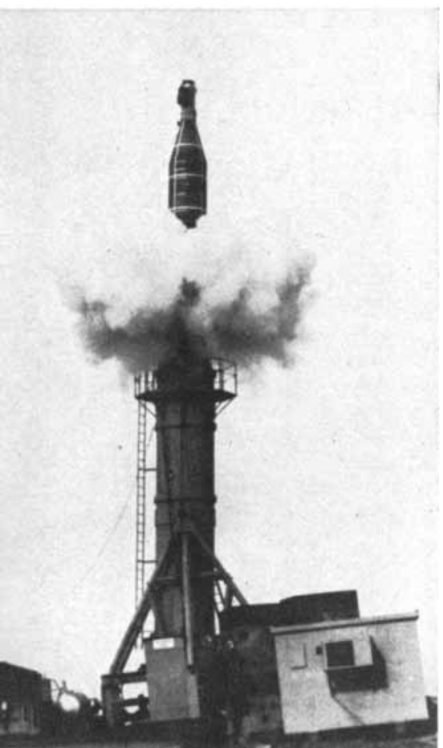
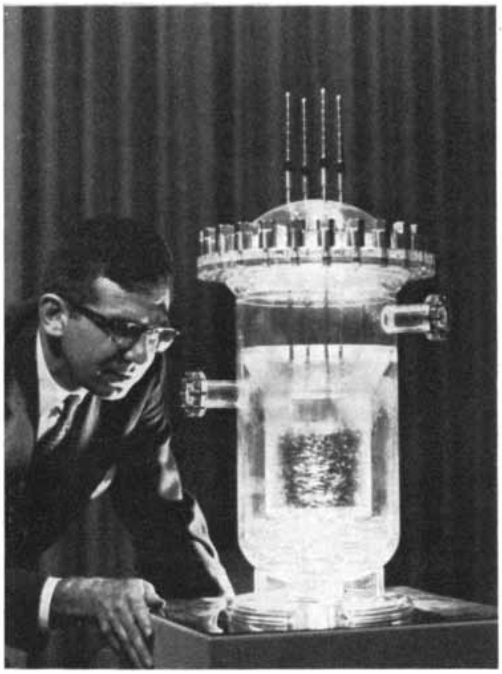
EXPERIENCED FIELD ENGINEERS are an important adjunct to Westinghouse engineering capabilities. Located at key locations abroad, in this country, and afloat—wherever Westinghouse equipment is in use—these field engineers supply the experience and information needed to fully utilize new equipment, help indoctrinate new personnel, and provide technical liaison with the manufacturing plants of the Defense Products Group.

HUMAN ENGINEERING—mating man and the machine—is important in electronic equipment design. Continuing scientific study and research at Westinghouse facilitate advantageous application of this concept—from missile analysis to maintenance design—in developing better avionic systems. ***Air Arm Division***



UNDERWATER IRBM LAUNCHER for the submarine-based Polaris missile, shown here during early test launching with dummy missile, was designed and built by Westinghouse. Design features developed for this system appear applicable for use in other solid fueled missile launching systems.

AIRCRAFT ELECTRICAL SYSTEMS. From Jenny to jet, Westinghouse has been producing aircraft electrical equipment representing the day's most advanced state-of-the-art. Systems for today's finest aircraft—including the Boeing 707 jetliner, Convair B-58 bomber, and North American A3J-1 twin-jet fighter—are Westinghouse designed and developed. These systems include the entire a-c power system, control and protective devices, and feature the world's first brushless generator . . . result of pioneering experience dating back to the first airborne, strut-mounted a-c generator built by Westinghouse in 1917. ***Aircraft Equipment Department***



NUCLEAR ENGINEERING experience is still exceedingly uncommon, but Westinghouse probably has more knowledge in this very specialized area than any other company in the world. Westinghouse has designed and developed more nuclear power reactors than anyone else. Its engineers have worked in almost every field related to atomic energy. Five different commercial reactor designs are now under active development.

UNDERWATER WEAPONS SYSTEMS. Westinghouse engineers designed the Navy's first all-electric torpedo in 1942. Since then, Westinghouse engineers have continued work on new and improved underwater systems, to include high resolution sonar and a high speed, long range anti-submarine torpedo. Technologies involved include hydrodynamics, acoustic systems, servo mechanisms, and guidance control. ***Ordnance Department***

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Alert tape manufacturers filled this need by using Du Pont "Mylar"* polyester film as the base for Video Tape. "Mylar", which had already proved its reliability in missile tracking and data computing, provided the necessary strength and toughness in thin gauges to meet the exacting demands of TV recording equipment.

This is but one of the many ways "Mylar" is helping industry improve product performance, develop new products and lower costs. Electric motors, for example, can be made smaller and more efficient with insulation of "Mylar". Manufacturers of electrical cable can cut material costs by using tough, thin "Mylar" as a core binder.

For additional information, write today for our new booklet. E. I. du Pont de Nemours & Co. (Inc.), Film Dept., Room SA-5, Wilmington 98, Del.

*"Mylar" is Du Pont's registered trademark for its brand of polyester film. Du Pont manufactures the base material "Mylar"—not finished Video Tape.

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Artificial Satellites and the Theory of Relativity

The phenomena predicted by the general theory of relativity are difficult or impossible to measure. Earth satellites may soon provide new ways of testing the theory by observation

by V. L. Ginzburg

"What a pity the earth has no moon in an orbit just outside its atmosphere!" With this exclamation, addressed to an evening sky in 1918, Albert Einstein closed a discussion with the young Austrian physicist Hans Thirring. The community of physics was then just beginning to contend with the implications of the general theory of relativity. Thirring and his compatriot Josef Lense had made a new deduction from the theory. Since all concerned were seeking an opportunity to confront the theory with an observational test, there was great interest in the Thirring-Lense paper.

The two Austrian physicists demonstrated that the rotation of a celestial body such as the sun or one of the planets should cause a slow rotation in the orbit of a satellite—an effect not foreseen in the classical Newtonian theory. The effect, they found, would be greatest for very close satellites. Unhappily no planet travels close enough to the sun to show a measurable effect in less than several thousand years. Furthermore, as Thirring and Einstein now concluded, the orbit of the moon lies too far from the earth to be perceptibly affected by the earth's rotation within any reasonable period of time. There was thus no prospect that the Thirring-Lense prediction could provide the basis for an observational test of general relativity.

Today, of course, several artificial satellites traverse the outer regions of the earth's atmosphere. They have already furnished valuable information about the upper atmosphere, cosmic rays and solar radiation. In the not-too-distant future they may also make possible several fruitful tests of the general theory of relativity. It was in connection with experiments I have proposed along these lines that Thirring remembered how Einstein anticipated us more than 40 years ago.

The general theory of relativity, published in complete form by Einstein in 1916, occupies a rather peculiar position in modern science. In essence the general theory is a gravitational field-theory that generalizes Einstein's special theory of relativity (published in 1905) to encompass Newton's law of universal gravitation. Unsurpassed in elegance and depth, general relativity has strongly influenced the development of physics, geometry and cosmology. Yet engineers never have to deal with it, and physicists and astronomers use it rarely. The theory assumes central significance only in cosmology: the realm of astronomy that deals with the large-scale features of the universe.

The theory is peculiar in another respect. The new theories of physics in our century have typically been verified by observation soon after their formulation. Indeed, the recent revisions in the conservation laws concerning parity were confirmed in a matter of months. The general theory of relativity, by contrast, still remains inadequately verified. It is so truly general that it yields few predictions of events that can be accurately observed in the time and space scale of human experience. To be sure, practically no one doubts the validity of the theory. But the history of physics has seen no end of cases in which the certain has turned out to be false. A theory so fundamental to modern science must be rigorously verified if it is to be applied with complete confidence to the further development of cosmology and other areas of physics.

Einstein himself proposed three significant tests of general relativity. Two of them concern the effects of gravity on light. The famous equation of special relativity, $E=mc^2$, which declares the equivalence of matter and energy, tells us that light possesses mass. Light must therefore be attracted by other masses. But the effect is so minute that it can be observed only in the case of a massive body such as the sun. Calculation shows that a beam of light that just skims the disk of the sun should be deflected through an angle of about 1.75 seconds of arc (one second equals one 3,600th of a degree). This narrow angle approximates that subtended by a matchbox at a distance of three miles.

Such refined measurement is not beyond the power of modern astronomical instruments. Theoretically it is necessary only to compare the position of a star when the sun is close to it in the sky with its position when the sun is elsewhere. Because of the sun's brilliant light the key observation can be made only during a total eclipse. The eclipse of 1919 provided the first opportunity. Photographs made at that time provided an approximate confirmation of Einstein's prediction and caused a worldwide sensation. Since 1919, however, the effect has been observed only seven times. The measurements of angular dis-

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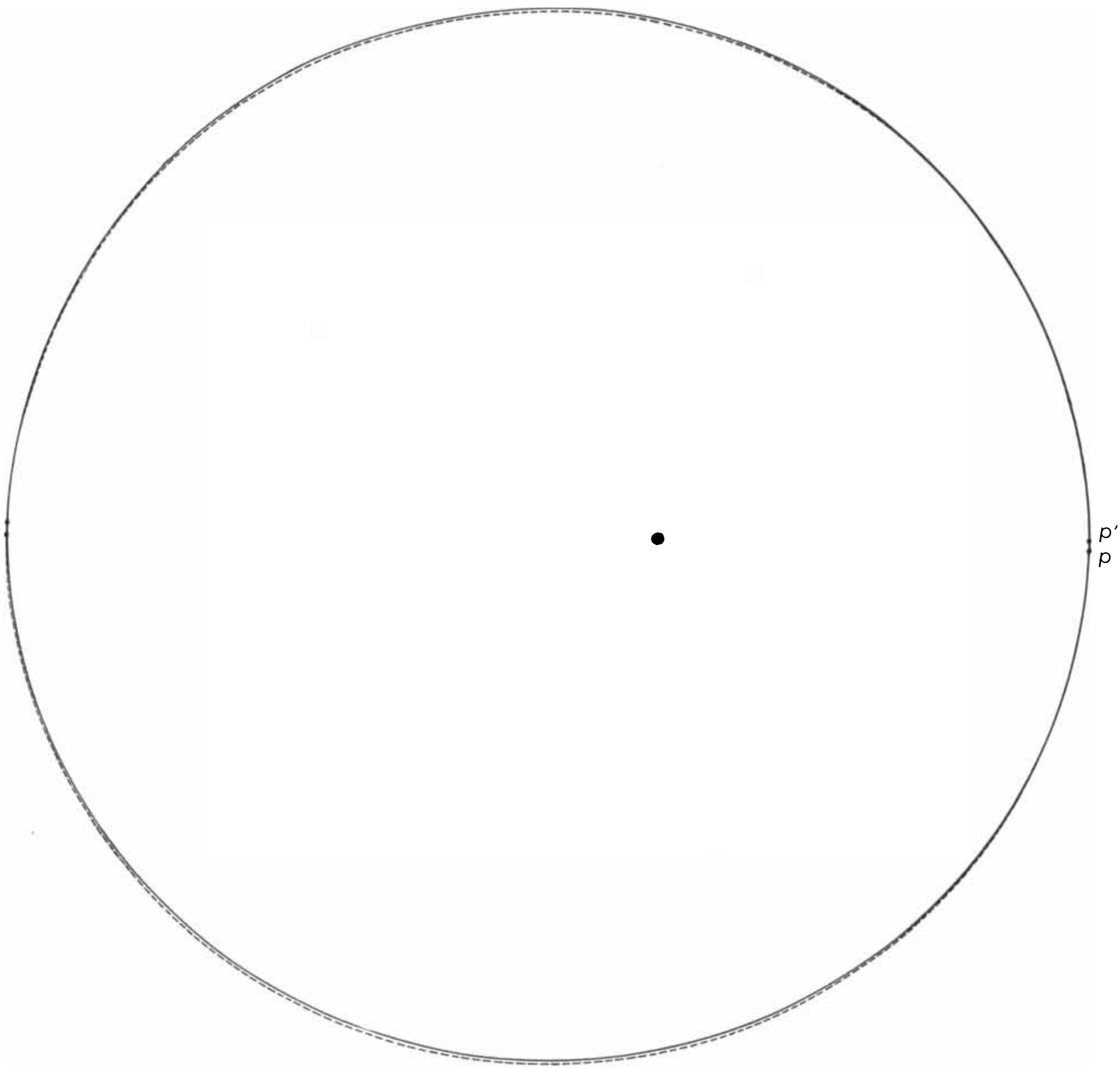
placement average out to 1.98 seconds, which fits the predicted value with an error of between 10 and 15 per cent. The theory also predicts that the angle of deflection will depend on how close to the sun the light passes, but this prediction requires such refined measurement that it has yet to be tested.

The second effect of gravity upon light which Einstein derived from general relativity involves the so-called gravitational red-shift. When a photon of light leaves the surface of a star, it loses energy because it must work against the gravity of the star. For a photon a loss in energy is equivalent to a decrease in frequency, that is, a shift to the lower-frequency, longer-wavelength end of the spectrum. Thus the lines in the sun's spectrum are shifted toward the red [*see illustration on page 154*]. To speak of this gravitational effect as a red-shift is somewhat misleading, for when light approaches a massive body, it picks up energy and the spectral lines actually shift in the opposite direction, toward the violet.

Sunlight that reaches the earth undergoes both a red-shift due to the sun's gravity and a much smaller violet-shift due to the earth's gravity. The net red-shift, amounting to about .01 angstrom unit in the wavelength of the light, is large enough to be measured with present spectroscopic techniques, but it cannot be observed unambiguously because it is masked by other shifts in the sun's spectrum. A white-dwarf star shows a much larger red-shift because its enormous density and small radius give it an intense gravitational field. But since we cannot accurately measure the radii of these stars, we have no reliable basis for computing the strength of the gravitational fields at their surfaces. As a result



PERIHELION OF MERCURY (the point on its orbit closest to the sun) rotates slowly around the sun. The rotation, observed during the 19th century, was first explained in 1916 by the general theory of relativity. The effect is minute: the arc *pp'* represents the shift over a period of 10,000 years. Broken ellipse shows the changes in the planet's orbit during the same interval.

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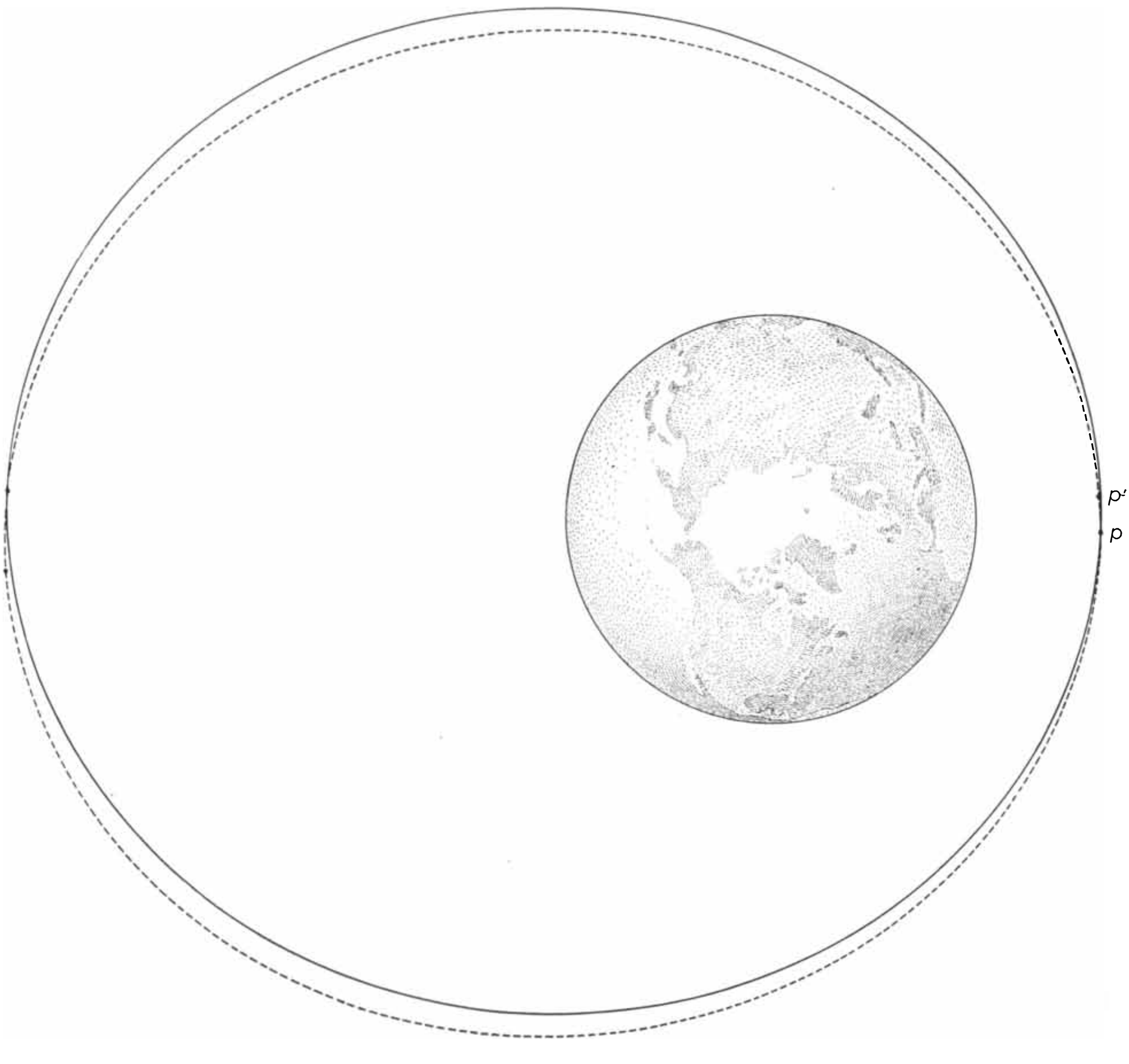
we cannot tell whether the observed shift fits the predicted values.

The third test of general relativity proposed by Einstein involves the celebrated shift of the perihelion of Mercury. This anomaly in the rotation of the sun's nearest planet had troubled classical astronomers for more than a century. General relativity shows that it arises from the motion of bodies and the finite velocity of propagation of gravity.

Newtonian theory predicts no difference between the attraction of masses at rest and in motion. It assumes, moreover, that any change in the attraction will be instantaneous. If the sun, for example, were suddenly to break in two (happily there is no reason to expect this), the earth's motion would change in the same instant. The special theory of relativity, however, asserts that no action can propagate at a velocity greater than that of light (some 186,000 miles per second). Once this basic principle was established, gravitational attraction could no longer be regarded as instantaneous. It became apparent that the classical theory of celestial mechanics corresponds only roughly to reality. Within the solar system the approximation is fairly good, since the planets move very slowly compared to the velocity of light; the earth, for example, moves along its orbit at a velocity of only 18 miles per second—a ten thousandth the speed of light. On the other hand, the divergence from observation is not inconsiderable, as is suggested by the fact that it takes light (and gravity) some eight minutes to propagate from the sun to the earth. Thus the Newtonian theory needed a generalization to bring it into agreement with special relativity. Einstein supplied that generalization



PERIGEE OF AN EARTH SATELLITE (the point on its orbit closest to the earth) should show a rotation similar to that of the perihelion of Mercury, but considerably more rapid. The arc *pp′* and the solid and broken ellipses show the shift in perigee and the change in orbit over a period of 10,000 years for a satellite whose mean distance from the center of the earth is 10,500 miles.

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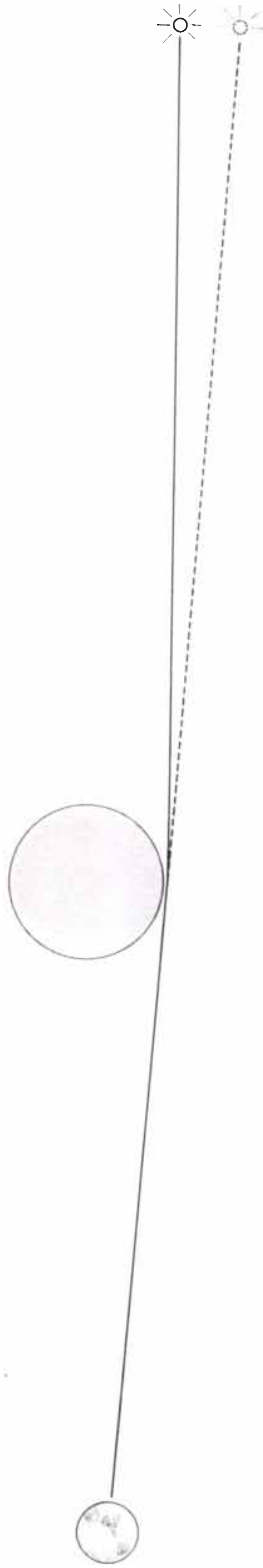

LIGHT RAYS BEND when they pass close to a massive body such as the sun. When the sun's gravitational field bends light from a star (*solid line*), the position of the star as observed from earth appears to shift (*broken line*). The drawing does not show sizes and distances in true proportion.

with the general theory of relativity, which introduces the concept of the gravitational field.

An analogy from electrodynamics may help to clarify this basic concept of general relativity. When charges are at rest or moving slowly enough, the principal forces between them are electrostatic. These forces decrease as the square of the distance between the charges, and so resemble gravity as described by Newton's law. If the charges are moving fast enough, however, the situation becomes more complicated. Moving charges generate magnetic fields, and the interaction of the fields generates new electromagnetic forces that are proportional to the velocities of the charges.

If one of the two charges changes its motion, the effect upon the other is not instantaneous but occurs after the time it takes an electromagnetic wave to travel across the distance between them. In the same way the general theory of relativity says that the gravitational force between moving masses is no longer exactly the same as that between stationary masses. As one might expect, this change leads us to look for certain changes in the motion of celestial bodies that are dependent in part upon their velocities.

According to the classical theory, a planet moves in an elliptical orbit with the sun located at one of the foci of the ellipse. According to the general theory of relativity, we may still regard the planet as moving on the classical ellipse, but we must visualize the ellipse itself as rotating slowly in its plane in the direction of the planet's motion [*see illustration on page 150*]. This effect is generally referred to as the shift of the perihelion, the point on the orbit nearest to the sun. The general theory predicts that in a single revolution of the planet around the sun the perihelion will shift through an angle that is of the order of magnitude of the ratio between the square of the planet's velocity and the square of the velocity of light. Since planets move very slowly as compared with light, this ratio is extremely small. For the earth the ratio is about one to 100 million; the predicted shift of the perihelion from one revolution to the next is correspondingly minute.

The perihelion of Mercury exhibits a much larger shift, because this planet is closest to the sun and hence moves most rapidly around it. Even for Mercury, however, calculation shows that the shift should amount to only 43 seconds of arc per century. For more distant planets it drops off rapidly, as shown in the top table on page 156. Obviously it is difficult to measure changes of this magnitude. Moreover, it is apparent that the accuracy of such measurement will depend upon the eccentricity of the orbit, for the location of the perihelion on a more elliptical orbit is more easily estab-

APPARENT CHANGES in star positions observed during the total eclipse of 1952 agree only roughly with those predicted by the general theory of relativity. Stars (*dots*) closest to the sun (*arbitrarily indicated by a cross*) show the best agreement between observed shifts (*colored arrows*) and pre-

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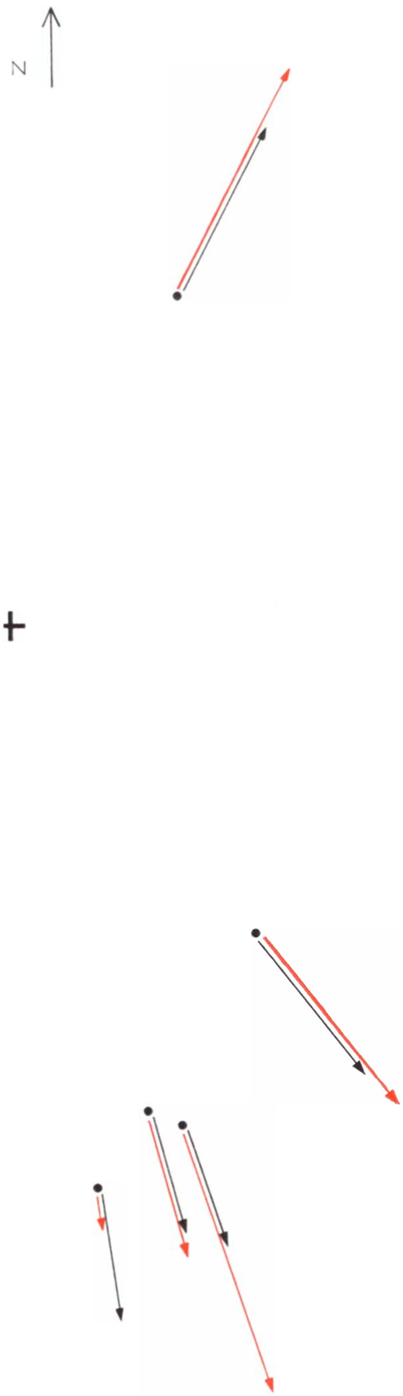
lished. By a lucky coincidence Mercury not only has the highest velocity of the planets but also has a comparatively large eccentricity of orbit. That is why it was possible for the French astronomer Urbain Jean Joseph Leverrier to observe the shift in the perihelion of Mercury a



dicted shifts (*black arrows*). For stars farther from the sun, the observed and predicted shifts may even be in opposite directions. This drawing exaggerates the shifts 900 times as compared with distances between stars. The measurements were made by George van Biesbroeck of Yerkes Observatory.

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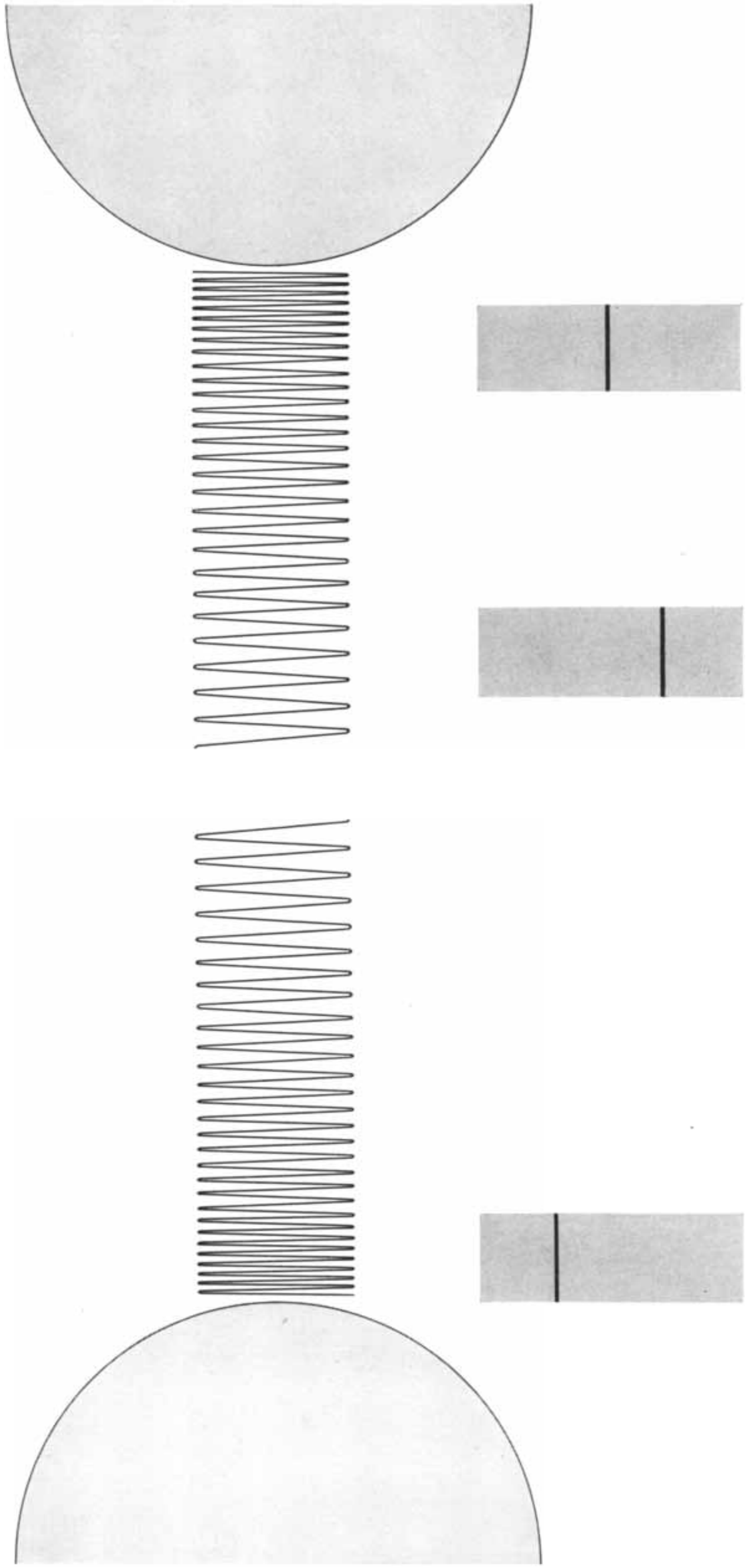

FREQUENCY OF LIGHT WAVES SHIFTS in a gravitational field. Light leaving the surface of a massive body (*top*) decreases in frequency; lines in its spectrum shift toward the red, as suggested by the two drawings at upper right. Light approaching a massive body (*bottom*) decreases in frequency; its spectral lines shift toward the violet (*lower right*).

century ago. Since the shift could not be explained by perturbations due to other planets, this observation presented a riddle until it was explained by the general theory of relativity. Modern measurements of the shift are in close agreement with the predictions of the theory. The much smaller rotation of the earth's perihelion has also been measured, but the margin of error is far too great. The shift in the orbits of other planets is too small even to be observed.

As Thirring and Lense showed, general relativity predicts a further, but much smaller, shift in the perihelion of a satellite that is induced by the rotation of the parent body. On the basis of Newtonian theory, of course, a satellite will move around a rotating sphere in exactly the same way that it moves around a stationary one. But on the basis of the general theory of relativity the forces acting on a satellite are modified by the rate at which the central body rotates upon its axis. To return to the analogy with electrical theory, a charged sphere at rest creates only an electrical field. A rotating sphere, however, creates a magnetic field as well, the strength of which depends on the speed of rotation. Such a magnetic field will subject a moving charge to a force that is proportional to the ratio between the velocity of the charge and the velocity of light. According to the general theory of relativity, an analogous gravitational force set up by the rotation of the sun should cause an additional shift in the perihelions of the planets.

Even in the case of Mercury, however, the predicted increment comes to only .01 second of arc per century. The very rapid rotation of Jupiter and Saturn should exert a much more pronounced effect on their nearer satellites, but unfortunately we cannot yet plot the motions of these satellites with sufficient accuracy to measure the effect. As for the earth's moon, it is too far away to respond significantly to the effect of the earth's rotation. The predicted shift of its orbit comes to only .06 second of arc per century; the eccentricity of its orbit is so low that even this slight shift is obscured.

In sum, we cannot rest content with the opportunities nature has afforded for testing the general theory of relativity. They have provided confirmation, but only after a fashion. Measurements of the gravitational deflection of light fit the theory with an accuracy no greater than 10 per cent; the gravitational shift in the frequency of light has been observed but not measured. The shift in

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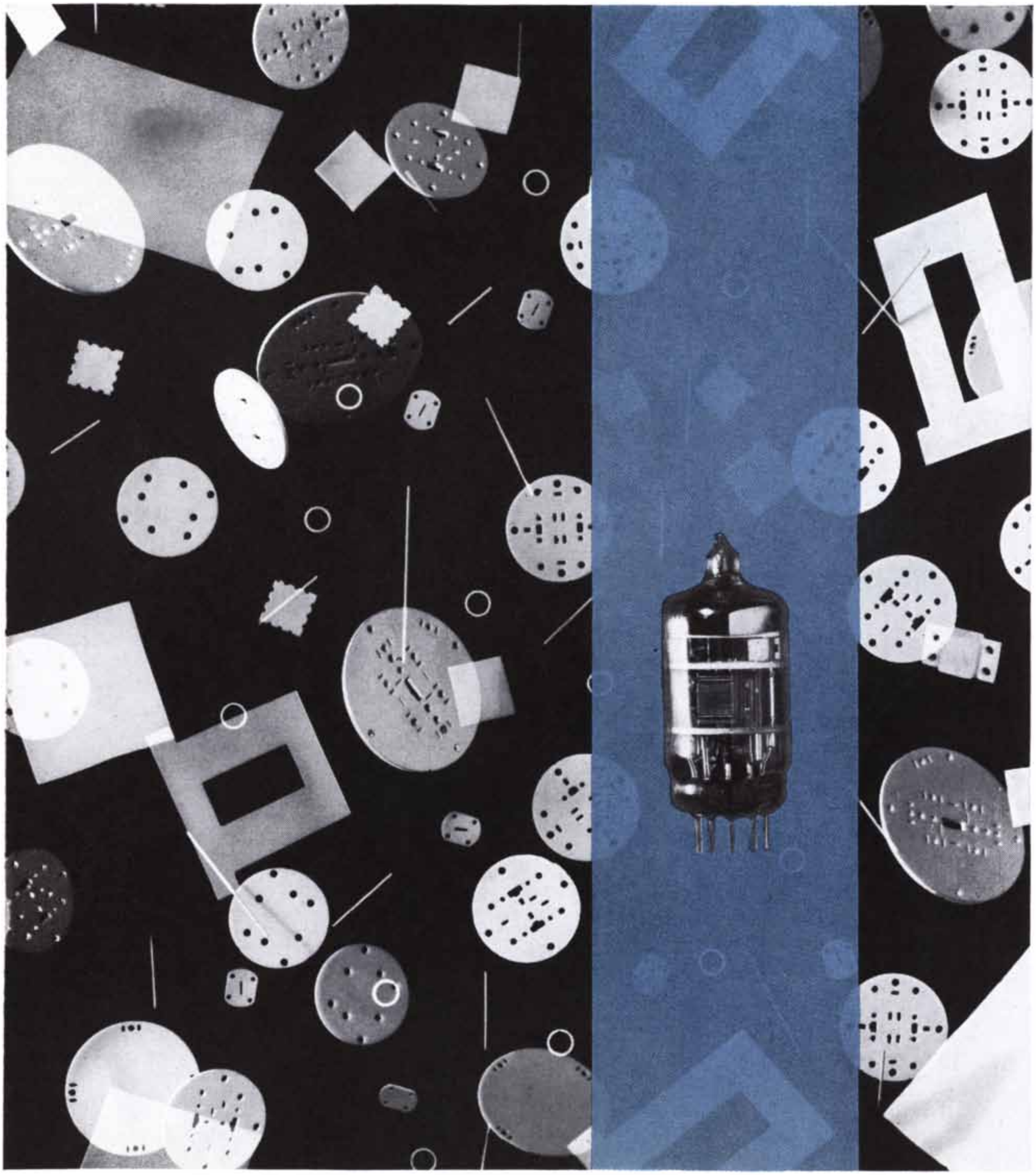

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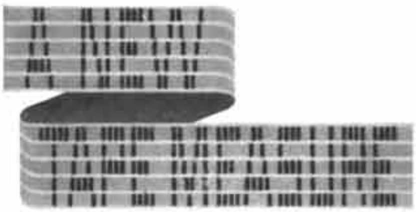

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the perihelion of the planets attributable to the velocity of their motion on their orbits has been observed, but only in the case of Mercury has it been possible to make a significant measurement. The additional perihelion shift, attributable to the sun's rotation, remains hopelessly too small to be measured or observed.

Future decades of astronomical observation will certainly give us firmer data on the motions of the planets and their satellites. More refined techniques may eventually provide accurate measurements of the gravitational deflection of light and shift of frequency. The history of science suggests, however, that rapid progress results more often from the adoption of new methods than from refinement of old ones. Artificial earth satellites offer just such a new method for verifying the general theory of relativity.

An artificial satellite moves around the earth in an elliptical orbit like that of a planet around the sun. The perigee of this orbit—the point where the satellite comes closest to the earth—should therefore rotate as does the perihelion of a planet. Since the earth's gravity is far smaller than that of the sun, even a close satellite will move more slowly in its orbit than the earth moves around the sun, and the perigee shift per revolution will be small indeed: of the order of 1 per cent of the perihelion shift of Mercury. However, if we consider the shift in a given time interval, the situation improves.

Mercury takes 88 days to circle the sun, while a satellite at not too high an altitude can travel around the earth in an hour and a half. In a century the perigee of such a satellite will shift nearly a third of a degree, 30 times the shift of the perihelion of Mercury. Moreover,

	THEORETICAL PERIHELION SHIFT (SECONDS OF ARC PER CENTURY)	ECCENTRICITY FACTOR (SECONDS OF ARC PER CENTURY)	OBSERVED PERIHELION SHIFT (SECONDS OF ARC PER CENTURY)
MERCURY	43.03	8.847	42.56 ± .94
VENUS	8.63	.059	
EARTH	3.8	.064	4.6 ± 2.7
MARS	1.35	126	
JUPITER	.06	.003	

PERIHELION SHIFT is far greater for Mercury than for any other planet, since it decreases rapidly with increasing distance from the sun. Thus for all planets but Mercury the observed values of the shift are either extremely inaccurate or nonexistent. The eccentricity factor gives a rough measure of the relative ease with which the shifts can be observed.

SATELLITE	MEAN DISTANCE (MILES)	ECCENTRICITY	PERIGEE SHIFT (SECONDS OF ARC PER CENTURY)	ECCENTRICITY FACTOR (SECONDS OF ARC PER CENTURY)
MOON	240,000	.06	.06	.0036
I	4,200	.01	1450	15
II	10,500	06	146	9
III	10,500	.40	195	78
IV	4,500	.02	1250	25
V	6,200	.25	587	147

PERIGEE SHIFT is immeasurably small for the moon but large for satellites orbiting close to the earth. Shown here are calculated shifts for five hypothetical satellites with orbits of varying distances and eccentricities. Mean distance refers to distance from the center of the earth; thus Satellite I would circle the earth about 200 miles above the surface.

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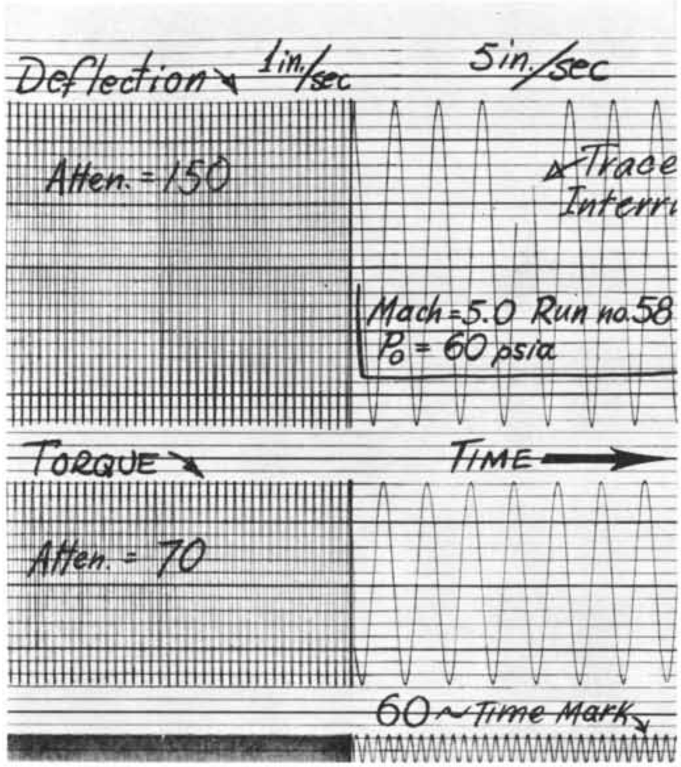

In science . . .

This "diary" of an airframe in wind-tunnel flight is an instantly-readable record taken on a Model 906A Visicorder by ARO, Inc., at the USAF Arnold Engineering Development Center, Tullahoma, Tennessee, the ARDC wind tunnel facility. This record measures damping-in-pitch derivatives for a clipped-delta-wing-body configuration over a Mach number range of 2.0 to 5.0 so that these measurements could be compared with Mach number trend predicted by theory. The values discovered through this experiment showed discrepancies from theoretical values because the theory pertained to simpler bodies than that used in the tests. The new set of Visicorder data will result in more accurate predictions for future design.

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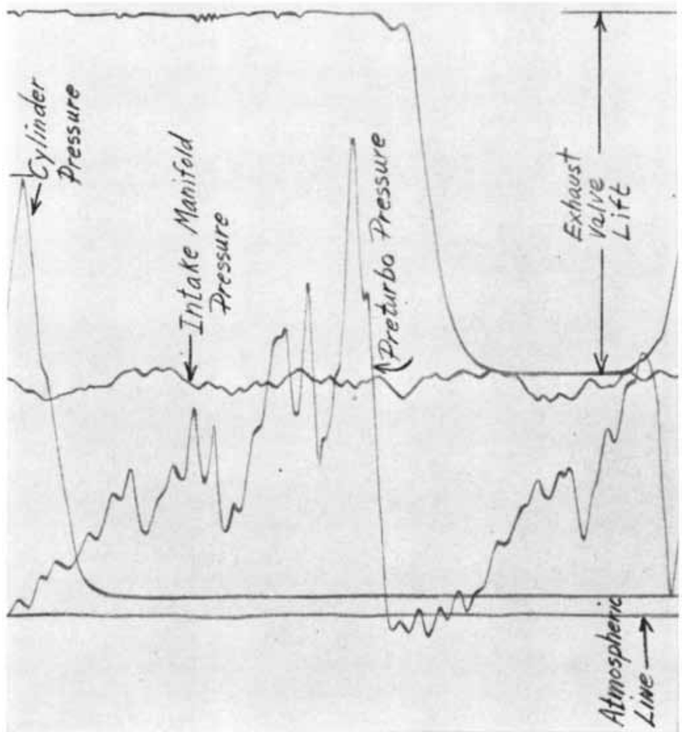

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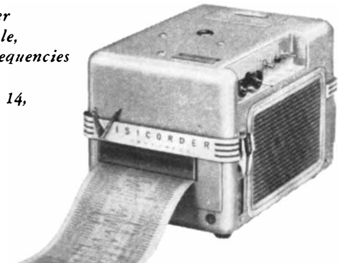

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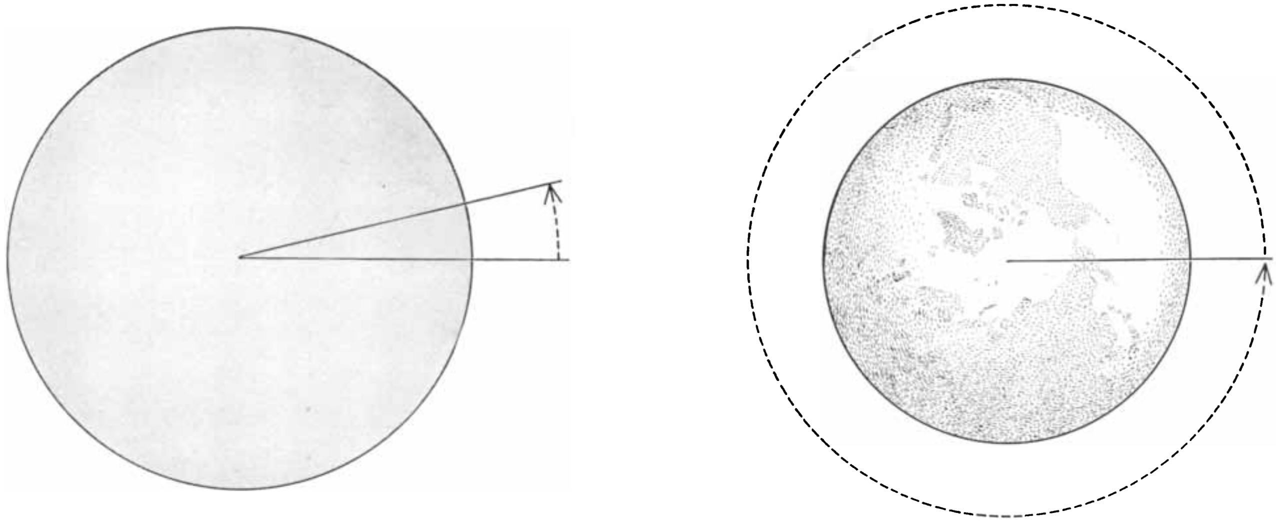

ROTATION OF CELESTIAL BODIES produces a small additional relativity effect on the motions of their satellites. Broken arcs show the 24-hour rotation of the sun (*left*) and earth (*right*). The rapid rotation of the earth might make this relativity effect large enough to be measurable for close satellites. The sun rotates too slowly and its planets are far too distant for the effect to be observable.

the orbit of the satellite can be given much higher eccentricity than that of Mercury; this makes it possible to locate the perigee with much greater accuracy and even has the effect of increasing the shift of the perigee very slightly. Finally, the displacement of the perigee can be measured with greater precision because the satellite can be tracked by radio as well as by optical instruments. From the standpoint of accuracy, a year's observation of a satellite may perhaps equal a century's observation of Mercury.

On the other hand, the interpretation of such observations is a great deal more complicated for a satellite than for a planet. Orbits of both types are subject to many perturbations, some of them much greater than the shifts due to general relativity. For Mercury it is comparatively easy to sort out these other perturbations, because the masses and motions of the other members of the solar system that cause them are well known. The moon similarly perturbs the orbit of an artificial satellite of the earth; this correction is easily made because the data for the moon are well established. But the orbit of the satellite is also perturbed by irregularities in the earth's shape and density, and the speed of the satellite is slowed by the earth's atmosphere, even at altitudes of several hundred miles. We still know relatively little about the magnitude of these factors; much of what we do know has come from observation of the few satellites so far launched. How soon we will develop the necessary data and how much effort it will take to isolate and measure the relativistic effect remains unclear. Yet the possibility does exist.

With artificial satellites it should also be possible to perform the experiment which Einstein momentarily envisioned 40 years ago for a moon in orbit just outside the earth's atmosphere, that is, to measure the additional perigee shift due to the earth's rotation. The effect of the sun's rotation on the motion of the planets is too small to be observed. On the other hand, the earth, with a much higher rate of rotation, has an angular velocity 25 times greater than that of the sun. As a result of this and of the nearness of the artificial satellites we can look for a rotation effect upon their orbits 5,000 times greater in magnitude. For close satellites the effect may amount to 50 seconds of arc per century, as great as the total relativistic effect for Mercury.

Satellites may also help us to obtain precise measurements of the gravitational frequency shift. Light emitted from a satellite will increase in frequency (that is, will shift toward the violet) as it "falls" toward the earth, because it will gain energy from the acceleration of gravity. The farther it falls, the greater the effect. This experiment will therefore require a satellite orbiting at a maximum rather than a minimum distance from the earth. Because the earth's gravitational field is so much weaker than the sun's, the violet-shift will amount to only .03 per cent of the analogous red-shift in the sun's light. Since we cannot now measure so minute a shift in light waves, the prospect seems uninviting. But radio waves also undergo a gravitational frequency shift, and they may provide a way to test this effect. Atomic or molecular frequency-stabilizers give us just enough precision to measure the shift, which should amount to as much as seven ten-billionths (7×10^{-10}) of a given wavelength in the case of a sufficiently distant satellite.

Alternatively we can place an atomic clock in our satellite. Due to the violet-shift such a clock will appear to run fast in comparison with an identical clock on earth. For a very distant satellite the difference in clock readings would be only .02 second per year. But this tiny measurement can be made with entirely satisfactory precision.

For closer satellites the gravitational frequency shift decreases and becomes masked by other frequency shifts due to the satellite's motion. The chief offender is the ordinary Doppler effect, which raises or lowers the frequency according to whether the satellite is moving toward or away from the receiver. To get rid of this effect, measurements can be made when the satellite's course is perpendicular to the line of observation, so that the satellite is neither approaching nor receding. However, the satellite's high velocity also produces a second-order Doppler effect predicted by the special theory of relativity. This effect involves the slowing-down of a moving clock compared to one at rest; it is the basis of the "clock paradox" which promises to keep high-velocity space travelers younger than the contemporaries they leave behind on earth. There is no need to go to the trouble of instrumenting a satellite to test this prediction. It is al-

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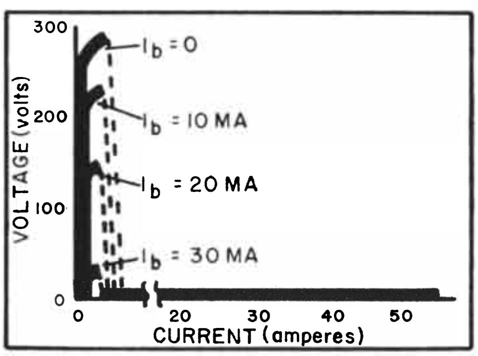

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Westinghouse Electric Corp., Semiconductor Department, Youngwood, Pa.

ready confirmed by solid experimental evidence; fast mesons, for example, "live" longer before decaying than do mesons at rest.

The slowing of the clock aboard the satellite must be allowed for, however, in connection with the effects predicted by general relativity. Since clocks run slower as velocity increases, and since satellite velocity increases with closeness to the earth, the effect of the clock paradox runs exactly counter to the gravitational frequency shift, which increases with distance from the earth. At an altitude of about 2,000 miles the two effects cancel out: the satellite clock will keep perfect time with the earth clock. Satellite clocks at lower altitudes will run slower than the earth clock; for the very closest satellites the difference will be about .01 second per year.

At present we can measure time accurately enough to sort out these conflicting effects, but only with the aid of equipment that is both delicate and bulky. The construction of precise atomic clocks that are small enough to fit into a satellite and sturdy enough to withstand the stresses of launching will obviously pose difficult design and engineering problems. Admittedly it may prove easier to measure the gravitational frequency shift by means of instruments resting on the solid earth. The signal from a transmitter placed on a mountain three miles above the observing station will show a frequency shift of about 1 per cent of that observable with a close satellite. As yet there is no apparatus that can measure such minute frequency differences. But the instruments needed for the satellite experiment have not yet been made either. It is hard to say which experiment will be performed first.

The minuteness of all of the effects involved in the experimental verification of general relativity may perhaps cast doubt upon the importance of the theory itself and upon the value of the effort required to verify it. I should like to emphasize, therefore, that the value of the theory can in no way be "measured" by the magnitude of any effects, especially those that can be observed within the confines of our solar system. It takes light but eight minutes to reach us from the sun. But the world's largest telescope on Palomar Mountain can be used to observe galaxies whose light takes billions of years to reach the earth. The minuteness of the general relativity effects within our tiny solar system should never lead us to regard the theory as trivial in the study of the universe.

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THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

NEW! A MIRROR THAT MAKES HEAT TO BEAT SLEET

You're jockeying a big trailer-truck along a winding road in New England. It's winter and you run into a real storm—a mixture of snow, rain, sleet. You flip a switch and . . .

Your outside rear-view mirror is *clear* in a matter of minutes. From a heavy coating of ice to *all* clear is only a matter of five minutes, even at −20°F.

The mirror, as you might guess, isn't just ordinary glass. It's one of Corning's PYREX brand glasses, and on its surface is an electrically conductive coating that's permanently fired in.

This coating (a metallic oxide) is what turns your mirror into a *heating* element when a current is applied. The heat melts ice and snow, prevents fog or drizzle from condensing on the surface.

If you use EC (electrical-conducting) glass for self-defrosting mirrors you get a bonus, since the coating also provides a non-glare surface.

But don't go away just because you gave up dreaming about driving a truck-and-trailer years ago. This PYREX® electrical-conducting glass comes in a wide choice of applications.

For example, there are some enterprising people who build radiant heaters, both portable and permanent, around such glass panels.

Comfort, safety, and convenience are the big selling points. Comfort because a panel of EC glass is an area *heat* source putting out long waves. Safety because there are no exposed wires or moving parts. Convenience since you have no burning, no need to do extensive remodeling in order to install it.

These same reasons have made PYREX brand radiant heating units attractive to industry—for heating, drying, curing, baking.

And, if you turn a panel of this glass *around*, it becomes an infrared reflector you can see through—blocking heat but still passing about 75% of the visible light.

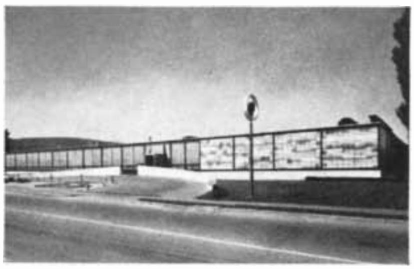
Facts? Ask for PE-34, a 4-page data sheet, and/or PE-60, all about industrial heating units. Please use the coupon.

YOU ARE CORDIALLY INVITED

. . . to visit the Corning Glass Center located in Corning, in the rolling hills just south of New York State's Finger Lakes region. The Center is dedicated to the history, science, art, and industry of glassmaking.

Among the Center's most-visited attractions are the Corning Museum of Glass and the Hall of Science and Industry.

At the Museum you'll find a comprehensive and renowned collection of glass *objets d'art*. You will find vases and other glass forms produced by by-gone civilizations. And you will see the ways in which today's craftsmen, around the world, use glass in varied art forms.



The Hall of Science and Industry is filled with exhibits and devoted to the roles glass plays in industry, business, and science. Many exhibits contain full-scale working models and demonstrations.

And, there's also a library devoted exclusively to books and other reference materials on glass.

It all awaits you. So come to the Glass Center. You'll find it stimulating and rewarding. Bring the family, too. You'll all enjoy the trip.

Open daily except Mondays from 9:30 to 5.

If you'd like a few more facts, send for a free folder. But plan to come soon.

HOW TO GET A RECTANGULAR BEAM FROM A ROUND LENS

This is no ordinary floodlight lens. It produces, despite its circular shape, a rectangular beam.

Why? Because a large oil company asked Crouse-Hinds of Syracuse, N. Y., to provide a floodlight to illuminate rectangular signs, 4′ x 8′. Besides being rectangular, the request called for lighting that had no "hot spot" which might make the sign unreadable.

So Crouse-Hinds turned to Corning. And through the talents of one of our product engineers, we designed a *round* lens that puts out a rectangular beam.

Unusual? Yes, but typical of the special problems we handle almost daily (we once made a lens producing a square beam for the same people).

Moral: Whatever your interest—be it lighting, corrosion, high temperatures, precision shaping, or what have you—maybe we already make what you need from glass.

As a start, take a look through "This Is Glass." (To get a copy, check the coupon.)

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Please send me: ☐ PE-34, 4-page data sheet on glasses for industrial use; ☐ PE-60, booklet on heating units; ☐ Brochure on the Glass Center; ☐ "This Is Glass"

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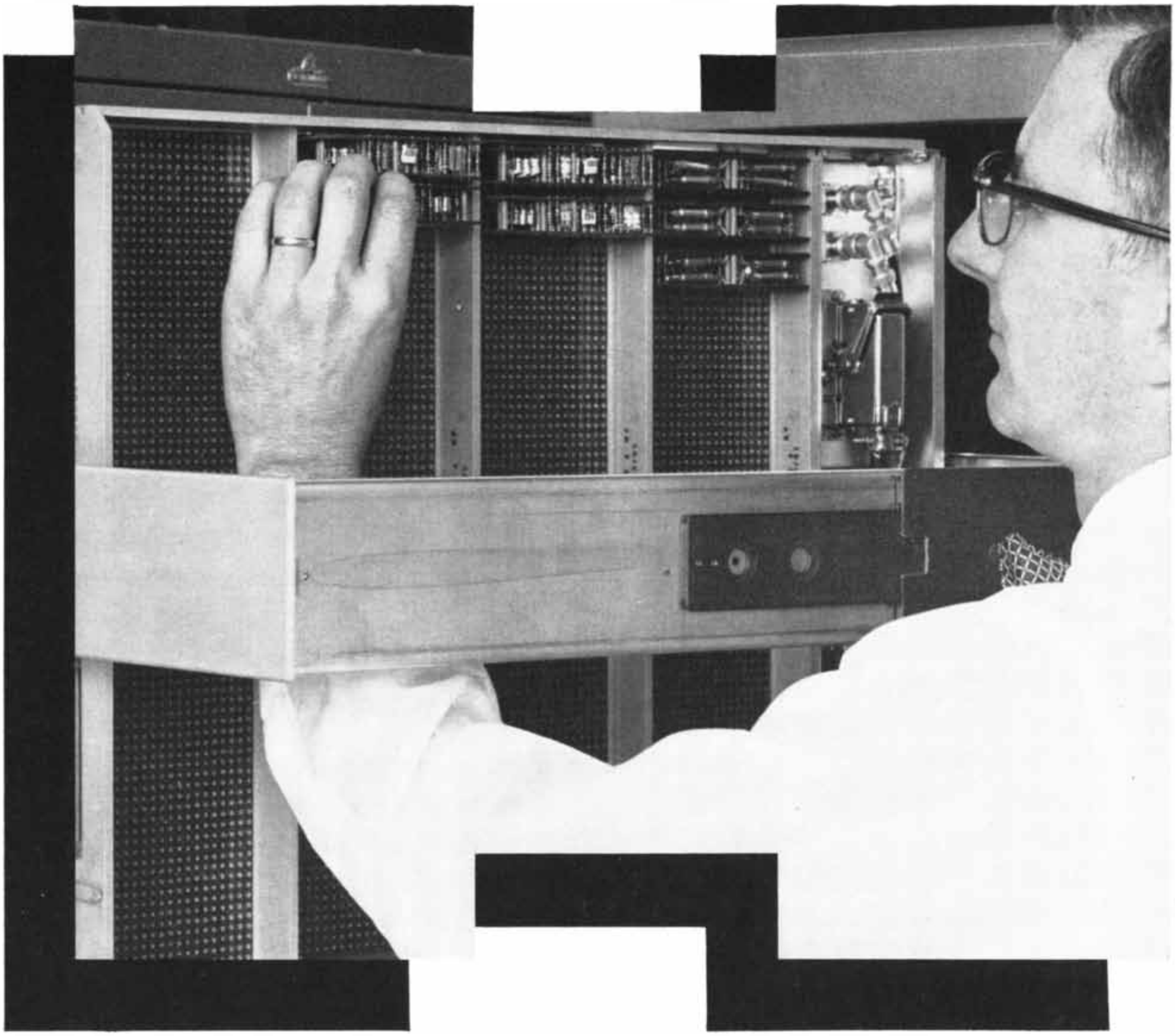
Packing circuits to circle



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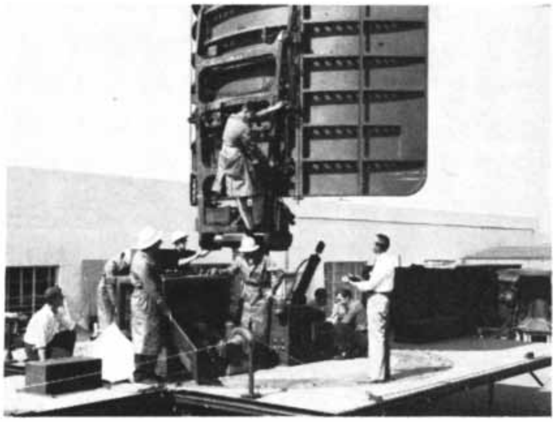
the world



New Electronic Scanning radar antenna—Frescanar—developed by Hughes at Fullerton, positions beams in space by electronic rather than mechanical means.

Purity Plus—Hughes Products Division engineer checks semiconductor materials to insure purity.

"Project Cordwood" is a new Hughes Communications project which has produced low-cost, widely interchangeable circuit modules *(see photo on left-hand page)*. Other projects under way at the Hughes Communications Division involve the development of systems which deflect their signals from meteors and artificial satellites. Allied to this is the Hughes adoption of the wire-wrapping technique to obtain compact, reliable and automatically applied wiring.

Because of the dynamic growth in communications, Hughes has established a separate, major Communications Division. Already, work has extended past the *transfer* of information to the *use* of information to supplement man's abilities where human resources are inadequate.

From the discovery of basic scientific knowledge through the creation of working hardware, the systems approach is typical of Hughes activities . . . in Airborne Electronics Systems, Space Vehicles, Plastics, Nuclear Electronics, Microwaves, Ballistic Missiles and many others.

This atmosphere offers creative engineers and scientists the widest possible scope of opportunity for personal and professional growth.

Similar opportunities are open at Hughes Products, where Hughes developments are translated into commercial products —semiconductors, specialized electron tubes, and industrial systems and controls.

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Field Engineering	Systems Analysis
Industrial Dynamics	Technical Writing
Digital Computer Eng.	Electron Tubes
Microwave Engineering	Industrial Systems

Write in confidence, to Mr. Tom Stewart, Hughes General Offices, Bldg. 6-H5, Culver City, California.

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MATHEMATICAL GAMES

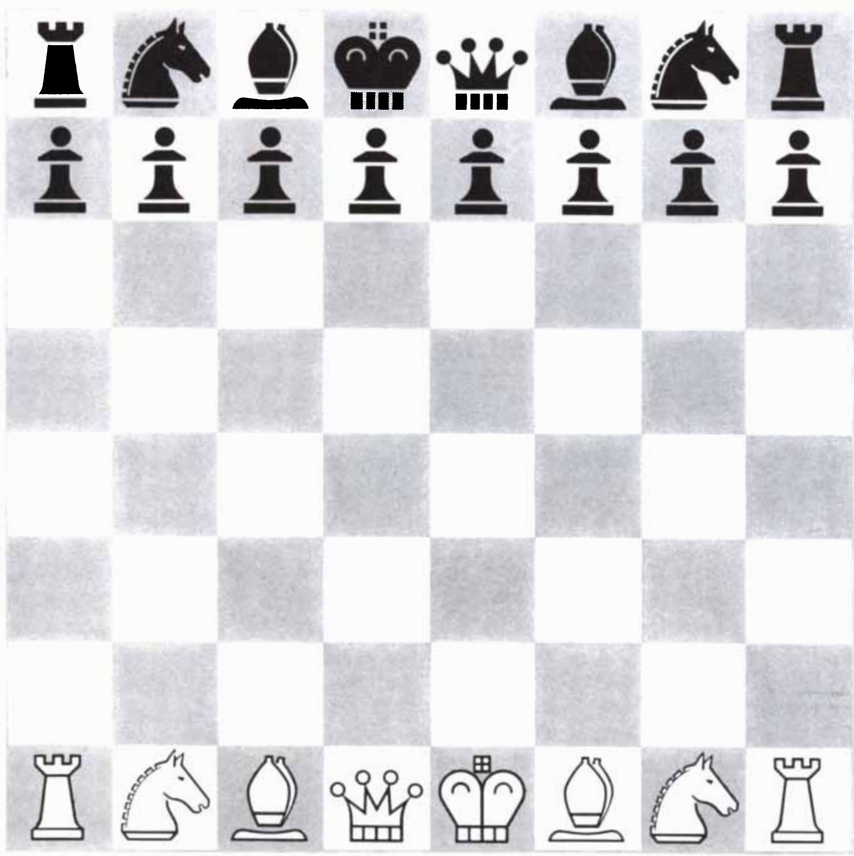
Another collection of "brain-teasers"

by Martin Gardner

It has been the custom of this department to present a varied collection of short problems once every eight months or so. This is the fourth such collection. Because the answers to the problems, published a month after the problems themselves, go to press at about the same time that the problems appear, it is not possible to take full advantage of corrections, comments and elegant solutions sent in by readers. This may be regrettable in connection with this month's first problem, for which, so far as I know, no general procedure has yet been proved to yield optimum answers. If any readers hit upon a better solution than the one to be explained next month, the problem will be discussed again at the first convenient opportunity.

1.

An unlimited supply of gasoline is available at one edge of a desert 800 miles wide, but there is no source on the desert itself. A truck can carry enough gasoline to go 500 miles (this will be called one "load"), and it can build up its own refueling stations at any spot along the way. These caches may be of any size, and it is assumed that there is no evaporation loss. What is the min-



Lord Dunsany's chess problem

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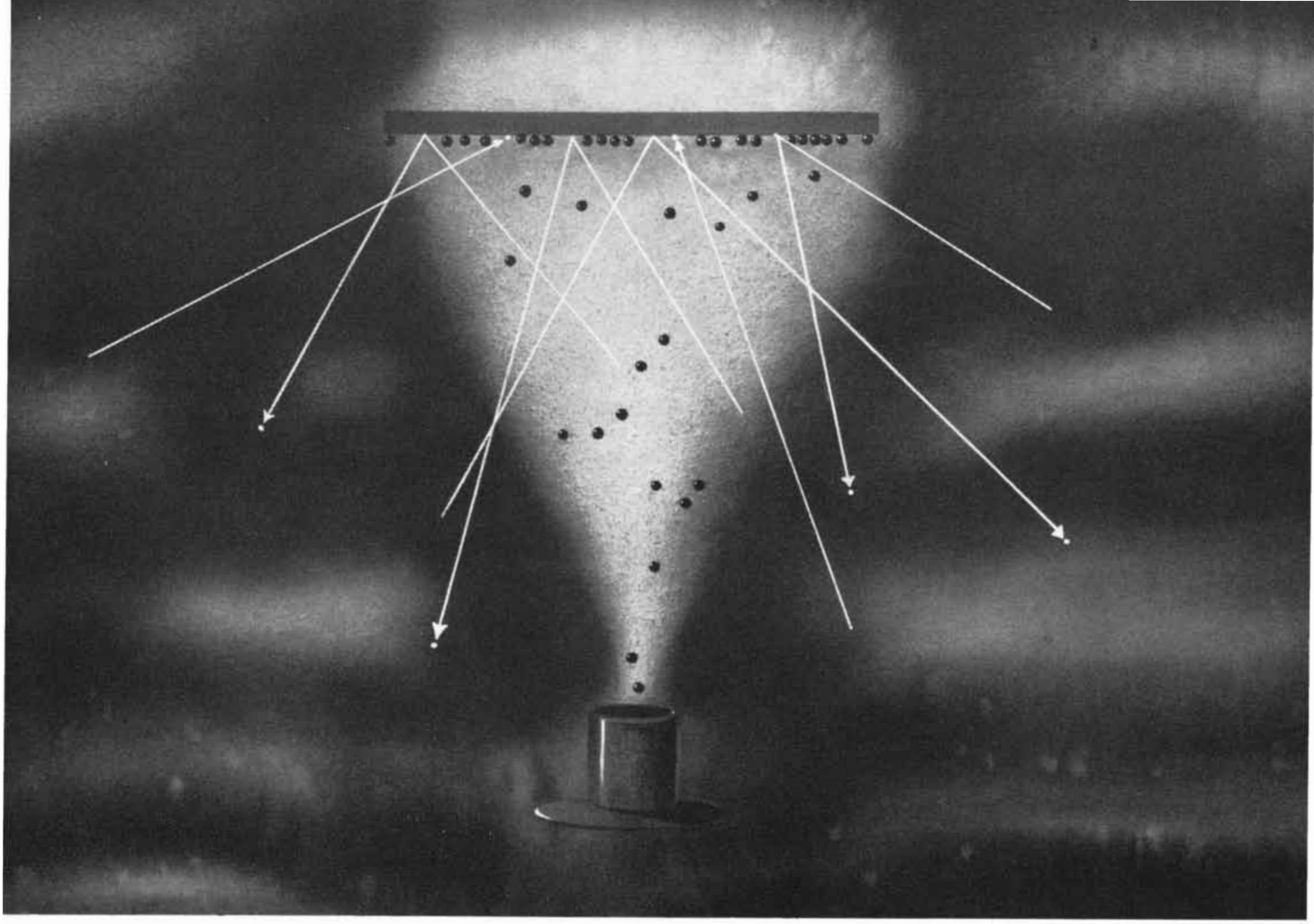

Report from IBM Yorktown Research Center, New York

ULTRA-HIGH VACUUM AND THIN METALLIC FILMS

The superconducting properties of a metallic film are significantly affected by its purity. A group of scientists and engineers at the IBM Yorktown Research Center is studying problems involved in producing superconducting thin films by vacuum deposition techniques. The immediate objective is to produce thin films with superconducting characteristics equivalent to those of pure bulk material.

In conventional vacuum metalizing, a chamber is evacuated to a pressure of 10^{-6} mm. Hg, the metal is heated to vaporization temperature, and a thin metallic film is condensed on a substrate. During this process, gas molecules remaining in the chamber contaminate the film. For example, if the deposition rate were such that the thickness increased by 100Å per second, the gas impurity in the resulting film could be as much as one atom for every 75 metal atoms.

One way to decrease this contamination is to work in a higher vacuum. Newly developed techniques, using an all-metal ultra-high vacuum system, permit the use of working pressures as low as 10^{-10} mm. Hg, thus decreasing the amount of gas present in the film by a factor of 10,000.

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imum amount (in loads) of gasoline the truck will require in order to cross the desert? Is there a limit to the width of a desert the truck can cross?

2.

Mr. Smith has two children. At least one of them is a boy. What is the probability that the other child is a boy? Mr. Jones has two children. The older is a girl. What is the probability that the other child is a girl?

3.

Admirers of the Irish writer Lord Dunsany do not need to be told that he was fond of chess. (Surely his story "The Three Sailors' Gambit" is the funniest chess fantasy ever written.) Not generally known is the fact that he liked to invent bizarre chess problems which, like his fiction, combined humor and fantasy. The problem depicted at the bottom of page 164 was contributed by Dunsany to *The Week-End Problems Book*, compiled by Hubert Phillips. Its solution calls more for logical thought than skill at chess, although one does have to know the rules of the game. White is to play and mate in four moves. It is assumed that the position is one that could occur in actual play.

4.

When Professor Stanislaw Slapenarski, the Polish mathematician, walked down the down-moving escalator, he reached the bottom after taking 50 steps. As an experiment, he then ran up the same escalator, one step at a time, reaching the top after taking 125 steps. Assuming that the professor went up five times as fast as he went down (that is, took five steps to every one step before), and that he made each trip at a constant speed, how many steps would be visible if the escalator stopped running?

5.

The most popular problem ever published in *The American Mathematical Monthly*, its editors recently disclosed, is the following. It was contributed by P. L. Chessin of the Westinghouse Electric Corporation to the April, 1954, issue.

"Our good friend and eminent numerologist, Professor Euclide Paracelso Bombasto Umbugio, has been busily engaged in testing on his desk calculator the 81×10^9 possible solutions to the problem of reconstructing the following exact long division in which the digits

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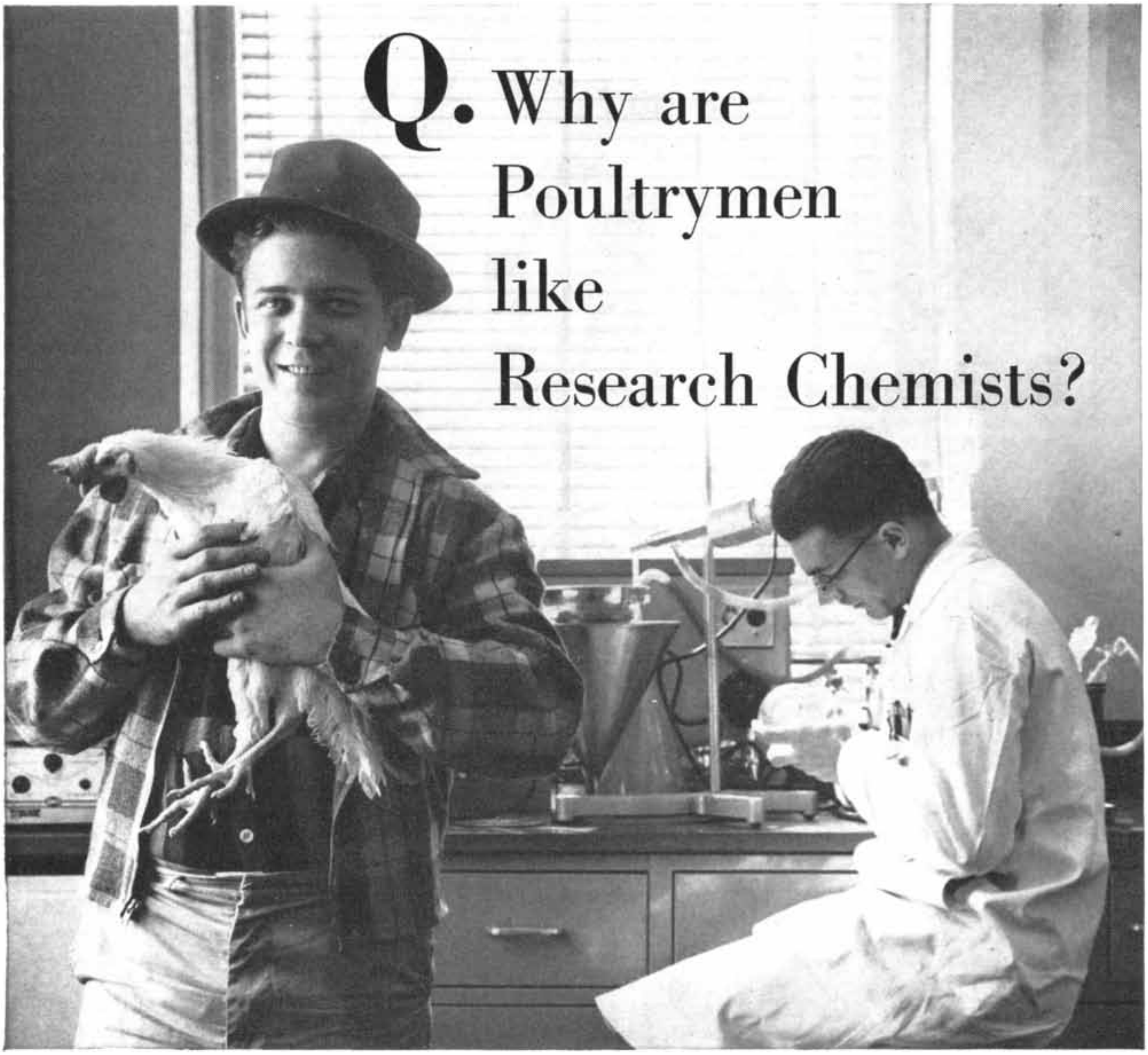

A. ***The tools of progress in both fields are forged from products developed and produced by Merck.***

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Too, poultrymen are sending a higher percentage of each flock to market. Products of Merck research—resulting in therapeutic feed supplements and medications that control many previously rampant poultry diseases—have, in a large measure, contributed to this result.

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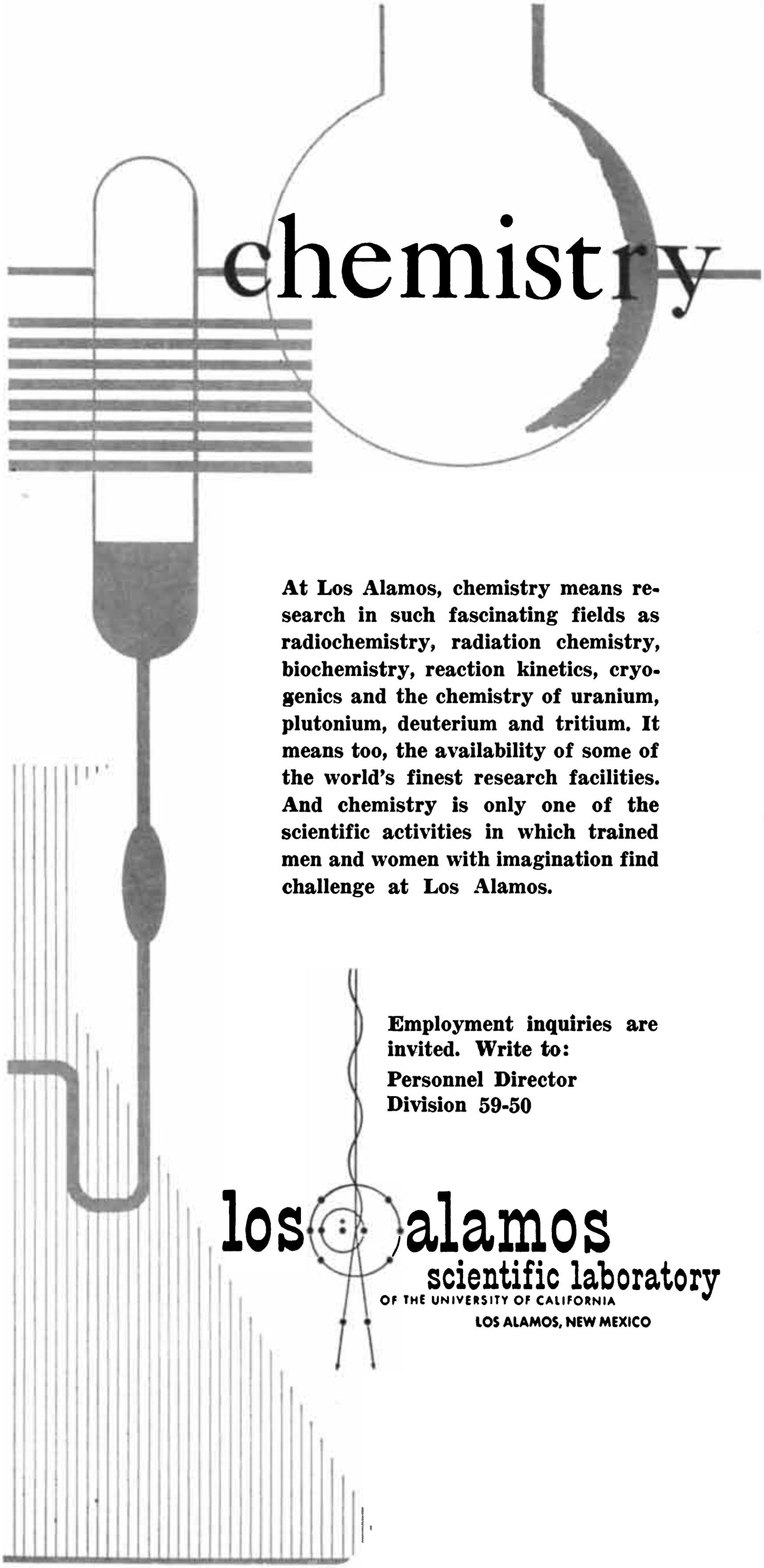
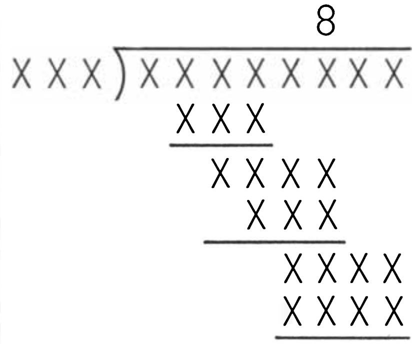


were indiscriminately replaced by *x* save in the quotient where they were almost entirely omitted:



"Deflate the Professor! That is, reduce the possibilities to $(81 \times 10^9)^0$."

Because any number raised to the power of zero is one, the reader's task is to discover the unique reconstruction of the problem. It is easier than it looks, yielding readily to a few elementary insights.

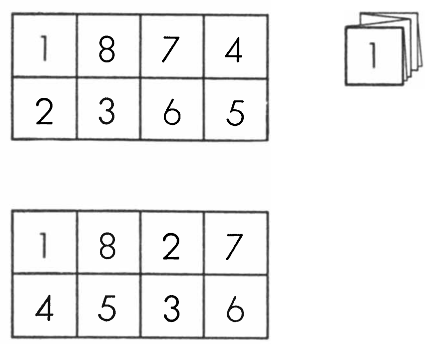
6.

There is a simple procedure by which two people can divide a cake so that each is satisfied he has at least half: One cuts and the other chooses. Devise a general procedure so that n persons can cut a cake into n portions in such a way that everyone is satisfied he has at least $1/n$ of the cake.

7.

Mathematicians have not yet succeeded in finding a formula for the number of different ways a road map can be folded, given n creases in the paper. Some notion of the complexity of this question can be gained from the following puzzle invented by the British puzzle expert Henry Ernest Dudeney.

Divide a rectangular sheet of paper into eight squares and number them on one side only, as shown at top left in the illustration below. There are 40 different



Dudeney's map-folding puzzle

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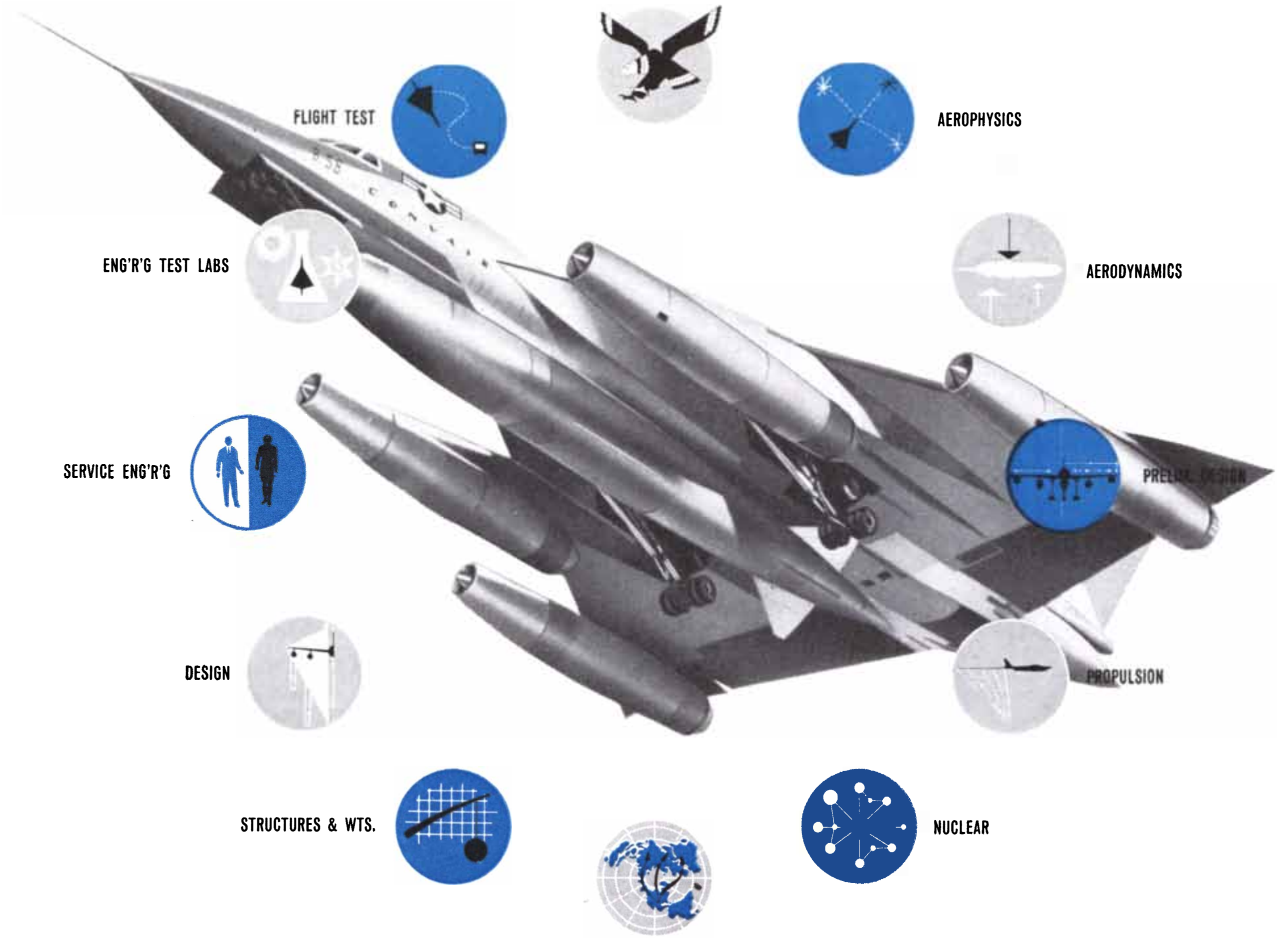
"Best individual effort...



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ways that this "map" can be folded along the ruled lines to form a square packet which has the "1" square face-up on top and all other squares beneath. The problem is to fold this sheet so that the squares are in serial order from 1 to 8, with the 1 face-up on top. If you succeed in doing this, try the much more difficult task of doing the same thing with the sheet numbered in the manner pictured at the bottom of the illustration.

8.

An absent-minded bank teller switched the dollars and cents when he cashed a check for Mr. Brown, giving him dollars instead of cents, and cents instead of dollars. After buying a five-cent newspaper, Brown discovered that he had left exactly twice as much as his original check. What was the amount of the check?

9.

A familiar chestnut concerns two beakers, one containing water; the other, wine. A certain amount of water is transferred to the wine, then the same amount of the mixture is transferred back to the water. Is there now more water in the wine than there is wine in the water? The answer is that the two quantities are the same. Raymond Smullyan writes to raise the further question: Assume that at the outset one beaker holds 10 ounces of water and the other holds 10 ounces of wine. By transferring three ounces back and forth any number of times, stirring after each transfer, is it possible to reach a point at which the percentage of wine in each mixture is the same?

The answer to last month's problem about the carnival dice game is that a player can expect to win $8.64 for every $10 that he loses. There are 216 equally probable ways three dice can fall, of which 91 are wins for the player. His chances of winning, therefore, are 91/216. Assume that he bets $1 each time. On 75 of his wins his number appears only once, giving him a profit of $75. On 15 wins the number shows twice, earning him $30. All three dice will show the number on one of his wins, earning him $3. His total winnings will then be $108 as against a total loss of $125, or $8.64 for every $10 loss. Last month's question of how many different pieces can be achieved by cutting a doughnut with three planes will be answered next month, together with the answers to this month's problems.

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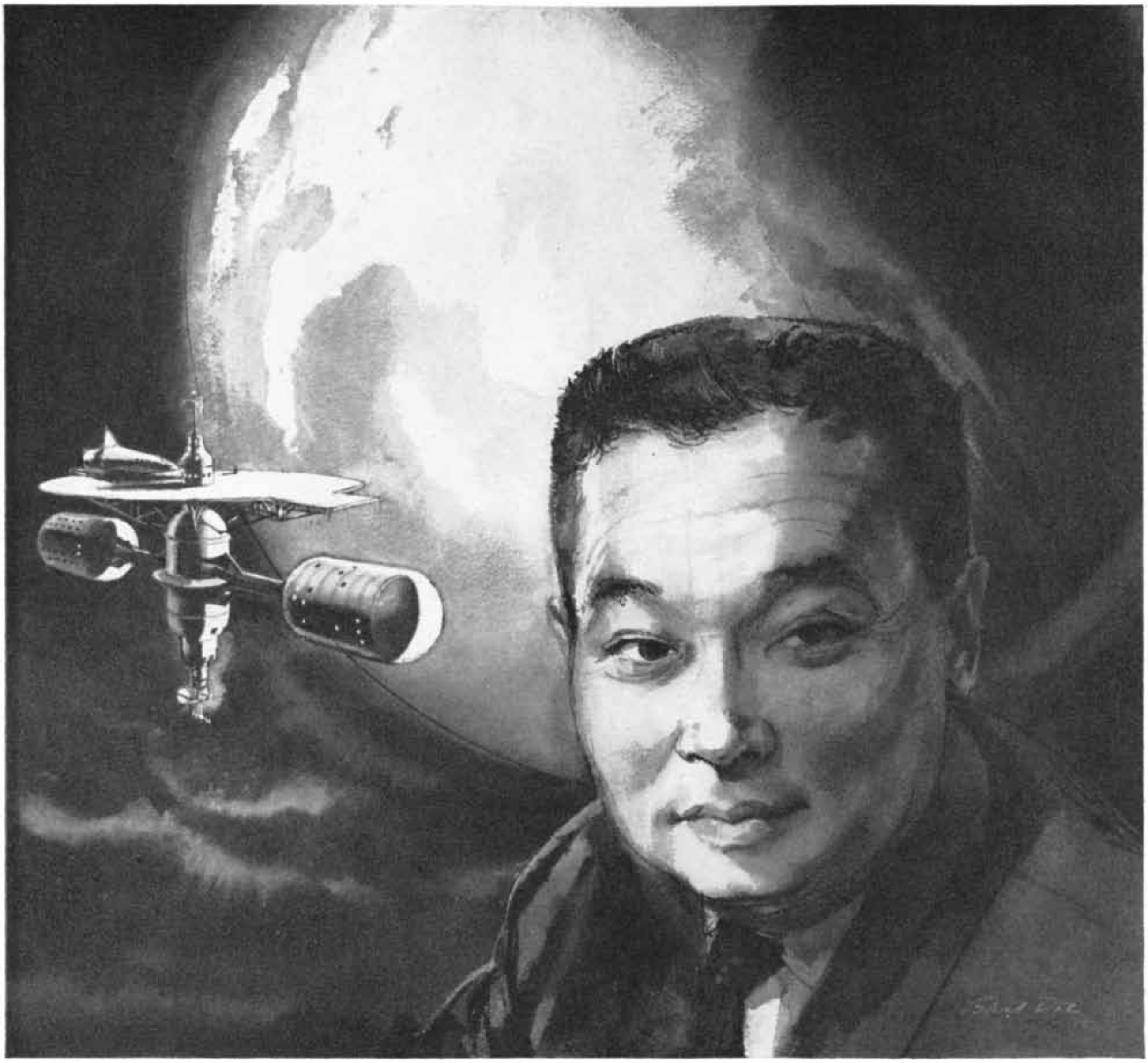

Y.C. Lee

His full name is Yuan Chu'en Lee, but to most of us at Aerojet, he's known as "Y.C." As Director of Corporate Research, Y.C. is in charge of our astronautical, other-planetary endeavors.

Y.C. and his associates are grappling with the knottier questions of space technology and advanced propulsion. They're studying advanced magnetohydrodynamics, extraterrestrial physics, and relativistic problems. They're looking for new fuels based on ions, gaseous free radicals, and nuclear plasmas.

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TECHNOLOGY

MAGNETOHYDRODYNAMICS: Lockheed's 3rd Annual Symposium* on this important new field—which deals with the behavior of conducting fluids in magnetic fields—attracted physicists from all over the world. As portrayed by the artist, man's earliest experiments with magnetic forces involved the use of the ancient lodestone. Solar prominences are a dramatic example of such forces under investigation today.

Lockheed Missiles and Space Division has complete capabilities in more than 40 areas of science and technology—from concept to operation. Headquarters are at Sunnyvale, California, on the San Francisco Peninsula, with research and development facilities located in the Stanford Industrial Park in nearby Palo Alto and at Van Nuys in the San Fernando Valley of Los Angeles. A 4,000 acre, company-owned test base, 40 miles from Sunnyvale, conducts all phases of static field testing. In addition, complete flight testing is conducted at Cape Canaveral, Fla., Alamogordo, N.M., and Vandenberg AFB, Calif. as an integral part of every stage of missile and space programs at Lockheed.

The Division's advanced research and development programs now under intensive study provide a fascinating challenge to creative engineering. These programs include: man in space; space communications; electronics; ionic, nuclear and solar propulsion; magnetohydrodynamics; oceanography; computer research and development; operations research and analysis; human engineering; electromagnetic wave propagation and radiation; materials and processes and others.

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*Copies of the proceedings of the first two symposiums were published by the Stanford University Press, Palo Alto, Calif. and are available in book form. Results of this year's symposium will be published shortly by the same house.

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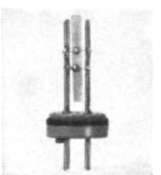
Pilot Production of Grown Quartz Crystals Achieved at Western Electric

Quartz crystal units are manufactured by Western Electric for use by the Bell System in almost all long distance communication systems. Quartz is noted for its piezoelectric characteristic: when an electrical impulse is applied, there is a resulting mechanical motion. Moreover, a plate cut from quartz crystal will oscillate at one specific frequency, which can be made a few cycles per second or up to millions of cycles per second, by precisely controlling physical dimensions of the plate.

The piezoelectric characteristic of quartz is utilized by the Bell System in filters, oscillators and other devices. Thousands of quartz crystal units, each designed to respond to a specific frequency, are used as a means of separating the individual conversations from the multi-message signals transmitted over the same telephone channel.



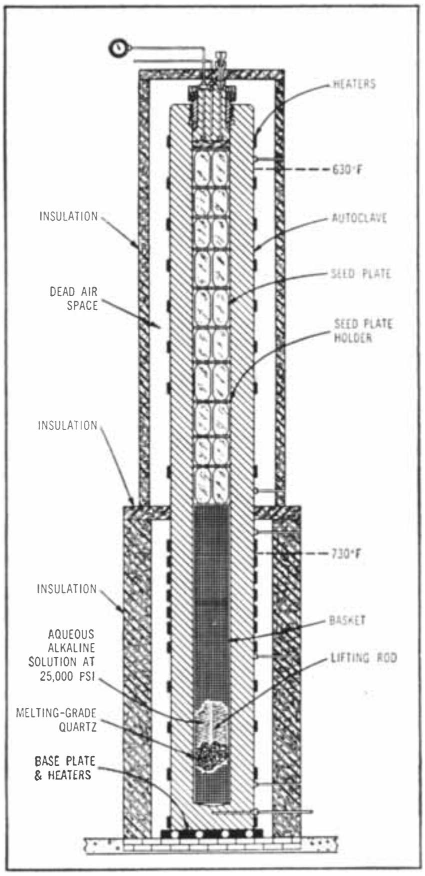
Crystal unit (without cover).

Deposits of quartz crystals are found in many parts of the world and are probably the result of natural processes over a period of centuries which may no longer be operating. Natural quartz crystals of suitable size and quality for telephone use are from a foreign source of supply which has become somewhat unstable and costly.

Man-Made Quartz

The instability of this foreign supply, especially in time of national emergency, and the increasing cost of high quality natural crystals accentuated the need for a domestic source. Realizing this, our research colleagues at Bell Telephone Laboratories started experimental work on synthetic quartz in 1946, culminating in a hydrothermal laboratory process in which crystals were "grown" successfully from thin quartz "seed" plates.

Basically, the hydrothermal process for growing quartz consists of placing small pieces of melting-grade quartz in the bottom of a long, narrow cylindrical vessel capable of withstanding high



Simplified schematic drawing of pressure assembly vessel.

pressures. Thin sections of perfectly formed quartz crystals are suspended in the upper or growing section of the vessel. The vessel is then partially filled with a solution of sodium hydroxide and sealed. Heat is applied to the vessel, and by careful control, a calculated temperature differential is maintained between the bottom and top or growing zone. The melting-grade quartz is dissolved in the bottom of the vessel and transported by convection currents to the growing zone. There, the quartz is crystallized out on the seed plates because the saturated solution, when cooled to lower temperature, releases some of the dissolved silica.

Not long ago, Western Electric built a pilot plant to explore the feasibility of growing quartz artificially on a production basis, employing the basic parameters of the laboratory process.

Our engineers started by designing a high pressure autoclave weighing some two tons (see diagram). Where the laboratory model had used a cover which was welded in place to achieve satisfactory sealing, Western Electric engineers developed a screw type metal-to-metal seal which can withstand up to 30,000 pounds pressure per square inch at 800°F without leaking. This combination of high temperature, pressure and corrosive solution is believed to be one of the most severe conditions encountered in any industrial process.

Grown quartz crystals.

Other design problems which had to be solved included: methods of heating, an adequate control system and proper insulation, together with safety procedures which would preclude any hazardous working conditions. From the outset, Western Electric engineers have worked very closely with Bell Telephone Laboratories chemists to perfect optimum crystal growth conditions. At the present time large, perfectly formed quartz crystals can be grown on a repetitive basis. Compared with natural quartz, these man-made crystals have fewer cracks and impurities . . . and because of their uniform dimensions they appear to be ideally suited to modern production methods.

Though refinements are constantly being made, it is expected that growing quartz by this process will ultimately be placed on a production basis.

Here again is demonstrated the creative engineering which goes on at Western Electric in concert with our Bell Laboratories associates. One result is constantly improving, low-cost Bell telephone service.

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THE AMATEUR SCIENTIST

How to recreate the apparatus with which the charge of the electron was measured

Conducted by C. L. Stong

While working with a Wilson cloud chamber 50 years ago this spring Robert A. Millikan, then professor of physics at the University of Chicago, learned how to make a drop of water hang in mid-air like Mahomet's fabled coffin. The drop was poised so delicately between gravity and a counteracting electric field that it would respond easily to a force on the order of a trillionth of an ounce—a force some 10,000 times smaller than the smallest that could be detected with the best mechanical balance of the day. With his technique Millikan proved the existence of the electron, measured its charge and thereby helped touch off the revolution in physics that has continued up to the present.

At the turn of the century many physicists held to the notion that electricity behaves like a fluid, that the amount of charge on an electrode can be altered by any desired amount. But some argued otherwise. For example, the emission of electrically charged particles by zinc exposed to light (the "photoelectric effect"), and the production of ions in a gas-discharge tube, supported the notion that electricity comes in tiny particles. The British physicists C. T. R. Wilson and H. A. Wilson had independently attacked the question by observing the response of a cloud of water droplets to X-rays and an electric field. Millikan decided to sharpen the experiment by concentrating on the behavior of individual drops instead of the whole cloud.

To form the drops he set up a modified version of C. T. R. Wilson's cloud chamber: a glass cylinder equipped with a piston. When the piston was pulled down quickly, expansion lowered the temperature of humid air inside the cylinder and caused a cloud of water droplets to form. Millikan fixed electrodes inside the chamber at the top and bottom and connected them to a 4,000-volt storage battery. He lighted the droplets from the side with an arc lamp and observed them through a small telescope. When the chamber was expanded and the field applied, most of the droplets drifted to the bottom under the influence of gravity. Some of the droplets, however, picked up electric charge during the expansion; most of these promptly darted toward one electrode or the other, depending upon the sign of their charge. A scattered few of the droplets hung in space for a second or two, their tendency to fall being precisely balanced by the upward tug of the electric field. Then evaporation would reduce their weight enough to upset the balance and start them moving toward the upper electrode. It was these droplets that caught Millikan's interest. He soon learned how to compensate for the evaporation by gradually lowering the voltage across the electrodes.

Occasionally he found it possible to make a drop stand still for as long as a minute. Now and again he observed that one of these stationary drops would take off abruptly toward one or the other of the electrodes. Moreover, a drop that had started to move in this manner would occasionally pick up speed during its flight, or stop in its tracks. Millikan therefore suspected that the drops must be picking up or losing elementary charges, perhaps the "atoms of electricity" for which the British physicist G. J. Stoney had suggested the name "electron" in 1891. "This experiment," Millikan later wrote in his book *The Electron*, "opened up the possibility of measuring with certainty, not merely the charges on individual droplets as I had been doing, but the charge carried by a single atmospheric ion. By taking two speed measurements on the same drop, one before and one after it had caught an ion, I could obviously eliminate entirely the properties of the drop and of the medium and deal with a quantity that was proportional merely to the charge on the captured ion itself."

In the fall of 1909 Millikan undertook a new series of experiments with a modified apparatus. The cloud chamber was replaced by a simple container fitted with windows and a pair of flat metal plates spaced about 5/8 inch apart. Light oil was sprayed into the top of the chamber by an ordinary atomizer. Some of the droplets found their way into the space between the plates through a pinhole in the middle of the upper plate. These droplets were lighted and observed by the same technique used with the water drops. The oil drops reacted like the water drops to an electric field established between the plates, but did not evaporate perceptibly during the period of observation. By manipulating the field to compensate for charges picked up from the air, it was possible to keep a selected drop under observation indefinitely. Within a matter of months the new apparatus enabled Millikan not only to prove the existence of the electron but also to measure its charge with fair accuracy and, incidentally, to measure the number of atoms in a gram of hydrogen. Before the series of experiments had ended he had independently established the approximate mass and size of the electron, confirmed Albert Einstein's explanation of the photoelectric effect and derived the value of Planck's constant experimentally! Few experiments have been more productive—or more fascinating to those who have repeated it.

One of these is George O. Smith of Highlands, N. J. Smith writes: "It may come as a pleasant surprise to a generation accustomed to thinking of atomic research in terms of cyclotrons and other complex apparatus that Millikan's equipment is easy to reproduce yet precise enough to challenge the most advanced instrument-maker.

"The experiment is based on the principle of balancing against the force of gravity the electric force acting on a small drop of oil. The electric force is determined by the interaction of the charge on the drop with the charge on the electrodes of the apparatus. The charge on the electrodes can be measured directly with a voltmeter. But the

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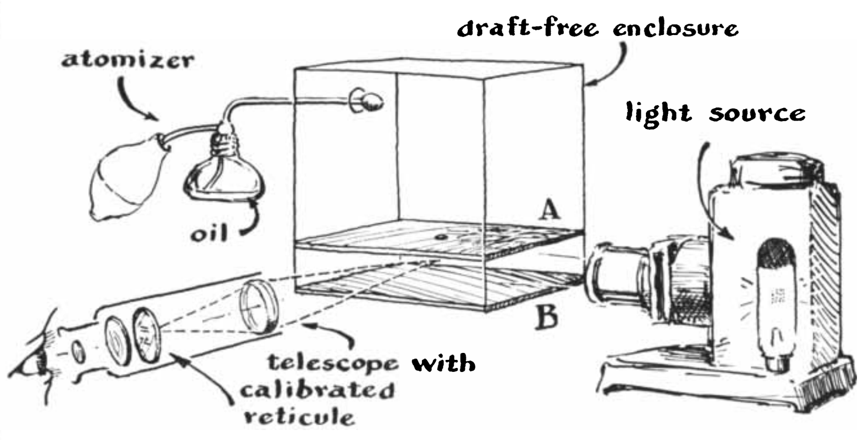
charge on the drop must be determined indirectly by the speed with which the drop moves through the air. The speed varies with the intensity of the charge and the size of the drop, so the size of the drop must be found. This can be done by observing the maximum speed, or 'terminal velocity,' of a drop in free fall through the air. The terminal velocity of a drop is reached when the force set up by friction between the drop and the air equals the force of gravity. The two forces act in opposite directions and cancel, with the result that the speed of the drop remains constant. Since the force of gravity is known, and the terminal velocity can be determined by timing the drop in free fall through a known distance, the size of the drop can be calculated by means of a simple formula that takes certain properties of the air into account. The charge on the drop can then be calculated by inserting the known values in another simple formula and doing the arithmetic.

"The accuracy of the method depends on the care taken in the construction of the apparatus. The electrodes are enclosed in a housing that can be rectangular [*see illustration below*], or cylindrical. The sides of the housing can be made of glass, lucite or any similar transparent material. Lucite is easier to work than glass, but has no functional advantage. The dimensions of the enclosure are not critical. One measuring some seven centimeters wide, 10 centimeters long and 15 centimeters high is adequate. The space between the electrodes should not be more than about an eighth of the height. The electrodes should make a loose fit with the inner walls of the housing so that they can be removed easily for cleaning. The fit should not be so loose, however, that air can circulate freely between the compartments of the housing.

"The upper electrode is supported by a pair of lucite blocks. These may be cut from a slab of lucite about a centimeter thick. In addition to acting as spacers between the electrodes, the blocks serve as windows through which the drops can be lighted from the side. The ends of the blocks should make an easy fit with the walls of the box. Their width is not important. Their outer and inner sides must be polished sufficiently to permit good light transmission. The rough faces can be first smoothed against successively finer grades of garnet paper supported on a flat surface, then polished against crocus cloth until all scratches disappear, and finally finished against wrapping paper charged with rouge of the sort used to polish glass. The optical quality of the polished surfaces need not be better than that of window glass.

"Plates for the electrodes can be cut from any kind of metal. Brass is preferred. The facing surfaces of these plates must be flat to better than a hundredth of a millimeter. The upper plate must be thick enough to prevent sagging. The facing surfaces can be smoothed against crocus cloth supported on a flat surface, and finished against wrapping paper charged with rouge. The corners and edges may be rounded slightly by grinding them against the finest grade of garnet paper. A pinhole approximately a millimeter in diameter is drilled in the center of the top plate and the burs removed. The use of heavy stock will be appreciated when the apparatus goes into operation, because the weight of the upper plate holds the electrode assembly together. (The experimenter will spend a good part of his time cleaning oil from the apparatus. He is therefore advised to resist the temptation of drilling, tapping, screwing and otherwise fastening the apparatus together in a solid but time-wasting structure.) The heavier the plate is made, the less it is likely to be displaced during an



Semi-schematic drawing of apparatus for determining the charge of the electron

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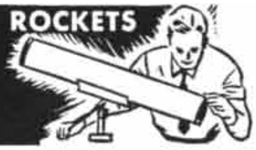

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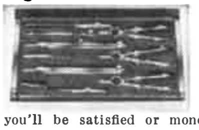

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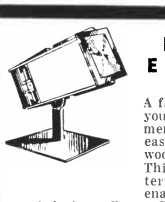

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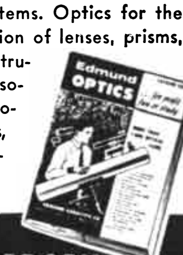

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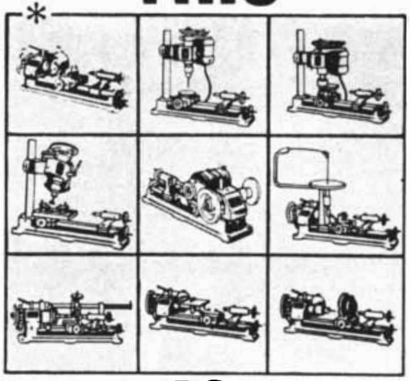

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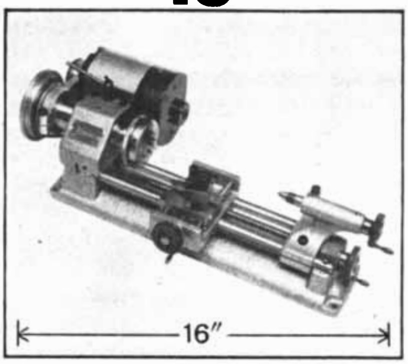

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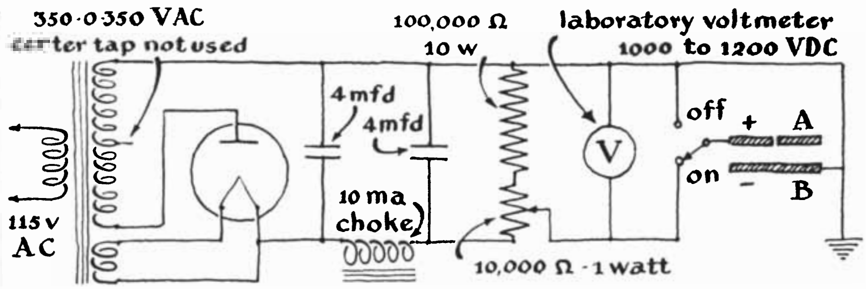

Circuit diagram for the power supply of the apparatus

experimental run. Electrical contact with both plates is made through flat springs as shown in the accompanying illustration [*page 180*]. The box is closed at the bottom by the lower electrode and at the top by a third metal plate.

"An observation port is drilled in front of the box at the level of the electrode space and fitted with a microscope cover-glass. The glass is held in position by a retaining ring of piano wire. A hole for the atomizer is drilled near the top of the box; holes are also drilled through the metal cover and the upper electrode for a thermometer. The bulb of the thermometer should be located as far as possible from the pinhole in the center of the upper electrode. The scale of the thermometer should also be kept away from the oil spray to avoid fogging.

"After the assembly is completed, the space between the electrodes must be measured. Any distance on the order of a centimeter that chances to come out in the construction is satisfactory. But this distance, whatever it may be, must be determined to the extreme limit of the experimenter's ability, because the charge on the electron cannot be determined to greater accuracy than that with which the distance is known.

"The magnifying telescope may be improvised from a microscope, from the small telescope of a war-surplus bombsight, from a telescope gunsight, from half a binocular or from any similar instrument that provides a tube and an eyepiece. The objective lens should have a focal length on the order of 50 millimeters, depending upon the distance between the observation port and the axis of the pinhole in the upper electrode. The lens from a 35-millimeter camera will do. As an alternative, the focal length of the telescope objective may be shortened by adding an auxiliary lens. The diameter of the objective lens is unimportant. Any combination of objective and eyepiece that can resolve light reflected by a sphere .006 millimeter in diameter is adequate. The eyepiece must be equipped with a reticle capable of spanning a vertical distance of at least a millimeter on the axis of the pinhole midway between the electrodes.

"Once the telescope has been adjusted so that drops falling through the pinhole are in sharp focus, it should be clamped in position. The optical system must then be calibrated. A target ruled with accurately spaced hairlines is placed vertically on the axis of the pinhole, and the image of the lines is noted with respect to those on the reticle. The calibration must be made with the greatest possible care. Microscope slides ruled with hairlines spaced in fractions of a millimeter are available from optical-supply houses. A similar target may be made by ruling hairlines on a metal plate by means of a height gauge of the type used by toolmakers.

"Power for charging the electrodes may be derived from a conventional vacuum-tube rectifier [*see circuit diagram above*]. Electrolytic capacitors are not manufactured for voltages in this range, and oil capacitors rated at 1,000 volts are costly. The ripple current and load are low, however, so if one is willing to risk an occasional blowout, oil capacitors of 400-volt rating may be used. (I have had a bank of 600-volt oil capacitors across 2,000 volts for longer than I care to remember. On the average, I lose one about every two years.) The field voltage should be held as constant as possible during an experimental run. This is best accomplished by inserting a variable transformer such as a Variac in the power line. A 10,000-ohm variable resistor in series with the 100,000-ohm bleeder resistor is next best. The field voltage should be monitored constantly with a good laboratory voltmeter during a run. Do not turn off the power supply to observe drops in free fall; use the switch shown in the diagram. This switch not only cuts off the voltage but simultaneously grounds and short-circuits the electrodes, thus killing the field completely.

"A 35-millimeter slide projector makes an adequate light source. Contrast will

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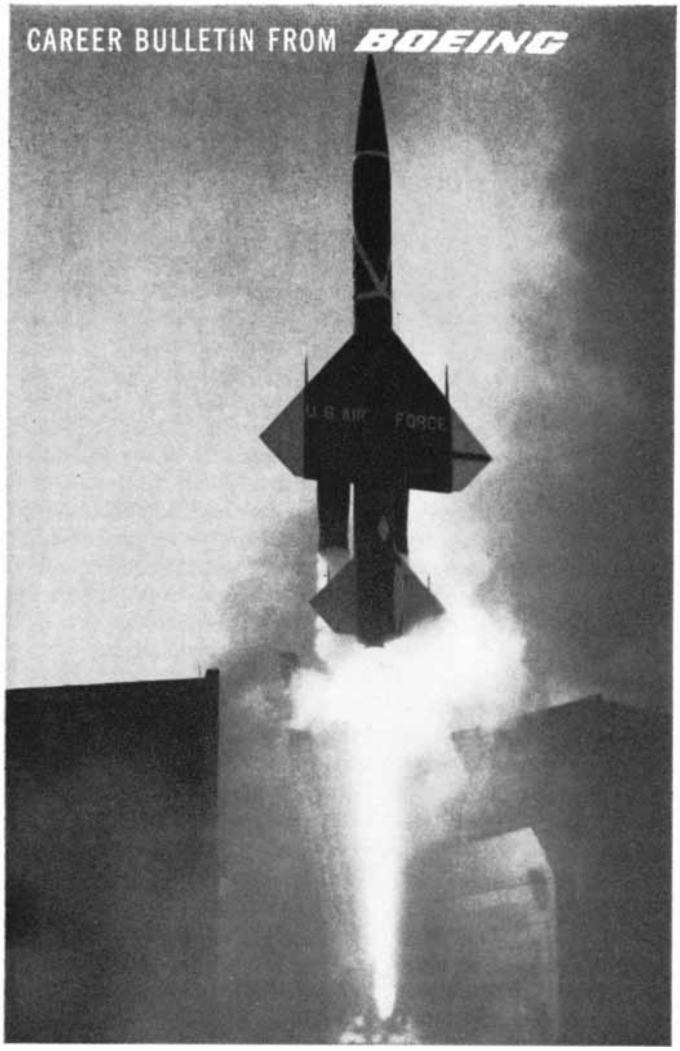

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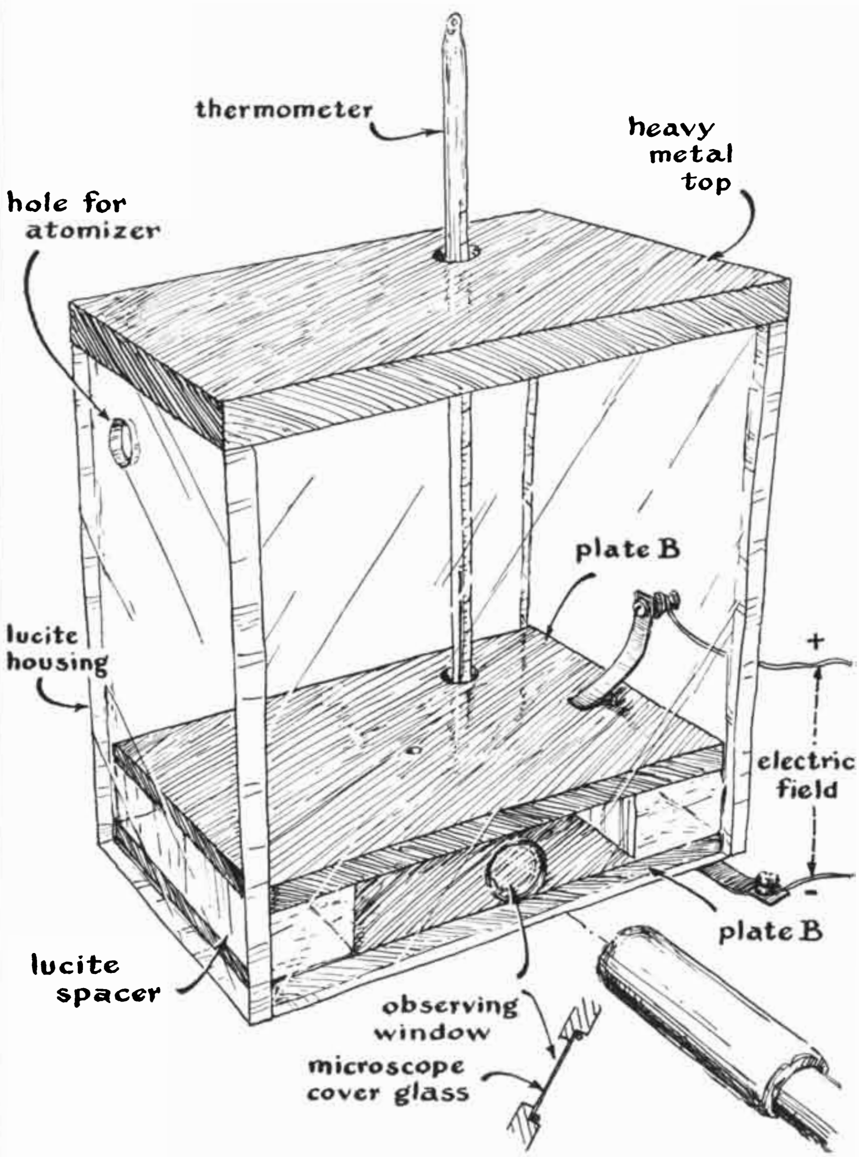
be improved by covering the rear wall of the enclosure at the level of the space between the electrodes with a swatch of black velvet. The drops should appear as brilliant points of light against a jet-black field.

"One note of caution: Never forget that you are working with lethal voltage. Resist the temptation to grope for the field switch or other controls while squinting through the telescope. Finally, provide writing materials, a stop watch and a good barometer.

"To make a run, fill the atomizer with a light, nonvolatile oil. Do not use watch oil, which reacts chemically with lucite. Check to assure that the field voltage is off, then spray the smallest possible amount of oil into the upper chamber. (Excess oil accomplishes nothing beyond increasing the frequency of clean-ups.) Then relax for 10 minutes or so. Interesting drops in free fall cover about three millimeters per minute, so they require an appreciable interval to find their way through the pinhole into the observation space. In the meantime a table may be ruled, headed like the one made by Millikan [*see page 183*]. Now light the region beneath the pinhole with the slide projector. When the telescope shows drops in the field, switch on the field voltage momentarily to eliminate drops carrying heavy charges.

"Now enter the barometric pressure and the temperature of the chamber on the table just prepared. Apply the field again and search for a drop that rises slowly. (This assumes that the telescope is equipped with an erector system. If it is not, the motion will appear reversed.) Permit the drop to rise about a milli-



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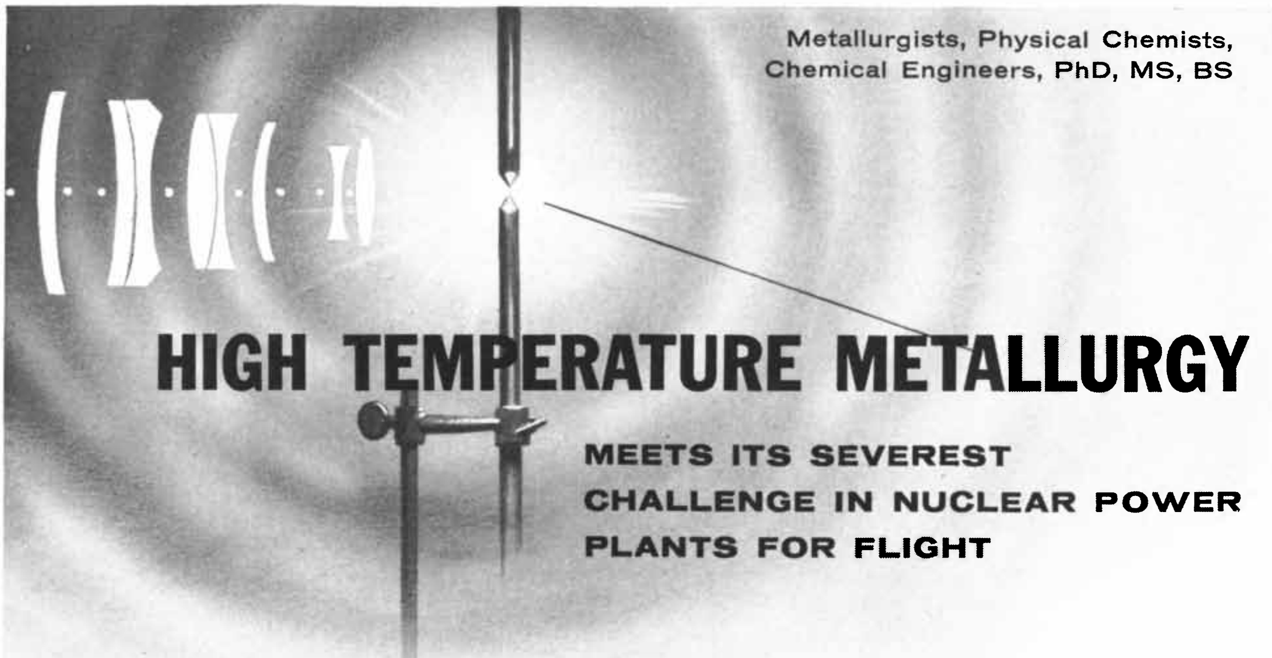

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meter above a selected graduation on the reticle. Then switch off the field and time the drop in free fall. Permit the drop to move a millimeter beyond the terminal graduation. Record the reading on the table under 'free fall.' Then switch the field on and time the return transit. If the field is heavily populated by drops, it may be difficult to keep track of a selected drop while looking away to record the transit time. This difficulty can be overcome either by learning to make entries on the table while keeping one eye on the drop, or by enlisting a helper to do the recording while you call out the observations.

"Occasionally a drop will collide with an ion and change speed. Record the transit and go right on tabulating. You can throw out the questionable entry later. Try to record 50 or more transits before shifting to another drop.

"For the experiment to have meaning the drop must collide with at least one ion while under observation; the more ions it collides with, the better. Such collisions may become infrequent as the run continues, because ions created by the injection of oil tend to recombine and therefore to decrease in number. The experiment will proceed much more rapidly if the supply of ions can be replenished by irradiating the space between the electrodes with X-rays. An X-ray machine of the type described in 'The Amateur Scientist' by Harry Simons of Kearny, N. J. is inexpensive and easy to make [see "The Amateur Scientist," July, 1956]. The extreme hazard of working with X-rays must not be overlooked. The tube must be shielded by a container of lead at least three millimeters thick. A hole equal in diameter to the space between the electrodes is drilled in the tube end of the shield. The fan-shaped pattern of radiation from the hole is directed into the observation chamber through the lucite spacer opposite the light source. Stand well behind the X-ray unit when it is in operation. An exposure of a second or two will provide a good supply of ions.

"After the times of free fall and rise have been tabulated, the constant values are recorded. These are the distance in centimeters between the electrodes, the distance of rise and fall, the field potential, the oil density (the reciprocal of the weight, in grams, of one cubic centimeter of oil), the temperature, the barometric pressure and the viscosity of air.

"The rest is plain arithmetic. First, run off the average time of free fall for all the drops observed. Note that Millikan's table lists only 11 observations of free fall. This compares favorably with the

DISTANCE BETWEEN ELECTRODES	.7135 CENTIMETER
DISTANCE OF RISE AND FALL	.145 CENTIMETER
POTENTIAL OF ELECTRIC FIELD	735 VOLTS
BAROMETRIC PRESSURE	74.26 CENTIMETERS OF MERCURY
TEMPERATURE	21.5 DEGREES CENTIGRADE
DENSITY OF OIL	.893 GRAMS PER CUBIC CENTIMETER
VISCOSITY OF AIR	.0001817

TIME OF FREE FALL (SECONDS)	TIME OF RISE WITH FIELD (SECONDS)	AVERAGE TIME OF RISE (SECONDS)	CALCULATED CHARGE ON DROP (ELECTROSTATIC UNITS)	NUMBER OF CHARGES ON DROP	MAGNITUDE OF INDIVIDUAL CHARGE ($10^{10} \times e$)
34.4	28.6				
33.9	28.5				
34.5	28.6				
34.3	28.7				
34.0	29.0				
34.4	29.1				
34.2	29.1				
34.3	28.4				
33.9	28.9				
33.8	29.0				
34.2	29.1	28.77	4.79×10^{-10}	1	4.79
	28.6				
	28.7				
	28.3				
	28.6				
	28.7				
	29.1				
	28.9				
	29.0				
	28.6				
	28.8				
	10.1				
	10.2				
	10.5				
	10.3				
	10.2				
	10.2	10.31	9.45×10^{-10}	2	4.725
	10.6				
	10.2				
	10.5				
	10.4				
	10.2				
	6.1				
	6.0				
	6.2				
	6.1	6.11	14.43×10^{-10}	3	4.81
	6.2				
	6.1				
	6.1				
	4.5				
	4.6				
	4.4				
	4.4				
	4.3	4.47	18.93×10^{-10}	4	4.73
	4.5				
	4.5				
	4.6				
	4.4				

A typical table of observations from Robert A. Millikan's oil-drop experiment

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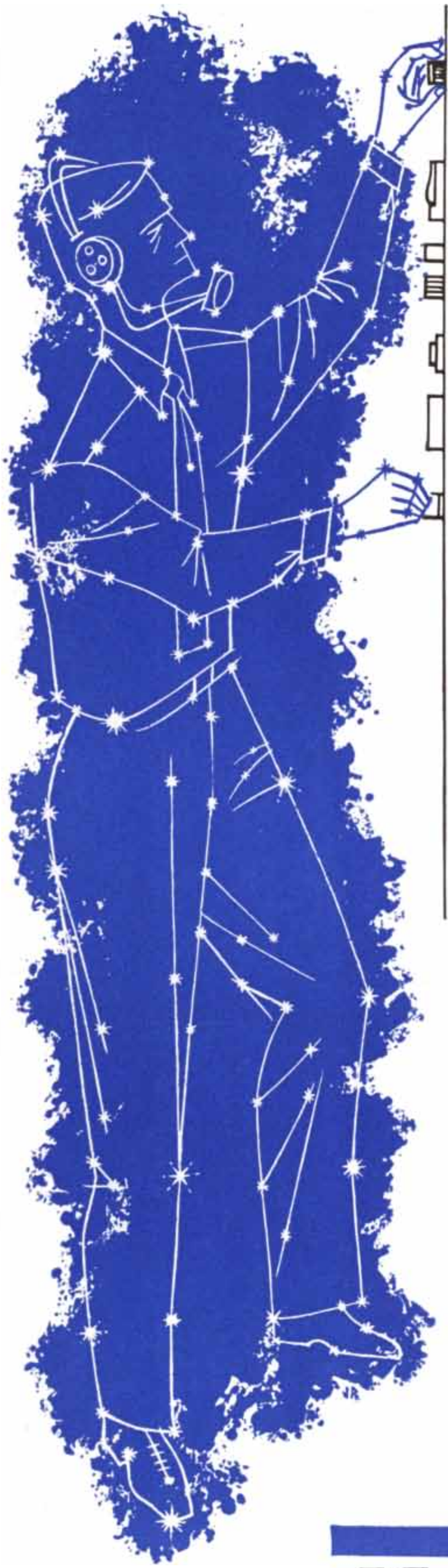

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number of rise times observed for each state of charge on the drop. The figures are therefore about equally good. The rise times for each state of charge are then averaged and entered on the table. The distance of rise and fall is now divided by the average times to give the speed of the drops in centimeters per second. (On Millikan's table the average time of free fall through .145 centimeter is 34.17 seconds. This converts to a velocity of .00424 centimeter per second.) The computed value is entered as the terminal velocity (V) in the formula for the radius of the drop (r) given in the accompanying table [*below*]. The remaining values required by the formula are taken from the table and from a reference text such as *Handbook of Chemistry and Physics.*

"The radius of the drop is then computed and entered in the formula for electric charge (q), also given in the table. After inserting the other constant values required by the formula, the charge is computed for each of the rise times and entered on the table under 'Calculated Charge on Drop (Electrostatic Units)'. Determine the difference

$$r = \frac{-\frac{b}{P} \pm \sqrt{\frac{b}{P^2} + 4 \cdot \frac{9V\eta}{2g(\rho - \rho_m)}}}{2}$$

where:

r = radius of drop in cm
V = terminal velocity of drop in cm/sec
g = acceleration of gravity in cm/sec^2
ρ = density of oil in gm/cm^3
ρ_m = density of atmosphere in gm/cm^3
η = viscosity of atmosphere
b = .000 617
P = barometric pressure in cm of mercury

$$q = \frac{4\pi r^3 g(\rho - \rho_m)}{3E} \cdot \frac{V + V_1}{V}$$

where:

q = electronic charge in electrostatic units
V = terminal velocity (downward) of drop in cm/sec
V_1 = terminal velocity (upward) of drop in cm/sec
r = radius of drop as computed
E = electric field in volts/cm

(all other units as previously defined)

Equations for the oil-drop experiment

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between each of the tabulated charges by subtracting the lower value from the next higher for all computed tabulations. A certain minimum difference will be found. The total charge on each drop will be some integral multiple of this minimum, which should approximate 4.8×10^{-10}. Dividing the calculated charge on the drop by this minimum gives the number of charges on the drop. (The quotient must be rounded off to the nearest whole number.) The calculated charge on the drop is then divided by the number of charges. This quotient is entered in the final column ('Magnitude of Individual Charge') and compared with the most recent determination for the charge on the electron: $4.8029 \pm .0001 \times 10^{-10}$ electrostatic units."

Some appreciation of the far-reaching consequences of this experiment can be gained by considering its influence upon the theory of the photoelectric effect. All substances emit electrons under the influence of light. By placing a negative electrode close to the substance and connecting a battery between the two, a voltage can be found that is just sufficient to stop outward-bound electrons. It turns out that the stopping voltage depends solely on the color of the light and not at all on its intensity. Einstein explained this in 1905 by supposing that all the ejected particles carry an identical charge, which when multiplied by the stopping voltage just equals the product of a certain quantity h (which Max Planck had derived to explain the radiation of energy from a "black body") and the frequency of the light minus the amount of energy required by the particle to break free of the substance. This theory made no sense to most physicists of the day, because it required the light to be radiated in chunks of a size determined by the constant h, which Planck apparently had pulled out of thin air.

"At the time it was made," wrote Millikan, "this prediction [by Einstein] was as bold as the hypothesis which suggested it, for at that time there were available no experiments whatever for determining anything about how the potential necessary to stop the discharge of the negative electrons varied with the frequency of the light or whether the quantity h to which Planck had already assigned a numerical value appeared at all in connection with photoelectric discharge. We are confronted, however, by the astonishing situation that after ten years of work at the Ryerson Laboratory this equation of Einstein's seems to us to predict accurately all of the facts which have been observed!"


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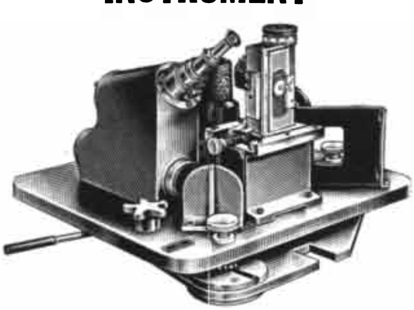

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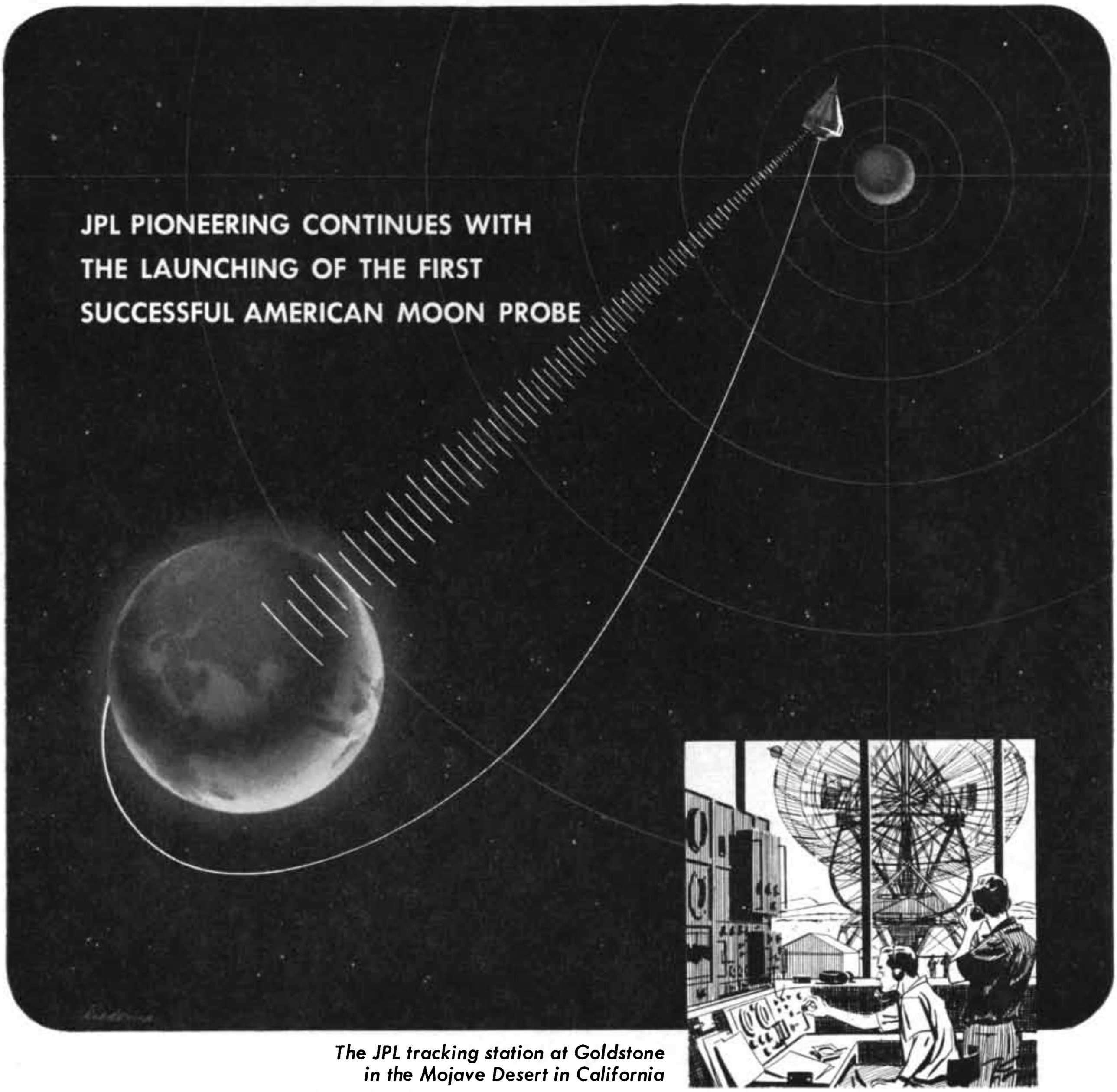

The JPL tracking station at Goldstone in the Mojave Desert in California

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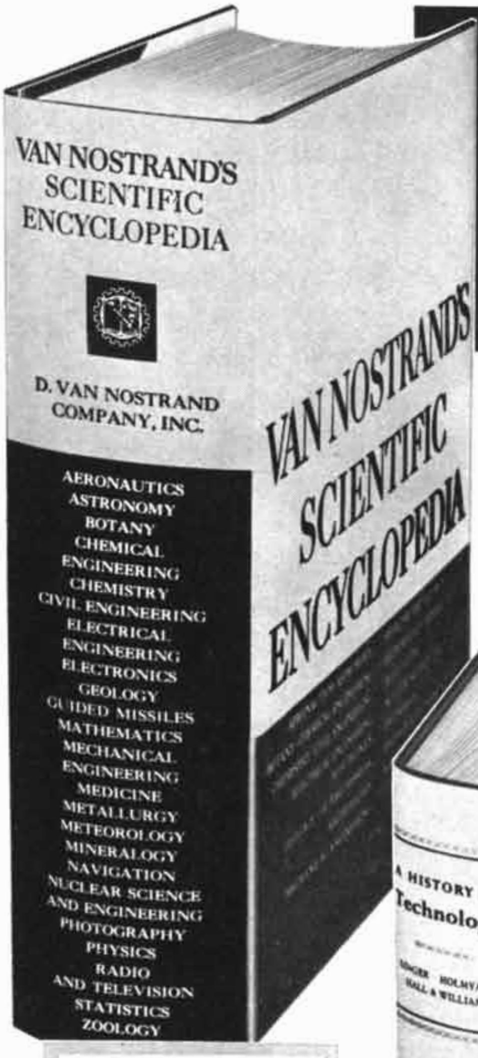

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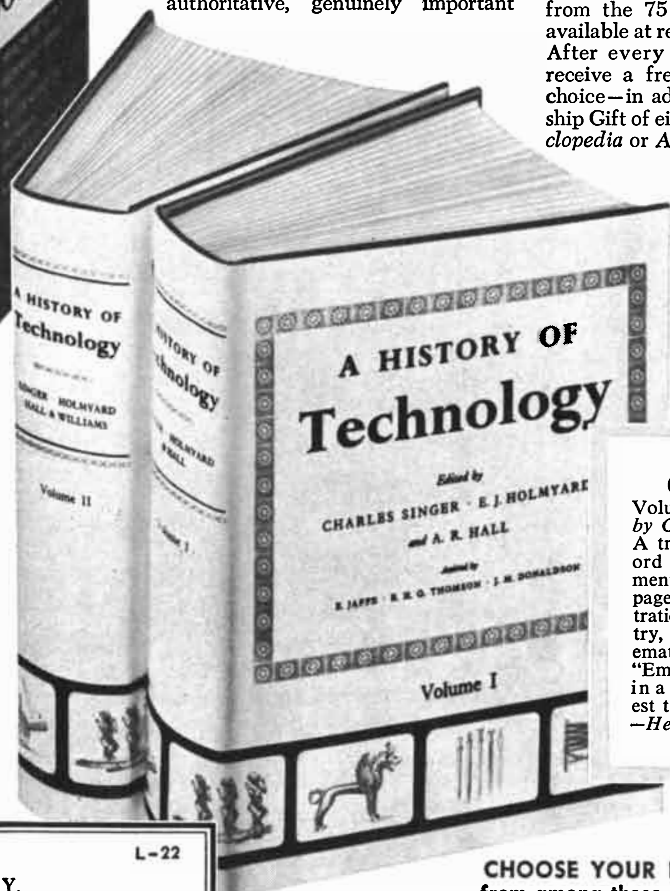

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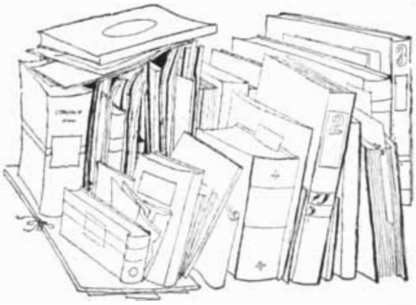

BOOKS

Concerning the philosophy which holds that the conclusions of science are never final

by Stephen E. Toulmin

The Logic of Scientific Discovery, by Karl R. Popper. Basic Books, Inc. ($7.50).

Criticizing creative work is one thing; formulating the canons of criticism is another. Working scientists, like artists, have a direct but often inarticulate grasp of what it is that makes a new piece of work worthwhile; they will argue about each other's original theories and ideas in a way that is sometimes rough but usually just, without pausing to state in so many words the standards on which their judgments are based. Indeed, in both art and science the theory of criticism has tended to become divorced from the practice of the craftsman—even from the practice of the critic—and this double removal can make the philosophy of science (like philosophical esthetics) unintelligible to the craftsman whose work it is supposed to fit. There is a story of the great English painter J. M. W. Turner sitting for a whole evening while a circle of his intellectual friends talked with high seriousness about the Principles of Art: Turner himself sat silent until it was time to go, and, as he buttoned his greatcoat across his stocky figure and passed through the door, he was heard to utter the words: "Rummy thing, painting!" How many scientists who have heard a philosopher expounding the principles of their own work are tempted to echo this comment!

Of course the philosophy of science has to be tackled, and it can be tackled well or badly. Topflight scientists can be as interesting and perceptive in their remarks about the nature of their craft as the most articulate painters and writers. (One thinks of men like Werner Heisenberg and the nerve physiologist E. D. Adrian.) We must nonetheless feel a little uneasy at the breadth of the gulf that now separates scientists and philosophers in their talk about the nature, methods and principles of science, and the appearance in English translation of Karl R. Popper's notable book *Logik der Forschung* (*The Logic of Scientific Discovery*) provides a natural occasion for asking some questions about this gulf. Is it broader than it need be? Are logicians setting about their task from the right angle? Can we hope to restore communications between the practitioners and the philosophers of science?

One false ideal has especially beguiled philosophers in their attempts to state the canons of good science. This is the ideal of pure mathematics and symbolic logic, with their strict methods of proof, their formal structure and the seeming certainty of their certified results. The philosophical rationalists of the 17th and 18th centuries dreamed of finding for natural science a method, and canons of adequacy, as final and rigorous as those of mathematics. "With the principle of non-contradiction alone," claimed Leibniz, "the whole of mathematics can be proved"; and by the sole addition of his Principle of Sufficient Reason he thought he had made the principles of "natural philosophy"—as scientific theory was then called—as "real and demonstrative" as mathematics. This extreme ambition had to be abandoned after Kant, yet there is a less drastic hope that even philosophical empiricists have nourished. Of course the foundation of all science (they would say) is experiment and observation: Without a basis in experience there can be no discovery about nature. But let us at any rate state the rules for making discoveries, the exact forms that our scientific inquiries and arguments must take in order to certify for ourselves that our results, while rooted in our experience, are securely rooted, rigorously inferred and uniquely established—in a word, proved. It was not Francis Bacon alone who dreamed of a new "organon": a system of logic that would do for the methods of scientific discovery what Aristotle did for the formal syllogism. Bacon was but one figure in a long tradition, of which the most influential representative in the last century has been John Stuart Mill, and whose present standard-bearer is Rudolf Carnap, formerly of Vienna and now at the University of California at Los Angeles. The logician's task in his study of science, these men would claim, is to show how we can justify the explanations the scientist gives by formalizing his arguments, and to characterize in logical terms the ways in which he passes from his observations to either a *true* conclusion (*e.g.*, that all known planets have elliptical orbits) or a *probable* one (*e.g.*, that all crows are black, or that smoking causes cancer). And if there turns out to be some difficulty in presenting the arguments of sophisticated modern scientists in these simple and seemingly conclusive forms—well, that shows only that quantum mechanics, say, has not yet been formulated strictly "according to the rigorous standards of modern logic."

In opposition to this tradition in the philosophy of science stands another, of which in recent years Karl Popper has been one of the most vigorous spokesmen, both in Vienna before the *Anschluss* and later in England. The reader in Britain or the U. S. who has encountered Popper probably knows him best for his views on political theory and the philosophy of history. In a series of passionate yet acutely argued books and papers he has rubbed our noses in the faults that afflict so many theories about the march of history. Physics is one thing; history is another. The laws of motion and of gravitation apply directly to the solar system, for example, as a result of special circumstances that no longer hold when we study the historical process; the idea that the lives of men and of nations are subject to deterministic and comprehensive "laws of historical development" is a fallacy born of a false analogy. This false analogy between the study of history and such sciences as planetary dynamics he calls "historicism," and to historicists, or to those whom he suspects of that heresy, Popper shows no mercy. Let them excuse the variability of actual events by dubbing the laws of history "dialectical," let them seek to find a loophole for free

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will in the deterministic chain-mail of history that they have constructed for themselves—however they twist and turn, Popper is after them, declaiming forcibly and to good effect (sometimes unfairly), seeking out and denouncing error wherever it may be found. As a result, those of us who have read and reflected on his books *The Open Society and Its Enemies* and *The Poverty of Historicism* have had our vision permanently reoriented. We can no longer pick up Hegel or Marx or Spengler or even Toynbee without detecting a whiff of burning: the scent of heresy. The idea of the "historical dialectic" has lost its intellectual attraction for us.

The campaign against historicism has, however, been only incidental to Popper's chief aims as a philosopher. To see clearly the differences between physical science and history it is not enough to keep a clear head about history: one must also have a thorough understanding of the methods of physics. Indeed, Popper's arguments about sociology and history have always been based on his more general views about science and its methods. *Logik der Forschung* has been available in German for a quarter of a century now; it was published in Vienna in 1934. But though rumor has told us for a dozen years that one translator or another had an English version almost ready for the press, we have waited until 1959 for the writer himself to provide us with an authorized translation into the English language. The book has been rendered with a scrupulousness and a fidelity to the original that most of us would reserve for other men's work. Though Popper must presumably have had some fairly drastic second thoughts in these intervening years, he rarely lets us glimpse them here, and we are given the 1934 text unaltered apart from the addition of some new footnotes and appendices. These second thoughts are to be published separately, in a postscript to be called *After Twenty-Five Years,* and this we are promised in a few months.

Popper's opposition to the Baconian tradition is stated uncompromisingly in the final paragraphs of the book; and these are worth quoting, for they form one of the best passages he has written.

"The old scientific ideal of *epistēmē*—of absolutely certain, demonstrable knowledge—has proved to be an idol. The demand for scientific objectivity makes it inevitable that every scientific statement must remain *tentative forever.* It may indeed be corroborated, but every corroboration is relative to other statements which, again, are tentative. Only in our subjective experience of conviction, in our subjective faith, can we be 'absolutely certain.'

"With the idol of certainty (including that of degrees of imperfect certainty or probability) there falls one of the defences of obscurantism which bars the way of scientific advance, checking the boldness of our questions, and endangering the rigour and integrity of our tests. The wrong view of science betrays itself in the craving to be right; for it is not his *possession* of knowledge, of irrefutable truth, that makes the man of science, but his persistent and recklessly critical *quest* for the truth.

"Has our attitude, then, to be one of resignation? Have we to say that science can fulfill only its biological task; that it can, at best, merely prove its mettle in practical applications which may corroborate it? I do not think so. Science never pursues the illusory aim of making its answers final, or even probable. Its advance is, rather, towards the infinite yet attainable aim of ever discovering new, deeper, and more general problems, and of subjecting its ever tentative answers to ever renewed and ever more rigorous tests."

Two things stand out here: Popper's rejection of the idea that scientific conclusions can ever be finally proved, and his insistence on the indispensability—indeed, the crucial importance—of boldness and imagination in science. We must be by turns bold and critical, free in our speculations and severe in putting them to the test. We must not confine our thoughts to the methodical tracks laid down for us by Bacon and Mill: Any idea, however novel, can prove its worth by standing up better than its predecessors to "ever renewed and ever more rigorous tests." The belief that there must be a royal road by which we can march along to safely verified scientific conclusions Popper sweeps aside as the fundamental error. The best ideas and theories are those that best resist our attempts to falsify them; not verification but falsification is the key idea from which he would have us start. In this manner he certainly goes a long way toward escaping from the mathematical ideal. A scientific theory does not require demonstrative *proof;* rather, it must be shown to be *sound;* and we test the soundness of our ideas in the way a civil engineer tests the soundness of a bridge's foundations or materials—by putting them through progressively more severe and ingenious ordeals. It is even a mistake, Popper argues, to think that theories can be shown to be "highly probable," and to attempt,

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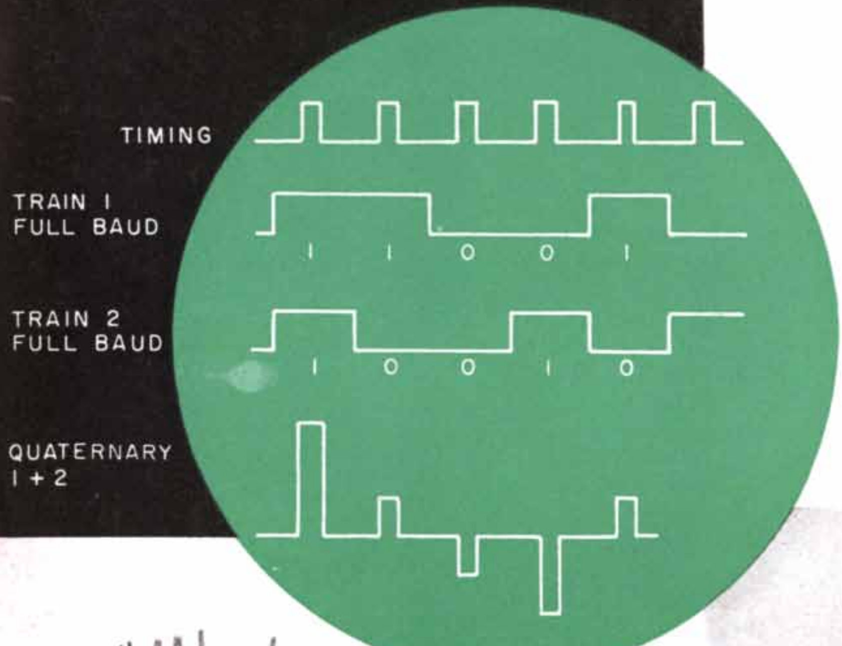

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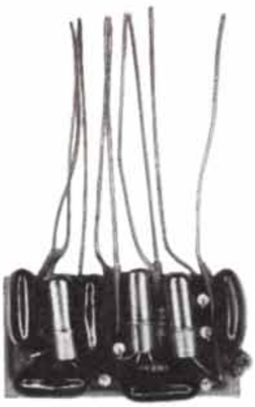

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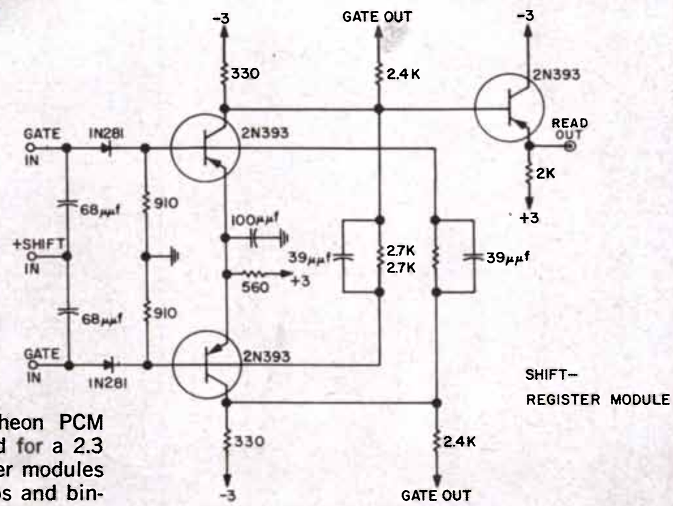

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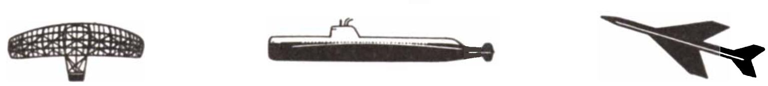

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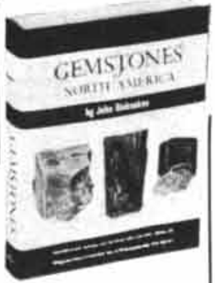

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like Carnap, to construct a mathematical system for computing the "degree of confirmation" conferred on a theory by this set of observations or that. The idea that theories are rendered "probable" or partially verified by experiment is as objectionable, in his view, as the idea that they are completely so verified. Both ideas spring from misconceiving the relevance of the facts we observe in the field or discover in the laboratory to the general statements and theories that these facts serve to corroborate.

There is much here that is sound and memorable and worth repeating. Surely it was always rather puzzling that logicians should have concentrated their attention on statements at so puerile a level of generality and abstraction—statements that were entirely untheoretical and intuitive, like "All swans are white." It was all very well for them to tell us that their formal systems were intended to apply to quantum mechanics only *in principle*. Surely it was not enough to say that modern physics looks different from the logician's model because no one had put his mind to the task of recasting physics in the proper form. Something else was amiss, too, for in one crucial respect quantum mechanics was always quite unlike a naturalist's generalizations. Quantum mechanics essentially involves the introduction of new ideas, and new ideas need something other than common-sense observations and formal demonstrations to establish them. We prove what they are worth to us as we go along, just as we do with new alloys or new techniques.

These objections Popper keeps well before our minds. Any last fears that we had missed the point of the Baconian approach he calms and dismisses, and he sets to work to provide an alternative account of the things that make a new theory worthwhile. His polemic sounds convincing; now let us go along with him and see what constructive alternative he has to offer. We read on. As we do so, a new puzzlement grows on us. The account he proceeds to give us is as formal as the one he rejected. In the place of Carnap's mathematical theory of "confirmation" and "probability" Popper offers us not a discursive examination of the things that go to establish the merits of a theory, but a rival formal theory of "corroboration" and "confirmability." He has conducted his polemic against the Baconians by arguing in their own terms. These means have now become an end in themselves, and his escape from the mathematical ideal is in consequence only partial.

Yet Popper's most suggestive and il-

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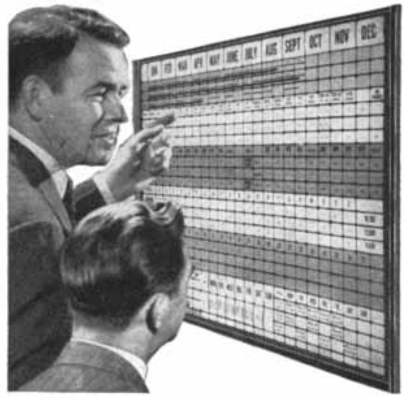

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luminating remarks are again and again nonformal ones. Take, for instance, the following image:

"The various ideas and hypotheses [of a science] might be visualized as particles suspended in a fluid. Testable science is the precipitation of these particles at the bottom of the vessel: they settle down in layers (of universality). The thickness of the deposit grows with the number of these layers, every new layer corresponding to a theory more universal than those beneath it. As a result of this process ideas previously floating in higher metaphysical regions may sometimes be reached by the growth of science, and thus make contact with it, and settle. Examples of such ideas are atomism; the idea of a single physical 'principle' or ultimate element (from which the others derive); the theory of terrestrial motion (opposed by Bacon as fictitious); the age-old corpuscular theory of light; the fluid-theory of electricity (revived as the electron-gas hypothesis of metallic conduction). All these metaphysical concepts and ideas may have helped, even in their early forms, to bring order into man's picture of the world, and in some cases they may even have led to successful predictions. Yet an idea of this kind acquires scientific status only when it is presented in falsifiable form; that is to say, only when it has become possible to decide empirically between it and some rival theory."

This passage is significant not just for its vivid expression and for the justice of the point Popper here makes. Even more, it points the way to a new sort of philosophy of science, which Popper only adumbrates and which others today (such as Norwood Hanson of the University of Indiana) are actually trying to bring to birth. For Popper was not only right in seeing that we demand soundness of a scientific theory, rather than mathematical proof; he is right, too, in hinting that we shall find the process by which science grows best exemplified in the actual *history* of scientific ideas. Like new forms of organism, novel scientific theories and notions prove to have greater or less survival value. Some of them "have what it takes" in order to catch on; others fall by the wayside. Once philosophers of science have recognized this, they have a choice between two courses of action. They can continue to discuss the merits of theories *a priori*, in which case they will produce either tautologies ("the survival value of a theory is in proportion to its degree of confirmation") or else vague legislative decrees ("a theory ought to be accepted

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only if it explains the largest possible number of facts"). Alternatively, they can become frankly historical and evolutionary in their methods, and can look to see how the classic theories in science actually did come to establish themselves in our minds—to see what were in fact the merits that commended them to the great scientists of the past.

Is this too drastic a change to ask philosophers to make? Is it perhaps rather a comedown to consider how theories have *in fact* established themselves, when one was really hoping to state the principles on which theories *ought* to be accepted? Is it too much like asking an esthetic philosopher to conduct an empirical survey of the preferences for pictures the public has actually displayed? After all, we know the sort of crudities which by that test would prove to have the greatest survival value.

Actually the change is not as drastic as the analogy seems to imply. If a philosopher of science is determined to examine the principles of science, and not just its practice, he can still do so in a historical framework. Carnap is the last of a long line of philosophers who have treated the logic of science as a kind of mathematical code of laws; many of us now see the real task as being more like common law. One learns what the common law is by studying precedents; and these precedents are as binding as any statute can be. May we not learn more about the methods of science and the canons of scientific criticism by studying precedents than by trying to lay down *a priori* a system of rules of permanent validity?

Even working scientists must sometimes resort to common-law arguments. This came clearly to light in a recent report (published as *Observation and Interpretation*) of a meeting at the University of Bristol, where a group of physicists and philosophers were discussing problems of quantum theory. Since the two sides of the main dispute disagreed even about the basic acceptability of quantum mechanics in its present form, they could not conduct their argument within the framework that it might otherwise have provided. Instead, the rival physicists began citing "old saws and modern instances"—countering each other's arguments with such statements as "I'm only doing the sort of thing Maxwell did when he talked of 'displacement current,'" or "Be careful not to end up as Duhem did, when he ridiculed J. J. Thomson!" In this way they illustrated a point that Popper himself has frequently emphasized—the part that is played by tradition

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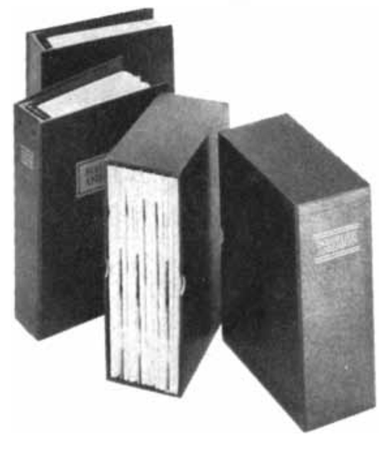

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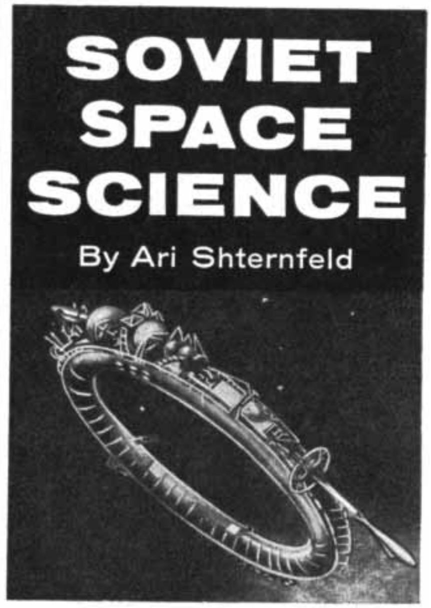
in the craft of scientific research and speculation.

The actual ways in which scientific ideas have succeeded one another are in fact often surprising, and scarcely any of the stories to which we find Popper referring—atomism, "ultimate principles" and so on—has been told fully and perceptively enough. Yet many of the surprises are those for which a knowledge of evolutionary biology might have prepared us. Functionless variations in a group of organisms have turned into structures of extreme adaptive importance to their descendants, and if one looks at the concept of "atomic number" one finds a similar tale. When the 19th-century chemists ordered the elements according to their atomic weight, they wrote down the integers on the left-hand margin for convenience of reference. To begin with, these numbers were mere ciphers, with no more significance than the numbers one might allot to species of plants in a botanical handbook; if there had been 92 letters in the alphabet these might have been used instead. Yet this same idea of atomic number acquired after H. G. J. Moseley and Niels Bohr an absolutely central position in atomic theory. What had been only their index numbers became, subject to a few amendments, the most important characteristics of the chemical elements. These integers were now interpreted as the numbers of unit electric charges of the atomic nuclei, which determined the number and arrangement of the satellite electrons characteristic of each substance, and so its chemical properties. Rummy thing, science!

This sort of development is surely one with which no formal "logic of scientific discovery" can cope. Frontline theories in science are always so much in process of change and development that even Popper's notion of corroboration is too cut-and-dried to meet the case. (When, for instance, was the place of atomic number in physical theory adequately justified?) Perhaps the esthetic analogy was not so bad after all. For the art historian studies not the vagaries of popular preference, but the ways in which creative artists themselves have worked at different periods. Art criticism properly informed by a knowledge of art history is far more illuminating than the subjective reactions of contemporary art journalists—to say nothing of those geometrical theories that were once supposed to determine what "must" be beautiful in art. Science criticism is also a matter for appreciation, not calculation; informed analysis, not *a priori* legislation. The future task for the philosophy

The Russians' Own Story of Artificial Satellites



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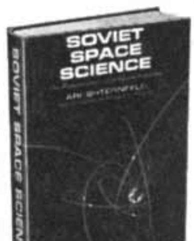
Just published, this comprehensive new account of Russian theoretical and practical progress in the field of astronautics is written by a leading Soviet space scientist and now appears in English in the official U.S. Air Force translation. Here is the definitive history of the Soviet satellite program, with actual photographs, drawings, tables and technical data — much of it based on the author's own original research. Among the contents are: Plans for a Revolutionary "Fixed Star" Satellite, Construction of a Space Platform, Scientific Objectives of Space Flight, Design and Construction of Space Ships, Survival of Man in Space, Flights to the Moon, Problems of Re-entry into the Earth's Atmosphere, and many others.



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of science, which Popper could only hint at in *Logik der Forschung*, has in the 25 years since its first appearance become both clearer and more urgent.

Short Reviews

A HISTORY OF TECHNOLOGY, VOL. V, edited by Charles Singer, E. J. Holmyard, A. R. Hall and Trevor I. Williams. Oxford University Press ($26.90). The readers who have been following this admirable work, who have gained immense satisfaction from its authoritative, richly varied content, and who have anticipated with pleasure the appearance of each of its elegantly printed, beautifully illustrated volumes, will regret that with this volume the survey comes to a close. It is not often the student of the history of science can enjoy such a repast. The period covered in this last installment is the last half of the 19th century. Many of the technologies were introduced in earlier volumes, and are now described in their later phases of development. In this category are metallurgy, the steel industry, the steam engine, food production and preservation, shipbuilding, cartography and aids to navigation, the chemical industry, textile manufacture, ceramics, glass technology, printing and related trades. But in these 50 years innumerable technological innovations—processes, crafts, methods, machines—which drastically transformed the world made their first appearance. Among those here discussed are aeronautics; high explosives; internal-combustion engines; the generation, distribution and utilization of electricity; photography; railway engineering; telegraphy and telephony. In many of these advances that were to change men's lives more than they had been changed in the whole preceding history of technology—altering their food habits, their homes, their methods of travel and communication, their war-making, their social and economic status—there is reflected the growing influence of science upon technology. Systematic assaults were being made upon physical problems such as the structure of matter, the properties of materials, the behavior of gases, the nature of heat, light and electricity; and the results of the various breakthroughs in knowledge were incorporated in hundreds of industrial arts. No one can begin to understand the great political currents of the 19th and 20th centuries without considering the social and economic background, and this in turn is incomplete unless it is animated by the constant movement of science and technology. *A History of Technology* is not

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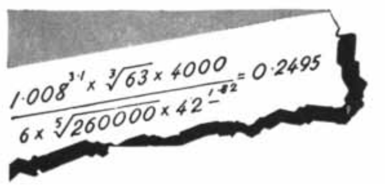

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an interpretive survey. It was not designed for this purpose and does not achieve it. Moreover, it is a great pity that the history ends with the last century; one might have wished that it would carry through to our time, even though the task of reporting the technology of the past 50 years might well have required an additional three or four volumes. But it is ungracious to grumble over what has been given us. For the serious student and specialist, no less than for the average educated reader, these books will be a source of joy and meticulous instruction; and for those intrepid enough to take on the formidable task of interpretation, as well as those who may continue where the present editors have left off, this work will serve both as an inspiration and an incomparable source.

DRINKING AND INTOXICATION, edited by Raymond G. McCarthy. The Free Press ($7.50). "To drink," wrote William Congreve, "is a Christian diversion / Unknown to the Turk or the Persian." He was wrong on all counts. Drinking is an ancient social custom—as is getting drunk—practiced in almost all cultures. To "y-wet one's jolly whistle" (as Chaucer wrote in *The Canterbury Tales*) moderately or gluttonously was an indulgence already well established in Neolithic times: Stone Age beer jugs have been discovered. Many ancient records refer to alcoholic beverages; the word alcohol itself comes from the Arabic *al kohl*, which originally meant a fine powder of antimony used to color the eyelids. The Egyptians, Persians, Greeks, Romans and Hebrews all imbibed various kinds of fermented beverages. So did, among others, the Gauls, the people of Ultima Thule, the Spaniards and the Portuguese, the Ligurians, the Lusitanians, the Ethiopians, the Tyrrhenians, the Etruscans, the Balearic islanders (when they could get wine; usually having none, "they desired it all the more"), the Carthaginians, the Babylonians, the Scythians, the Germans. The Numidians, however, were abstemious, as were the Moors, who lived a severe life without any bread, wine or, in the words of Procopius, "any other good thing." Over the centuries drinking habits have ebbed and flowed in different societies—mostly flowed. This volume of selected readings presents a very informative survey of social practices, attitudes and controls. It considers the physiological and psychological effects of alcohol; drinking in the classical world, among nonclassical peoples, in Central and South America, in

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India, China and Japan, in old and new Russia, in France, England, Canada and the U. S.; drinking among high school and college students today; the motivational patterns; group influences; cultural, religious and ethical factors; attempts at controls in Sweden, Finland and the U. S. Useful supplementary reading lists are attached to each section. The editor concludes that the problem itself is a complex feature of a complex social structure, requiring much more study and certainly not to be solved by such piecemeal and often absurd measures as restrictive legislation, authoritarian fiat, "appeals to intelligence or to spiritual motive," increased prices for beverages, arrests and sentences for drunkenness, increased taxation on the beverage industry. After all, as long as many men believe that drinking "keeps the unhappy from thinking / And makes e'en the valiant more brave," it will be a hard practice to stamp out, even assuming that absolute temperance is a good thing.

THE ETRUSCANS, by Raymond Bloch. Frederick A. Praeger, Inc. ($5). Man knows next to nothing about his past, and even in the little he knows are imbedded profound mysteries. Of these none is more profound than the mystery of the Etruscans. For some six or seven hundred years, from about 700 B.C. to a short time before the Christian era, they spun their history on the Italian peninsula. At the zenith of their power they dominated Italy from the plain of the Po to Campania, with Tuscany the heart of their empire. They warred with the Greeks over the hegemony of the Mediterranean; they subjugated the Romans. They built great cities. They exploited large mineral deposits—iron, copper, zinc and tin—which were at the root of their wealth and power. They had a literature; they practiced a most elaborate ritualistic religion; they produced sculpture, paintings, intaglios and jewels of the highest artistic value. All this we know from the writings of Livy, Virgil and other Latin and Greek authors, from the remains of Etruscan cities and tombs, and from the many examples of their arts and crafts brought to light over the centuries in chance discoveries and systematic excavations. Yet the gaps in our knowledge about the Etruscans are almost incredible. Where did they come from? What were the roots of their culture? What language did they speak? These remain unanswered questions, enigmas "which combine to give to these first inhabitants of Tuscany a strange and secret air." Their literature has vanished without trace, except for occasional epigraphic documents. Even these cannot be read, because the language, despite long, persistent attempts, has resisted deciphering—"One of the most astonishing failures of modern linguistic studies." Nevertheless Etruscan studies have yielded a good deal of information about this remarkable civilization, information that is lucidly summarized in this fascinating book. The author, a leading French archaeologist who has made important field discoveries in Italic cultures, discusses the history of Etruscology, the conflicting theories as to the origins of the Etruscans and their history, the researches on their language, their institutions, customs, literature, religion and art. The story is supported by a collection of superb illustrations. A jewel of a book, in the delightful and distinguished Ancient Peoples and Places series edited by Glyn Daniel.

ORIGINS: A SHORT ETYMOLOGICAL DICTIONARY OF MODERN ENGLISH, by Eric Partridge. The Macmillan Company ($16). This latest work by a learned and indefatigable lexicographer traces the origins of the 12,000 "commonest words of the English language" from the indefinite article "a" to the prefix "zyzzo-." With the aid of cross references the field has been considerably widened to include altogether about 20,000 terms. A treat for amateur or professional philologists who, as Cowper wrote:

". . . chase
A panting syllable through time and
 space,
Start it at home, and hunt it in the
 dark,
To Gaul, to Greece, and into Noah's
 ark."

THEORY OF RELATIVITY, by W. Pauli. Pergamon Press ($6). The late Wolfgang Pauli's famous article on relativity was written for the German Mathematical Encyclopedia 38 years ago, when he was only 21. It now appears in an English translation for the first time, with 25 pages of supplementary notes prepared by Pauli at Princeton in 1956, covering selected information about later developments connected with relativity theory and giving his personal views upon some "controversial questions" such as the cosmological problem and unified-field theories.

PHILOSOPHY OF STRUCTURES, by Eduardo Torroja. University of California Press ($12.50). A long essay on

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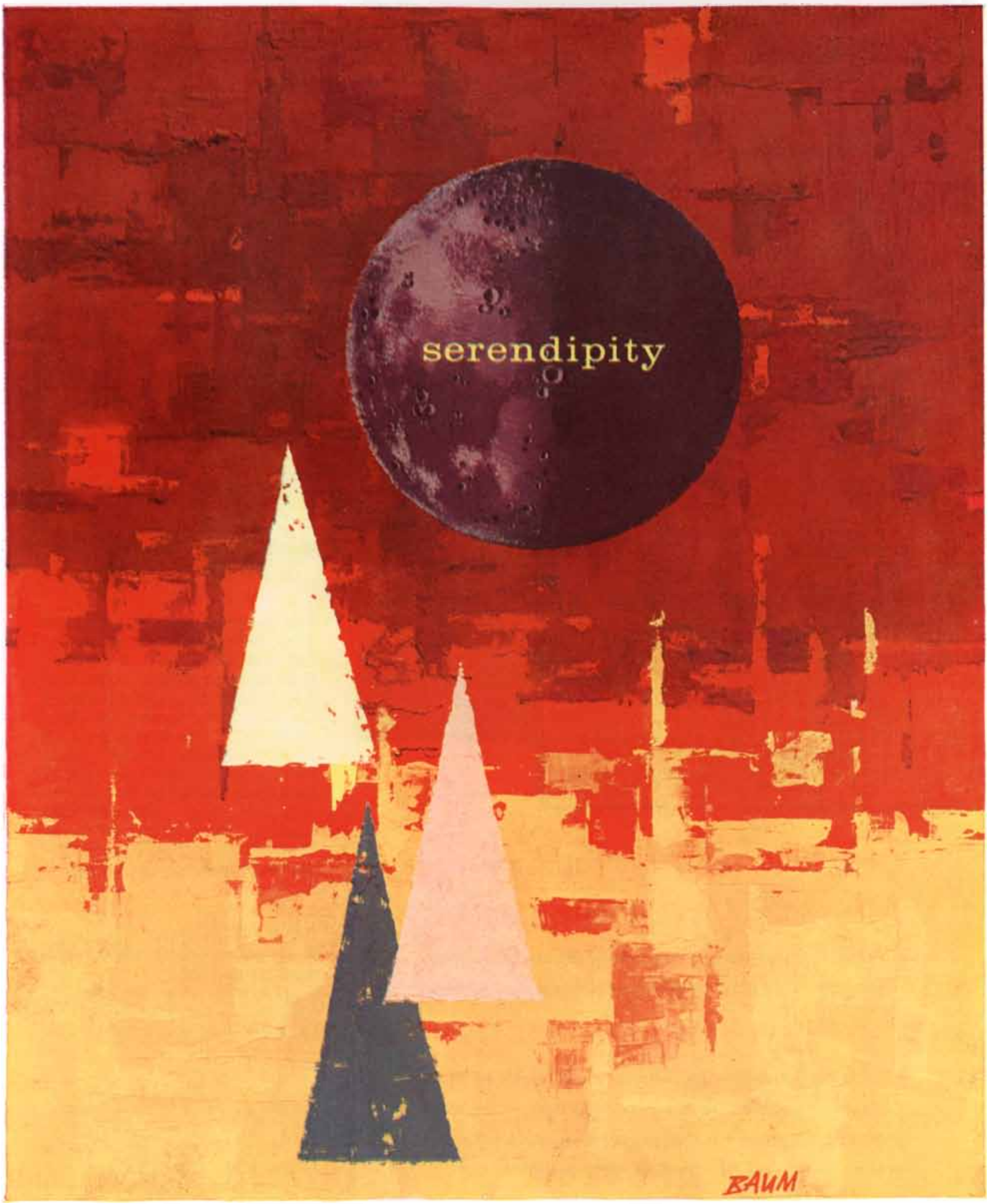

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structural design by a noted Spanish engineer and architect. The book contains lucid discussions of problems of stress, uses of materials, construction methods, design of bridges, dams, aqueducts and domes, and explains the nonesthetic justification for the many unusual forms adopted in modern architecture. Instructive and thoughtful; good illustrations.

NUCLEAR EXPLOSIONS AND THEIR EFFECTS. Publications Division of India ($4). Revised and enlarged edition of an authoritative and unbiased compendium on the nature and effects of nuclear explosions. It contains a copious amount of technical information on physical and biological phenomena, and is an invaluable reference guide for the specialist. But even the average reader willing to take thought will have no difficulty comprehending what it has to say about the hazards of global fallout and the dreadful prospect of nuclear war.

HISTORY UNEARTHED, by Sir Leonard Woolley. Ernest Benn, Ltd. (30 shillings). The noted excavator of Ur of the Chaldees presents a picture book, with its text reduced to a minimum, of 18 archaeological sites throughout the world, among them Nimrud, Troy and Mycenae, Maiden Castle, the Fayum and Oxyrhynchus, Anyang, Knossos, the tomb of Tutankhamen, Jericho, Serindia, Kara Tepe, Piedras Negras, the frozen tombs of Pazarik. The brief introductions to each subject and the picture captions are admirable; the photographs are very well chosen but not always well reproduced. Altogether an absorbing popular survey.

Notes

THE PHILOSOPHY OF SPINOZA, by Harry Austryn Wolfson. Meridian Books ($1.95). A paper-back reissue of a comprehensive critical evaluation of Spinoza's *Ethics*, published in 1934. The index of references has been omitted; otherwise this edition is complete.

A HISTORY OF PUBLIC HEALTH, by George Rosen. MD Publications, Inc. ($5.75). A readable and authoritative account of community-health action from its beginnings in the Greco-Roman world to its present state of development in economically and technologically advanced countries, especially Great Britain, France, Germany and the U. S.

BEHAVIOR AND EVOLUTION, edited by Anne Roe and George Gaylord Simpson. Yale University Press ($10). A collection of papers presented at two conferences of the American Psychological Association and the Society for the Study of Evolution, dealing with the relation and interaction between evolution and behavior. Simpson's stimulating epilogue, summarizing and weaving together the views of the various contributors, adds considerably to the value of the book.

GÖDEL'S PROOF, by Ernest Nagel and James R. Newman. New York University Press ($2.95). A much enlarged version of an essay that first appeared in this magazine, explaining this epochal achievement of modern logic to the nonspecialist.

A HISTORY OF PHILOSOPHY, by Wilhelm Windelband. Harper and Brothers ($3.50). This paper-back reissue of a justly esteemed history of philosophy is perhaps the best single work of its kind. Another of the excellent Harper Torchbooks.

LIVING RESOURCES OF THE SEA, by Lionel A. Walford. The Ronald Press Company ($6). A most intelligent and wide-ranging discussion of the sea's incomparable resources, many of which we have only barely glimpsed, much less begun to exploit. Any one of several chapters in this book, for example the one on farming brackish waters or on poisonous marine organisms, is of extraordinary interest and importance.

THE ILLUMINATED BOOK: ITS HISTORY AND PRODUCTION, by David Diringer. Philosophical Library ($25). A general account, fully illustrated, of the art of book-illumination, which made the medieval book one of the glories of creative imagination. A rich and varied volume.

BIOGRAPHY MEMOIRS OF FELLOWS OF THE ROYAL SOCIETY, VOL. IV. The Royal Society (30 shillings). Commemorative notices of 27 Fellows of the Royal Society, among them Viscount Cherwell, Walter Elliot, Douglas Hartree, John Graham Kerr, Irving Langmuir. Most of these memoirs give full accounts of the subject's life and work; each is accompanied by a photographic portrait.

A MODERN INTRODUCTION TO ETHICS, edited by Milton K. Munitz. The Free Press ($7.50). A skillful and discriminating selection of readings from classical and contemporary sources: John Dewey, Plato, Nietzsche, Bertrand Russell, Gilbert Murray, Aristotle, Epicurus,

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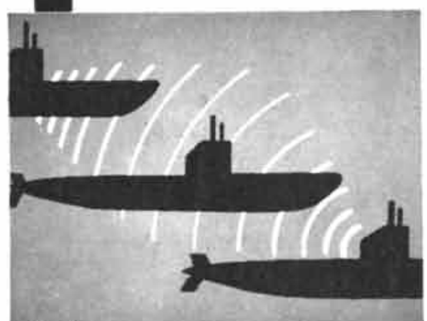

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John Stuart Mill, Kant, Schopenhauer, Santayana, Ernest Nagel, Sigmund Freud, Morris Cohen, G. E. Moore, A. J. Ayer, Epictetus and many others.

Statistical Physics, by L. D. Landau and E. M. Lifshitz. Addison-Wesley Publishing Company ($12.50). The fifth volume in the authors' nine-volume *Course of Theoretical Physics*, this book, translated from the Russian, is devoted to an exposition of statistical physics and thermodynamics. The first edition, published in 1938, contained only an exposition of classical statistics; the work has now been entirely rewritten to cover quantum statistics as well.

100 Years of Railroad Cars, compiled and edited by Walter A. Lucas. Simmons-Boardman Books ($8.50). Authentic pictures and drawings of more than 200 freight and passenger cars, taken from *The Car Builder's Cyclopedia* and the files of *Railway Age*. A most interesting guide to one aspect of U. S. industrial life.

Zoogeography, edited by Carl L. Hubbs. American Association for the Advancement of Science ($12). Fifteen papers from two symposia held in 1957, encompassing the field of zoogeography, with due attention to the underlying data of geomorphology, paleoclimatology, paleontology and physiology.

Biographical Memoirs, National Academy of Sciences, Vol. XXXII. Columbia University Press ($5). Robert Aitken, Francis Benedict, Benjamin Duggar, Wendell Latimer, Elmer Merrill, Henry Norris Russell, Thomas Vaughan and John von Neumann are among the scientists whose life and work are treated in these eloges.

Elliptic Integrals, by Harris Hancock. Dover Publications, Inc. ($1.25). Lectures on the Theory of Elliptic Functions Analysis, by Harris Hancock. Dover Publications, Inc. ($2.55). Paper-back reprints of standard monographs on this branch of advanced calculus.

Mathematics of Physics and Modern Engineering, by I. S. Sokolnikoff and R. M. Redheffer. McGraw-Hill Book Company, Inc. ($9.50). This volume, a successor to the senior author's *Higher Mathematics for Engineers and Physicists*, is an excellent text for the beginner in applied mathematics, and will be of considerable use to practicing engineers.

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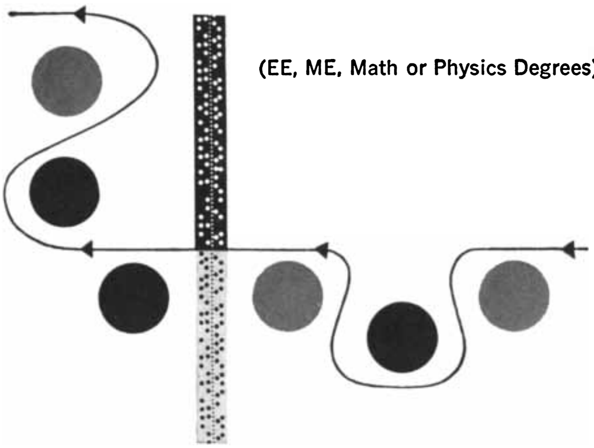

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These opportunities are with General Electric's Computer Dept.—now engaged in the design and development of a comprehensive DATA PROCESSING SYSTEM, handling problems which cannot be stated in terms of standard technologies.

Staff expansion is under way. Immediate openings exist for operations and systems analysts at both the Washington, D. C. office and the Phoenix, Arizona headquarters.

Write for further information on the scope of the USAF Data Processing Program and the exceptional opportunities it offers for career development.

Replies will be held in confidence.
Mr. J. E. Torrey, Div. 59-ME
COMPUTER DEPARTMENT
GENERAL ELECTRIC
13430 N. Black Canyon Highway, P.O. Drawer 270, Phoenix, Arizona

BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful.

NUCLEAR ROCKETS

ELECTRICAL PROPULSION SYSTEM FOR SPACE SHIPS WITH NUCLEAR POWER SOURCE. Ernst Stuhlinger in *The Journal of Astronautics*, Vol. 2, No. 4, Part I, pages 149-152; Winter, 1955. Part II, Vol. 3, No. 1, pages 11-14; Spring, 1956. Part III, Vol. 3, No. 2, pages 33-40; Summer, 1956.

NUCLEAR ROCKET PROPULSION. Robert V. Bussard and R. D. DeLauer. McGraw-Hill Book Company, Inc., 1958.

BALLOON ASTRONOMY

PHOTOELECTRIC ANGULAR ERROR SENSORS. R. A. Nidey and D. S. Stacey in *The Review of Scientific Instruments*, Vol. 27, No. 4, pages 216-218; April, 1956.

PHOTOGRAPHIES DE LA PHOTOSPHÈRE ET DES TACHES SOLAIRES. J. Rösch in *l'Astronomie*, Vol. 71, pages 129-141; April, 1957.

SOLAR ACTIVITY. K. O. Kiepenheuer in *The Sun*, edited by Gerard P. Kuiper, pages 322-458. University of Chicago Press, 1953.

ZUR SONNENGRANULATION. G. Thiessen in *Zeitschrift für Astrophysik*, Vol. 35, Band 4, pages 237-244; January, 1955.

THE ORIGIN OF DARWINISM

EVOLUTION, OLD AND NEW. Samuel Butler. E. P. Dutton & Company, 1914.

LECTURES ON PHYSIOLOGY, ZOOLOGY, AND THE NATURAL HISTORY OF MAN. W. Lawrence. Printed for J. Callow, 1819.

THE NATURAL HISTORY OF MAN. James Cowles Prichard. H. Baillière, 1845.

RESEARCHES INTO THE PHYSICAL HISTORY OF MANKIND. James Cowles Prichard. Sherwood, Gilbert & Piper, 1836.

ZOONOMIA. Erasmus Darwin. Printed by T. & J. Swords, 1796.

EXPERIMENTS IN COLOR VISION

COLOR VISION AND THE NATURAL IMAGE. PART I. Edwin H. Land in *Pro-*

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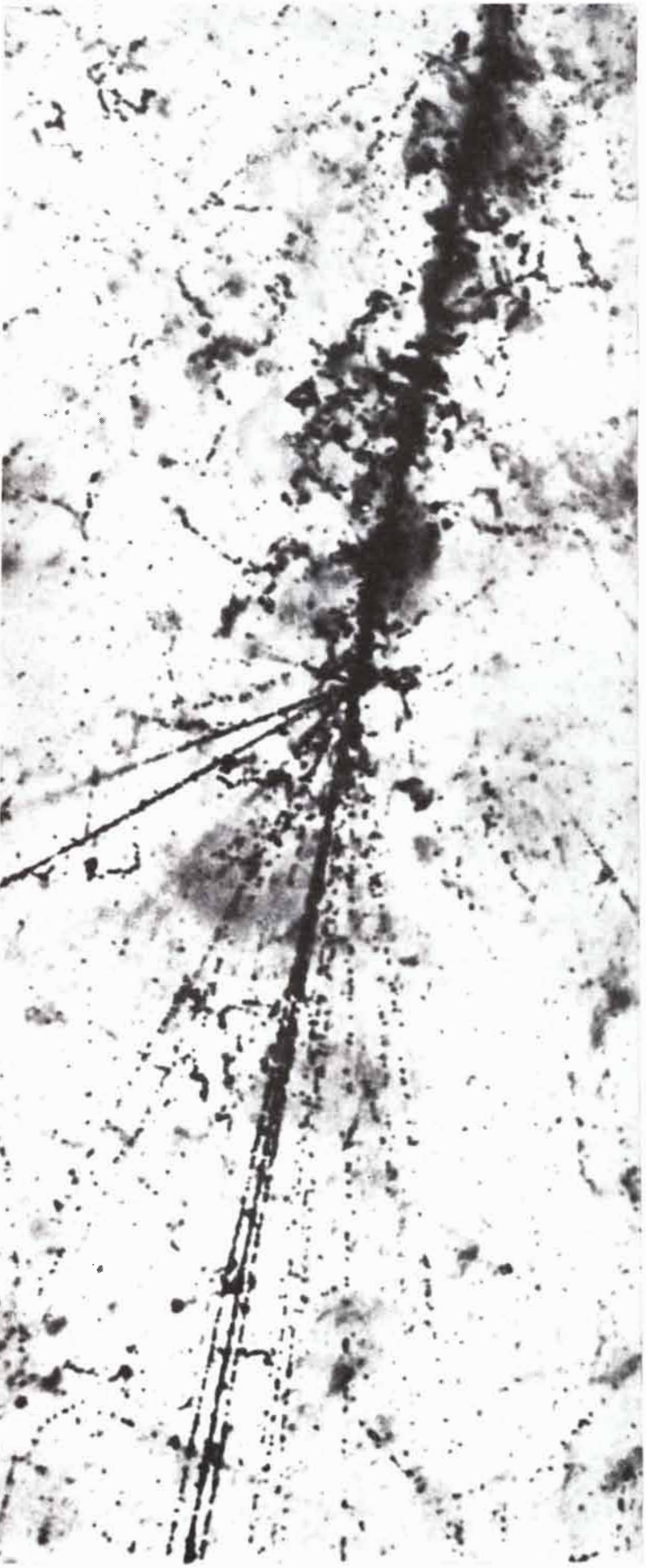

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Cosmic ray (an iron nucleus) smashes a nucleus in a photographic emulsion exposed by Herman Yagoda of the Air Force Cambridge Research Center. Such events are a primary source of high-energy radiation.

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ceedings of the National Academy of Sciences, Vol. 45, No. 1, pages 115-129; January, 1959.

COLOR VISION AND THE NATURAL IMAGE. PART II. Edwin H. Land in *Proceedings of the National Academy of Sciences,* Vol. 45, No. 4, pages 636-645; April, 1959.

SYMPOSIUM ON NEW DEVELOPMENTS IN THE STUDY OF COLOR VISION. *Proceedings of the National Academy of Sciences,* Vol. 45, No. 1, pages 89-115; January, 1959.

SENSATION AND PERCEPTION IN THE HISTORY OF EXPERIMENTAL PSYCHOLOGY. Edwin G. Boring. Appleton-Century-Crofts, Inc., 1942.

THE LATE BLIGHT OF THE POTATO

THE BLIGHT, THE BLIGHTER, AND THE BLIGHTED. John S. Niederhauser in *Transactions of the New York Academy of Sciences,* Series II, Vol. 19, No. 1, pages 55-63; November, 1956.

BLIGHT-RESISTANT POTATOES. Donald Reddick in *Phytopathology,* Vol. 18, No. 6, pages 483-502; June, 1928.

BREEDING FOR RESISTANCE TO LATE BLIGHT IN THE POTATO. F. J. Stevenson, E. S. Schultz, C. F. Clark, Lillian Cash, Reiner Bonde in *Phytopathology,* Vol. 27, No. 11, pages 1,059-1,070; November, 1937.

CARGO CULTS

THE TRUMPET SHALL SOUND: A STUDY OF "CARGO" CULTS IN MELANESIA. Peter Worsley. Macgibbon & Kee, 1957.

TISSUES FROM DISSOCIATED CELLS

THE COMPOUNDING OF COMPLEX MACROMOLECULAR AND CELLULAR UNITS INTO TISSUE FABRICS. Paul A. Weiss in *Proceedings of the National Academy of Sciences,* Vol. 42, No. 11, pages 819-830; November, 1956.

ARTIFICIAL SATELLITES AND THE THEORY OF RELATIVITY

EXPERIMENTELLE PRÜFUNG DER ALLGEMEINEN RELATIVITÄTSTHEORIE. V. L. Ginzburg in *Fortschritte der Physik,* Vol. 5, Heft 1, pages 16-48; 1957.

THE AMATEUR SCIENTIST

THE ELECTRON. Robert Andrews Millikan. University of Chicago Press, 1924.

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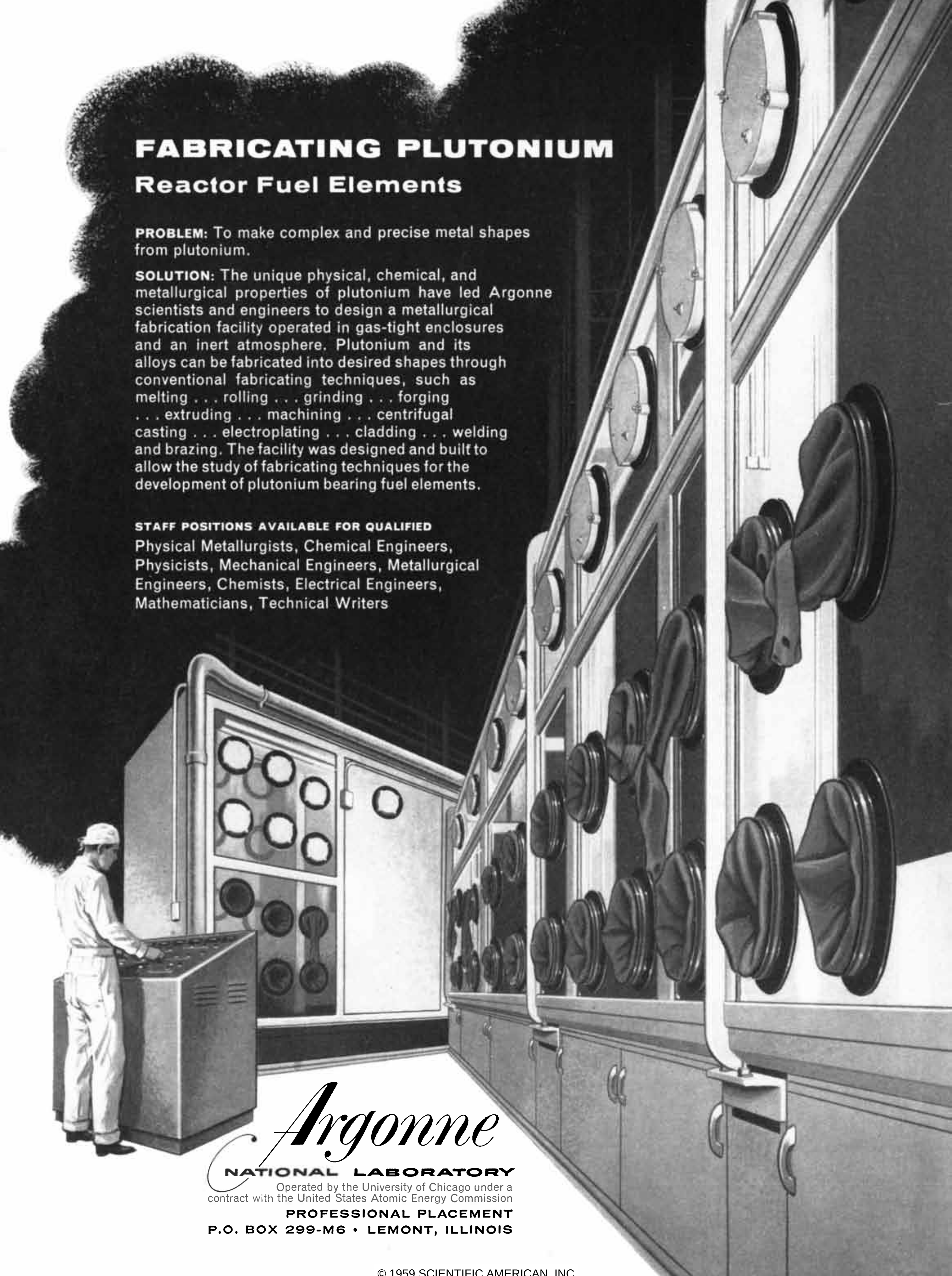

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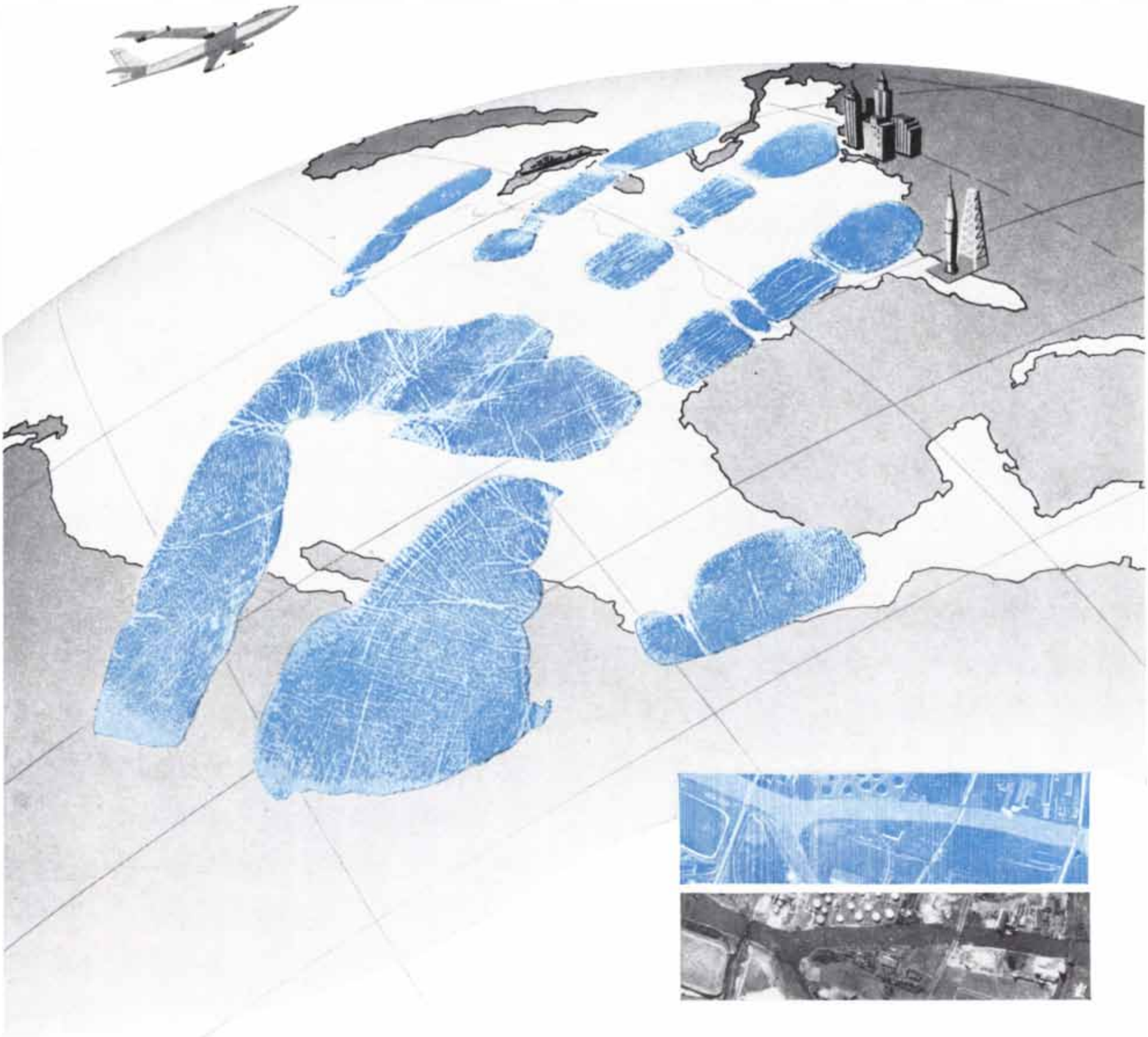

INFRARED FINGERPRINTS

for reconnaissance, interpretation and prediction

Aerial reconnaissance systems of the future will depend on infrared detectors and scanners for operation around the clock. Each surveillance target or object of military or geophysical significance will have its own characteristic fingerprint in the infrared spectrum.

Infrared scientists at Bendix Systems Division, backed by years of experience in these techniques, are developing important new approaches to the interpretation and prediction of infrared reconnaissance data.

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PHOTOSTRESS—new look in experimental stress analysis

About two years ago, a Budd subsidiary—Tatnall Measuring Systems Company—acquired the services of a young French scientist who brought with him a unique method of stress analysis known as PhotoStress. This system is a highly refined use of photoelasticity for making surface strain patterns visible in any material subjected to stress. Dr. Felix Zandman, inventor of the method, has since refined it even further by developing instruments which make it easily possible to analyze the visual strain patterns quantitatively, and with great precision.

In use, the structure to be stress-analyzed is coated with a special clear plastic that becomes doubly refractive when stressed. Under polarized light the overall distribution of surface strains appears as black (isoclinics) and color (isochromatics) fringes in the plastic. The technique differs from conventional photoelastic techniques in that a transparent plastic is bonded to an actual part and stresses are determined under the actual loading system instead of making models out of plastic. It acts, in effect, as an infinite number of strain gages of virtually zero gage length, uniformly distributed over the surface of the structure to be studied.

To carry an analysis to completion, one reading of the black fringes is taken, with light penetrating the special plastic at normal incidence. This gives the value of the difference of principal strains—therefore, the maximum shear strain ($\gamma_{max} = \epsilon_1 - \epsilon_2$). An additional reading of the colored fringes, with light penetrating the plastic at an oblique incidence, when combined with the normal incidence reading, gives the values and signs of the two principal strains, ϵ_1 and ϵ_2.

The convenience of the system lies in its two stages. First, liquid or sheet plastic can be applied quickly to a structure or component. Immediately upon the application of stress, strain patterns and directions become obvious to the observer. These can be preserved by simply making a color photograph of them. The second stage, or quantitative analysis with instrumentation, can be performed at the same time, or can be deferred until a later date, after strain patterns have been more thoroughly analyzed.

To date, the system has been highly successful in stress analyses performed upon such diverse structures as missiles, bridges, airplanes and machine components. In cases such as these, failure points have been predicted with great accuracy.

Information about PhotoStress can be obtained from Tatnall Measuring Systems Company, P. O. Box 245, Phoenixville, Pa.

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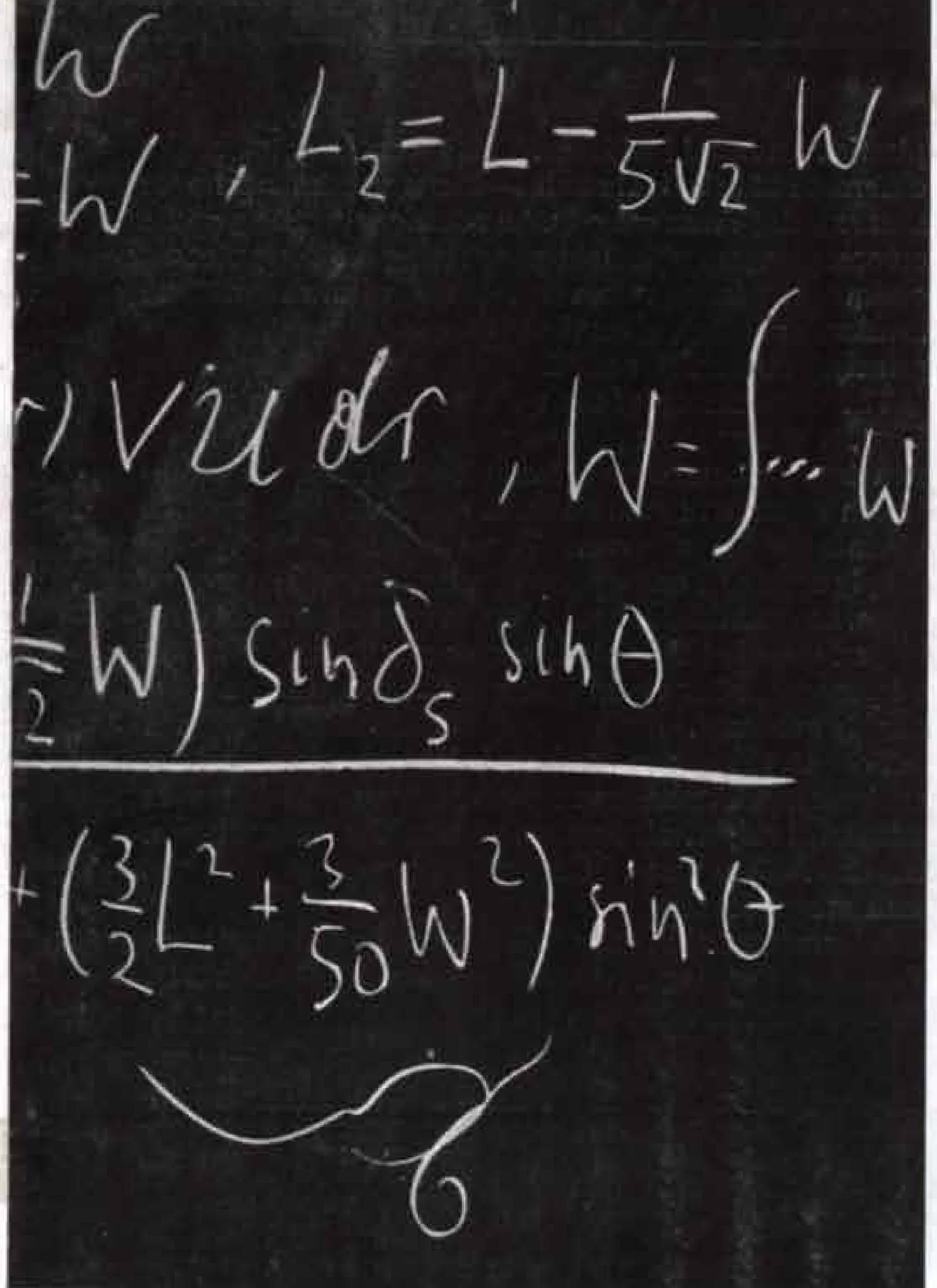

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