SCIENTIFIC AMERICAN

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May 1956

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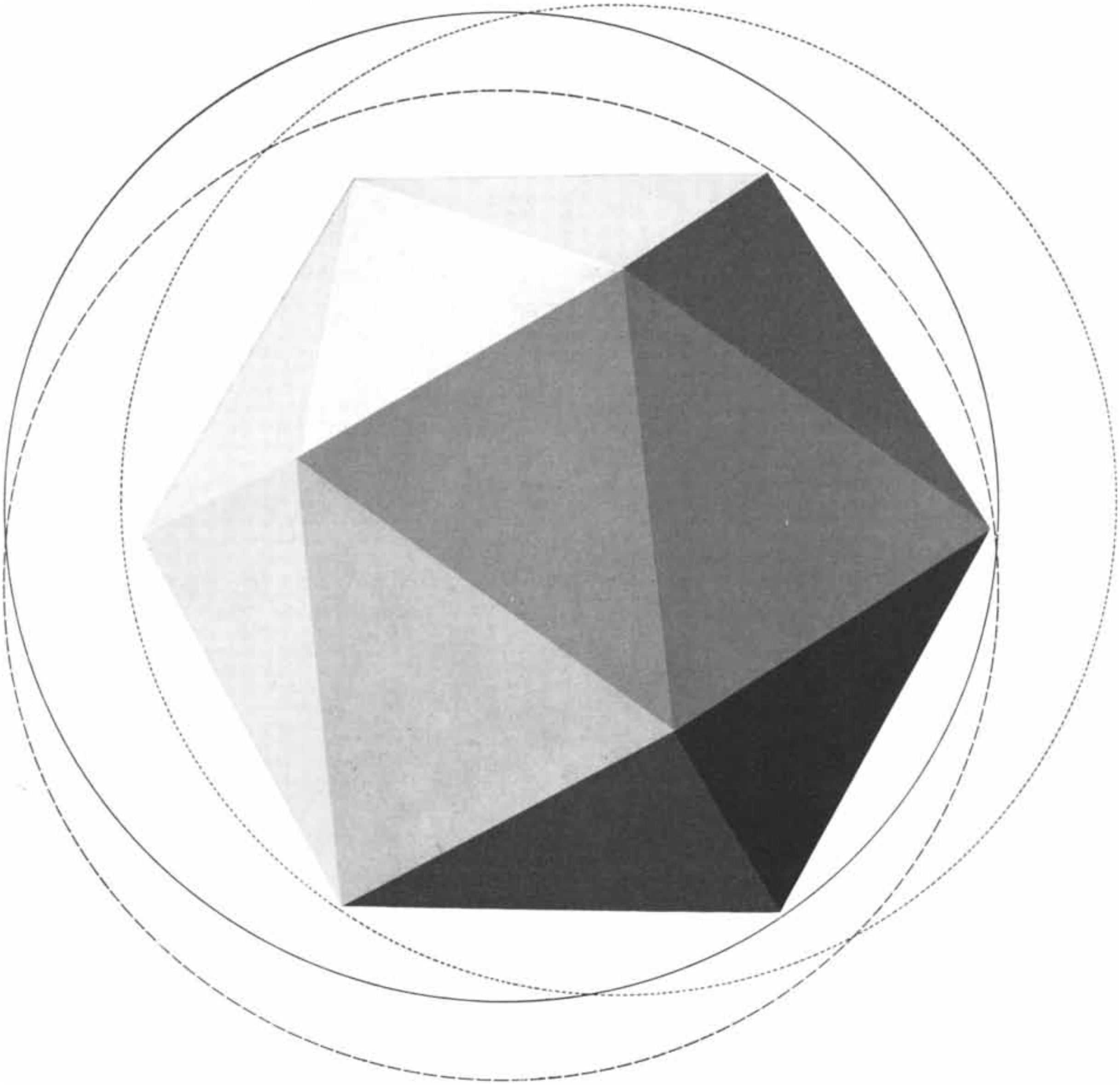

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I

Established 1845 **SCIENTIFIC AMERICAN** May, 1956 Volume 194 Number 5

ARTICLES

DEPARTMENTS

THE COVER

The painting on the cover depicts a laboratory study at Princeton University of how mushrooms are able to grow with almost explosive rapidity (*see page* 97). When the mushroom in the center and the one at lower left first pushed above ground, they were painted with a vertical row of carmine spots the same size and the same distance apart. As the mushrooms grew, the size of the spots and the distance between them changed, reflecting the pattern of growth. The right side of the painting is cut away to show the structure of the mature and immature mushroom, and to reveal threads of the mycelium just below the surface of the soil. At lower right is the foundation of the "flat" in which the mushrooms are grown.

THE ILLUSTRATIONS

Cover painting by John Langley Howard

Page	Source
35	Paul Weller
36	Irving Geis
37	Paul Weller
38	Irving Geis
39	Irving Geis (*top*), Oak Ridge National Laboratory (*bottom*)
40-47	Herman Yagoda
48-51	John Langley Howard
52	R. W. Sperry
69	Metropolitan Museum of Art
70-76	Eric Mose
84-90	Duveen Historical Library
97-100	K. Kent Kane and Raphael H. Levey
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112-116	James Egleson
118	Massachusetts Institute of Technology
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122-127	Bunji Tagawa
133-137	Gernsheim Collection
156-158	Roger Hayward

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b. Electrolytic Nickel (Watt bath) 14.7
c. Kanigen Nickel-Phosphorus, as plated 13.7
d. Kanigen Nickel-Phosphorus after heat treatment at 1000°F for one hour 12.3
e. Kanigen Nickel-Phosphorus after heat treatment at 1200°F for one hour 8.3
f. Kanigen Nickel-Phosphorus after heat treatment at 1400°F for one hour 6.1

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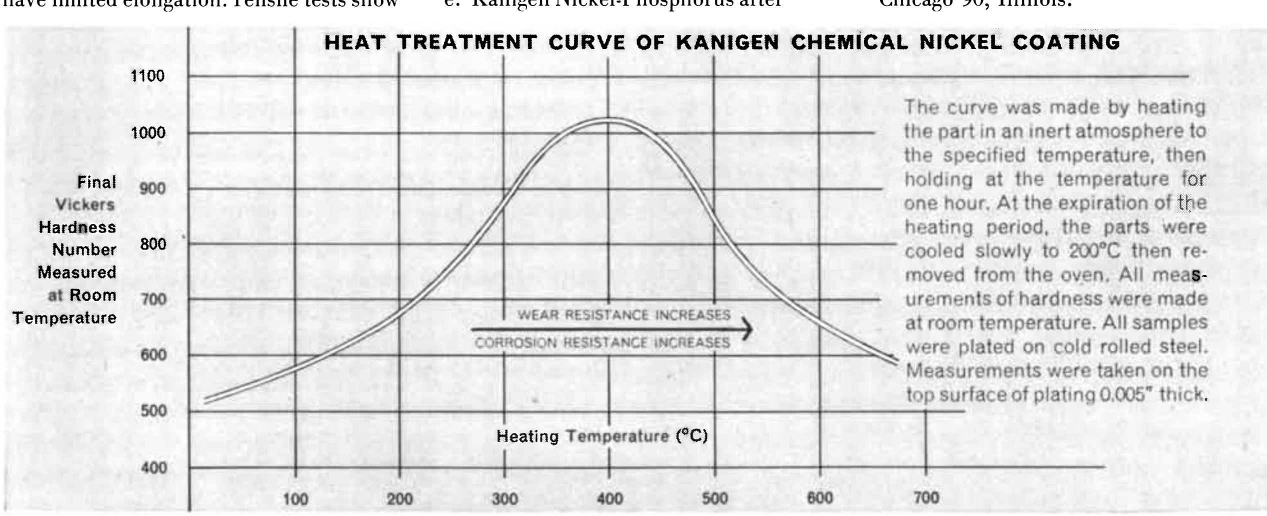

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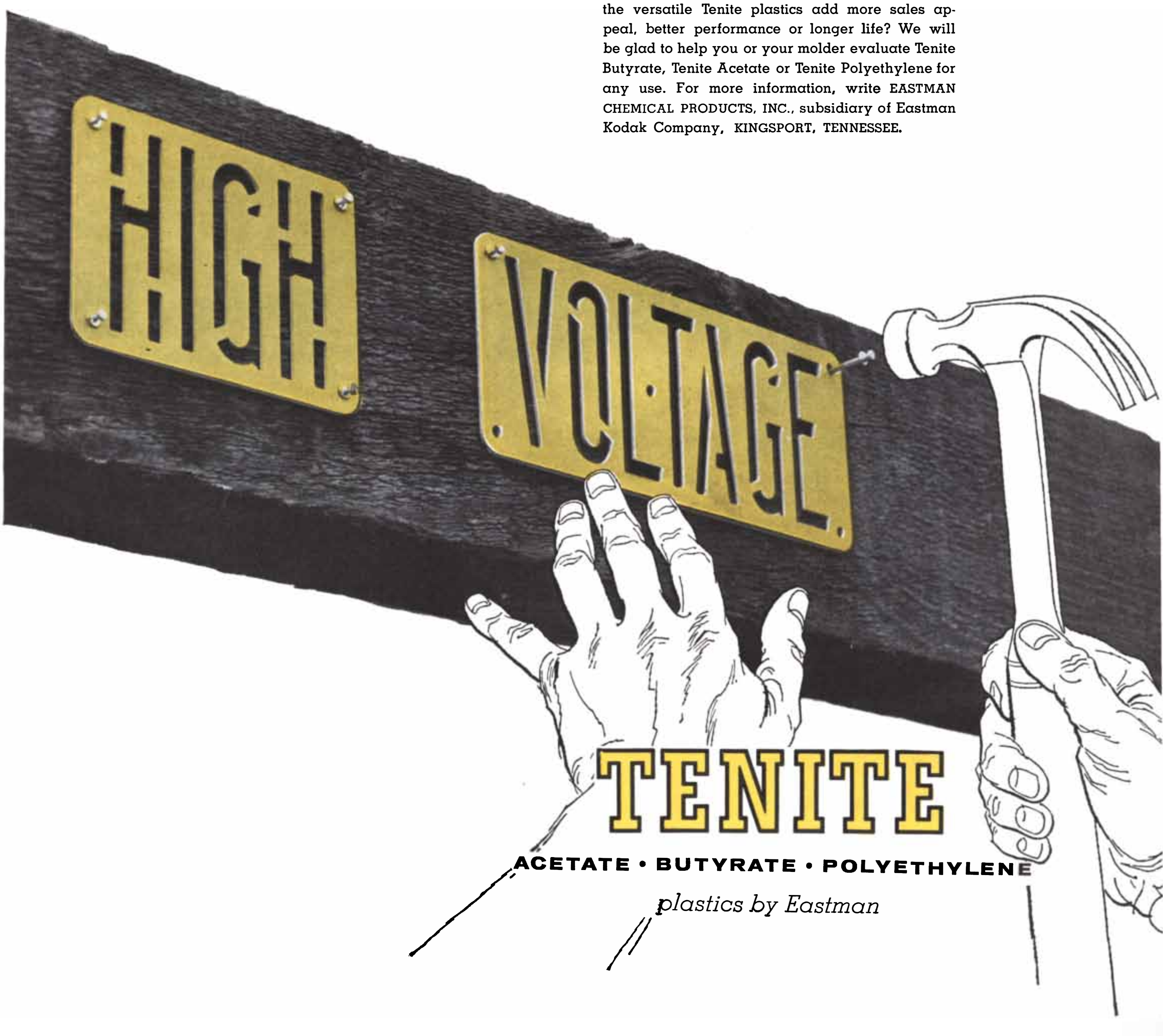

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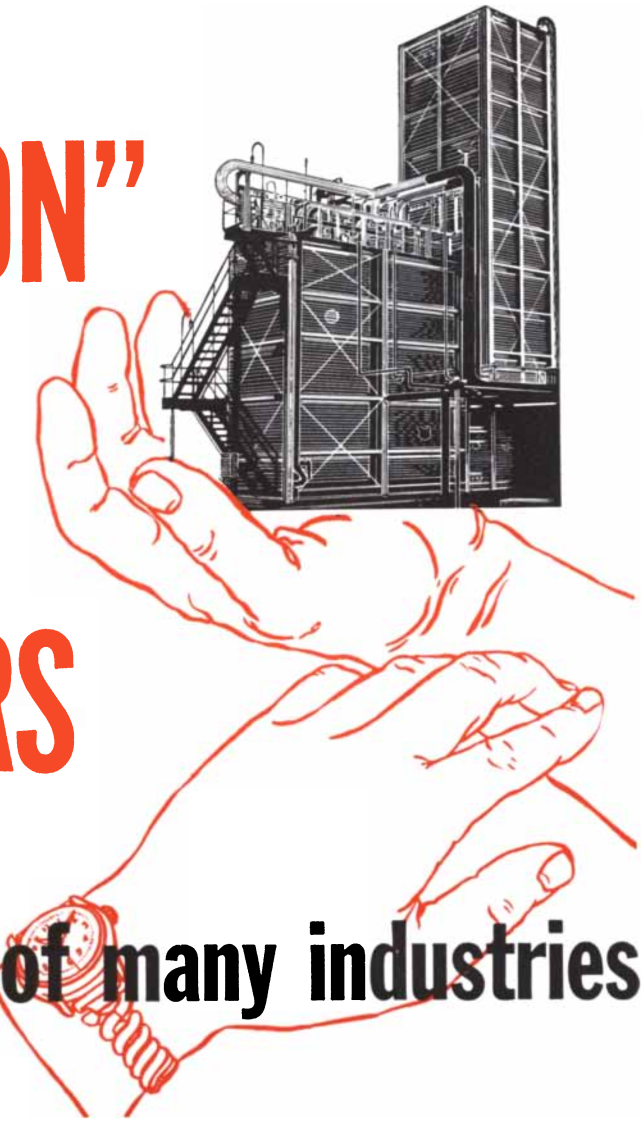

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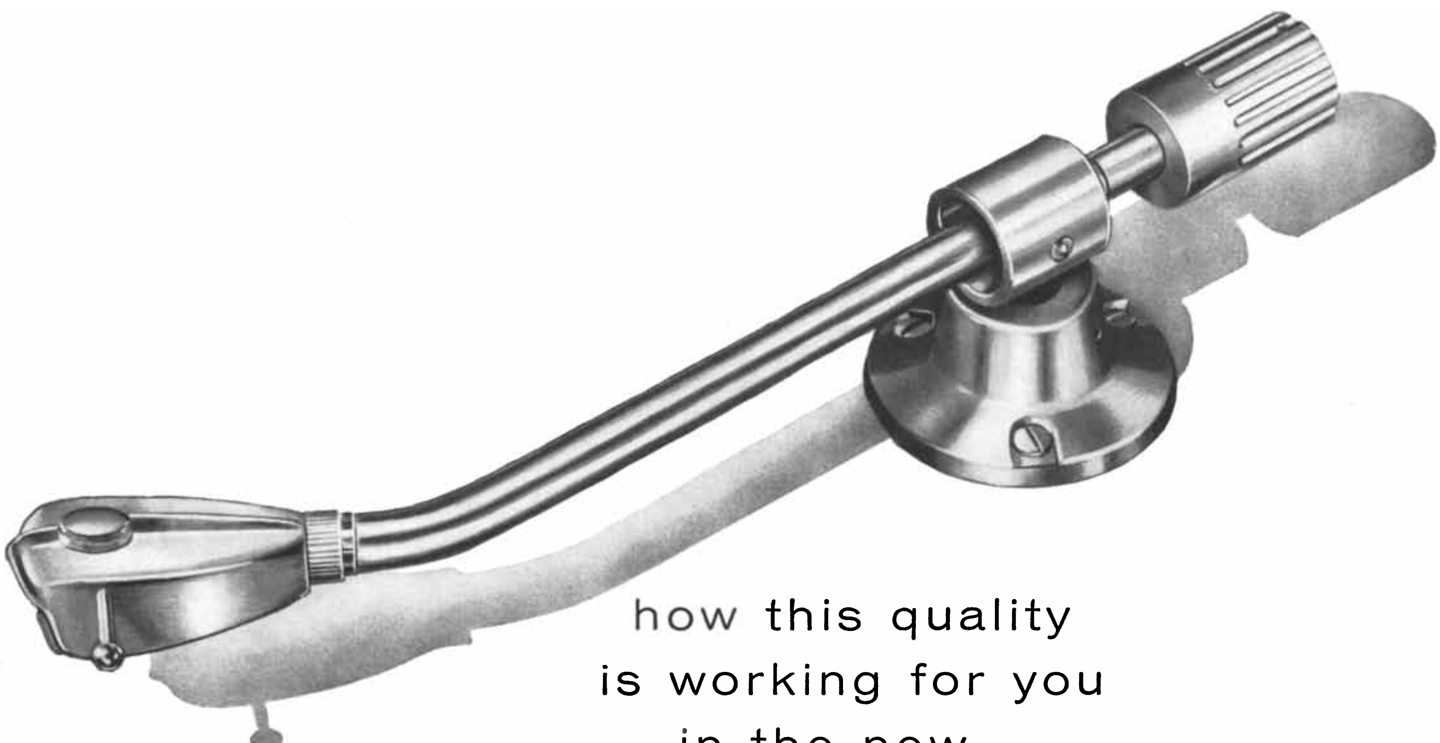

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So free and effortless is the motion of this arm, so sensitive its suspension, that in a state of perfect balance, a mere feather can tip the scale.

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LETTERS

Sirs:

I should like to comment on Harrison Brown's account [SCIENTIFIC AMERICAN, March] of the Velikovsky controversy, inasmuch as I was the author of one of the magazine articles he describes as "sensational" and have not withdrawn from the position I then took (*Harper's*, January, 1950; see also *Science*, August 7, 1953). His imputation, in his concluding sentence, that such a continuing interest as mine could be based only on commercial motives is gratuitously insulting and fully representative of the attitudes among scientists which he then seeks to justify.

The question at issue here is how to handle iconoclasm—how the iconoclast is to behave, how those confronted with him are to behave. As one who has participated in this affair from an early stage, I am of the opinion that Dr. Velikovsky has behaved better than his detractors, and Dr. Brown does not convince me otherwise. His account of the Macmillan Company's action in abandoning *Worlds in Collision* is disingenuous in the extreme, since he does not mention the main reason for it—the threat of boycott, clearly expressed both in word and act by individual scientists. He later describes this pressure as "unfortunate," which is an inadequate term. It was a disgrace to American science, and will so remain long after the substance of the dispute has been contained and dissolved in the flow of the scientific process.

Scientific American, May, 1956; Vol. 194, 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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I also find evasive his statement that the major reason for the over-emotionalism of scientists about Velikovsky is the amount and nature of the publicity received, since highly adverse opinions were fully publicized before the book appeared in journals that scientists could be expected to read, such as *Time* or *The Reporter*. A more illuminating reason seems to me to lie in the nature of the challenge Velikovsky offered—in the fact that, unlike the run-of-the-mill heretic, he was scholarly and in earnest. I am glad to see that Dr. Brown is finally willing to concede Velikovsky's motives, since many of his colleagues have not always been this generous—and have permitted themselves the use of intemperate language they would do well to repudiate.

For my own part, after receiving my share of academic ill-temper and abuse, I can only say that I was shocked to discover how slender is the faith of many scientists in the open testing of ideas and how many of them tend to suppose their own beliefs and "science" to be identical. Respect for scientific method fortunately does not require blanket acceptance of all the current orthodoxies, even where they are not in conflict, and I share with Dr. Brown the hope that this respect will generally tend to increase. If, however, as he suggests, the Velikovsky controversy is "an outstanding case of lack of communication between scientists and nonscientists," then there are other lessons in it than the ones he draws.

For one thing, despite their repeated assertions that he will soon be forgotten, scientists seem unable to leave Velikovsky alone; and each new position they take is a retreat from the previous one. Dr. Brown is far more restrained in his remarks this time than he was previously, and I respect his determination to be as fair as he can. He does not, on the other hand, review the new Velikovsky book, *Earth in Upheaval;* instead he offers us a description of his own mental processes plus a tendentious account of events he knows only at hearsay. If this is science, you are welcome to it.

ERIC LARRABEE

Harper's Magazine
New York, N. Y.

Sirs:

As a long-time subscriber to *Harper's Magazine* I have often admired Mr. Larrabee's intelligence and his ability. His first piece concerning *Worlds in Col-*

lision puzzled me and at the time I was convinced that he had "been taken." But his continued blind faith in the validity of a nonsensical theory, which he obviously does not understand, puzzles me even more. During the last few years Mr. Larrabee has, I believe deservedly, been pressed into a corner. My only regret is that he has now become so angry about it.

With the appearance of *Earth in Upheaval* I took the opportunity of reviewing the Velikovsky affair to the best of my ability, with the information available to me. I believe strongly that all of us—magazine editor, scientist and book publisher alike—have much to learn from the episode, and I attempted to draw the lessons as I saw them.

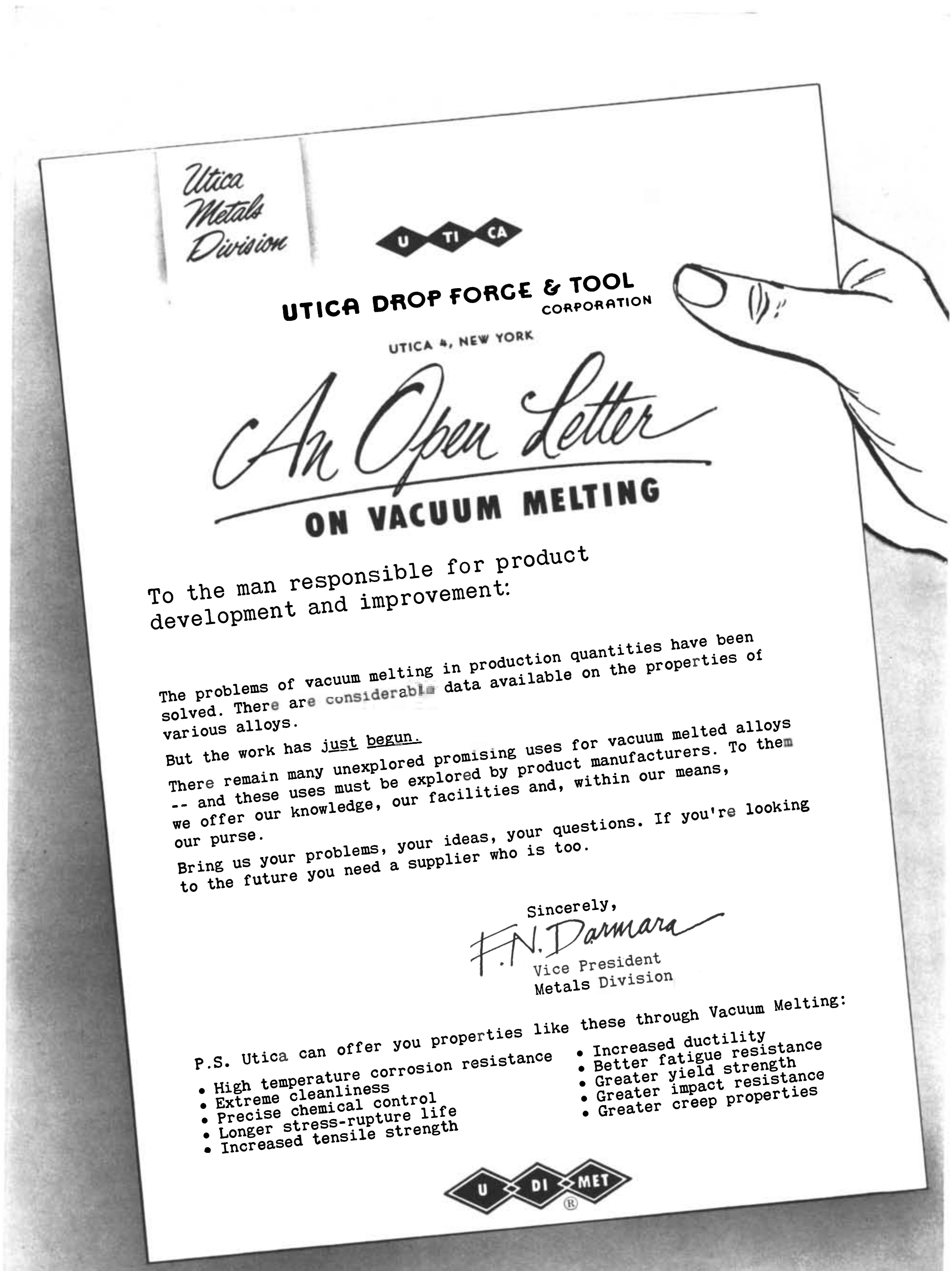
So far as I am concerned my discussion of the Velikovsky matter stands. But for the record I would like to make one point absolutely clear. Mr. Larrabee states that "scientists seem unable to leave Velikovsky alone; and each new position they take is a retreat from the previous one. Dr. Brown is far more restrained in his remarks this time than he was previously. . . ." This implies that during the last few years I have modified my views concerning Velikovsky's theories. I would like to stress that I considered these notions nonsense when I first read them. I have read each of Velikovsky's subsequent books carefully. I consider his theories to be fully as nonsensical today as they were yesterday.

As to our being unable to leave Velikovsky alone—he continues to write books, and this in effect compels us not to leave him alone. As Mr. Larrabee knows so well, books are meant to be read, discussed and criticized or praised, as the case may be.

I believe that scientists have a moral obligation to combat pseudo science whenever it arises. In my own case, when I see the public being fed distorted facts

ERRATUM

In the article "World Population," by Julian Huxley (SCIENTIFIC AMERICAN, March), two charts were incorrectly labeled. The second of four charts on pages 70 and 71 was described as showing the birth and death rates of England and Wales. The third of the four charts was described as showing the birth and death rates of the U. S. Actually the second chart refers to the U. S., and the third to England and Wales.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An Open Letter
ON VACUUM MELTING
To the man responsible for product development and improvement:
The problems of vacuum melting in production quantities have been solved. There are considerable data available on the properties of various alloys.
But the work has just begun.
There remain many unexplored promising uses for vacuum melted alloys -- and these uses must be explored by product manufacturers. To them we offer our knowledge, our facilities and, within our means, our purse.
Bring us your problems, your ideas, your questions. If you're looking to the future you need a supplier who is too.
Sincerely,
F.N. Darmara
Vice President
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and exaggerations and when I see it being fed glamorous and sensational theories *which can be proved wrong,* I am compelled to speak up. As long as Velikovsky continues to write what my colleagues and I believe to be nonsense, I shall continue to say publicly that I believe he is writing nonsense. I fear that Mr. Larrabee will continue to be unhappy.

HARRISON BROWN

California Institute of Technology
Pasadena, Calif.

Sirs:

Julian Huxley presents an excellent scientific study of population trends ["World Population," SCIENTIFIC AMERICAN, March]. But his interpretation of the data seems to surpass the scope of natural sciences, yielding value judgments as conclusions. From statistics on population distribution, average daily calorie consumption, birth and death rates, a scientist cannot determine the quality of (human) lives (page 66), man's ultimate satisfactions (page 67), and modern standards of art and ceremonials (page 71).

If we follow Dr. Huxley's suggestion and seek a more rational view of the population problem, we must recognize taboos which transcend various cultures and religious forms as being most probably rooted in human nature. Civilized society is conditioned by these drives and restraints. If any one of these conduct patterns is habitually transgressed, the individual's personality has lost its integrity, tending to compromise all the other accepted norms of conduct. It seems contradictory that people "could be encouraged to retain faith in the essential validity of their indigenous arts and ceremonials, and helped in the task of adapting them to modern standards (page 71)." The psychological analysis of Gandhi's solution to the problem, begins: "As a result of his disgust at his own indulgence . . . (page 70)." The disgust is a datum; its existence is a factor making the whole problem more than a laboratory exercise. As a scientist I can share the author's regret that "this enormous human ant heap . . . is so uncontrollable (page 69);" but as a human, I cherish that uncontrollable element.

ROBERT Y. O'BRIEN, S. J.

Woodstock College
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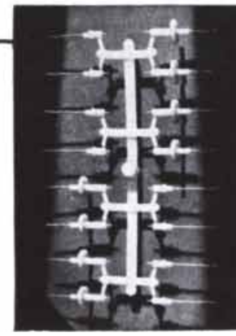

Blood-donor and receiver needles as they come from the mold illustrate how Du Pont "Zytel" is readily molded around metal inserts.

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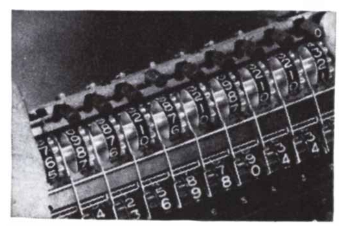

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	170°F.	7,600 p.s.i.	D-638-46T
Elongation	—70°F.	1.6%	D-638-46T
	73°F.	90%	D-638-46T
	170°F.	320%	D-638-46T
Modulus of elasticity	73°F.	400,000 p.s.i.	D-638-46T
Shear strength		9,600 p.s.i.	D-732-46
Impact strength, Izod	—40°F.	0.4 ft.-lb./in.	D-256-47T
	73°F.	1.0 ft.-lb./in.	D-256-47T
Stiffness	73°F.	200,000 p.s.i.	D-747-48T
Flexural strength	73°F.	13,800 p.s.i.	D-790-45T
Compressive stress at 1% deformation		4,900 p.s.i.	D-695-44T
Creep in flexure		90	**
Hardness, Rockwell		R 118	D-785-48T

THERMAL

Flow temperature	480°F.	D-569-48
Coefficient of linear thermal expansion per °F.	5.5×10^{-5}	D-696-44
Thermal conductivity	1.7 B.T.U./hr./sq.ft./°F./in.	—
Specific heat	0.4	—
Deformation under load at 122°F. and 2000 lb./sq.in.	1.4%	D-621-48T
Heat-distortion temperature 264 lb./sq.in.	150°F.	D-648-45T
Heat-distortion temperature 66 lb./sq.in.	360°F.	D-648-45T

ELECTRICAL

			METHOD
Dielectric strength, short-time		385 V/MIL	D-149-44
	step by step	340 V/MIL	D-149-44
Volume resistivity	4.5×10^{13}	OHM-CM.	D-257-46
Dielectric constant,	60 cycles	4.1	D-150-47T
	10^3 cycles	4.0	D-150-47T
	10^6 cycles	3.4	D-150-47T
Power factor,	60 cycles	0.014	D-150-47T
	10^3 cycles	0.02	D-150-47T
	10^6 cycles	0.04	D-150-47T

MISCELLANEOUS

Water absorption	1.5%	D-570-42
Flammability	self-extinguishing	D-635-44
Specific gravity	1.14	D-792-48T
Average mold shrinkage	0.015 in./in.	—
Compression ratio	2.1	D-392-38
Resistance to weathering	good	—
Basic color	light cream, translucent	—
Resistant to:	esters, ketones, common solvents, alkalies, weak acids	
Not resistant to:	phenol, formic acid, concentrated mineral acids	

*Some of the physical properties are dependent on the moisture content of the nylon which may be as high as 2-2.5% under normal exposure.

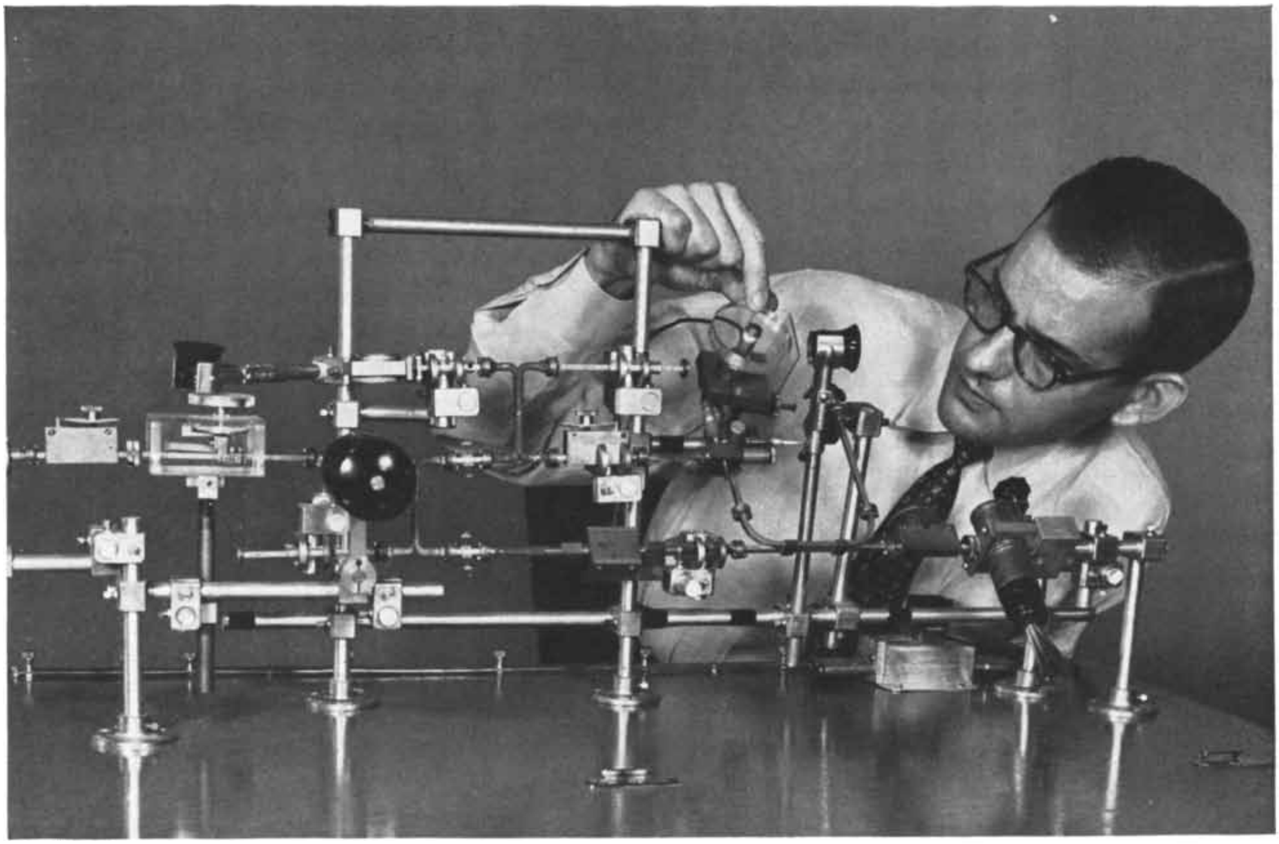
**Term "creep in flexure" is a measure of the deformation under a prolonged standard load. Results here represent mils deflection in 24 hrs. of a ⅛"x ½" bar, 4" span, center-loaded flatwise to 1,000 lb./sq. in. minus the initial deflection.

Note: This table shows the typical property data for Du Pont "Zytel" 101 nylon resin.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MAY, 1906: "In the immediate presence of the great catastrophe of the San Francisco earthquake of April 18, in which hundreds of lives have been lost and the city has been almost entirely destroyed, it is not to be expected that much of scientific value should be recorded. All that is here possible is to describe briefly the course of events. The first and greatest shock was heralded by no warning tremors or earth sounds. It occurred at 5:13 A.M. (that is, 1:13 P.M. Greenwich mean time); perhaps, as the seismographic evidence would imply, a few minutes earlier. The duration of the shock was considerable, not less than two or three minutes, and it was in this time that the chief part of the destruction, so far as it was directly due to the earthquake, was accomplished. Five minutes later another and less violent shock was felt, and, in the midst of almost continuous tremors, a third prominent shock took place at 8:15 A.M., and others shortly before 10 A.M., and about 1:30 and 7 P.M. Soon after the first shock, fires broke out in several parts of the city and spread rapidly, the water mains having been injured. Attempts, on the whole successful, were made to limit their extension by blowing up passages through the crowded parts, with the result that about one quarter of the city may be ultimately saved. That San Francisco was situated within or close to the epicentral area is shown by the continuous aftershocks, and by the effects of the shock. Observers in the open air state that the streets could be seen to bulge and wave as if about to crack open. The absence of news from neighboring places, and especially from the Lick Observatory, is disquieting; the extent of the disturbed area will remain unknown until inquiries have been made, but it is curious how few details on the subject have been published. If the line drawn so as to bound the known area of destruction be even approximately correct, there can be no doubt that the epicenter was submarine and situated some little distance from the coast. In all parts of the world



Physicist G. K. Farney checks the frequency of Bell's new klystron, which is located at far right. Tube's output is about 20 milliwatts.

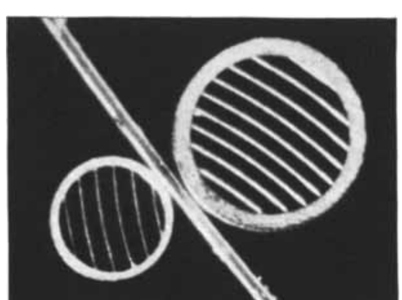
Sixty billion vibrations per second

A great new giant of communications—a waveguide system for carrying hundreds of thousands of voices at once, as well as television programs—is being investigated at Bell Telephone Laboratories.

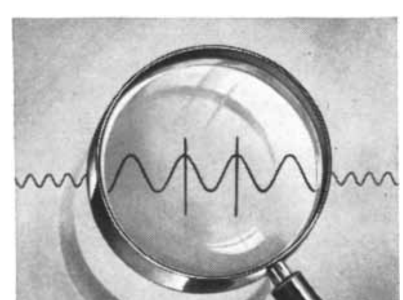
Such a revolutionary system calls for frequencies much higher than any now used in communications. These are provided by a reflex klystron tube that oscillates at 60,000 megacycles, and produces waves only 5 mm. long.

The resonant cavity that determines the frequency is smaller than a pinhead. The grid through which the energizing electron beam is projected is only seven times as wide as a human hair, and the grid "wires" are of tungsten ribbon 3/10,000 inch in width.

G. K. Farney, University of Kentucky Ph. D. in nuclear physics, is one of the men who successfully executed the development of the klystron. Dr. Farney is a member of a team of Bell scientists whose exciting goal is to harness the immense bandwidth that is available with millimeter waves . . . and to make certain that your telephone system remains the best in the world.



Grids in new tube, enlarged 30 times, with human hair for comparison. Electronic beam passes through smaller, then larger, grid.



Wavelengths produced by the klystron tube are only .2 inch long—1/15 that of the transcontinental radio relay system.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH

delicate seismographs soon afterward recorded the occurrence of a violent earthquake. The first waves reached Victoria, B. C., at 1:15 P.M.; at Washington the movement was so strong that the pen passed off the recording sheet. In a quarter of an hour the seismographs of Great Britain took up the tale, large disturbances being recorded at Shide, Bidston, and Edinburgh; at Birmingham the pointer of the Omori horizontal pendulum swept three times off the drum. The pendulums at Florence shared the fate of those at Washington and Birmingham. The seismograph at Cape Town also registered the movement, while those in Japan were disturbed by the waves proceeding in the opposite direction across the Pacific. When we consider the great area covered by the injured towns in California, the displacement of the superficial soil, the crumpling of the railway tracks, and the widespread registration of the unfelt waves, it is clear that we must give to the San Francisco earthquake a place inferior, no doubt, to the Lisbon earthquake of 1755 and the Indian earthquake of 1897, but probably one in the same rank as the Neapolitan earthquake of 1857, the Japanese earthquake of 1891, and the Indian earthquake of 1905."

"A few years ago Prof. Mosso, of Turin, made some researches in connection with the question of asphyxiation at great altitudes. He came to the conclusion that to enable the influence of highly rarefied air to be successfully combatted, it was necessary to inhale oxygen mixed with a strong proportion of carbonic acid. Mr. Agazzotti, one of Prof. Mosso's pupils, has now had himself inclosed in a large bell in which the air, by means of a pump, was gradually rendered more and more rarefied. The bell was provided with a tap, communicating with the outer air, by means of which the foul air was expelled. The experimenter then covered his face with a mask provided with valves, one of which permitted the inspiration of a mixture of 67 per cent oxygen, 13 per cent carbonic acid, and 20 per cent nitrogen. When thus equipped Mr. Agazzotti entered the bell and the air was rarefied up to a pressure of 440 millimeters, almost equal to the atmospheric pressure prevailing on Mont Blanc. A few minutes after he entered (when the rarefaction of the air had reached 360 millimeters), symptoms of asphyxiation were observed. The mixture of oxygen and carbonic acid was now brought into play, and an immediate improvement

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was noted in the condition of the subject in the glass bell. The pressure was now brought down to 122 millimeters of mercury. On leaving the bell Mr. Agazzotti said to the attendants: 'I could have stood a still greater rarefaction.' "

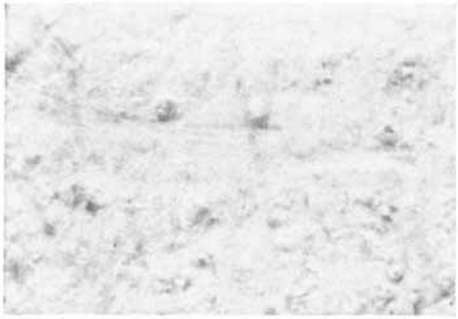
"One of the most valuable discoveries of the British School of Archaeology in Egypt during the past winter season was the identification of the ancient Hebrew Temple of Onias by Prof. Flinders Petrie. When the persecution of the Jews by Antiochus caused them to flee, many of the fugitives settled in the east of the delta, and in this sanctuary Onias IV, one of the high priests, erected a temple after the design of that at Jerusalem, in order that this spot might serve as a rallying point for those in flight. This temple is duly mentioned by the historian Josephus, who states that it was erected on the site of an old Egyptian town. Some time ago it was realized that the position of this settlement was the town of Tel el Yehudiyeh, which is some 18 miles north of Cairo, but it has been left to Prof. Petrie to prove the identity of the location conclusively."

SCIENTIFIC AMERICAN

MAY, 1856: "Alexis St. Martin, noted in the annals of medical science, and whose case is described in all our elementary works on physiology as having, when a soldier, shot himself accidentally in such a manner as to lay open his stomach and expose the entire process of digestion to scrutiny, has been in New York for a few weeks lately. A number of our physicians have been experimenting upon him with different kinds of food with the view to ascertaining the time required to digest them. A thermometer introduced into his stomach through the opening rose to 101 degrees Fahrenheit. The carrot is consumed in five to six hours. Rare roast beef will thoroughly digest in an hour and a half."

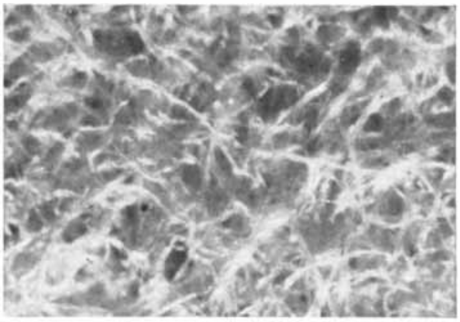
"In the last number of the *North British Review* it was stated—as taken from Dr. Wilson's work—that one person out of every eighteen was unable to distinguish different colors. If it be true that color blindness is as prevalent as Dr. Wilson has stated; then all the engineers and switchmen on our railroads, and all the pilots on our rivers, should be thoroughly examined respecting their capacity to distinguish colored signals."

How a paper machine turns



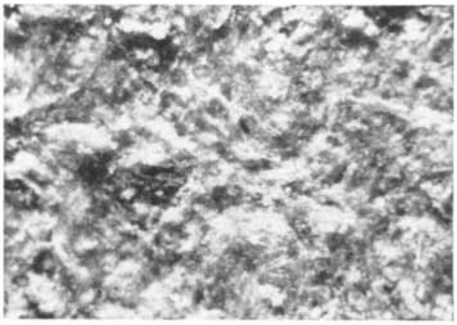
PHOTOMICROGRAPH OF NEWSPRINT

Conventional paper—like that used in your newspaper, for example — is made of millions of short cellulose fibers matted closely together. Fine printing and writing papers are made by adding clay and other fillers to the mixture while the paper is in the watery pulp stage of manufacture.



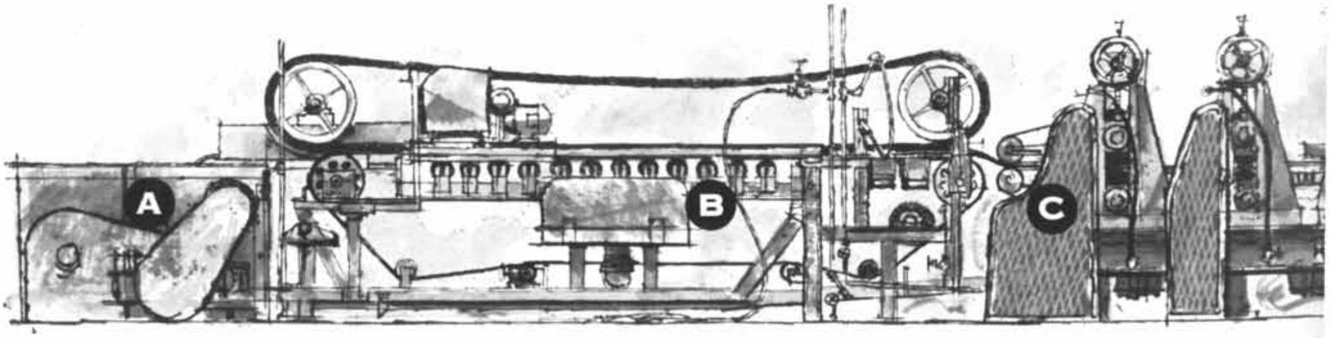
PHOTOMICROGRAPH OF RESIN-SATURATED FILTER PAPER

Resin-saturated material designed for filtering oil is composed of short cellulose fibers that appear to lie across each other like matchsticks. Fibers are coated with a thin coat of resin which stiffens them and helps maintain proper fiber spacing. This allows maximum flow of the fluid to be filtered, yet traps a maximum of dirt particles.



PHOTOMICROGRAPH OF RUBBER-SATURATED GASKET MATERIAL

Rubber-saturated materials which are intended for use as gasketing are designed to be impervious. The fiber structure is somewhat tighter than that used for filter material, and finely ground cork is added to the mix. A patented beater-saturation process coats both fibers and cork with a uniform layer of rubber that blocks the passage of gases and liquids.



As it enters the machine, paper is 99% water and 1% wood pulp. In the special Armstrong materials, this 1% can include rubber latex, synthetic resins, and finely ground cork.

The mixture moves in regulated amounts from the "head box" (A) onto a moving wire screen called a Fourdrinier wire (B). Much of the water drains through the screen.

THE AUTHORS

G. H. CARTLEDGE ("Studies in Corrosion") is a group leader at the Oak Ridge National Laboratory in Tennessee. He was born in Georgia, graduated from Davidson College in North Carolina, and took a Ph.D. at the University of Chicago in 1916. He went to Oak Ridge after World War II, following a long career as professor of chemistry at the Johns Hopkins University, the University of Buffalo and King College in Tennessee. His present work, he says, is an outgrowth "of the application to corrosion inhibitors of an electrostatic point of view which I have found useful in the interpretation of various chemical phenomena over the past 30 years." "Corrosion," he adds, "is, of course, one of the major problems in the operation of certain types of nuclear reactors. It was almost a new field to me when I first came to the Oak Ridge National Laboratory." Cartledge is active in the Presbyterian church and in 1947 delivered the Smyth Lectures at the Columbia Theological Seminary in Georgia on the interrelations of science and religion.

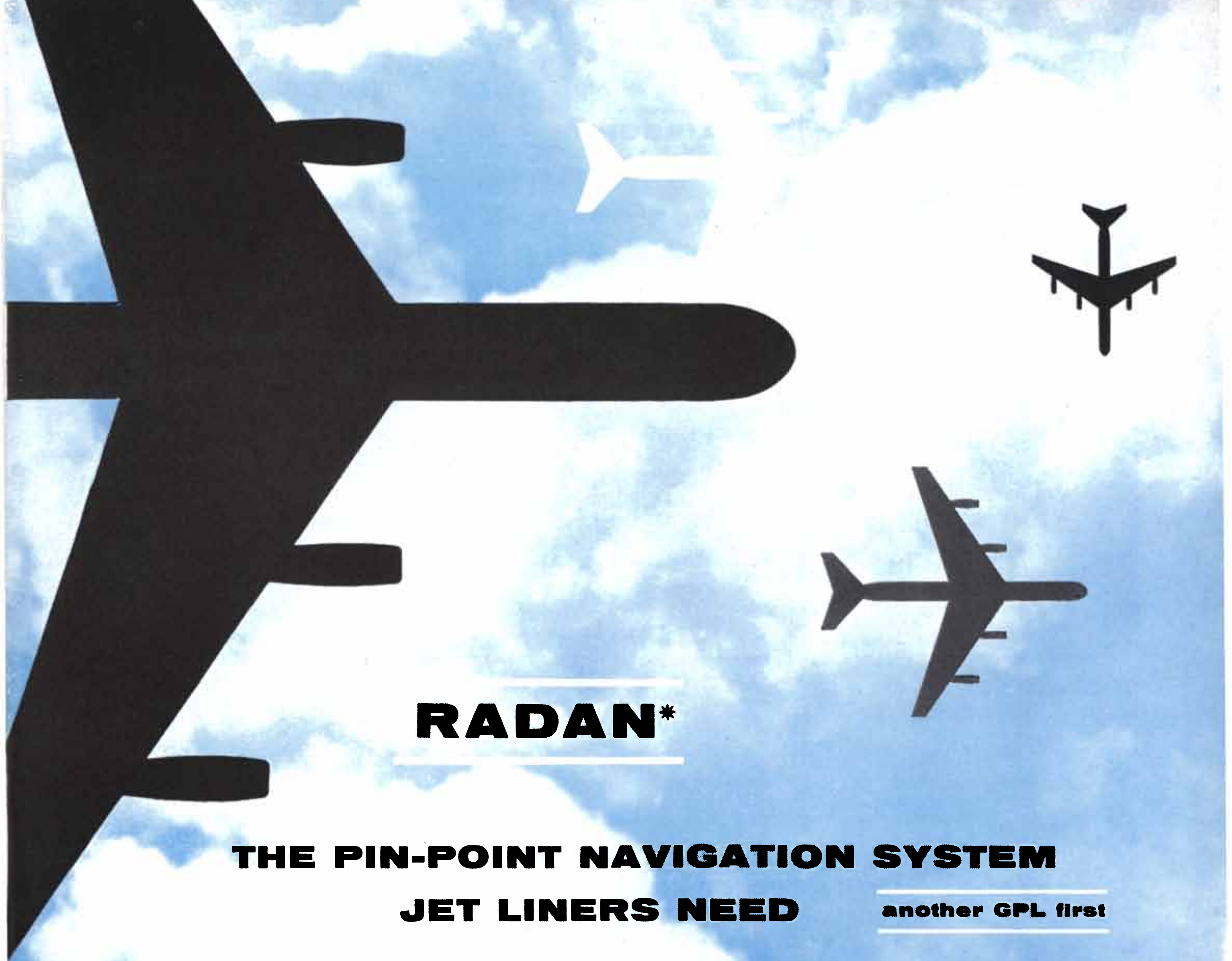
HERMAN YAGODA ("The Tracks of Nuclear Particles") is a physical chemist at the National Institutes of Health in Bethesda, Md. A New Yorker, he graduated from Cooper Union in 1929 and took his master's degree at New York University in 1931. Later he had a Baker research fellowship at Columbia University. He worked for a chemical company and as an assistant chemist in the U. S. Customs Laboratory in New York before joining the National Institutes of Health in 1942. His interest in cosmic rays and nuclear emulsions grew out of work in microchemical analysis. Yagoda has written a comprehensive book entitled *Radioactive Measurements with Nuclear Emulsions*. He still considers himself a chemist: "I tell my friends that I have achieved the ultimate goal of microchemists—the ability to identify a single atom of matter."

R. W. SPERRY ("The Eye and the Brain") is a psychobiologist in the department of biology at the California Institute of Technology. He graduated from Oberlin College in 1935, and in 1941 took a Ph.D. in zoology at the University of Chicago. He then did several years of research at Harvard University and at the Yerkes Laboratories of

Primate Biology. From 1946 to 1952 he taught anatomy at the University of Chicago, and from 1952 to 1954 he was chief of developmental neurology at the National Institutes of Health. Since 1954 he has been Hixon Professor of Psychobiology at Cal Tech. His work has covered various aspects of the functioning of the central nervous system, including the mechanisms involved in perception, learning and memory.

JULIAN H. STEWARD ("Cultural Evolution") is an anthropologist at the University of Illinois. Of his own cultural evolution he gives the following account: "The point of view expressed in the article developed from an interest in seeing new places and peoples, a predisposition toward the exact sciences and a social conscience. I was concerned that the approach in anthropology in the U. S. seemed to be purely particularistic—immersed in a vast amount of unrelated detail. The Great Depression, I am sure, stimulated all social scientists to look for causes. About this time I began attempting to develop a methodology for identifying cause-and-effect relationships in culture change. In 1934, at the University of California, I made a preliminary effort toward developing the point of view expressed in my article. At the Smithsonian Institution, 1935 to 1946, the approach took a more definite form. I went to Columbia University as professor in 1946. My study of Puerto Rico in 1949-1950 was the first systematic attempt to apply this point of view to field research. Since 1952 I have been graduate research professor of anthropology at the University of Illinois, where I have worked on plans for a field study of populations in Mexico, Peru, West Africa, Uganda, and Indonesia or Japan."

DENIS I. DUVEEN ("Lavoisier") is the president of a Long Island soap company. A chemist, he was born in London in 1910, graduated from Oxford University in 1929 and did research in organic chemistry at the Collège de France. He came to the U. S. in 1948, having been during World War II technical assistant to the director of an explosives factory run by the British Ministry of Supply. Duveen maintains a scholarly interest in the history of chemistry. A general collection of alchemical and early chemical works which he assembled is now at the University of Wisconsin. Duveen has what is probably the most extensive collection of Lavoisier's printed works and manuscripts and recently collaborated in pub-



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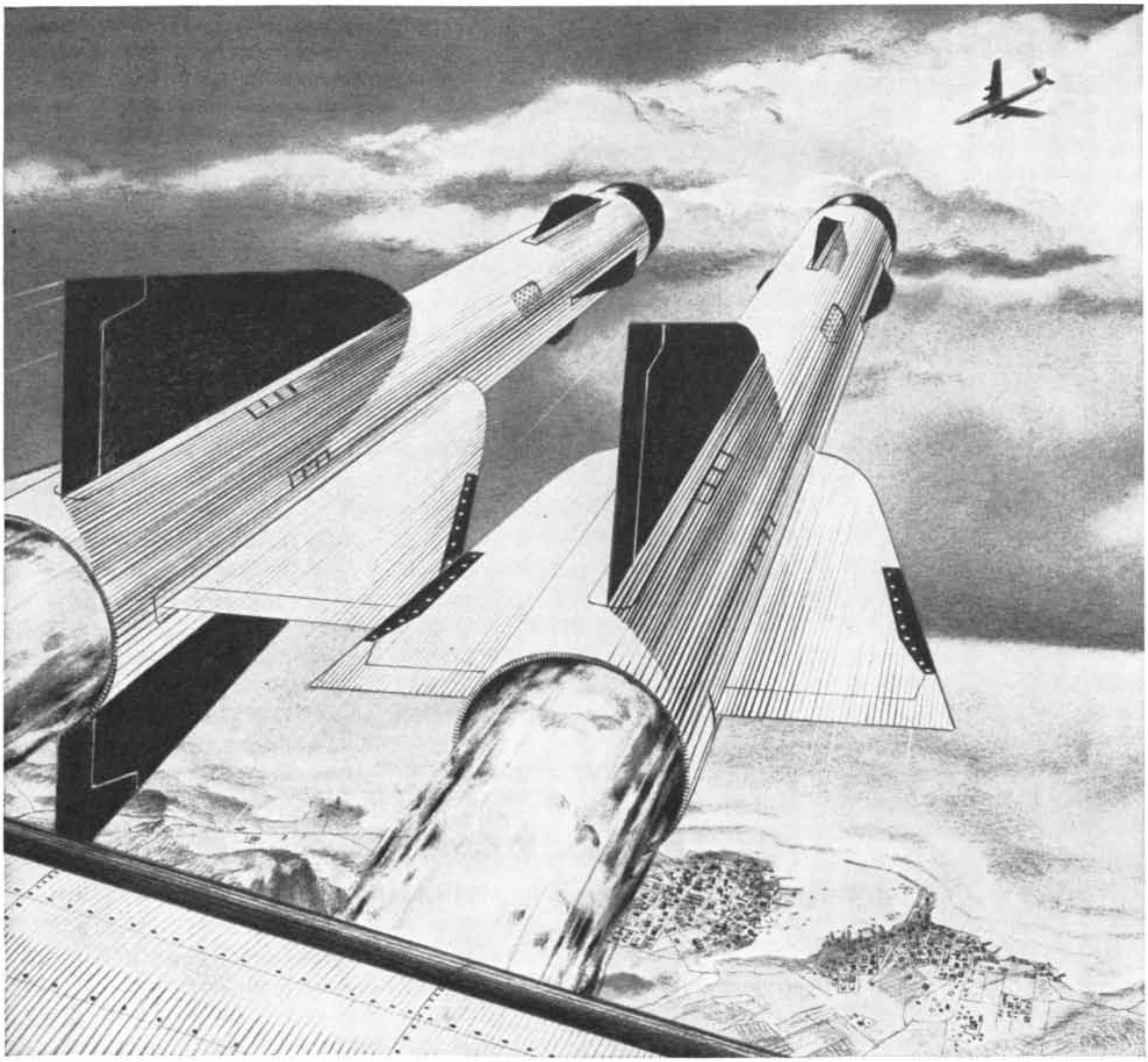
lishing a full bibliography of the great chemist's writings. His nonscientific hobby is big-game fishing.

JOHN TYLER BONNER ("The Growth of Mushrooms") is a Princeton University biologist who specializes in studying very simple organisms, especially slime molds, about which he has written for SCIENTIFIC AMERICAN ("The Social Amoebae"; June, 1949). He was a junior fellow at Harvard University and for his Ph.D. he did research on fungi under William H. Weston. Since 1947 he has been teaching at Princeton as an associate professor of biology. His most recent article in SCIENTIFIC AMERICAN was an account of the work of D'Arcy Wentworth Thompson, in the issue of August, 1952.

ERNEST RABINOWICZ ("Stick and Slip") is an assistant professor of mechanical engineering at the Massachusetts Institute of Technology. He was born in Berlin in 1926, went to England at the age of 10, studied physics as an undergraduate and graduate student at the University of Cambridge, and has been at M.I.T. since 1950, as a worker in the Lubrication Laboratory and a member of the Division of Industrial Cooperation. He started his studies of friction, using radioactive tracer methods, in the research laboratory of the department of physical chemistry at the University of Cambridge.

VICTOR A. McKUSICK ("Heart Sounds") is assistant professor of medicine at the Johns Hopkins University School of Medicine. He was educated at Tufts College and Johns Hopkins Medical School, and took his hospital training in the Osler Medical Clinic of the Johns Hopkins Hospital. His fields of interest have been internal medicine, cardiology and diseases of connective tissue. He has an identical twin brother—a lawyer in Maine. Intrigued by human genetics, Dr. McKusick has made a clinical study of hereditary disease which will be published this spring under the title *Heritable Disorders of Connective Tissue.*

JAMES R. NEWMAN, who reviews *The History of Photography* in this issue, conducts the book department and is a member of the Board of Editors of SCIENTIFIC AMERICAN. He edited two recently published books: *What Is Science?* and a new edition of *The Common Sense of the Exact Sciences*, by William Kingdon Clifford.



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Established 1845 SCIENTIFIC AMERICAN May, 1956 Volume 194 Number 5

Studies in Corrosion

Technetium, the synthetic element found in the products of uranium fission, strongly inhibits the oxidation of iron. This phenomenon suggests a new explanation for the action of corrosion inhibitors

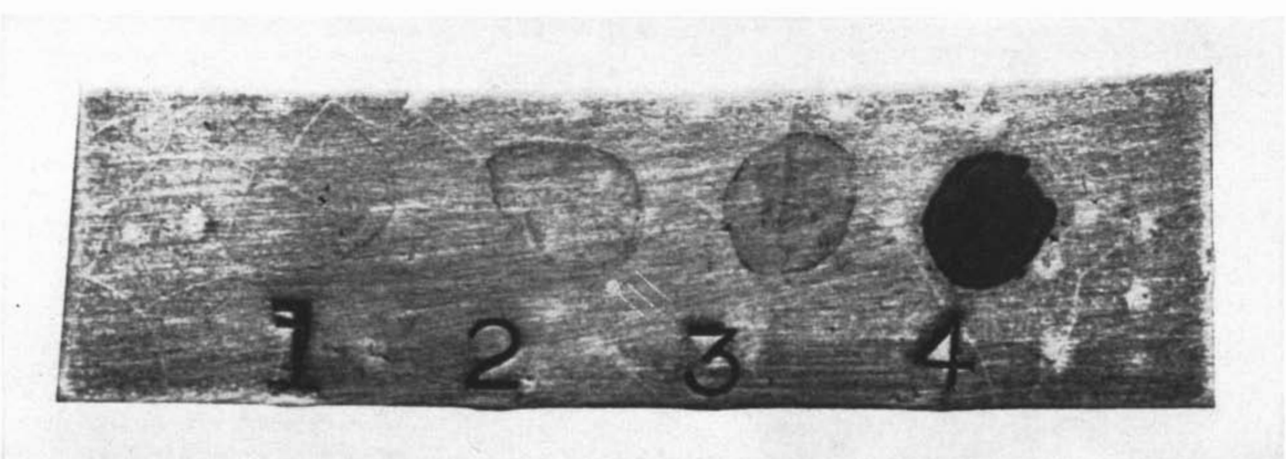
by G. H. Cartledge

All the apparatus of our industrial age, from egg beaters to nuclear power plants, is marching inexorably toward the junk heap. Today's gleaming machines are tomorrow's rusty scrap. As the world supply of raw materials shrinks, we must be increasingly concerned about finding ways to prevent the corrosion and decay of our metal.

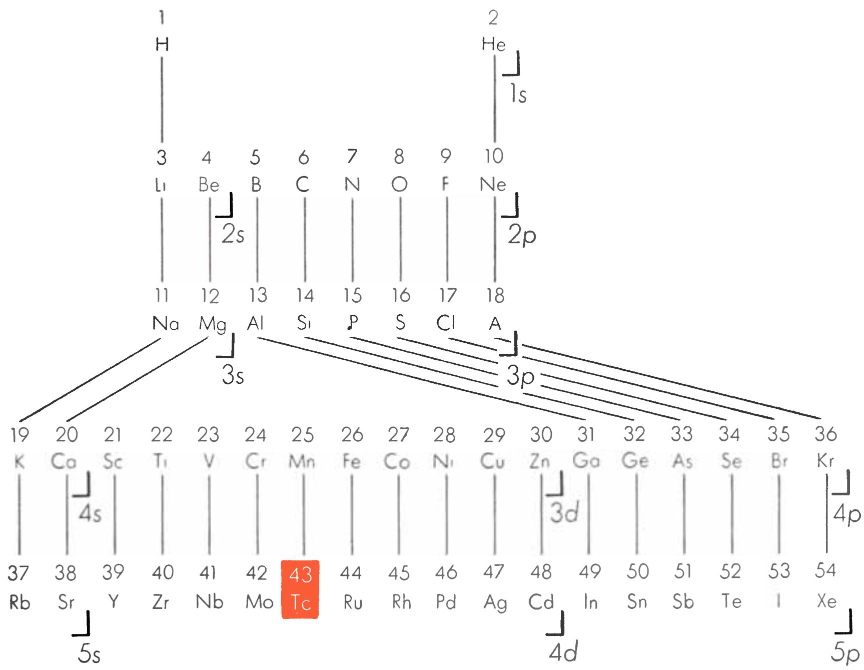
Like many other natural phenomena, corrosion is a subtle process which has been a stubborn problem for those who seek to understand it at the basic level. Chemists have, to be sure, devised some methods of combatting it. But the familiar rust inhibitor that you put in the radiator of your car is an empirical product: there are differing theories as to just how it operates to retard corrosion. It has been difficult to test these theories, or to discover principles which might lead to more effective solutions of the manifold corrosion problem.

Now such tests and studies have been facilitated by a new substance whose birth is itself a remarkable story. The substance is technetium—the element which man had never seen until he made it himself. Technetium has proved to be a corrosion inhibitor *par excellence*, and though it is still one of the rarest of all the elements on earth, the precious material is serving to unravel some of the unsolved mysteries of corrosion.

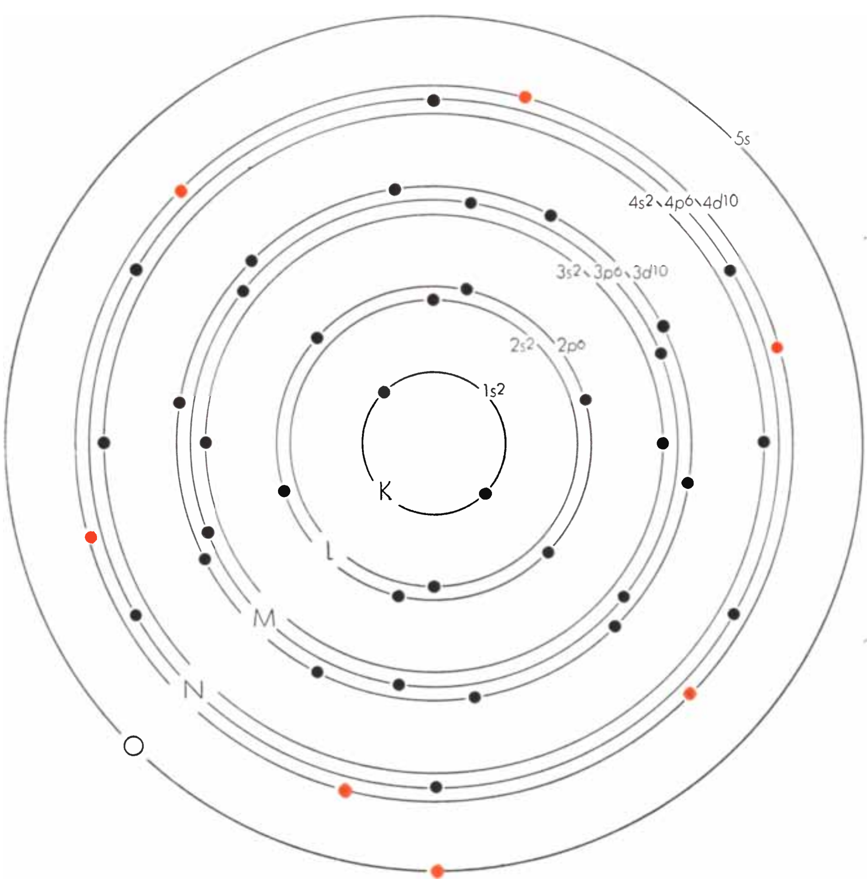
The story of technetium really goes back to Dmitri Mendeleyev and his construction of the table of elements in 1869 to 1871. In the column headed by manganese Mendeleyev left blank spaces for two elements which had never been found but which he was sure must exist. He called them eka-manganese and dvi-manganese. The second of these was identified in minerals in 1925 and named rhenium. But eka-manganese could not be found in nature. It is a radioactive element (radioactivity was unknown, of course, in Mendeleyev's day) whose most abundant isotope has a half-life of 220,000 years. Since the earth is billions of years old, the primordial technetium



FOUR DROPS of tap water, three of which contained corrosion inhibitors, were placed on this strip of very pure electrolytic iron. The first drop contained about 40 parts per million of technetium; the second, about 20 parts per million of technetium. The third drop contained potassium chromate. The fourth was plain tap water. After it had evaporated, the drop of plain water left a deposit of rust. The other drops inhibited the corrosion of the iron. The stains left by the first three drops are due not to corrosion but to thin deposits of unchanged inhibitor. The technetium stains are comparatively colorless; the potassium chromate stain is yellow.



PERIODIC TABLE shows the relationship of technetium (Tc) and the other elements up to xenon (Xe). At the end of each horizontal row in the table a shell of electrons is filled (*see drawing below*). The brackets beneath the rows denote the filling of electron subshells.



ELECTRON STRUCTURE of technetium gives it seven valence electrons (*colored dots*). The letters K, L, M, N and O schematically represent the shells of electrons in the technetium atom. The shells are also numbered (*upper right*) and divided into the subshells *s*, *p* and *d*. The last number in each subshell indicates the number of electrons needed to fill it.

must have virtually disappeared from our planet long ago.

Eka-manganese in Mendeleyev's table stood just after molybdenum. In 1937 C. Perrier and Emilio Segrè reported that they had bombarded molybdenum with deuterons and succeeded in transmuting molybdenum into the long-sought eka-manganese—element 43. In honor of man's first creation of an element it was named technetium.

Had technetium been limited to the infinitesimal amounts that could be produced in a cyclotron, it would have remained an element in name only. But it was to make a new and dramatic appearance in another arena. Examining the many fission products from the splitting of uranium in nuclear reactors, chemists came upon a product which was unmistakably technetium. George W. Parker and Willard J. Martin at the Oak Ridge National Laboratory have since extracted several grams of the element: technetium amounts to roughly 6 per cent of uranium's fission products. This material has been immensely useful in studying corrosion because of two fortunate properties: not only is it a powerful inhibitor of corrosion but, thanks to its radioactivity, it can be traced and measured in very tiny quantities—a considerable help in experimental work.

Our account of the technetium research must be introduced by a brief review of the questions raised by corrosion. The problem arises in the first instance from the unfortunate fact that metals as a rule are chemically unstable in the environments in which we wish to use them (*e.g.*, steel ships in salt water). To protect the metal we must somehow block the corrosive chemical reaction between the metal and the environment. A metal such as aluminum may provide its own protection by forming a nonporous film of oxide on its surface. Certain artificial rust inhibitors act in just this way: they form a film which interposes a physical barrier between the metal and the solution.

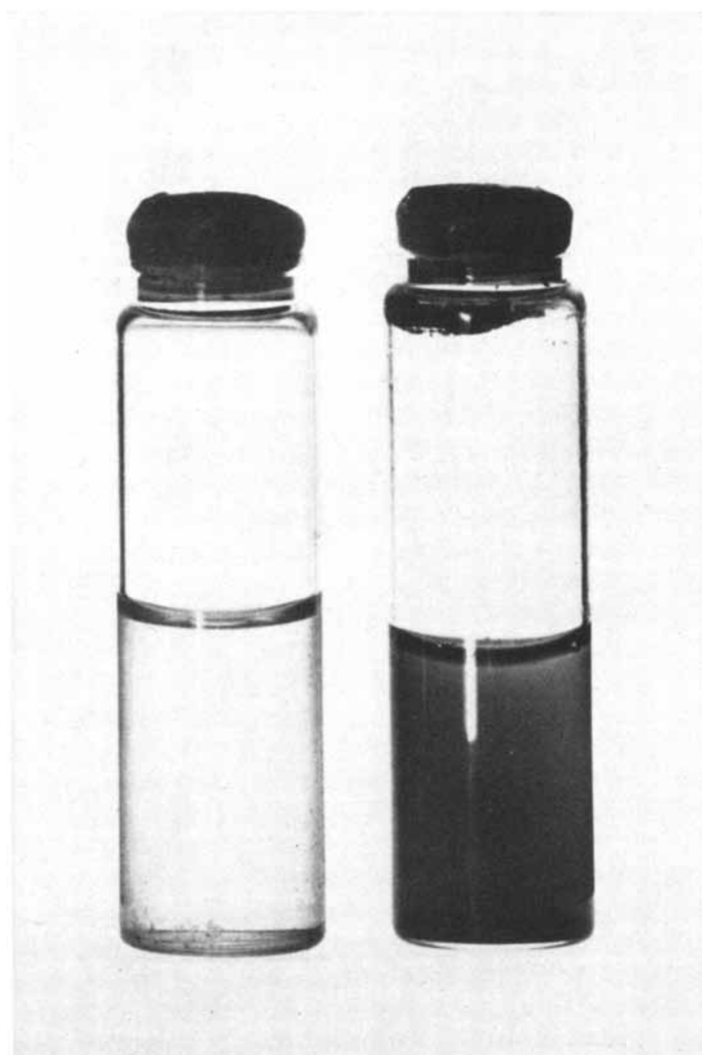
Our study is concerned with what may be another type of protection: chemical alteration of the metal surface itself to make it inactive. The most commonly used inhibitor of this kind is a chromate compound. In a solution of potassium chromate, for example, iron will remain rust free indefinitely.

How does the chromate change iron's behavior? U. R. Evans and T. P. Hoar of the University of Cambridge suggested that it assists iron to form an impervious coat. Iron, they assumed, normally is covered with an oxide film with many pores or cracks. Through these openings iron atoms which have given up two electrons, thus becoming ferrous ions (Fe^{++}), pass into solution. However, when chromate ions (CrO_4^{--}) are present, they remove a third electron from the emerging ferrous ions, converting them to ferric ions (Fe^{+++}). Ferric ions react with water to form an insoluble oxide. This plugs the pores or cracks and seals the iron surface against further reaction.

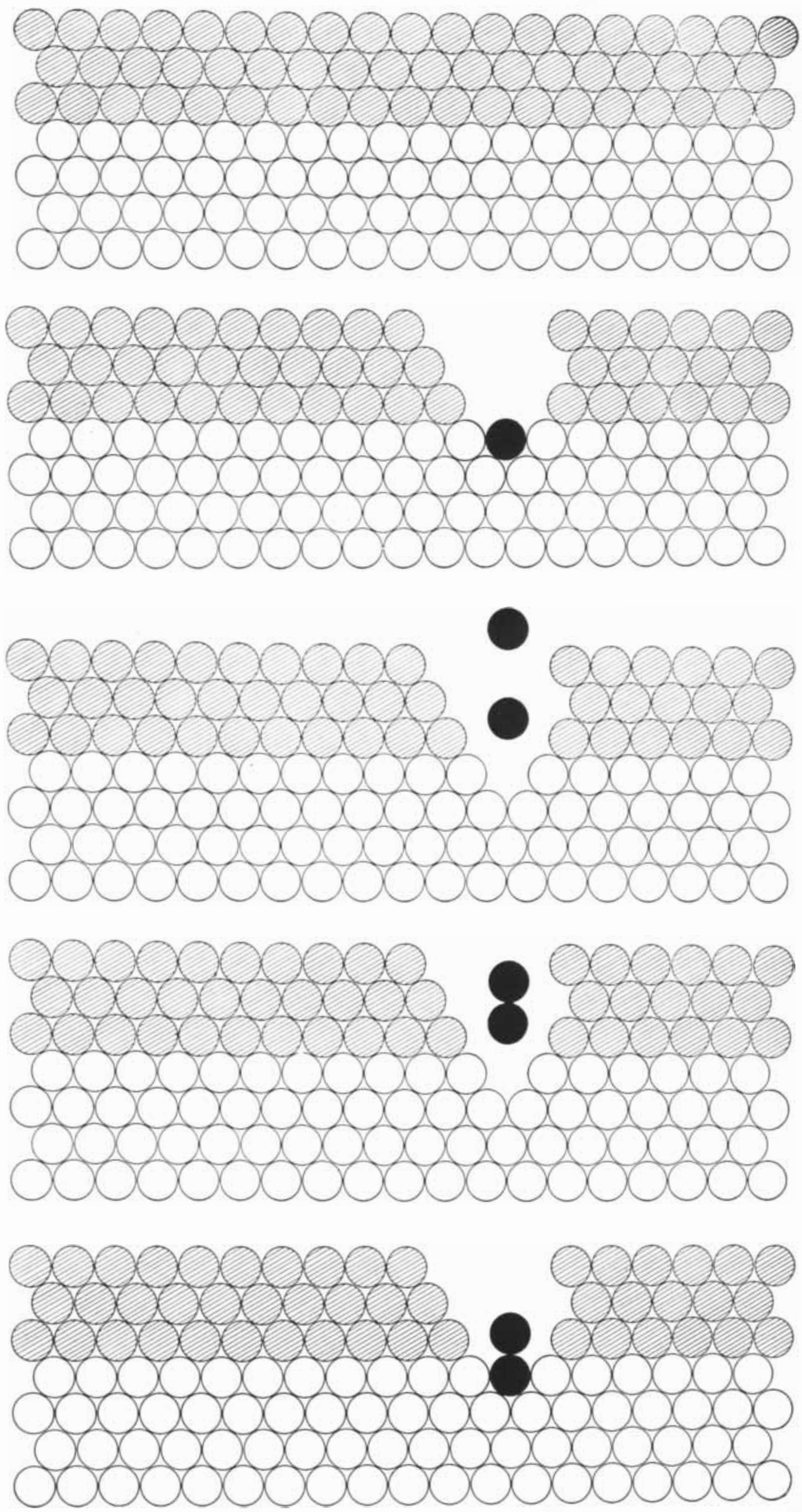
Herbert H. Uhlig of the Massachusetts Institute of Technology has another view. He argues that chromate ions adsorbed on a metal surface simply share electrons with its atoms, thus immobilizing the electrons and reducing the chemical activity of the metal.

Both theories, however, stumble on the fact that ions similar to chromate do not always behave as expected. The Evans-Hoar theory attributes chromate's anticorrosion effect to its property as a strong oxidizer, but some other strong oxidizing agents do not inhibit corrosion, while there are weak oxidizers that do inhibit. The adsorption theory fails to account for the fact that the sulfate ion (SO_4^{--}) is a poor inhibitor of corrosion.

The chromate and sulfate ions are so alike in their external features—size, shape and charge—that we were prompted to look into their internal characteristics for an explanation of the difference in their inhibitory property. Like all ions of this type, they have a tetrahedral structure, with a cage of four oxygen atoms surrounding the central atom—chromium in one case, sulfur in the other [*see diagram on page 39*]. Now there are good reasons for believing that the valence electrons between the central atom and the oxygens are distributed differently in the two ions. In the sulfate ion the electrons are probably shared between the sulfur and surrounding oxygen atoms in covalent bonds. As a result the central region of the ion is electrically nearly neutral. In the chromate ion, on the other hand, some of the chromium atom's electrons probably are detached from it and transferred to the oxygens. Thus the center of the ion



TECHNETIUM SOLUTIONS produced the effects demonstrated in these two photographs. The bottle in the photograph at left contains a solution of potassium pertechnetate and a specimen of mild steel. Although the steel has been in the solution since January 7, 1953, it is still bright. The bottle at left in the photograph at right contains a solution of potassium pertechnetate that was heated with a specimen of steel for 92 hours at a temperature of 450 degrees Fahrenheit. The bottle at right contains plain water that was heated to 450 degrees with another specimen. The first bottle is clear; the second is beclouded with rust.



ONE THEORY of how the chromate ion (CrO_4^{--}) inhibits the corrosion of iron is schematically presented. Aluminum (*top drawing*) is resistant to corrosion because its atoms (*open circles*) are protected by a coating of aluminum oxide (*crosshatched circles*). The oxide coating of iron (*second drawing*) may be broken by cracks or pores. This leads to the formation of a ferrous ion (*black disk*), which tends to leave the metal lattice (*third drawing*). If a chromate ion (*upper black disk*) is present, it will react with the ferrous ion to form an insoluble oxide (*fourth drawing*). In doing so it removes one of the electrons from the ferrous ion. The oxide precipitates, forming a plug which prevents corrosion.

should have a high positive charge. By virtue of this charge, a chromate ion adsorbed on a metal or oxide surface might well attract and engulf any free electrons in the surface. This would account for the ability of chromates to inactivate a metal chemically and protect it against corrosion.

If our hypothesis is correct, the effectiveness of an ion of this type in inhibiting corrosion should depend on the amount of the central positive charge. The chromium atom has six electrons to give up in its outermost shells; hence the maximum possible charge of the chromate ion's interior is six positive units. Any ion with a higher central charge should be an even better corrosion inhibitor than chromate, provided it is a sufficiently weak oxidizing agent to keep its integrity as an ion.

This line of thought pointed straight to technetium. It has seven electrons in its outer shells. It forms with oxygen an ion of the chromate type—pertechnetate (TcO_4^-). And the ion is only a mild oxidizing agent. Plainly an experiment with pertechnetate was indicated.

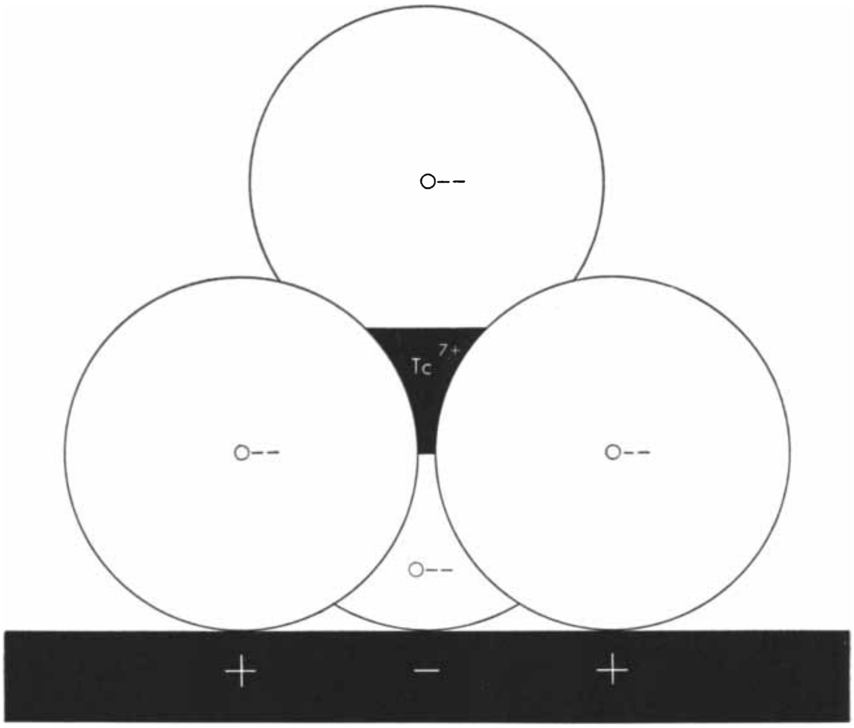
Technetium was available to us at Oak Ridge in milligram quantities. We made a very dilute solution of the compound potassium pertechnetate. Then we placed on a piece of clean iron a drop of this solution, a drop of ordinary tap water and other test drops for comparison. The tap water on evaporation left a little mound of rust. But the iron under the pertechnetate drop did not corrode at all. Further experiments demonstrated that pertechnetate is a more powerful corrosion inhibitor than chromate. It is effective at temperatures as high as 450 degrees Fahrenheit and at concentrations as low as five parts per million—an improvement on the performance of chromate in both respects.

Now the radioactivity of the technetium atom made it possible to carry out some specific tests of the various hypotheses about the mechanism of corrosion inhibition. The chemical reaction theory supposes that the inhibiting ions (chromate or pertechnetate) react with the iron and are precipitated in a film on the metal surface. This implies that if iron is exposed to a pertechnetate solution, an appreciable amount of technetium should become deposited on the iron surface as technetium dioxide. Technetium's radioactivity enabled us to measure precisely the amount of any such precipitation. We found that some technetium was precipitated. But the amount varied considerably from one trial to another without affecting the degree of corrosion inhibition. Indeed, corrosion was inhibited even when the precipitated technetium dioxide amounted to far less than would have been needed to form a film only one molecule thick over the metal surface. We found further that the amount of the deposit did not increase with time, as would be expected on the chemical-reaction hypothesis. Pieces of metal kept in pertechnetate solutions for as long as three years have not shown any detectable increase in deposited radioactivity during that time.

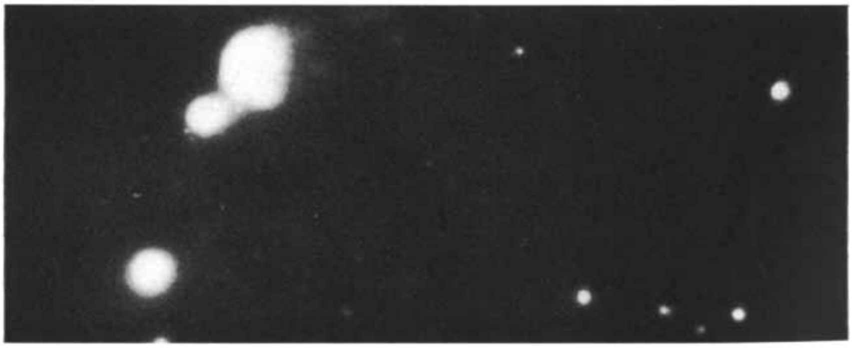
What of Uhlig's hypothesis that the inhibiting ions form electronic (*i.e.*, chemical) bonds with the atoms on the metal surface? Our experiments indicate that the force holding these ions to the surface is actually much weaker than a chemical bond. Pertechnetate ions, for example, are easily displaced from the surface by sulfate ions, which do not inhibit corrosion, when the latter are added to the solution. By measurements of changes in the electric potential of the metal we have demonstrated that these exchanges take place rapidly and in an oscillating manner, as if the two ions are competing with each other for places on the metal surface. As the concentration of sulfate ions increases, they pre-empt the positions on the metal, and corrosion begins. It is hard to escape the conclusion that the adsorption between pertechnetate ions and the metal is due not to a chemical bond but to a considerably weaker force of attraction. That is to say, the evidence supports the idea that the adsorbing force is an electrostatic attraction between the positively charged interior of the pertechnetate ion and electrons in the metal or its oxide.

Rhenium, the other cousin of manganese whose discovery Mendeleyev predicted, is an atom very like technetium. It has seven removable electrons in its outer shells and it forms a perrhenate ion (ReO_4^-). Since this ion is almost a twin of the pertechnetate ion, it might be expected to be an equally powerful corrosion inhibitor. But when tested in a similar way, it failed to inhibit. One obvious difference between the ions is that natural rhenium is not radioactive. This raised the novel, and rather incredible, possibility that technetium's radioactivity might play a part in its inhibitory action. The possibility was quickly ruled out by experiments with rhenium artificially made radioactive by bombardment with neutrons. It showed no change in behavior. The only plausible explanation left is that the interior of the perrhenate ion does not have as strong a positive charge as the pertechnetate ion. Rhenium is known to give up electrons less readily than technetium; it may have covalent bonds with the oxygen atoms in the ion instead of transferring its electrons.

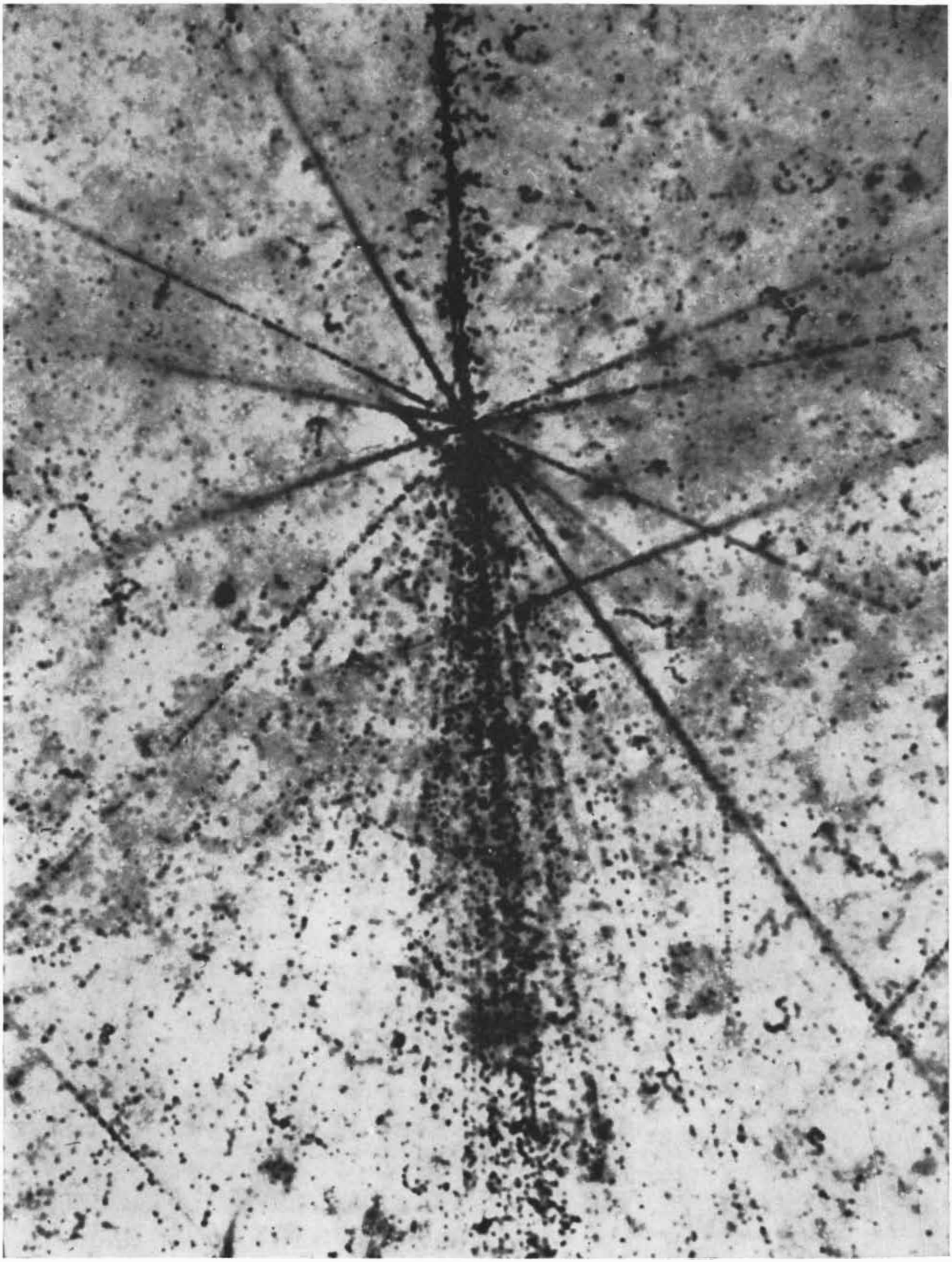
The experiments with technetium have opened a wide new avenue of inquiry into the problem of corrosion. Technetium itself will never be plentiful enough for general use as a rust inhibitor, though it may be employed for special purposes such as protecting the plumbing in nuclear reactors. But as more of it becomes available, through recovery from the fission products of power reactors, it will grow in usefulness as a tool of research, not only in corrosion but also in other problems involving the properties of metals.



ANOTHER THEORY of inhibition is partly based on the architecture of the pertechnetate ion (TcO_4^-). This consists of a technetium atom (Tc) with four oxygen atoms (O) arrayed around it in a tetrahedron. (The chromate and sulfate ions have the same structure.) The valence electrons of the technetium atom give it seven positive charges (7^+); the valence electrons of the oxygen atom give it two negative charges ($^{--}$). The distribution of these charges may be such that the core of the ion is positive and attracts negative electrons on the surface of iron. This would immobilize the electrons to some extent and block corrosion.



RADIOAUTOGRAPH was made by putting a piece of corroding iron in a solution of technetium, then washing it and placing it in contact with a sheet of photographic film. The radioactivity of the technetium exposes the film, showing where the technetium has adhered to the iron. In this print the exposed areas appear as bright spots. Technetium will inhibit the corrosion of iron in amounts insufficient to cover the metal with a layer one molecule thick. Apparently a stable oxide film can form when the inhibitor is present with oxygen.



GIANT SHOWER OF MESONS is recorded in this photomicrograph of a small section of nuclear emulsion carried to a height of 106,000 feet by a Navy "Skyhook" balloon. At the top of the photomicrograph is the heavy track of an enormously energetic iron nucleus in the primary cosmic radiation. Above the nucleus is a "star" resulting from the collision of the iron nucleus and a nucleus in the emulsion. Below the star is a jet of about 40 pi mesons. To the left and right of the star are heavier fragments of the target nucleus.

THE TRACKS OF NUCLEAR PARTICLES

Each constituent of the atom is characterized by its trajectory through matter. Here these signatures are discussed with special reference to their visualization in thick photographic emulsions

by Herman Yagoda

A nuclear physicist studying the elementary particles of nature is in much the same position as an explorer trying to picture unknown animals from their tracks. The physicist never can see the particles themselves—only their footprints in a cloud chamber or a photographic plate. But from these tracks he deduces a particle's mass, movements, speed, lifetime and social impact on its fellows. By now the tracks of some members of the nuclear family are almost as familiar and readable as the footprints of a domestic animal. Interesting new tracks keep turning up, some strange, some predictable—the latest to make its appearance is that of the long-sought antiproton. It seems a timely moment to survey the scene and review the gallery of footprints that identify the members of the strange population in the nucleus of the atom.

We shall consider the tracks as they are recorded in photographic emulsions. It was in this medium that the existence of particles in the nucleus of the atom was first detected—through the fact that Henri Becquerel left some uranium near photographic film in a drawer. Becquerel noted simply that radioactive emanations from the uranium had fogged his film. That the "fog" might consist of a network of tracks was not discovered until 13 years later. In 1909 Otto Mügge of Germany exposed some film to tiny crystals of zircon, a feebly radioactive mineral. To study the faintly developed image he had to use a microscope, and he then noticed that there were fine linear tracks radiating from the crystals. Not long afterward the tracks of alpha particles emitted by radium were recorded in fine-grained emulsions at Lord Rutherford's famous laboratory in England.

When a charged particle travels through a photographic emulsion, it forms a latent image in the silver bromide grains, just as light does. In the case of the moving particle, the latent image results from ionization by the particle along its path. This image, marking the track of the particle, is then made visible by development of the emulsion in the usual way. So that fast particles may be brought to a stop within the emulsion, it is usually made as thick as possible. Emulsions used to track cosmic rays and high-energy particles from accelerators are often more than one millimeter thick—about 100 times thicker than in ordinary photographic film. The length of a particle's track in the emulsion must be measured precisely to determine its kinetic energy. Since the path slants into the emulsion, its length cannot be measured directly: it is computed by means of the Pythagorean theorem from the two measurable distances—the depth at which the particle comes to rest in the emulsion and the horizontal distance along the emulsion surface from the point of entry to the point directly above the end of the track.

At best the search for particle tracks in emulsions is slow, tedious work. It takes many hours or days of poring over the photographic plate with a microscope to find and trace the faint lines of silver grains. For this reason physicists long preferred to use cloud chambers for particle detection work. But the photographic plate has an obvious advantage over a cloud chamber. Particles traveling through this denser medium are more likely to collide with atomic nuclei and produce interesting developments. A great deal of work has been done to improve nuclear emulsions. In 1947 Pierre Demers of the University of Montreal found a way to prepare stable emulsions containing 90 per cent silver bromide, instead of the usual 30 per cent, and in these more concentrated emulsions particles produce more robust tracks.

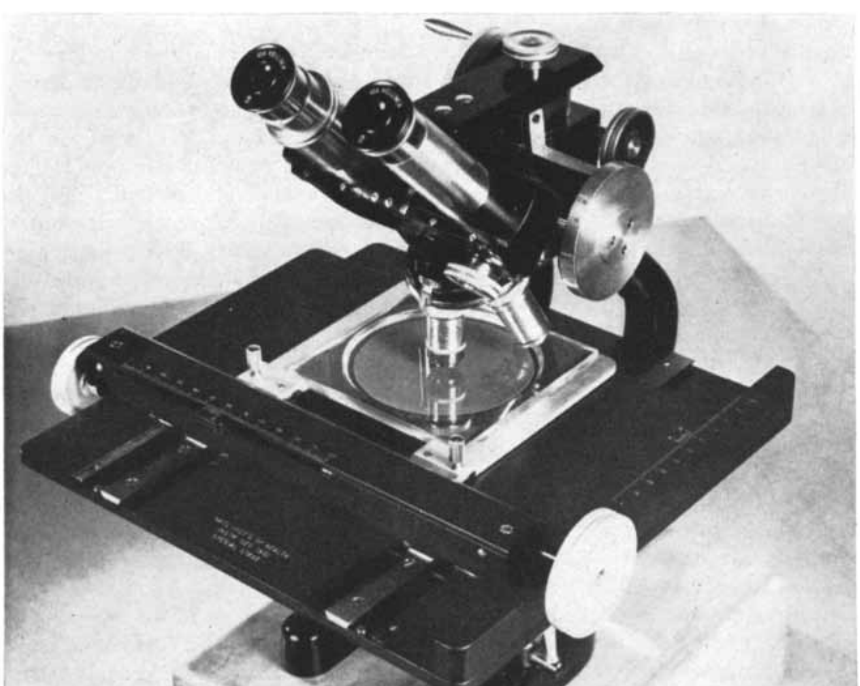
Let us proceed to examine some of the identifying tracks. We shall begin by immersing a photographic plate in a very dilute solution of a soluble compound of the radioactive element radium. After leaving it for a time (days, weeks or months) in a dark place, we remove the plate, develop it and inspect it under a microscope. Here and there on the plate we see starlike sets of short heavy tracks, each set radiating like spokes from a hub point. The tracks identify the particles as slow alpha particles, and the formation is known as an alpha star. At the center of the star a radium atom has emitted a series of alpha particles. The radium atom decays first to radon, then to other unstable descendants and finally to lead. In this spontaneous transmutation from radium to lead a total of five alpha particles (plus several beta particles) is emitted. Each in the series comes out with a characteristic kinetic energy, and the different energies (ranging up to 7.7 million electron volts) cause the tracks in a star to be of different lengths.

Occasionally the star seen in a photographic plate may represent the disintegration of not one but many radium atoms. This was made clear by an experiment performed by Mlle. C. Chamie at the Curie Institute in Paris. She exposed a plate in an extremely dilute solution of polonium, the last alpha-emitting descendant of radium in the transition to lead. It was supposed that single tracks of alpha particles, from separate atoms of polonium, would appear in the emulsion. Instead Mlle. Chamie found stars consisting of several hundred alpha tracks from a common center. All the tracks were of the same length, corresponding to the energy of alpha-emission from polonium. Evidently even in an extremely dilute solution the polonium atoms are not completely dissociated into individual ions but may cluster in groups of several thousand atoms. The collections have been named radiocolloids.

All matter contains traces of radioactive substances, and their energy fields have been pulsating in minerals since the earth's crust solidified eons ago. Nature strews the investigator's path with clues—if we could only see. Long before the discovery of radioactivity, geologists had observed that grains in certain minerals, such as mica, were sometimes surrounded with halos of colored material. They could find no way to explain how these colored bands might be formed. In 1907, when radioactivity was a topic of growing interest, John Joly in Ireland noted that the distance from the center of each tiny sphere to the halo around it was about the same as the range of an alpha particle emitted by radium or thorium. He suggested what is now taken to be the correct solution of the mystery: that alpha particles radiating from radioactive atoms at the center ionize iron atoms in the mica near the end of their path, cause the iron to become oxidized and thereby produce the colored bands.

Just as familiar, and as ubiquitous, as the footprints of alpha particles are the footprints of beta particles, or electrons. These light particles make very faint, highly scattered tracks in an emulsion. Originating from radioactive substances and from cosmic ray showers, flying electrons record their presence in emulsions wherever placed or however carefully shielded. Even at great depths underground a photographic plate will show about one million electron tracks per cubic centimeter for each day of its underground exposure.

No footprints are more fascinating than those of the strange particles known as mesons. Had present emulsions been in use in the 1920s, their tracks would have been discovered first and "explained" afterward; as it was, the particles were predicted by the theoretician Hideki Yukawa two years before they were actually found. Yukawa invented the meson to account for the binding force that holds particles together in the atomic nucleus. Tracks of a particle such as he had predicted—about 200 times heavier than the electron—were first discovered in 1937 in cloud chambers monitoring the products of cosmic rays. A mystery soon developed: the theory said that these particles should interact strongly with atomic nuclei, but experiments proved that they were rarely absorbed by nuclei.



SPECIAL MICROSCOPE is used to scan nuclear emulsions. The large stage enables the viewer to follow long tracks. Here the emulsion is a disk embedded in a rectangular Lucite frame fitted with a cover glass. The depth of the track is read on the wheel at upper right.

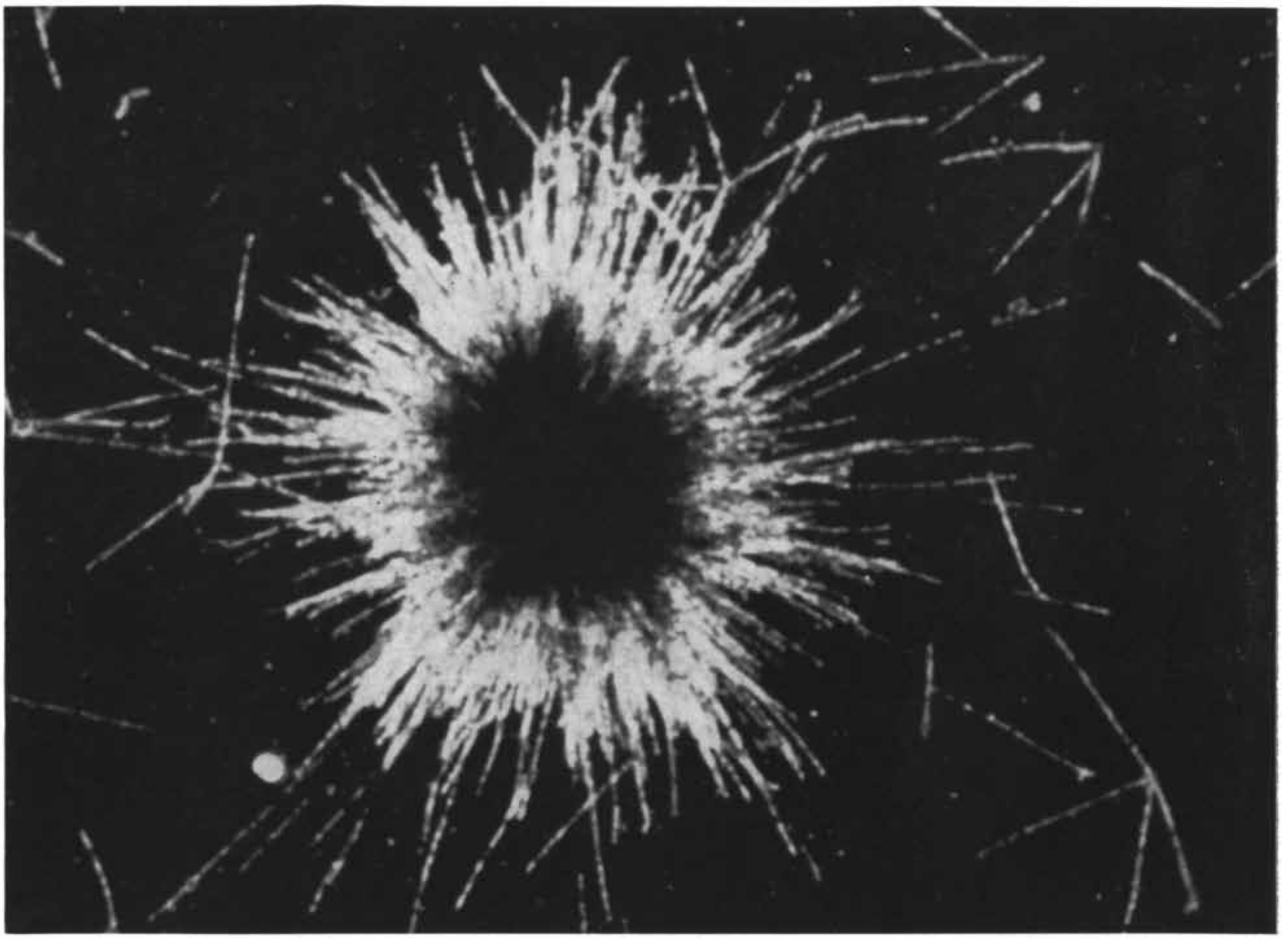
While the theoreticians were pondering this hiatus between theory and experiment, the younger physicists were busy climbing mountains and exposing photographic plates to the intense cosmic radiation high in the atmosphere. By 1947 they had discovered a second, heavier meson which did react strongly with matter [see "The Multiplicity of Particles," by Robert E. Marshak; SCIENTIFIC AMERICAN, January, 1952]. A Bristol University team of investigators headed by C. F. Powell obtained photographs showing that when the heavy pi meson came to rest it promptly decayed into the lighter mu meson.

A year later the young Brazilian C. M. G. Lattes, a member of the Bristol cosmic ray group, came to the University of California and in cooperation with Eugene Gardner succeeded in detecting mesons from nuclei attacked by a 400-million-electron-volt beam of alpha particles from the Berkeley cyclotron. Two types of pi meson tracks were then identified. Positively charged pi mesons decayed into mu mesons. Negatively charged pi mesons reacted with atomic nuclei, and the disintegration of the capturing nucleus produced a star.

Meanwhile the European investigators, lacking funds for the construction of expensive accelerators, continued to study mesons in the cosmic radiation—the poor man's cyclotron. These simple experiments gave birth to a perplexing number of new particles.

Their first addition to the growing fraternity of Greek-lettered mesons was the tau particle. The Bristol University investigators found its track in an electron-sensitive plate exposed beneath a 12-inch-thick block of lead at the Jungfraujoch High Altitude Research Station. The particle, heavier than a pi meson, produced an unusual three-pronged star on coming to rest. All three prongs could be identified as the tracks of pi mesons. From the available evidence Powell came to the conclusion that the tau meson was an unstable, singly charged particle about 1,000 times heavier than the electron. Powell's brilliant deductions tempt one to finish off his description with the admiring exclamation: "A new particle—elementary, my dear Watson!"

The heavy tau meson is very rare, but an extensive vigil has now detected a number of these events and established the particle's properties. Recent controlled experiments with the six-billion-electron-volt Bevatron at Berkeley indicate that the tau particle and certain other heavy mesons (known as K mes-



ALPHA PARTICLES made the image in this dark-field photomicrograph. The emulsion itself contains tiny colloid particles of radium, one of which is at the center of the image. The tracks were made by alpha particles emitted by radium and its daughter elements.

ALPHA STARS emerged from thorium atoms in this emulsion. The stars at left and right represent the serial decay of single thorium atoms. First the thorium atom emitted an alpha particle, then the daughter isotope emitted another alpha particle, and so on.

ons) probably are all the same particle showing alternate modes of decay.

Neutral particles unfortunately leave no footprints in an emulsion or cloud chamber. They may, however, signal their presence indirectly. For example, a fast neutron charging through an emulsion may collide head on with a hydrogen atom, rip away the latter's electron and cause the proton to recoil and make a track that tells the story of the collision.

At Berkeley all eyes are focused just now on the footprints of the antiproton, which at long last was generated by the Bevatron a few months ago. The antiproton—the negatively charged counterpart of the positive proton—has only a fleeting life, but it makes its existence unmistakably known by the spectacular manner of its death. When the particle comes to rest in an emulsion, there is an explosion which generates a large star.

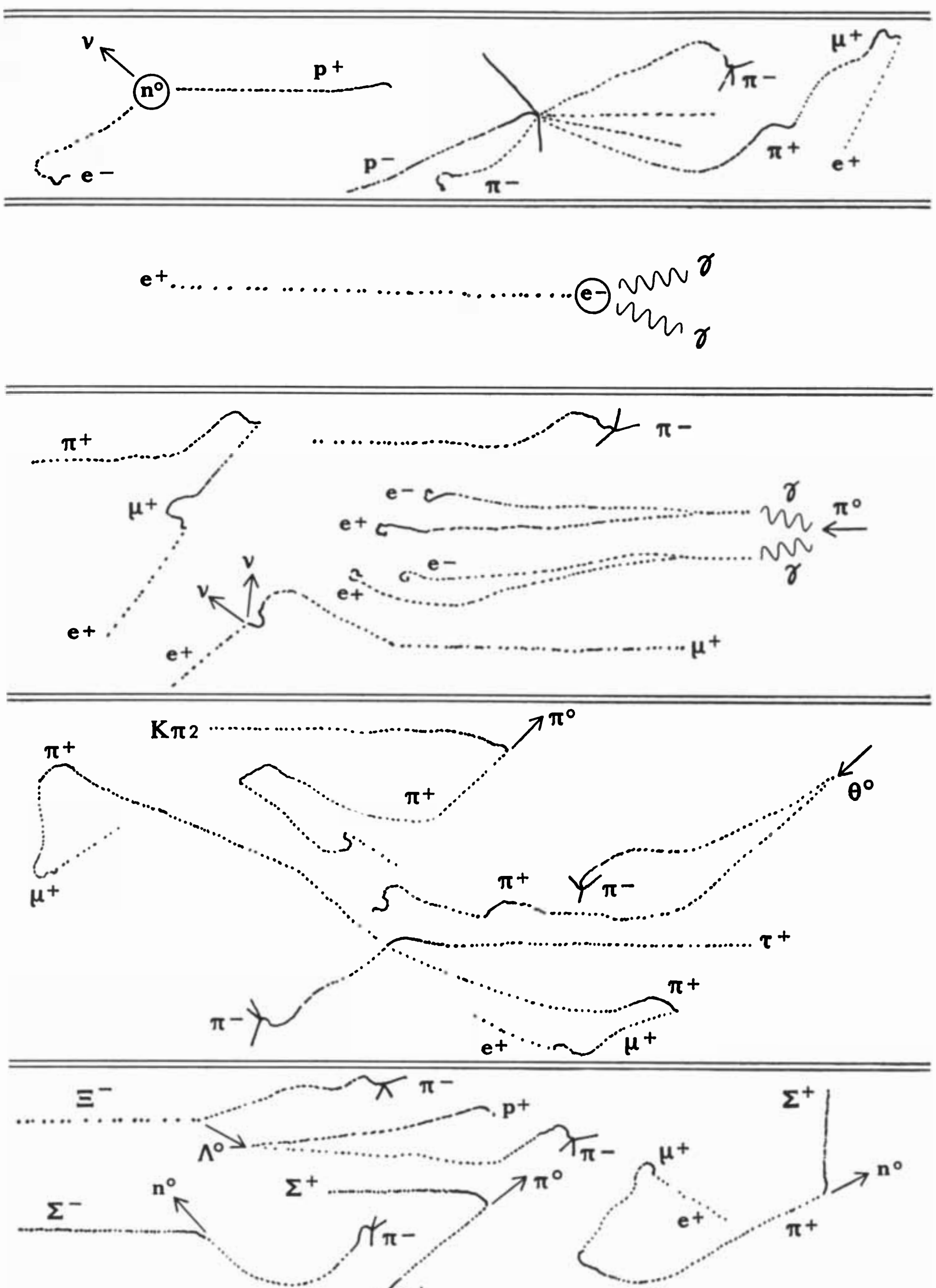
GROUP	MEMBERS	SYMBOL	REST MASS (ELECTRON MASSES)	MEAN LIFE (SECONDS)
NUCLEONS	PROTON	p^+	1836.13	STABLE
	ANTIPROTON	p^-	1840 ± 90	$\sim 5 \times 10^{-8}$
	NEUTRON	n^0	1838.65	750
LEPTONS	ELECTRON	e^-	1	STABLE
	POSITRON	e^+	1	ANNIHILATES
	NEUTRINO	ν	0	
LIGHT MESONS	NEGATIVE PI MESON	π^-	272.8 ± 0.3	2.44×10^{-8}
	POSITIVE PI MESON	π^+	273.3 ± 0.2	2.53×10^{-8}
	NEUTRAL PI MESON	π^0	263.7 ± 0.7	5×10^{-15}
	NEGATIVE MU MESON	μ^-	207 ± 0.5	
	POSITIVE MU MESON	μ^+	206.9 ± 0.4	2.15×10^{-6}
HEAVY MESONS	TAU MESON	τ^+	965.5 ± 0.7	$\sim 5 \times 10^{-8}$
	THETA MESON	θ^0	965 ± 10	1.6×10^{-10}
	CHI MESON	χ $(K\pi 2)$	963 ± 9	1×10^{-8}
		$(K\mu 2)$	960 ± 7	1×10^{-8}
	KAPPA MESON	K $(K\mu 3)$	955 ± 9	1×10^{-8}
		$(Ke3)$	~ 960	
HYPERONS	LAMBDA PARTICLE	Λ^0	2182 ± 2	3.7×10^{-10}
	POSITIVE SIGMA PARTICLE	Σ^+	2327 ± 4	$\sim 10^{-10}$
	NEGATIVE SIGMA PARTICLE	Σ^-	2325	$\sim 10^{-10}$
	CASCADE PARTICLE	Ξ^-	2582 ± 10	$\sim 10^{-10}$

FUNDAMENTAL PARTICLES are listed, together with their characteristic tracks in nuclear emulsions. The photon and graviton are omitted to simplify the organization of the chart. The light mesons are called L particles; the heavy mesons, K particles; the hyperons, Y particles. The chi and kappa mesons have dual symbols, the second of which segregates them according to their mode

The particles emerging from the explosion, among which are several pi mesons, have a large kinetic energy; the total energy released is about that predicted by the theory that the antiproton and a proton combine and annihilate each other, converting mass into energy.

The Bevatron produces antiprotons when a beam of high-energy protons (at 6.2 billion electron volts) hits a copper target. The fast protons attacking the nuclei of the copper atoms generate large numbers of heavy mesons and an occasional antiproton: the yield is about one antiproton per 62,000 mesons. The theory suggests that a high-energy proton interacts with a neutron to form an antiproton-proton pair.

DECAY SCHEME

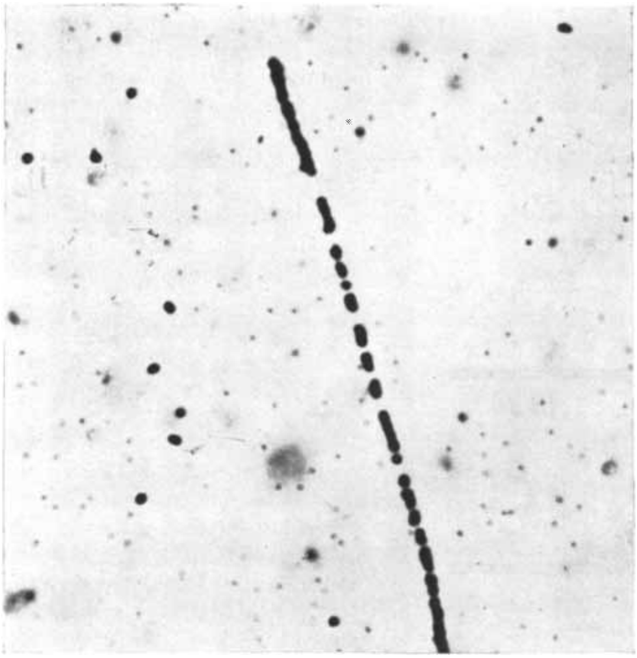


of decay. Kπ2, for example, indicates that this K (not kappa) particle decays into two pi mesons. The decay schemes may be followed by beginning with the particle in that group. The wavy lines (gamma rays), circles and arrows denote particles that do not make tracks.

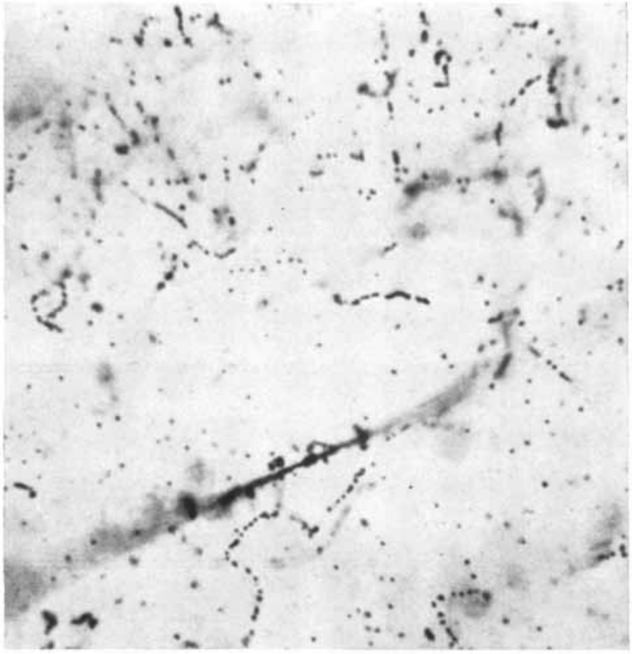
The antiproton has the same mass as a proton. One would therefore expect that it should have about the same probability of collision with atomic nuclei as it travels through matter. But experiments with the new particle show that the antiproton actually has about twice as great a collision probability, or cross section, as the proton. This surprising property has presented nuclear physicists with an intriguing problem.

Enlightening as the work with atom-smashing machines has been, the investigators of particles have not by any means lost interest in the wild assortment of nuclei and nuclear debris that rains into our atmosphere from the bombardment of the cosmic radiation. Of the primary cosmic radiation itself, little reaches ground level, for the atmosphere absorbs it as effectively as would a three-foot-thick layer of lead completely surrounding the earth. But physicists are capturing the footprints of primary particles coming in from space by floating their instruments and photographic plates to the top of the air ocean in balloons. Great impetus was given to this work by the U. S. Navy's development of the plastic "Skyhook" balloon. Unlike rubber balloons, the plastic vehicles can be held at a fixed, preset elevation. Stacks of emulsions have been flown to 100,000 feet—almost at the borders of empty space, for the weight of the overlying air there is only 13 grams per square centimeter, as against 1,030 grams at sea level.

As the primary cosmic rays smash nitrogen and oxygen atoms in the air, they generate a fallout of secondary and tertiary particles. The footprints of these fragments are being recorded at mountaintop stations all over the world. Men who risk their lives to climb a mountain simply "because it is there" are usually very cooperative with the cosmic ray physicists. A light package of photographic plates does not add appreciably to the burden of the climb, and it may add incentive as a form of applied mountaineering. In the ascent of Mt. Everest Sir Edmund Hillary took a small package of plates (given him by Professor Eugster of Zurich University) to the 25,850-foot camp site. Unfortunately, in the excitement of the triumphant descent from the peak the plates were overlooked. Sir John Hunt, the leader of the expedition, apologized in his book, *The Conquest of Everest:* "I very much



SLOW NEUTRON gave rise to this track in an emulsion containing lithium borate. The neutron encountered a lithium atom at the lower end of the short, heavy line at the top. The track was then made by two fragments of the nucleus recoiling from each other.



ELECTRONS made the faint, wavy tracks in this emulsion, which was aged for 50 days before it was developed. The heavy track at the bottom was made by an oxygen nucleus in primary cosmic radiation. The electron tracks along this image are called delta rays.

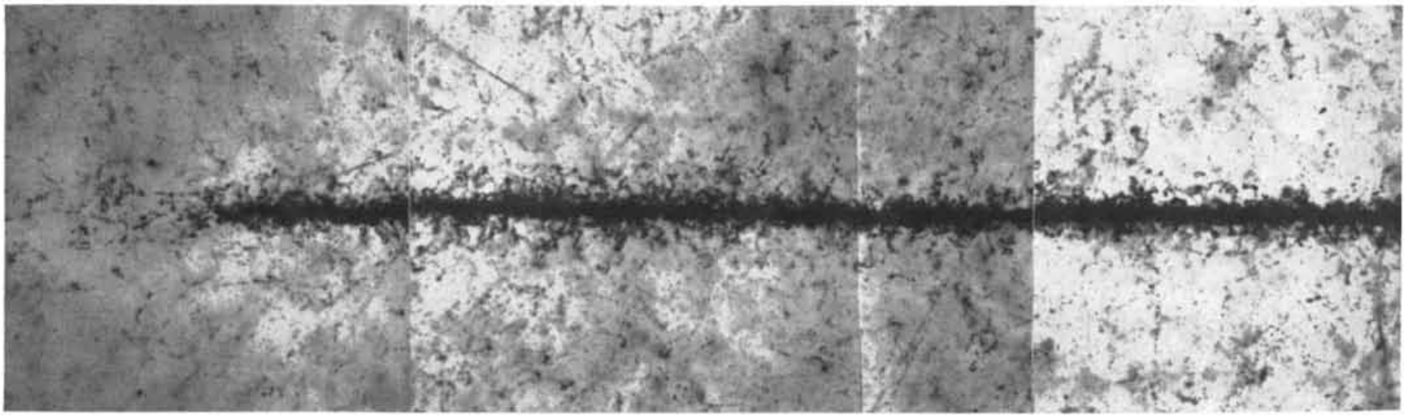
regret to say that the plates have remained on the South Col, where they must by now have made a very definite recording of . . . cosmic ray phenomena."

Among the first to get a recording of these phenomena was Marietta Blau of the University of Vienna. Nineteen years ago she exposed a series of photographic plates for four months on a mountaintop at Innsbruck. When she developed them, she found not only the familiar alpha stars from radioactive substances but also a number of bigger stars with much longer, less dense prongs. The tracks evidently were produced chiefly by protons. Dr. Blau surmised correctly that they were the debris of nuclei disrupted by cosmic rays; she followed up this finding and today is studying nuclear disruptions produced by the Cosmotron at the Brookhaven National Laboratory.

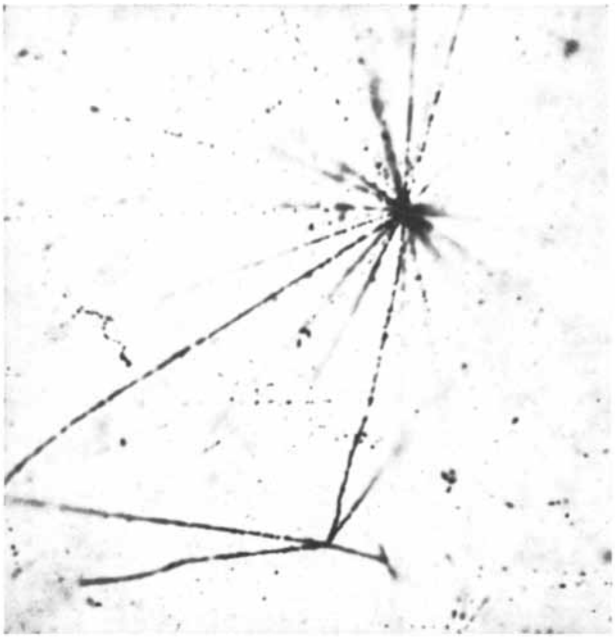
The smashing of nuclei by cosmic rays increases rapidly with altitude. At sea level in northern latitudes the rate of star production in photographic plates is about one per cubic centimeter of emulsion per day of exposure; at 14,260 feet on Mt. Evans in Colorado the rate is 20 times that; and in balloons near the top of the atmosphere, 2,500 times.

The tracks of the primary cosmic particles that arrive there from space are often extremely robust. These thick tracks are made by heavy nuclei, much larger than the nuclei of hydrogen atoms. The track is covered with a fur of spurs projecting from its sides—secondary ionizations which are known as delta rays. Since the amount of ionization by a particle along its path is proportional to the square of its charge, the amount of delta-ray ionization identifies the particle. The primary cosmic particles have been found to include the nuclei of almost all the elements from hydrogen to nickel. Iron nuclei often produce tracks heavy enough to be seen with the naked eye.

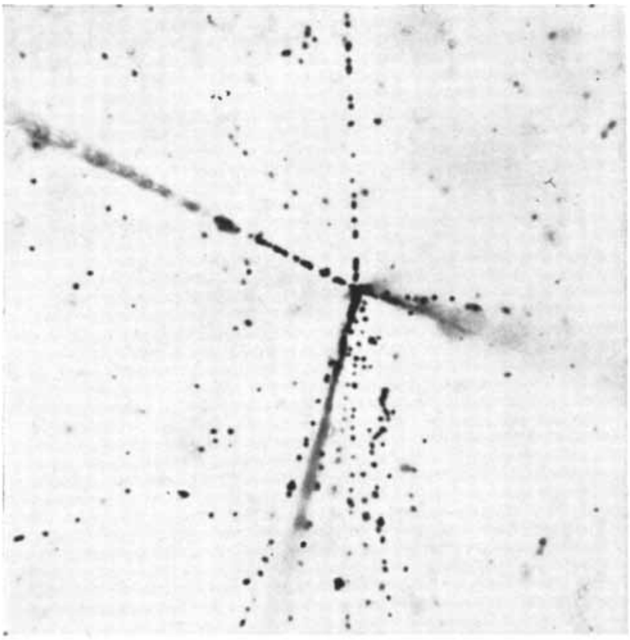
Sometimes the incoming heavy nu-



IRON NUCLEUS in primary cosmic radiation entered this picture from the left. Escaping catastrophic collision with nuclei in the emulsion, it finally came to rest at the right. Its energy was dissipated by a series of encounters in which it removed electrons



NEGATIVE PI MESON made the track between these two stars. At the top is a nucleus disrupted by a primary cosmic ray. At the bottom is a second nucleus disrupted by the pi meson. Negative mesons are readily absorbed by nuclei because of their opposite charge.



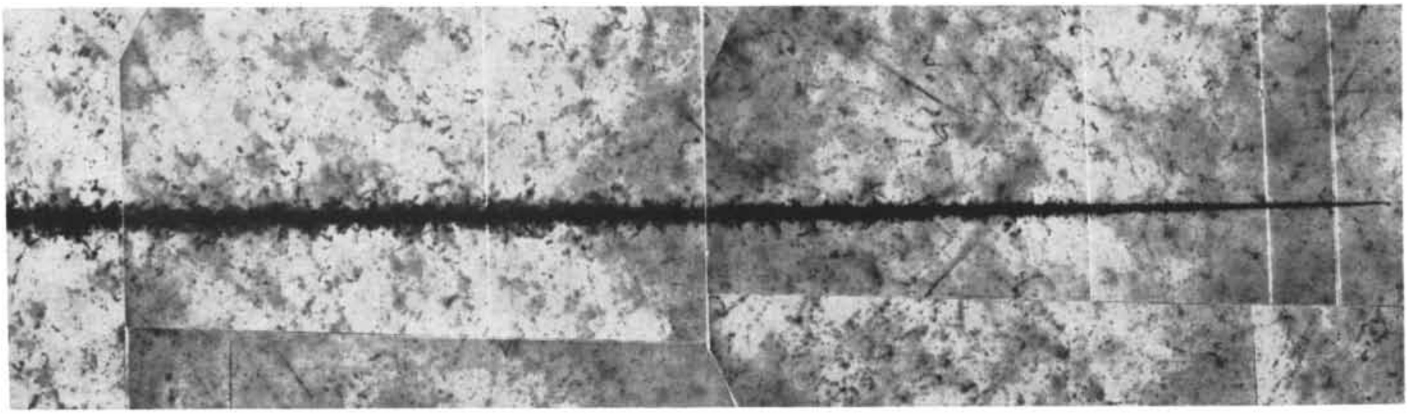
PROTON in primary cosmic radiation made the nearly vertical track at the top of this emulsion. The tracks produced by its encounter with a nucleus in the center of the emulsion are characteristic of fragments and/or particles with a single electric charge.

cleus is partly sheared off by a glancing collision in the air, and the separated bundles of nucleons diverge from the point of collision. Sometimes the cosmic primary hits an atom head on and disintegrates it, emitting a shower of heavy mesons: as many as 200 charged mesons have been seen in a single star. Many of the pi mesons decay during flight into mu mesons; the latter, nearly immune to capture by atoms, zip through the atmosphere and often plunge deep into the earth.

A small proportion of the heavy nuclei from space escape catastrophic collisions and are eventually slowed down by ionization processes in the atmosphere. When these particles are caught in an emulsion, they produce very spectacular tracks. The track is first thick and furry; then as the heavy nucleus slows down and begins to pick up electrons, the reduction of its positive charge diminishes the ionization it produces, so that its track tapers down to a needle point at the end of its flight.

The last grain at the rest point of a heavy primary cosmic particle is a thing to marvel at. Embedded within the grain of silver in the emulsion is an atom with a history unlike that of its neighbors. It is an atom which may have been blown out of a star in our galaxy millions of years ago. It was accelerated through interstellar space by magnetohydrodynamic fields. For millions of years it escaped collision with cosmic dust. Finally it plowed into the earth's atmosphere, and in a single moment lost its store of energy accumulated since birth. Such is the ever-increasing entropy of the universe, of which Swinburne wrote:

We thank with brief thanksgiving
Whatever gods may be
That no man lives forever,
That dead men rise up never;
That even the weariest river
Winds somewhere safe to sea.



from atoms in the emulsion. These electrons made the wavy tracks along the path of the iron nucleus. The track is about a 16th of an inch in length, too long to be shown in a single photomicrograph. It has accordingly been depicted in a mosaic of photomicrographs.

The Eye and the Brain

If the optic nerve of a newt is cut and its eye is turned through 180 degrees, the nerve regenerates and the animal sees upside down. Such results deeply affect our picture of how the nervous system develops

by R. W. Sperry

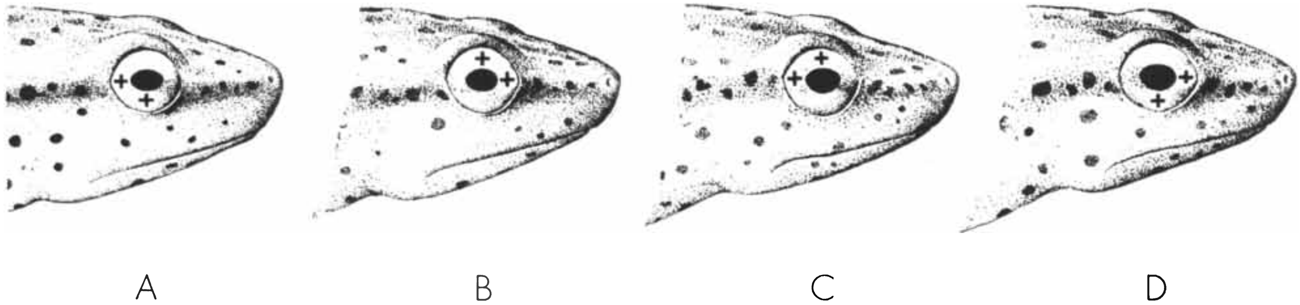
Probably no question about the behavior of living things holds greater general interest than the age-old issue: Heredity versus Learning. And none perhaps is more difficult to investigate in any clear-cut way. Most behavior has elements of both inheritance and training; yet each must make a distinct contribution. The problem is to separate the contributions. We can take vision as a case in point. An animal, it is often said, must learn to see. It is born with eyes, but it matures in the use of them. The question is: Just where does its inborn seeing ability end and learning begin? To put the matter another way: Exactly what equipment and instinctive skills are we born with?

This article is an account of experiments which have given some new insight into the heredity-learning question. The behavior studied is vision, and the story begins 31 years ago.

In 1925 Robert Matthey, a zoologist of the University of Geneva, delivered to the Society of Biology in Paris an astonishing report. He had severed the optic nerve in adult newts, or salamanders, and they had later recovered their vision! New nerve fibers had sprouted from the cut stump and had managed to grow back to the visual centers of the brain. That an adult animal could regenerate the optic nerve (and even, as Matthey reported later, the retina of the eye) was surprising enough, but that it could also re-establish the complex network of nerve-fiber connections between the eye and a multitude of precisely located points in the brain seemed to border on the incredible. And yet this was the only possible explanation, for without question the newts had regained normal vision. They would stalk a moving worm separated from them by a glass wall in their aquarium; they were able to see a small object distinctly and follow its movements accurately.

A long series of confirmations of Matthey's discovery followed. He transplanted an eyeball from one newt to another, with good recovery of vision. Leon S. Stone and his co-workers at Yale University transplanted eyes successfully from one species of salamander to another, and grafted the same eye in four successive individuals in turn, each of which was able to use the eye to regain its vision. Eventually experimenters found that fishes, frogs and toads (but not mammals) also could regenerate the optic nerve and recover vision if the nerve was cut carefully without damage to the main artery to the retina.

The optic nerve of a fish has tens of thousands of fibers, most or all of which must connect with a specific part of the visual area of the brain if the image on the retina is to be projected accurately to the brain. The newt, whose retina is less fine-grained than a fish's, has fewer optic fibers, but still a great many. The system is analogous to a distributor's map with thousands of strings leading from a focal point to thousands of specific spots on the map. How can an animal whose optic fibers have all been cut near the focal point re-establish this intricate and precisely patterned system of connections? Matthey found that the regenerating fibers wound back into the



EYE OF THE NEWT was turned in various ways by the experiments described in this article. In A the normal position of the eye is marked with crosses. In B the eye has been turned so that its front-back and up-down axes are inverted. In C the eye on the opposite side of the head has been transplanted to the side shown with its up-down axis inverted. In D the eye on the opposite side of the head has been transplanted to the side shown with its front-back axis inverted. In each case the operation is done on both eyes.

brain in what looked like a hopelessly mixed up snarl. Yet somehow, from this chaos, the original orderly system of communications was restored.

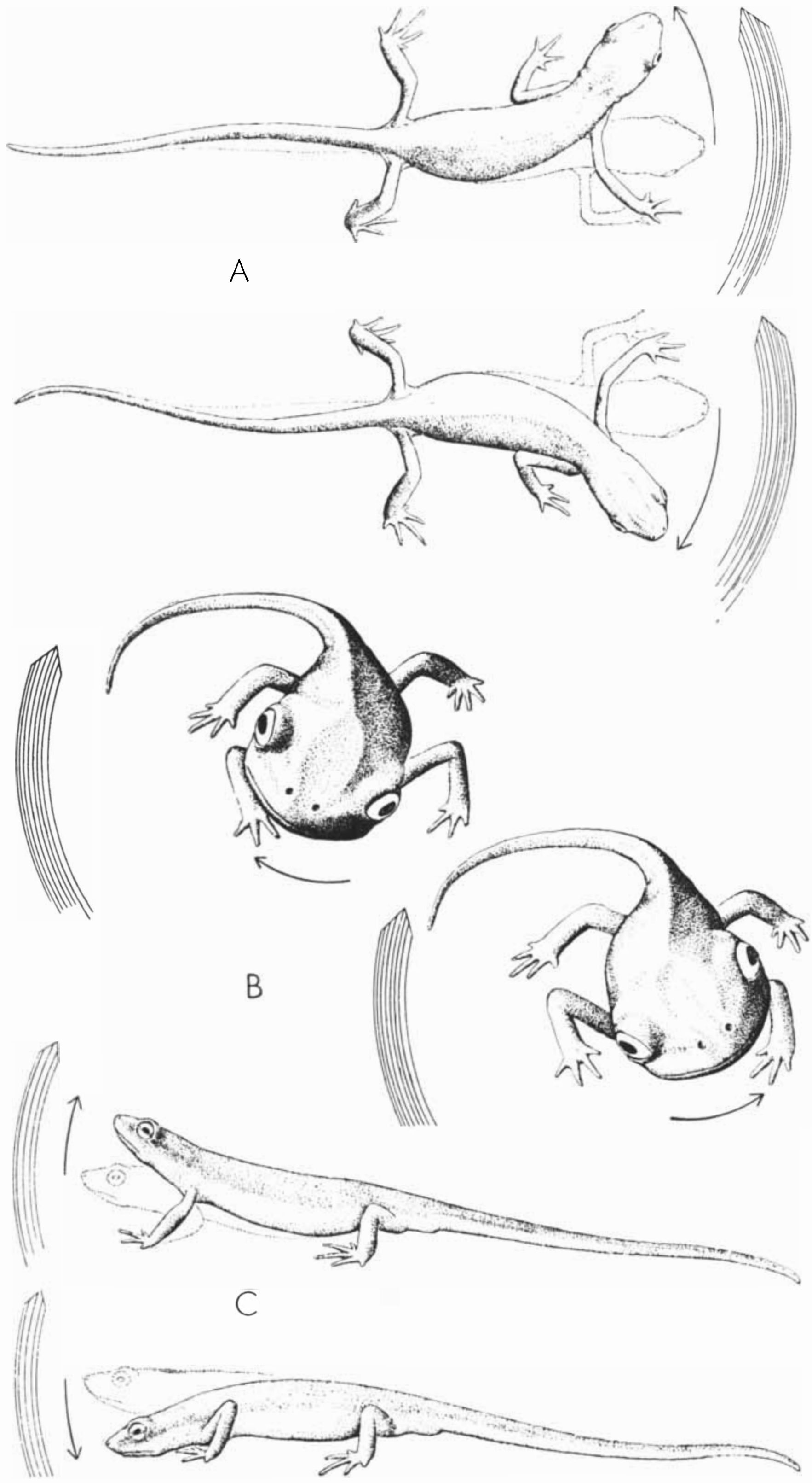
Two possible explanations have been considered. The one that was long regarded as the more plausible is that the connections are formed again by some kind of learning process. According to this theory, as the cut nerve regenerates a host of new fibers, branching and crawling all over the brain, the animal learns through experience to make use of the fiber linkages that happen to be established correctly, and any worthless connections atrophy from disuse.

The second theory is that each fiber is actually specific and somehow manages to arrive at its proper destination in the brain and reform the connection. This implies some kind of affinity, presumably chemical, between each individual optic fiber and matching nerve cells in the brain's visual lobe. The idea that each of the many thousands of nerve fibers involved has a different character seemed so fantastic that it was not very widely accepted.

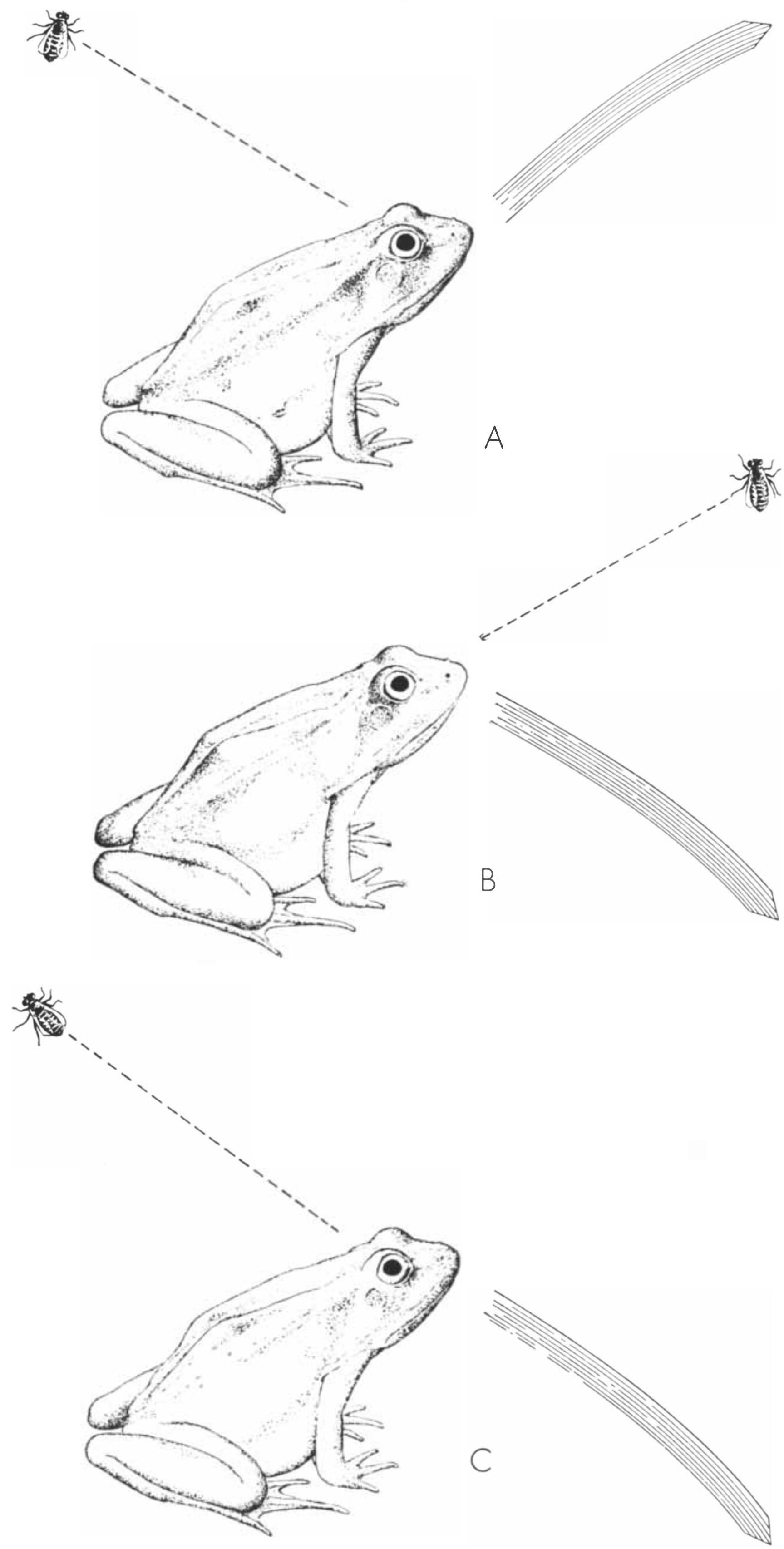
These were the questions we undertook to test: Does the newt relearn to see, or does its heredity, forming and organizing its regenerated fibers according to a genetic pattern, automatically restore orderly vision?

Our first experiment was to turn the eye of the newt upside down—to find out whether this rotation of the eyeball would produce upside-down vision, and if so, whether the inverted vision could be corrected by experience and training. We cut the eyeball free of the eyelids and muscles, leaving the optic nerve and main blood vessels intact, then turned the eyeball by 180 degrees. The tissues rapidly healed and the eyeball stayed fixed in the new position.

The vision of animals operated on this way was then tested. Their responses showed very clearly that their vision was reversed. When a piece of bait was held above the newt's head, it would begin digging into the pebbles and sand on the bottom of the aquarium. When the lure was presented in front of its head, it would turn around and start searching in the rear; when the bait was behind it, the animal would lunge forward. (Since its eyes are on the side of the head, a newt can see objects behind it.) As color-adapting animals, the newts with upside-down eyes even adjusted their color to the brightness above them instead of to the dark background of the aquarium bottom. Besides seeing everything up-



RESPONSE OF THE NEWT to moving objects varies with the operations depicted on the opposite page. The first newt in each of the three pairs of animals on this page is normal. When an object (*thick arrows*) is moved past the newt, the animal turns its head in the same direction (*thin arrows*). The second newt in each pair represents the behavior of the animal after one or more of the operations. The response of the second newt in A corresponds to operations B and D on the opposite page; in B, to operations B and C; in C, to C and D.



SAME OPERATIONS ON A FROG produce these effects when the animal strikes at a fly. In A the fly is above and behind a frog whose eyes have been turned by operation D on page 48; the animal strikes in the direction shown by the thick arrow. In B the eyes of the frog have been turned by operation C. In C the eyes of the frog have been turned by operation B.

side down and backward, the animals kept turning in circles, as if the whole visual field appeared to be whirling about them. Human subjects who have worn experimental lenses that invert the visual field have reported that any movement of the head or eyes tends to make everything seem to whirl around them.

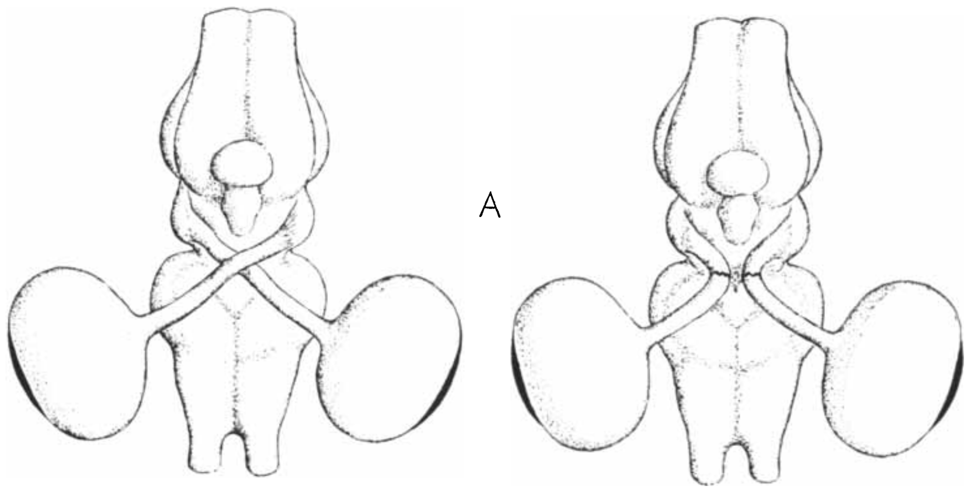
The operated newts never relearned to see normally during the experiment. Some were kept with their eyes inverted for as long as two years, but showed no significant improvement. However, when rotated eyes were turned back to the normal position by surgery, the animals at once resumed normal behavior. There was no evidence that their long experience with inverted vision had brought about any change in the functioning of the central nervous system.

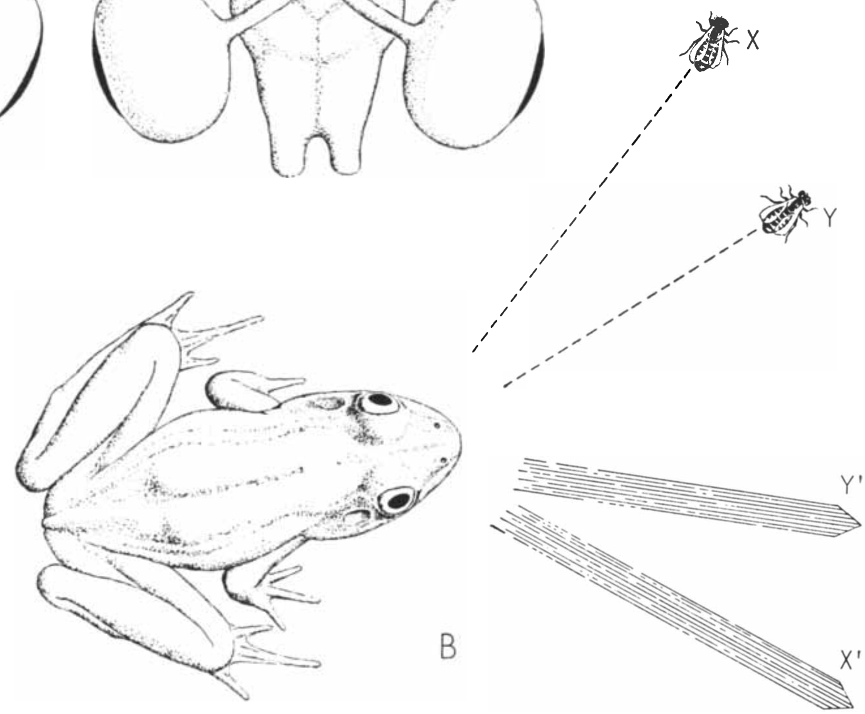
A second experiment bore out further the now growing suspicion that learning probably was not responsible for the recovery of vision by newts whose optic nerves had been cut. This time we rotated the eyeball and severed the optic nerve as well. The object was to find out whether the regenerating nerve fibers would give the newt normal vision, inverted vision or just a confused blur.

During the period of nerve regeneration the animals were blind. The first visual responses began to reappear about 25 to 30 days after the nerve had been cut. From the beginning these responses were systematically reversed in the same way as those produced by eye rotation alone. In other words, the animals again responded as if everything was seen upside down and backward. In these animals also the reversed vision remained permanently uncorrected by experience.

In another series of experiments we cut the optic nerves of the two eyes and switched their connections to the brain. Normally each optic nerve crosses to the side of the brain opposite the eye. We connected the cut nerve to the brain lobe on the same side. The result was to make the animals behave after regeneration as if the right and left halves of the visual field were reversed. That is, the animals responded to anything seen through one eye as if it were being viewed through the other eye. This switch too was permanent, uncorrected by experience. Frogs and toads responded to the experiment in the same way as newts.

By rotating the eyeball less than 180 degrees (*e.g.*, a 90-degree turn), and by combining eye transplantation from one side to the other with various degrees of rotation, we produced many





OPERATION ON THE OPTIC NERVES of a frog produced the effect shown at the lower right. At upper left the eyes of the frog are joined to the brain by the optic nerves. In the operation, which is depicted at top center, the nerves were cut and rejoined so that they did not cross. When a fly was at X, the frog struck at X'; when it was at Y, the frog struck at Y'.

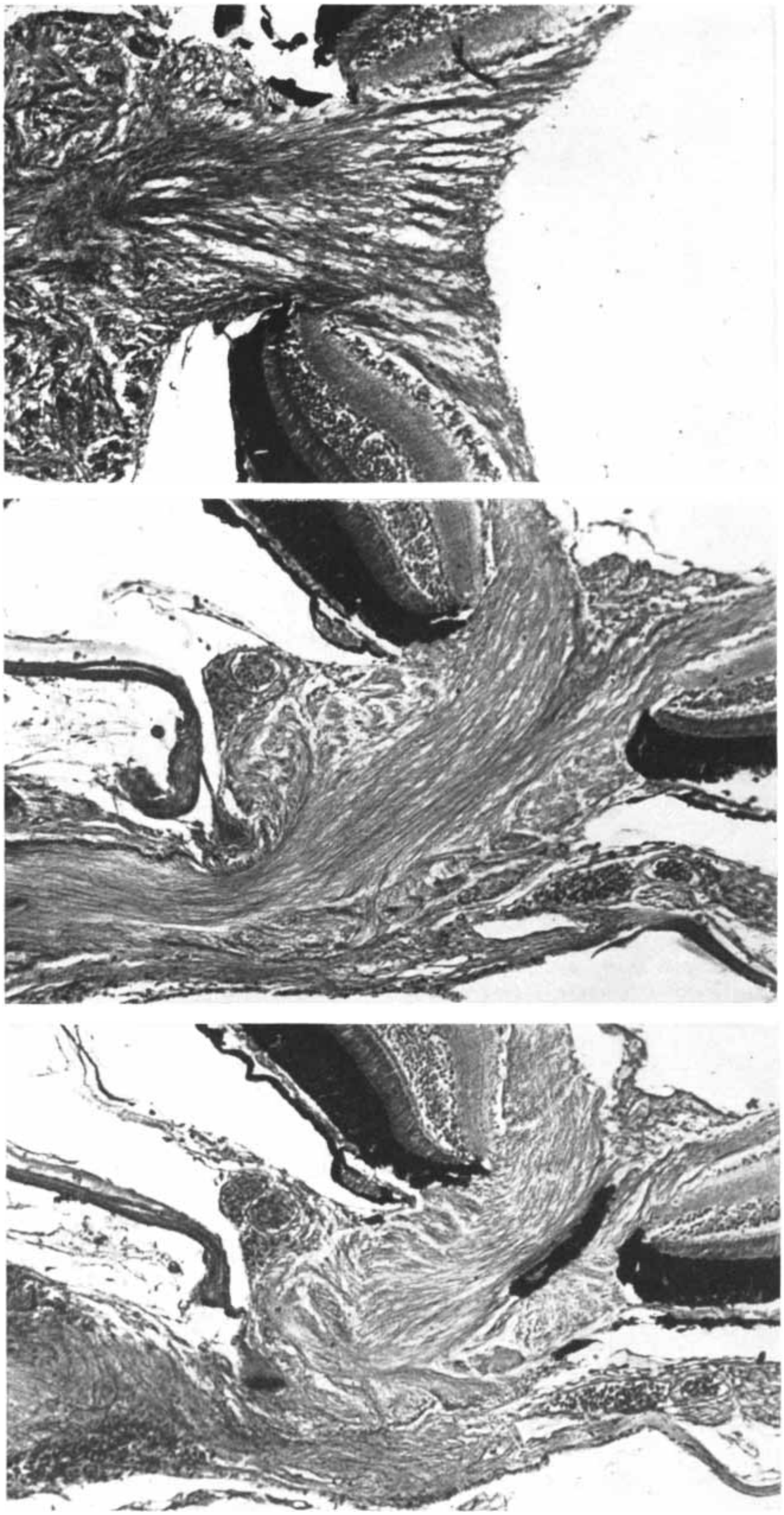
other forms of abnormal spatial perception. But every experiment had the same basic outcome: the animal—newt, frog, toad or fish—always regenerated an organized pattern of vision. The visual field as a whole might be turned upside down, or inverted on another axis, or displaced from the left to the right side, but always the spatial organization within the visual field itself was restored in the normal pattern. Evidently the individual nerve fibers from the retina, after regeneration, all regained their original relative spatial functions in projecting the picture to the brain.

This orderly restoration of the spatial relations could hardly be based on any kind of learning or adaptation, under the conditions of our experiments. Animals don't *learn* to see things upside down and backward or reversed from left to right: reversed vision is more disadvantageous than no vision at all. The results clearly demonstrated that the orderly recovery of correct functional relations on the part of the ingrowing fibers was not achieved through function and experience, but rather was predetermined in the growth process itself.

Apparently the tangle of regenerating fibers was sorted out in the brain so as to restore the orderly maplike projection of the retina upon the optic lobe. If we destroyed a small part of the optic lobe after such regeneration, the animal had a blind spot in the corresponding part of its visual field, just as would be the case in normal animals. It was as if each regenerated fiber did indeed make a connection with a spot in the brain matching a corresponding spot in the retina.

It follows that optic fibers arising from different points in the retina must differ from one another in some way. If the ingrowing optic fibers were indistinguishable from one another, there would be no way in which they could re-establish their different functional connections in an orderly pattern. Each optic fiber must be endowed with some quality, presumably chemical, that marks it as having originated from a particular spot of the retinal field. And the matching spot at its terminus in the brain must have an exactly complementary quality. Presumably an ingrowing fiber will attach itself only to the particular brain cells that match its chemical flavor, so to speak. This chemical specificity seems to lie, as certain further experiments indicate, in a biaxial type of differentiation which produces unique arrays of chemical properties at the junction places.

Such chemical matching would account for recognition on contact, but how does a fiber find its way to its destination? There is good reason to believe that the regenerating fibers employ a shotgun approach. Each fiber puts forth many branches as it grows into the brain, and the brain cells likewise have widespreading branches. Thus the chances are exceedingly good that a given fiber will eventually make contact with its partner cells. We can picture the advancing tip of a fiber making a host of contacts as it invades the dense tangle of brain cells and their treelike expansions. The great majority of these contacts come to nothing, but eventually the growing tip encounters a type of cell surface for which it has a specific chemical affinity and to which it adheres. A chemical reaction then causes the fiber tip to stop advancing and to form a lasting functional union with the group of cells, presumably roughly circular in



OPTIC NERVE of *Bathygobius soporator*, a fish of the goby family, was cut and allowed to regenerate. The regenerated nerve is shown in these three photomicrographic sections. In each photograph the eye is toward the right and the nerve runs from right to left. The top photograph shows a section of one nerve; the bottom two photographs show different sections of the same nerve. In all three sections the nerve fibers are tangled. Despite this apparent disorganization the fishes from which the sections were taken could see normally.

formation, which constitutes the spot in the brain matching the fiber's source spot in the retina.

The experiments on vision have been found to apply equally to other parts of the central nervous system. Normal function can be recovered through regeneration by general sensory nerves in the spinal cord, by the vestibular nerve in the ear mediating the sense of equilibrium and by other sensory and motor nerve circuits.

All the experiments point to one conclusion: the theory of inherent chemical affinities among the nerve fibers and cells is able to account for the kinds of behavior tested better than any hypothetical mechanism based on experience and learning. There is no direct proof of the theory, for no one has yet seen evidence of the chemical affinity type of reaction among nerves under the microscope. But an ever-growing accumulation of experimental findings continues to add support to the chemical theory.

We return to our original question: How big a role does heredity play in behavior? The experiments cited here show that in the lower vertebrates, at least, many features of visual perception—the sense of direction and location in space, the organization of patterns, the sense of position of the visual field as a whole, the perception of motion, and the like—are built into the organism and do not have to be learned. More general experiments suggest that the organization of pathways and associations in the central nervous system must be ascribed for the most part to inherent developmental patterning, not to experience. Of the thousands of circuit connections in the brain that have been described, not one can demonstrably be attributed to learning. Whatever the neural changes induced in the brain by experience, they are extremely inconspicuous. In the higher animals they are probably located mainly in the more remote byways of the cerebral cortex. In any case they are superimposed upon an already elaborate innate organization.

The whole idea of instincts and the inheritance of behavior traits is becoming much more palatable than it was 15 years ago, when we lacked a satisfactory basis for explaining the organization of inborn behavior. Today we can give more weight to heredity than we did then. Every animal comes into the world with inherited behavior patterns of its species. Much of its behavior is a product of evolution, just as its biological structure is.

Kodak reports to laboratories on:

not jarring the radiographer's delicately tuned sensibilities . . . a movie camera for high altitudes and latitudes . . . how goodly the body of microprint literature is

A new x-ray film

Monotonous is the word. Looking at radiographs of castings and weldments, which are what go on most *Kodak Industrial X-ray Film*, can be monotonous unto distraction. Fortunately for public safety, radiographers are able to stand it and even to keep themselves alert for certain occasional small signs that signal danger. Rarely would the signs attract the attention of the uninitiated. Only after long familiarity with the radiographic appearance of sound metal does the sight of the unsound set off the alarm. It is easy to see why changes that would alter the appearance of radiographs are resisted.

Nevertheless, progress ought not be barred, so long as it does not jar the radiographer's delicately tuned sensibilities. Right now progress takes the form of displacing his favorite *Kodak Industrial X-ray Film, Type A*, with *Type AA*. His radiographs look the same, but the speed is up 30% for low-voltage x-rays, 70% for medium-voltage, 130% for high-voltage x-rays and gamma-rays such as the boys are now getting from Co^{60} and Cs^{134}. If he wants the same film density as before, he can now get it with less milliamperage or shorter exposure time. If he cares to adjust himself to looking at higher densities, he can give the same exposure as he used to and see more detail, since the contrast continues to increase as density increases. As a third alternative, he can consider that insofar as the greater mass of metal he can get through is concerned, we have in effect bumped up the capacity of his equipment for him.

There are many interesting facts about film and x-rays that Eastman Kodak Company, X-ray Division, Rochester 4, N. Y., can tell you, if you can only ask the right questions.

K-100 in the cold

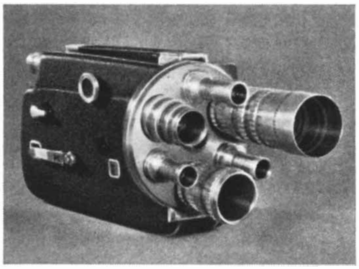
"Walt Disney Productions' Antarctic film will soon be shown on the Disneyland and Mickey Mouse Club TV Shows and will be released as a full-length movie which can be seen at your local movie theatre."

Printing the above sentence seems a fair price to pay for the privilege of saying that the *Cine-Kodak K-100 Cameras* of the Disney crews in Antarctica are functioning properly at −45F without the electric blankets which far costlier 16mm movie cameras require.

Actually, nowadays, smart outfits like the Disney organization find out from an environmental chamber test in advance just what they can or cannot expect from equipment being considered for strenuous duty. Then you hear from them only if the equipment failed to perform as in the test, in which case you hear plenty.

We could attribute the low-temperature performance of this camera to the extra care lavished by aging craftsmen on each *K-100* that leaves their devoted hands. A more credible explanation is afforded by the nylon gears, nylon pulldown cam, and the ball-bearing pulldown mechanism. The pre-stressed spring motor is also of some pertinence to the matter.

The *K-100* is now made in a turret model like this:



Those smaller tubes opposite each of the three *Kodak Cine-Ektar Lenses* contain their respective viewfinder telescope objectives. No Disney tie-in, unfortunately, because this model came out months after the Mickey Mouse emissaries shoved off.

Performance of the K-100 *in the cold should be just as exploitable at high altitudes as at high latitudes. Data recording, for example? A Kodak dealer is nearby.*

A snowball rolling

Somewhere your librarian has to draw the line. Some books and bound volumes simply cost too much in money and space for the good a given organization is likely to get from them. These words are promotion for the microprint idea. It pushes the line which your librarian has to draw about as far as anyone could want it pushed.

A microprint card* is a piece of stiff paper, generally 3″ x 5″ or larger, on which can appear as many as 60 greatly reduced book pages. These cards are read with the aid of optical devices. Of these we are prejudiced in favor of the *Kodagraph Microprint Reader* as the most comfortable to use.

A goodly body of the technical literature in the sciences, the humanities, and even the law and finance is now on sale in this form. To illustrate just how goodly is the body, we have just published a booklet entitled "What's Available on Microprint Cards." It is an attempt at a condensed consolidated catalog of the output of all microprint card publishers known to us and willing that we publicize their offerings. We alone are footing the bill for this project.

Our motives, of course, are selfish. Our scheme with the booklet is to convince a lot more scholars, librarians, and librarians' bosses that there is enough microprint literature around to justify the acquisition of microprint readers. Then, just as surely as the telephone, radio, and television industries grew, microprint grows. The publisher's market grows. The number of titles grows. The need for microprint readers where researchers foregather becomes more obvious. It even occurs to more large companies that since their research people already have readers for the open microprint literature, the companies' own internal reports might be more efficiently circulated in microprint form.

Since, as all this comes to pass, we shall sell more and more photographic materials with which to make microprint cards, there is no reason to hesitate about writing for a free copy of "What's Available on Microprint Cards" to Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.

Erratum: In an advertisement appearing some months ago in this publication, it was indicated that the natural compound cantharidin (with which we were comparing one of the Eastman Organic Chemicals) possesses a double bond in the ring structure. It does not.

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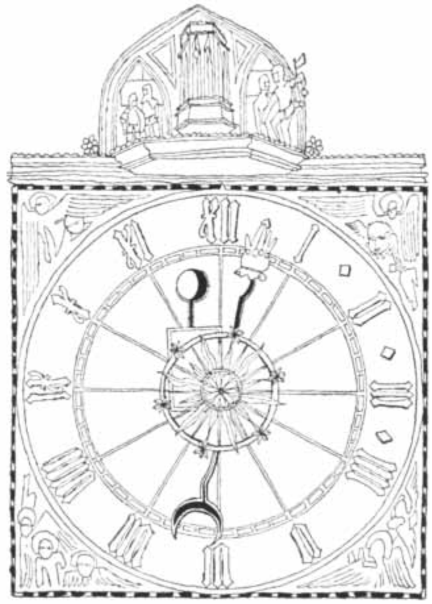
*The term "Microcard" is applied only to certain makes of microprint cards.

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

Kodak
TRADEMARK

SCIENCE AND



Emergency

To deal with the nation's shortage of technical manpower President Eisenhower last month appointed a National Committee for the Development of Scientists and Engineers. It is to develop programs for training and recruitment and to stimulate public interest in the problem. The Chairman of the Committee is Howard L. Bevis, president of Ohio State University. A subcommittee on scientists is headed by Detlev W. Bronk, president of the National Academy of Sciences, and one on engineers by Thomas H. Chilton, president of the Engineering Joint Council.

Wooing the Graduates

This year's college senior is a hunted man, especially if he is technically trained. George N. P. Leetch, placement director at Pennsylvania State University, reports that the average engineering graduate has received 10 to 12 job offers. Teachers can choose among 8 to 10 offers and business administration students from 5 or 6.

Starting salaries offered to engineers average about $410 per month; to other graduates, about $375 per month.

Arithmetic Rejected

A possible clue to the U. S. shortage of scientists and engineers is offered by a psychological test conducted simultaneously among school children in this country and in Japan. The results indicate that U. S. pupils develop a growing distaste for arithmetic, whereas Japanese youngsters incline to it more and more. George M. Haslerud of the University of New Hampshire and Takao Umemoto of the University of Kyoto gave some 900 children a choice of arithmetic or verbal problems. Among the fifth-graders in the American group only 43 per cent selected arithmetic, as compared with 52 per cent of their Japanese contemporaries. By the ninth grade the discrepancy was much greater: 31 per cent of the Americans chose arithmetic, against 69 per cent of the Japanese.

Haslerud believes that U. S. children reject mathematics because they are taught to treat numbers as abstractions. He deplores the tendency to ridicule children who give concrete meaning to numbers by counting on their fingers. The Japanese start using the abacus or soroban in the fourth grade and develop a concrete familiarity with numbers.

Loyalty and Competence

Last year President Eisenhower asked Detlev W. Bronk, president of the National Academy of Sciences, to look into the question whether scientists accused of disloyalty should be allowed to do unclassified research under Government grants-in-aid or contracts. Bronk appointed a committee, which delivered its report last month. Its conclusion was: "An allegation of disloyalty should not by itself be grounds for adverse administrative action on a grant or contract for unclassified research by scientifically competent investigators."

The committee held that scientific research should be judged on its own merits: a contribution to the cure of cancer "would be no less beneficial to all humanity for having been made by a Communist." It recommended that the test in awards of grants should be the scientific integrity and competence of the investigator and the merits of his research program. Accusations of criminal disloyalty should be dealt with by law enforcement agencies, not through the administration of research grants, said the committee.

Chairman of the committee was J. A. Stratton, vice president and provost of the Massachusetts Institute of Technology. Other members were Robert F. Bacher, professor of physics at the California Institute of Technology; Laird Bell, Chicago attorney; Wallace O.

Fenn, professor of physiology at the University of Rochester; Robert F. Loeb, professor of medicine at Harvard University, and Henry M. Wriston, president emeritus of Brown University.

In accepting the report, Sherman Adams, assistant to President Eisenhower, wrote Dr. Bronk: "It is gratifying that such an able group, made up of men with broad experience in a number of fields, was able to give the Government the benefit of its judgment on this important subject."

Atomic Power Package

A scheme for a relatively small and extremely hot atomic power plant which was rejected by the Atomic Energy Commission in 1947 is now being revived, the journal *Nucleonics* reports. It is a gas-cooled type, as opposed to the current models using liquid coolants. The reactor heats pure helium above 1,200 degrees Fahrenheit and uses it to drive a gas turbine. The difficulty of containing such intense heat and the uncertainties of gas turbines caused the design to be dropped when first considered. But now technological progress has made it feasible, *Nucleonics* asserts.

The main features and advantages of the power plant are described by Farrington Daniels of the University of Wisconsin, who originally sponsored the idea at Oak Ridge National Laboratory back in 1944.

The Daniels pile could operate efficiently at only 5,000 or 10,000 kilowatts. Being small, it is much easier to transport and assemble in isolated places. And since it requires no water for cooling, it can be operated in a desert.

To withstand its high temperatures the reactor would be built entirely of ceramics. Even the fuel would be in ceramic form—uranium carbide. The moderator would be graphite, which withstands heat well so long as no oxygen is allowed to attack it. Daniels points out that ceramic fuel is much easier to process than conventional uranium rods encased in aluminum cans.

Heavy Water Sale

The Atomic Energy Commission last month approved the sale of 129 tons of heavy water abroad. Sixteen tons have already been shipped at the current price of $56,000 per ton.

India is receiving 11 tons for use in a research reactor donated by Canada. Other countries sharing in the heavy water allotment are: Great Britain, 50 tons; France, 30 tons; Australia, 11 tons; Italy, 10 tons; and Switzerland, up to 7 tons. The Swiss order will go to Reactor, Ltd., a private firm which purchased from the U. S. the swimming pool reactor exhibited at the Geneva Atoms-for-Peace Conference last August.

Man-made Nova

About 2 a.m. on the night of March 14 a new star seemed suddenly to shine forth brighter than the planet Venus. Seen in the sky above New Mexico, it swelled to a disk four times the diameter of the moon and about half as brilliant. Then gradually it diffused, and by morning it had disappeared entirely.

The temporary nova was created by an Air Force Aerobee rocket shot from the Holloman Air Force Base. The missile released 20 pounds of compressed nitric oxide gas in the ionosphere. At its height of 60 miles the nitric oxide acted as a catalyst to recombine dissociated oxygen atoms into molecules. This reaction gives off enormous energy in the form of light.

The result of the test was no surprise to a team of Air Force scientists headed by chemist Murray Zelikoff. It merely duplicated on a vast scale some experiments they had carried out in the laboratory. But it did serve to demonstrate dramatically an idea previously suggested by other scientists: that the ionosphere may contain enough available chemical energy to power a fuelless rocket.

Pluto

Gerard P. Kuiper, the well-known expert on the planetary system, has concluded that the planet Pluto was once a satellite of Neptune. He presents this theory in the *Journal of the Royal Astronomical Society of Canada.*

Kuiper points out that Pluto is exceptional among the outer planets. It is small and rotates relatively slowly. Furthermore, its orbit is an elongated ellipse intersecting the nearly circular pathway of Neptune. He believes that it escaped from an orbit around Neptune itself as the big planet solidified and lost much of its gravitational mass by evaporation. Recent measurements show that Pluto rotates once every 6.39 days. This is about as long as a moon of Neptune

Laboratory motor is run at elevated temperatures to test heat-resistant characteristics of new magnet wire insulations.

should take to circle the planet and make a complete turn on its own axis.

Gamma Detector

Gamma rays are one of the most elusive of nuclear radiations. Being uncharged, they leave no track in a cloud chamber or a liquid bubble chamber. Occasionally while passing through a bubble chamber a gamma ray creates secondary electrons, which are evident as a string of bubbles. But it cannot be depended upon to do so, for the light liquids usually used in bubble chambers —liquid hydrogen or pentane—are almost transparent to gamma rays.

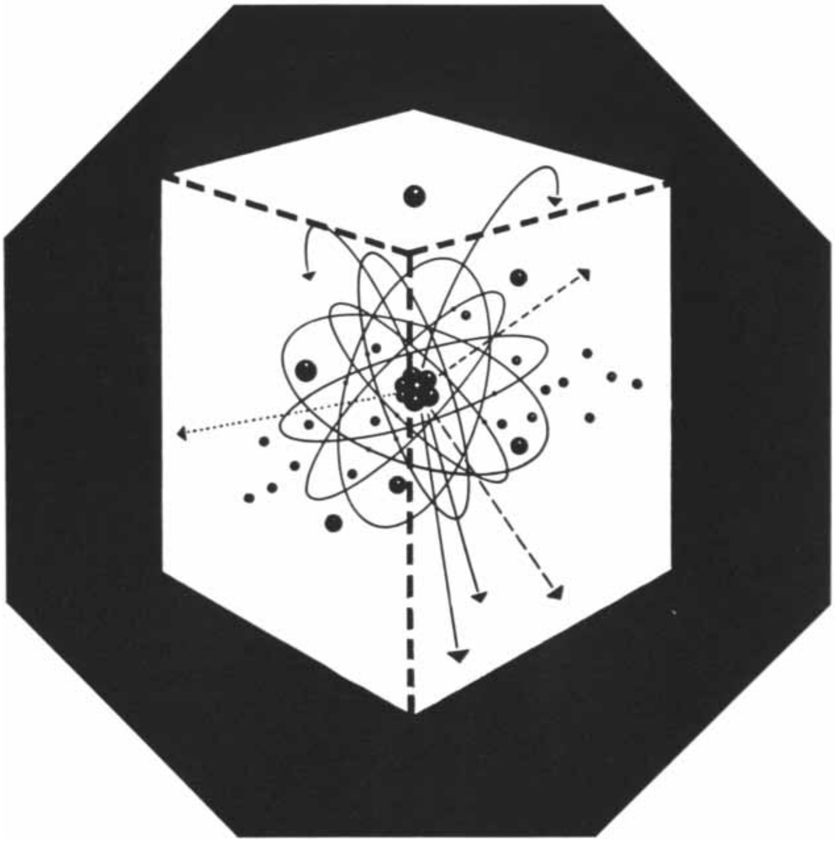
Physicists at the University of Michigan, where the bubble chamber was invented, have now modified it so that it can detect gamma rays with a high degree of regularity. Their innovation is to fill the chamber with the liquefied form of the noble gas xenon. The relatively heavy xenon atoms have a good chance of intercepting and reacting with gamma rays. While passing through 3.1 centimeters of liquid xenon, three out of four gamma rays will create a pair of electrons—one negative, the other positive. From the diverging paths of the electrons it is possible to calculate the energy and the path of the original gamma ray. No other instrument can trace the complete history of a gamma ray.

The first experiments with the xenon bubble chamber were unsuccessful, J. L. Brown, Donald A. Glaser and M. L. Perl report in an article in *The Physical Review*. Puzzled as to why particles failed to produce tracks in the liquid, the researchers recalled that radiation causes scintillations in gaseous xenon. Apparently the flying particles were dissipating their energy in the form of light instead of producing ionization. The experimenters added a little hydrocarbon to the xenon to quench the scintillations, and the tracks began to appear. They hope that by adjusting the amount of hydrocarbon they will be able to make a liquid xenon chamber display particles both as bubble trails and as flashes of light.

Xenon is costly: pure gaseous xenon distilled from liquid air now sells for $30 a liter. But since the element does not deteriorate, the new bubble chamber should prove no more expensive in the long run than photographic plates.

Radio Divining Rod

The classic radio method for finding the height of the ionosphere layers has been adapted to measure the depth of the water table beneath the Egyptian



desert. M. A. H. El-Said of Cairo University has worked out a way to find water by transmitting a radio wave through the ground. Part of the wave travels along the surface; another part goes downward until it strikes water, which completely reflects the energy. Thus two distinct waves, slightly out of phase, are picked up by an antenna placed on the ground several hundred feet from the transmitter. By moving the antenna or varying the transmitting frequency, El-Said can regulate the degree of interference of the waves and locate the depth of the layer of water.

Describing his technique in the *Proceedings of the Institute of Radio Engineers*, El-Said said it will work best where the ground is fairly level and the water is not more than 500 meters beneath the surface.

TB Vaccine Test

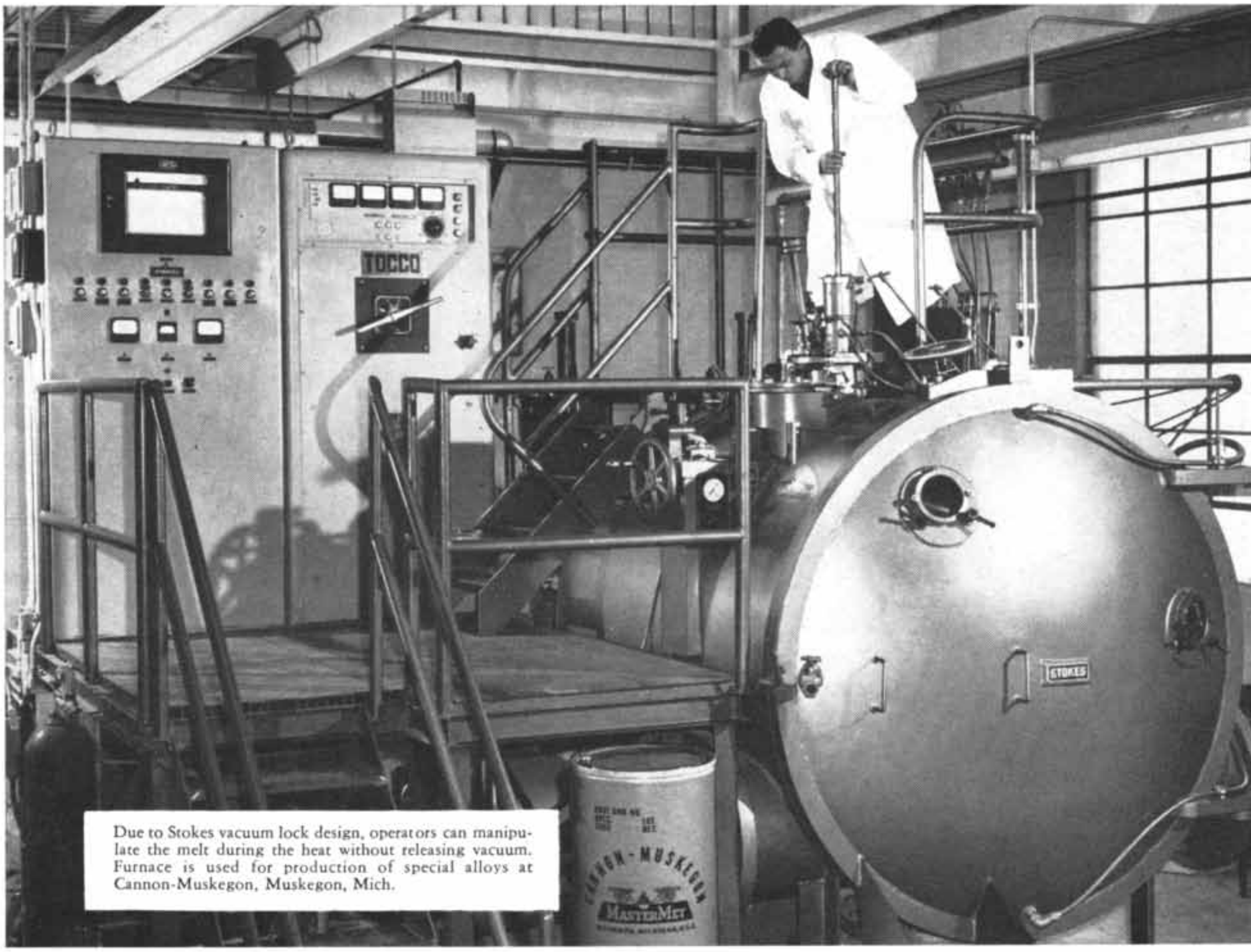
Since 1949 the Medical Research Council of Great Britain has been making a large-scale test of the controversial tuberculosis vaccine BCG (bacillus Calmette-Guérin, named for its French originators). The Council's testing committee now reports in the *British Medical Journal* that BCG has proved safe and beneficial. So, too, is another TB vaccine tested—the so-called vole bacillus vaccine.

A total of 34,100 British adolescents took part in the test: 14,100 were vaccinated with BCG, 6,700 with the vole bacillus vaccine and 13,300 left unvaccinated for comparison. In the unvaccinated group the TB disease rate proved to be 1.94 per thousand per year. Incomplete reports indicate that the vaccinations may be effective for at least four years. Unfavorable reactions to the vaccines were few.

Summing up the results, the committee said: "If none of the tuberculin-negative entrants had been vaccinated, 165 cases of tuberculosis would have been expected among them within 30 months of entry. If all of them had received BCG vaccine, 30 cases would have been expected. The difference of 135 cases represents a reduction of 82 per cent in the incidence of tuberculosis."

Live Polio Vaccine

Despite the success of the Salk poliomyelitis vaccine, efforts continue to develop a usable live-virus vaccine. *The Journal of the American Medical Association* reports some encouraging experiments by a group including workers



Due to Stokes vacuum lock design, operators can manipulate the melt during the heat without releasing vacuum. Furnace is used for production of special alloys at Cannon-Muskegon, Muskegon, Mich.

Cannon-Muskegon high temperature alloys produced in new Stokes Vacuum Furnace

FAMILIAR METALS are gaining superior qualities of high temperature strength, by new techniques of vacuum melting and casting. Excluding air's oxygen, nitrogen and water vapor from molten metal eliminates strength-sapping inclusions . . . makes possible alloys that withstand jet engine heat.

Notable among the "new" metals are "*MasterMet*" alloys, produced by Cannon-Muskegon Corporation, in the Stokes vacuum furnace shown here. Designed by Stokes in close cooperation with Cannon-Muskegon metallurgists, the furnace has a capacity of 500 pounds per heat . . . for the production of ingots for investment casting. It readily meets specifications for holding vacuum to 10 microns, and leak rates less than 8 microns per hour. Due to the unique Stokes vacuum lock, operators can manipulate the melt during the heating cycle, without breaking vacuum.

The leading developer and supplier of high vacuum furnaces, Stokes is the place to go when you plan to investigate the potential of vacuum metallurgy. For a consultation on your specific application, write to F. J. STOKES MACHINE COMPANY, *Vacuum Furnace Division*, 5506 Tabor Road, Philadelphia 20, Pa.

specialists in high vacuum

STOKES

from Lederle Laboratories, the health departments of New York and California, and the University of California School of Medicine.

They tested vaccines made with weakened live viruses in 225 child volunteers (in an unidentified mental institution). One third of the children got type 1 virus in capsules. The other two thirds were given type 2 virus mixed with milk. All developed antibodies against the respective viruses. They showed signs of infection in their alimentary tracts, but none seemed to suffer ill effects. The artificially induced disease was contagious, but playmates who caught it did not show symptoms of sickness.

The researchers are quietly optimistic. They believe that the future of live-virus vaccination is "bright from the point of view of scientific developments."

The Geometry of Viruses

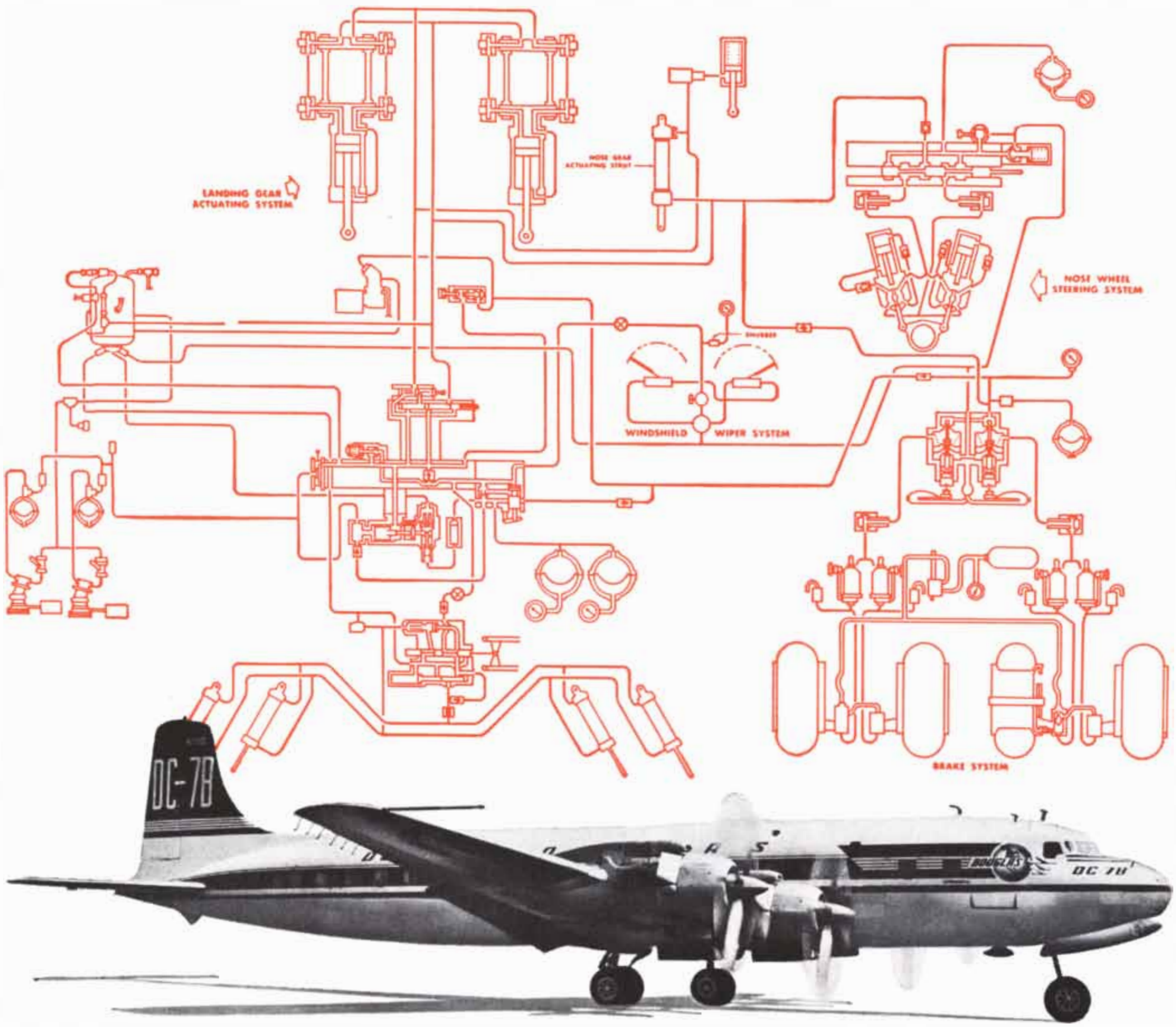
Why are almost all small viruses either rods or spheres, never any other shape? F. H. C. Crick and J. D. Watson of the Cavendish Laboratory at the University of Cambridge believe they have the answer.

Examining crystallized viruses, they find that every virus particle has a shell of small or moderate-sized protein molecules, packed in a completely regular array around a core of nucleic acid. Since in any given virus all the protein molecules are identical, they can be arranged only in a limited number of ways. Like atoms in a salt crystal, they must assume the same shape every time a virus is formed. In this sense, the researchers write in *Nature*, a small virus can be considered a single molecule.

Faster Mushrooms

A new way of growing mushrooms promises to produce them so cheaply and plentifully that they may become a staple foodstuff rather than a luxury garnish. At a meeting of the American Chemical Society in Dallas last month Seymour S. Block, associate professor of chemical engineering at the University of Florida, reported successful experiments in rapid culture of the fungus.

Block found that sawdust laced with oatmeal makes a much better "soil" for mushroom farming than the usual mixture of compost and straw [see "The Growth of Mushrooms," by John Tyler Bonner, page 97]. On a ton of his mixture Block has grown 500 pounds of mushrooms in 11 days. Conventional methods give only two or three crops a year; sawdust beds will yield about a



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Douglas chooses Enjay Butyl for rubber components of the hydraulic systems in many of its famous DC-7 airliners. These components, which help assure the dependable operation of everything from wing flaps to landing gear, are proving over millions of air miles their durability and resistance to wear.

Versatile Enjay Butyl rubber may well have a place in *your* operation. It will pay you to investigate the many technical advantages it has over other types of rubber. Its price and ready availability are advantages, too. For full information, and for technical assistance in the uses of Enjay Butyl, contact the Enjay Company today.

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dozen. Mushrooms will sprout from sawdust at temperatures as high as 78 degrees, whereas compost beds must be kept cooler than 60 degrees.

Block pointed out that mushrooms contain "all the amino acids required by the body and a lot of B vitamins."

Fatherless Turkeys

The hatching of an undersized and malformed turkey poult created excitement recently at the U. S. Department of Agriculture's research headquarters in Beltsville, Md. The most remarkable feature of the birth was that the chick had come from an egg which had not been fertilized.

Parthenogenesis, or virgin birth, is common among insects but rare among higher forms of life. During the last three years Marlow W. Olsen at Beltsville has incubated more than 13,000 unfertilized turkey eggs. A large number of embryos have developed, but only five have hatched alive. The bird hatched on March 10 was the first to have lived more than a day. Hampered by the lack of a fully formed tongue, it found eating difficult and died in 22 days.

Olsen's research is aimed at one of the turkey industry's chief problems: the infertility of eggs. He would like to raise one of his spontaneously fertilized poults to maturity and use it as a breeder in the hope that its extraordinary hatchability might be inheritable. In any case, parthenogenic poults would be excellent material for genetic studies, since they are completely inbred.

Ancient Ant

A tiny yellow ant surviving from an insect family that ranged the world 50 million years ago has been found in Ceylon and ensconced in the Harvard University Museum of Comparative Zoology. It was discovered during a 10-month ant hunt in the Southwest Pacific by Edward O. Wilson.

The primitive ant, *Aneuretus simoni* Emery, is only an eighth of an inch long and has two small spines jutting from its back. It lives in rain forests and feeds on small insects, which it stabs with a stinger in its tail. This stinger is significant, for it demonstrates the common ancestry of modern ants and wasps, according to Wilson and his co-investigator William L. Brown, Jr.

Caught Napping

Lazy lovers of culture have sometimes tried the experiment of playing educational records to themselves while

CERIUM OXIDE

—a rare earth that sparked a revolution in a long established art in the glass industry

a report by LINDSAY

Some twenty years ago in Switzerland, two technicians discovered the amazing glass polishing properties of Cerium Oxide. Soon it was being used extensively for polishing of precision lenses in Europe.

Then came World War II. Scientists in the optical industries in this country heard about Cerium Oxide . . . how it could polish faster and cleaner than any other known material. They thought that maybe this was the answer to the problem of accelerated production of precision optical pieces for our war machine. In a cloak and dagger operation, samples of Cerium Oxide were smuggled out of Switzerland. Tests confirmed the rumors . . . Cerium Oxide was IT!

This was early in the 40's when Hitler held most of Europe and the Japanese were driving toward Australia. The urgency of our growing war effort was putting fantastic demands on the optical industry. Lenses for bombsights, range finders, periscopes and other military instruments were needed desperately. Production had to be increased manyfold with no sacrifice of split-hair accuracy.

Lindsay, the nation's largest processor of monazite (the chief source of rare earths), undertook in 1942 the challenging task of producing Cerium Oxide. Day after day, Lindsay technicians worked with patience and speed to solve the inevitable production problems and in a remarkably short time, Cerium Oxide was being refined with the properties that met the demanding standards of the optical and glass industries. At about the same time, Barnesite, a rare earth oxide for ultra-high precision work, was developed and a few years later Lindsay took over exclusive production.

By war's end, Cerium Oxide had virtually revolutionized glass polishing practices in this country. Today, it is widely used in the production of distortion-free TV tubes, fine quality mirrors and precision optical lenses.

Opticians like Lindsay's Cerium Oxide (sold under the trade name Cerox) because it enables them to polish lenses to prescription specifications faster and to give you glasses exactly as the doctor ordered.

Leading automobile manufacturers use Lindsay's Cerium Oxide to polish out windshield scratches just before shipment. One of the largest producers furnishes its dealers with kits containing Cerium Oxide to remove nicks and scratches picked up in transit.

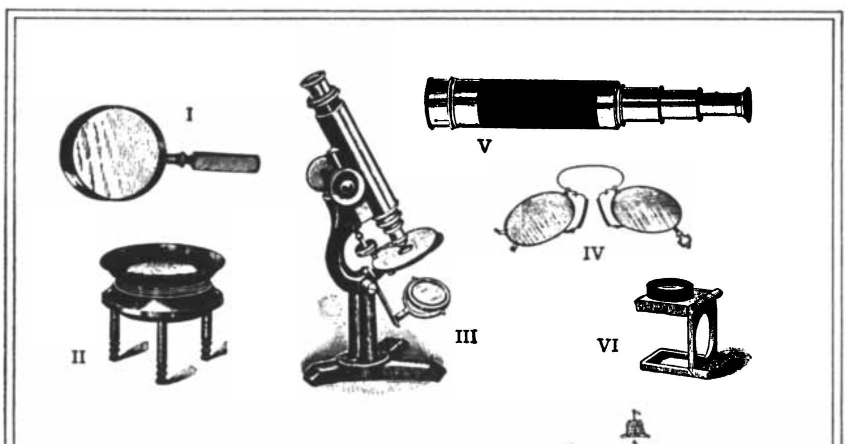
Why is Cerium Oxide such wonderful stuff when it comes to polishing? Frankly, nobody knows. Lindsay's technical people have tested and retested it, put it through countless laboratory analyses and peered at it for hours through high-powered microscopes. Just as scientists know how to *use* electricity, but don't know what it *is*, so too, they know that Cerium Oxide is a remarkably efficient polishing agent but *why* is still a mystery.

Like all the other rare earths, Cerium Oxide is a versatile material. Research disclosed its unique potentials (along with didymium, neodymium, and other rare earths) for use in coloring and decolorizing glass and it is extensively used for that purpose. Another interesting use is as a catalyst with some chemical materials.

Twenty-five years ago, most chemists had little knowledge or curiosity about the rare earths. Then the dramatic emergence of Cerium Oxide as an important factor in the optical industry excited interest in the full range of the 15 rare earth elements—atomic numbers 57 through 71.

There are technical people who think that some of the rare earths have greater possibilities of revolutionizing processes in their industries than Cerium Oxide has had for polishing practices. We are encouraged to think so, too. We are shipping rare earths regularly for use in the production of such diverse materials as steel, aluminum, glass, ceramics, textiles, ammunition and for a variety of applications in the electronic and atomic industries.

We can give you comprehensive data about the many rare earth and thorium salts available. Your technical staff may find it rewarding and profitable to take a long, thoughtful look at these unique materials, to examine their characteristics and, particularly, their potential applications to your own processes.



PLEASE ADDRESS INQUIRIES TO: **LINDSAY CHEMICAL COMPANY**

264 ANN STREET, WEST CHICAGO, ILLINOIS

asleep. Psychologists at the Rand Corporation in California now affirm that they have either been disturbing their slumbers or wasting electricity.

Charles W. Simon and William H. Emmons gave tape-recorded, nocturnal lessons to 21 subjects of above-average intelligence. At five-minute intervals through the night a loudspeaker in each subject's room would announce a question and give the answer: *e.g.*, "In what kind of store did Ulysses S. Grant work before the war? Before the war Ulysses S. Grant worked in a hardware store." The pupils' level of sleep was checked by a continuous recording of the electrical activity of their brains on an electroencephalograph. In the morning they took a multiple choice test on the material they had "studied."

So long as the subjects' electroencephalograms showed the so-called alpha rhythm (which waking persons have and sleepers do not), they absorbed the lessons more or less well. But their performance fell off as the degree of drowsiness at the time of hearing the answer increased. When the alpha rhythm had disappeared, they learned, or at least remembered, nothing: the test scores were no better than chance or the scores of a control group which had not heard the recordings.

Simon and Emmons published their report in the *Journal of Experimental Psychology*.

Art and Superfluity

Which, in terms of information theory, is more redundant—a painter or a musician? An engineer who has looked into the matter contends that the palm goes to painters by a wide margin.

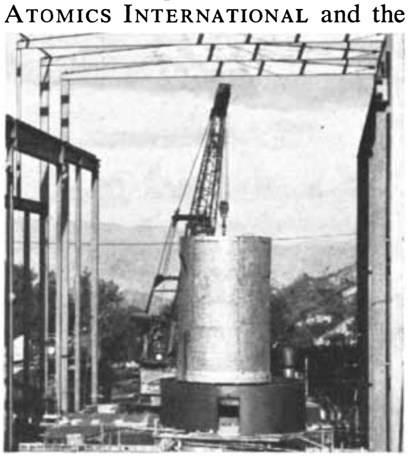
In his article, "Information Theory and Melody," in SCIENTIFIC AMERICAN for February, Richard C. Pinkerton estimated that simple nursery tunes are somewhat more than 50 per cent redundant. That is, the "information" they contain could be conveyed with something less than half the notes.

Now an estimate of the redundancy of pictures has been made by W. J. Cunningham, a professor of electrical engineering at Yale University, and he concludes that the best paintings are 98 per cent redundant. Presenting this view at a meeting of the Princeton Graduate School Alumni, Cunningham was promptly challenged by S. Lane Faison, professor of art at Williams College. Painting is redundant, he admitted, but not that redundant. He cited Paul Cézanne as an artist who conveyed information with great economy.

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

Principal Technical Details of the Sodium Reactor Experiment in California

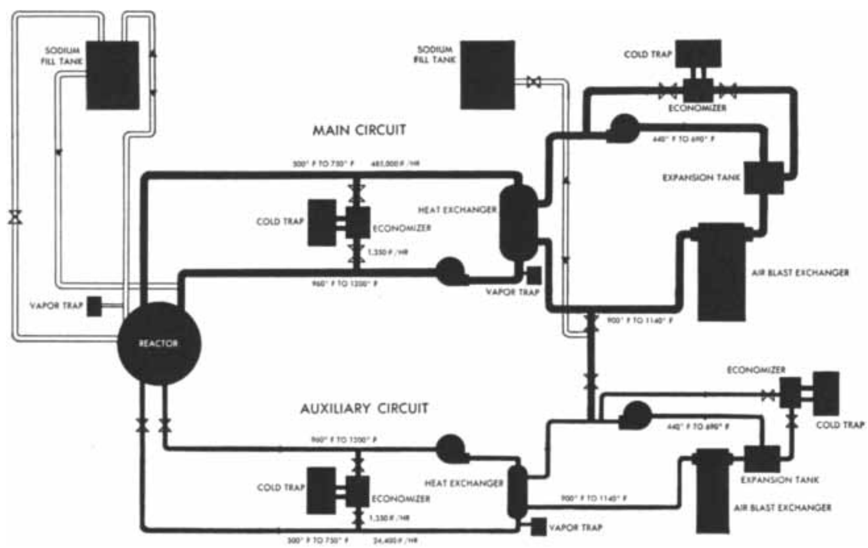
The Sodium Reactor Experiment is an important contribution to the Atomic Energy Commission's program to develop economical power from nuclear energy. Interest in the SRE approach is high. The Atomic Energy Commission has authorized ATOMICS INTERNATIONAL and the Southern California Edison Company to enter into an agreement for Edison to install electrical generating equipment with a capacity of 7,500 kilowatts adjacent to the SRE to convert the reactor's 20,000 kilowatts of heat into electricity which will be fed into the utility's power grid system. ATOMICS INTERNATIONAL and the



SRE reactor core is lowered into place deep in the Santa Susana Mountains

Consumers Public Power District of Nebraska are negotiating for the construction of a 75,000 kilowatt nuclear power plant utilizing a sodium graphite reactor based on SRE experience.

The Sodium-Cooled, graphite-moderated reactor design has many advantages. The use of sodium permits high temperature operation, good steam conditions and high thermal efficiency of power conversion without pressurization of the reactor and coolant circuit. The high thermal conductivity of sodium makes it an excellent heat transfer medium. Sodium boils at 1620°F.—is liquid at 208°F. This permits high coolant temperatures with the system at atmospheric pressure, creating a low-pressure heat extraction system which simplifies reactor construction. Further, the sodium design minimizes chemical reaction between fuel elements, coolants and structural materials—increases safety—allows the use of a variety of steels and alloys in construction.



Sodium Flow Diagram For SRE Cooling System

Nominally Rated Output of SRE with Uranium fuel (enriched with 2.80 atom percent U235) is 20 Thermal Megawatts. The reactor core is made up of fuel rods, moderator cans and control elements interspersed and immersed in sodium coolant. The fuel is composed of 6 inch slugs, 0.750 inches in diameter, formed in 6 foot columns tied in clusters of seven. The graphite moderator elements are canned in Zirconium, fabricated with an axial coolant channel. This prevents absorption of sodium into graphite. Much less costly than beryllium—graphite is also comparatively easy to handle.

Capital and Power Costs in Full Scale Power Stations—At present, with Uranium fuel, capital costs/installed Kw. are expected to total $300. With Thorium, costs may be $265/installed Kw. Power costs (based on 80% load factor and 15% annual fixed charges) may be 11 mills/kwh with Uranium, 9 mills with Thorium. Future costs with Thorium fuel are expected to be $200/Kw capital cost and 6.5 mills/kwh total power costs.

Atomics International is a major reactor builder—experienced in the design, construction and operation of nuclear reactors for research and the production of power. If you are interested in any phase of our activities, ATOMICS INTERNATIONAL is staffed and equipped to help you. Please write: Applications Engineering Service, Dept. SA-N2, ATOMICS INTERNATIONAL, P.O. Box 309, Canoga Park, California. Cable address: ATOMICS.

ATOMICS INTERNATIONAL

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PIONEERS IN THE CREATIVE USE OF THE ATOM

New trends and developments in designing electrical products . . .

Why General Electric Magnets clad in die-cast aluminum sheaths offer important design and cost advantages over the conventional methods of fabricating magnetic assemblies

THE MAN in the picture below is removing a section of a radar magnetron tube magnet from a piece of equipment that goes by the imposing title of "Lester-Phoenix Horizontal Cold Chamber H-HP-3X 400-Ton Die-Casting Machine."

This machine is in our Edmore, Michigan, magnet plant, and its sole function is to cast aluminum sheaths on General Electric Alnico Permanent Magnets.

These alclad magnets offer designers seven major advantages over conventional methods of fabricating magnetic assemblies.

1. Die casting strengthens the magnet structurally.
2. Whole assemblies can be designed and built as a single "package," speeding the final assembly job at the plant.
3. Design of mounting arrangements is simplified because pins, holes, and screws can be cast into the sheath, instead of the magnet.
4. Responsibility for the entire assembly is centered in a single source, simplifying purchasing procedures, and eliminating costly in-plant assembly operations.
5. Complete magnetic assemblies can be purchased premagnetized and/or pretested.
6. Die casting provides a consistent, more attractive finish for applications where appearance is important.
7. Die casting is a convenient, low-cost mass-production technique for magnetic assemblies that eliminates the problem of attaching crystalline cast magnets to other components.

The following examples will illustrate how these advantages can be turned to practical use.

Figure 1 is a relay drag magnet assembly, typical of those used in the meter and instrument industry. Before the manufacturer switched to this casting, it was necessary to cast a magnet against a piece of steel, bend the steel into the proper shape, and weld the ends together.

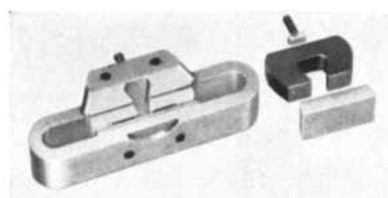

Figure 1

Now, however, magnet, mounting pin, and steel return path are assembled in a single operation—eliminating the difficult 3-stage fabrication job. This assembly—one of the most complex handled by the die-casting machine—illustrates the equipment's tremendous versatility.

Figure 2 is a generator rotor, consisting of eight G-E Alnico magnets held in position on a camshaft by the cast-aluminum matrix.

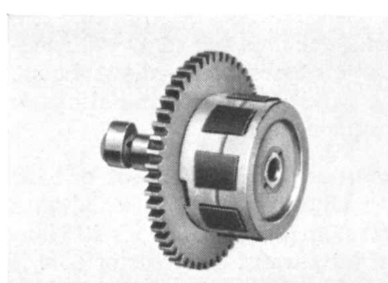

Figure 2

The casting supplements the strength of the magnets (which are subjected to high rotary speeds). And it eliminates difficult grinding, assembly, and banding operations.

The four radar magnetron tube magnets in Figure 3 give some idea of the wide range of sizes the machine is capable of handling. The smallest magnet (bottom, right) weighs only 1 lb., while a quarter section of the largest magnet weighs more than 11 lbs.

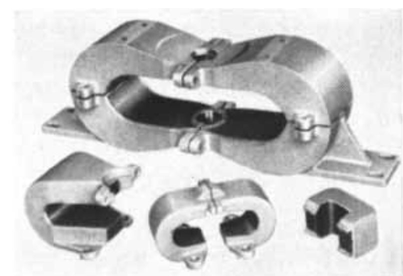

Figure 3

Here, the aluminum sheath improves magnetic stability by preventing direct contact between magnet surfaces and steel objects. In addition, the mounting brackets cast in the sheaths eliminate inserts normally cast in the magnets which would weaken its energy and structure.

Aluminum-sheathed magnets are often far less expensive than conventional magnets . . . especially on long production runs. And, in many of the cases where the unit cost of alclad magnets is higher, the tremendous advantages gained by die casting have more than offset the price difference.

The one best way to find out whether or not die casting is feasible on your application, is to check with a General Electric Magnet Engineer.

You can do this—or obtain information on any other problem in the realm of permanent magnets—by dropping a note to: *Carboloy Department of General Electric Company, 11199 E. 8 Mile Blvd., Detroit 32, Michigan.*

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CULTURAL EVOLUTION

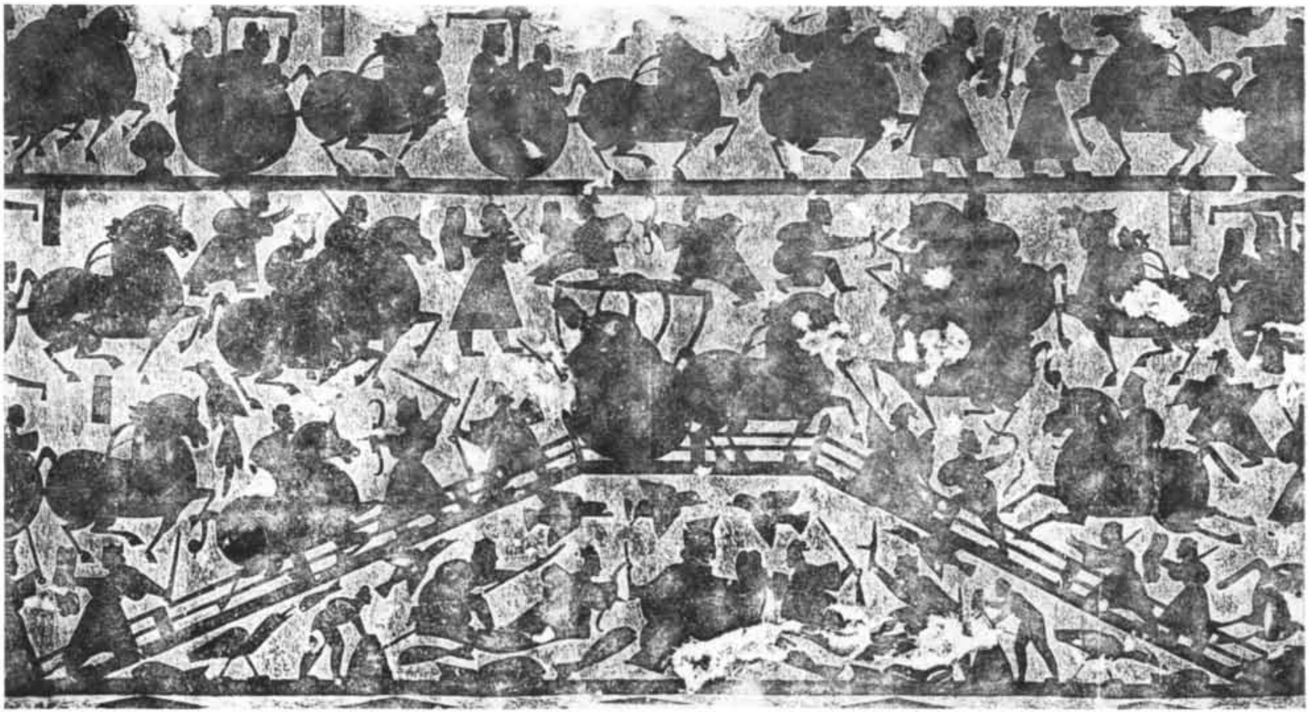
The 19th-century idea that cultures evolve in the same way as plants and animals was abandoned when anthropologists found that it did not jibe with their observations. Now the evolutionary approach is revived

by Julian H. Steward

It is almost 100 years since evolution became a powerful word in science. The concept of evolution, which Charles Darwin set forth so clearly and convincingly in his *Origin of Species* in 1859, came like a burst of light that seemed to illuminate all of nature—not only the development of the myriad forms of life but also the history of the planet earth, of the universe and of man and his civilization. It offered a scheme which made it possible to explain, rather than merely describe, man's world.

In biology the theory of evolution today is more powerfully established than ever. In cosmology it has become the primary generator of men's thinking about the universe. But the idea of evolution in the cultural history of mankind itself has had a frustrating career of ups and downs. It was warmly embraced in Darwin's time, left for dead at the turn of our century and is just now coming back to life and vigor. Today a completely new approach to the question has once more given us hope of achieving an understanding of the development of human cultures in evolutionary terms.

Before considering these new attempts to explain the evolutionary processes operating in human affairs, we need to review the attempts that failed. By the latter part of the 19th century Darwin's theory of biological evolution had profoundly changed scientists' views of human history. Once it was conceded that all forms of life, including man, had evolved from lower forms, it necessarily followed that at some point in evolution man's ancestors had been completely without culture. Human culture must therefore have started from simple beginnings and grown more complex. The 19th-century school of cultural evolutionists—mainly British—reasoned that man had progressed from a condition of simple, amoral savagery to a civilized state whose ultimate achievement was the Victorian Englishman, living in an industrial society and political democracy, believing in the Empire and belonging to the Church of England. The evolutionists assumed that the



CHINESE BAS-RELIEF of the second century A.D., here reproduced from a rubbing of the original stone, depicts a battle scene on a bridge. Organized combat of this sort is characteristic of one stage in the evolution of cultures based on irrigation farming. The development of irrigation farming led to the specialization of labor, the centralization of authority and, when agricultural production had leveled off, to aggressive warfare of the state against its neighbors. In China such warfare began around 1000 B.C.

universe was designed to produce man and civilization, that cultural evolution everywhere must be governed by the same principles and follow the same line, and that all mankind would progress toward a civilization like that of Europe.

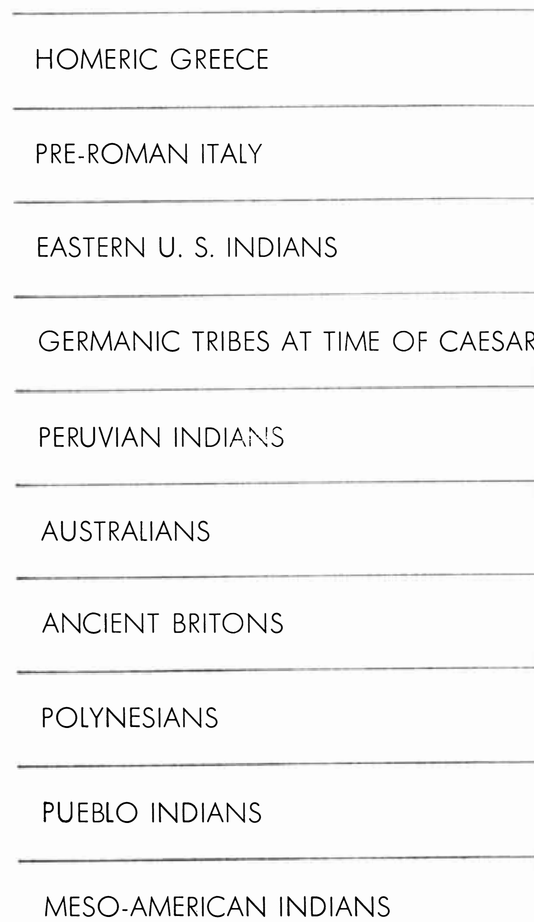
Among the leading proponents of this theory were Edward B. Tylor, the Englishman who has been called the father of anthropology; Lewis H. Morgan, an American banker and lawyer who devoted many years to studying the Iroquois Indians; Edward Westermarck, a Finnish philosopher famed for his studies of the family; John Ferguson McLennan, a Scottish lawyer who concerned himself with the development of social organization, and James Frazer, the Scottish anthropologist, historian of religion and author of *The Golden Bough*. Their general point of view was developed by Morgan in his book *Ancient Society,* in which he declared: "It can now be asserted upon convincing evidence that savagery preceded barbarism in all the tribes of mankind, as barbarism is known to have preceded civilization." Morgan divided man's cultural development into stages of "savagery," "barbarism" and "civilization"— each of which was ushered in by a single invention.

These 19th-century scholars were highly competent men, and some of their insights were extraordinarily acute. But their scheme was erected on such flimsy theoretical foundations and such faulty observation that the entire structure collapsed as soon as it was seriously tested. Their principal undoing was, of course, the notion that progress (*i.e.*, toward the goal of European civilization) was the guiding principle in human development. In this they were following the thought of the biological evolutionists, who traced a progression from the simplest forms of life to *Homo sapiens.* Few students of evolution today, however, would argue that the universe has any design making progress inevitable, either in the biological or the cultural realm. Certainly there is nothing in the evolutionary process which preordained the particular developments that have occurred on our planet. From the principles operating in biological evolution—heredity, mutation, natural selection and so on—an observer who visited the earth some half a billion years ago, when the algae represented the highest existing form of life, could not possibly have predicted the evolution of fishes, let alone man. Likewise, no known principle of cultural development could ever have predicted specific inventions such as the bow, iron smelting, writing, tribal clans, states or cities.

The Facts

When, at the turn of the century, anthropologists began to study primitive cultures in detail, they found that the cultural evolutionists' information had been as wrong as their theoretical assumptions. Morgan had lumped together in the stage of middle barbarism the Pueblo Indians, who were simple farmers, and the peoples of Mexico, who had cities, empires, monumental architecture, metallurgy, astronomy, mathematics, phonetic writing and other accomplishments unknown to the Pueblo. Field research rapidly disclosed that one tribe after another had quite the wrong cultural characteristics to fit the evolutionary niche assigned it by Morgan. Eventually the general scheme of evolution postulated by the 19th-century theorists fell apart completely. They had believed, for example, that society first developed around the maternal line, the father being transient, and that marriage and the family as we know it did not evolve until men began to practice herding and agriculture. But field research showed that some of the most primitive hunting and gathering societies, such as the Bushmen of South Africa and the aboriginal Australians, were organized into patrilineal descent groups, while much more advanced horticultural peoples, including some of the groups in the Inca Empire of South America, had matrilineal kin groups. The Western Shoshonis of the Great Basin, who by every criterion had one of the simplest cultures, were organized in families which were not based on matrilineality. Still another blow to the evolutionists' theory was the discovery that customs had spread or diffused from one group to another over the world: that is to say, each society owed much of its culture to borrowing from its neighbors, so it could not be said that societies had evolved independently along a single inevitable line.

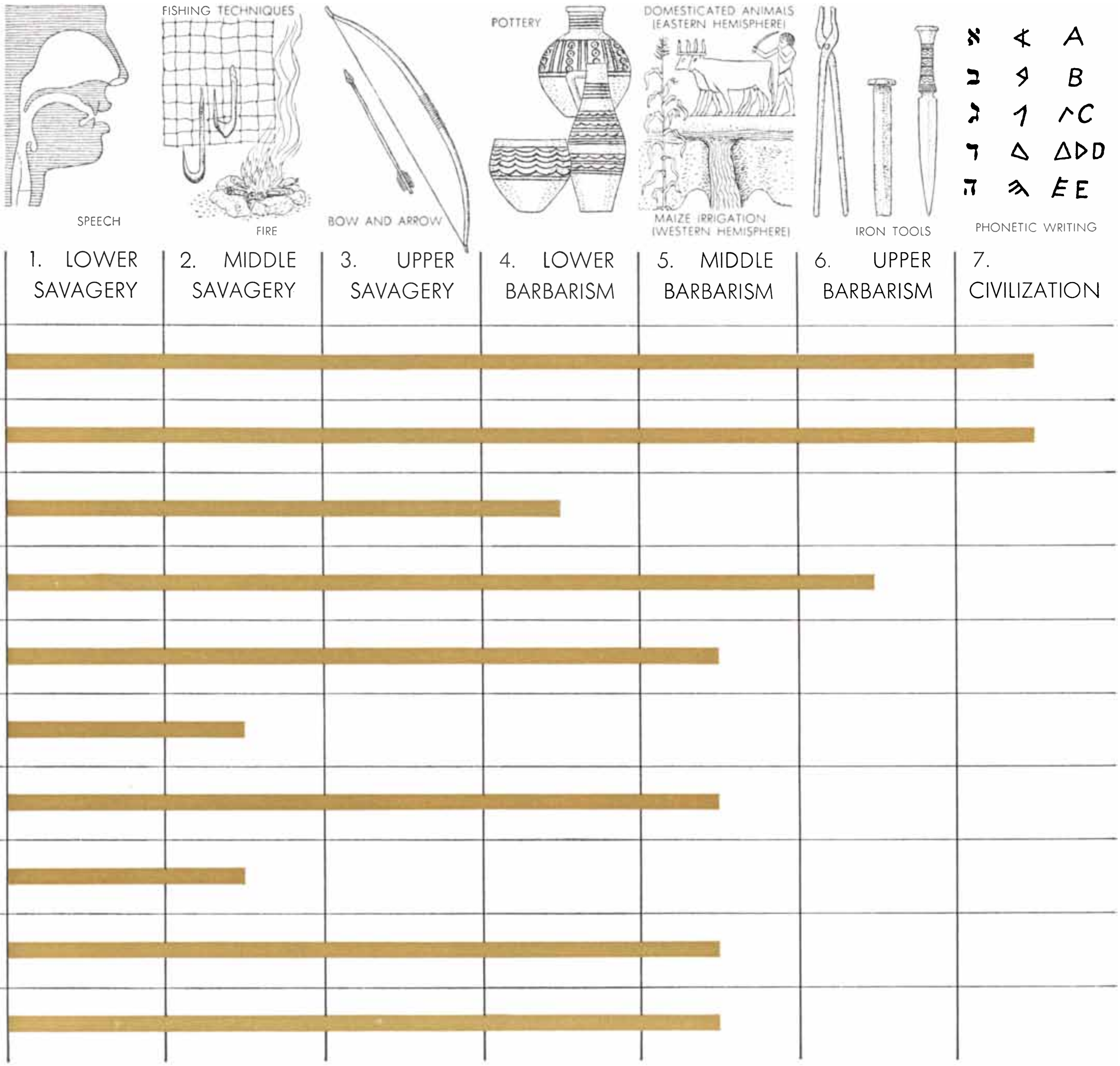
The collapse of the theory that cultural evolution had followed the same line everywhere (what we may call the "unilinear" scheme) began with the researches of the late Franz Boas, and the *coup de grâce* was dealt by Robert H. Lowie in his comprehensive and convincing analysis, *Primitive Society*, published in 1920. When the evolutionary hypothesis was demolished, however, no alternative hypothesis appeared. The 20th-century anthropologists threw out



EARLY THEORY of cultural evolution is depicted in this chart based on the scheme

the evolutionists' insights along with their schemes. Studies of culture lost a unifying theory and lapsed into a methodology of "shreds and patches." Anthropology became fervently devoted to collecting facts. But it had to give some order to its data, and it fell back on classification—a phase in science which F. S. C. Northrop has called the "natural history stage."

The "culture elements" used as the classification criteria included such items as the bow and arrow, the domes-



of Lewis H. Morgan, a 19th-century anthropologist. Ten cultures are listed at left. The putative stages of their evolution are at the top. Above the name of each stage is its cultural criterion. The bars represent the stages through which each culture passed.

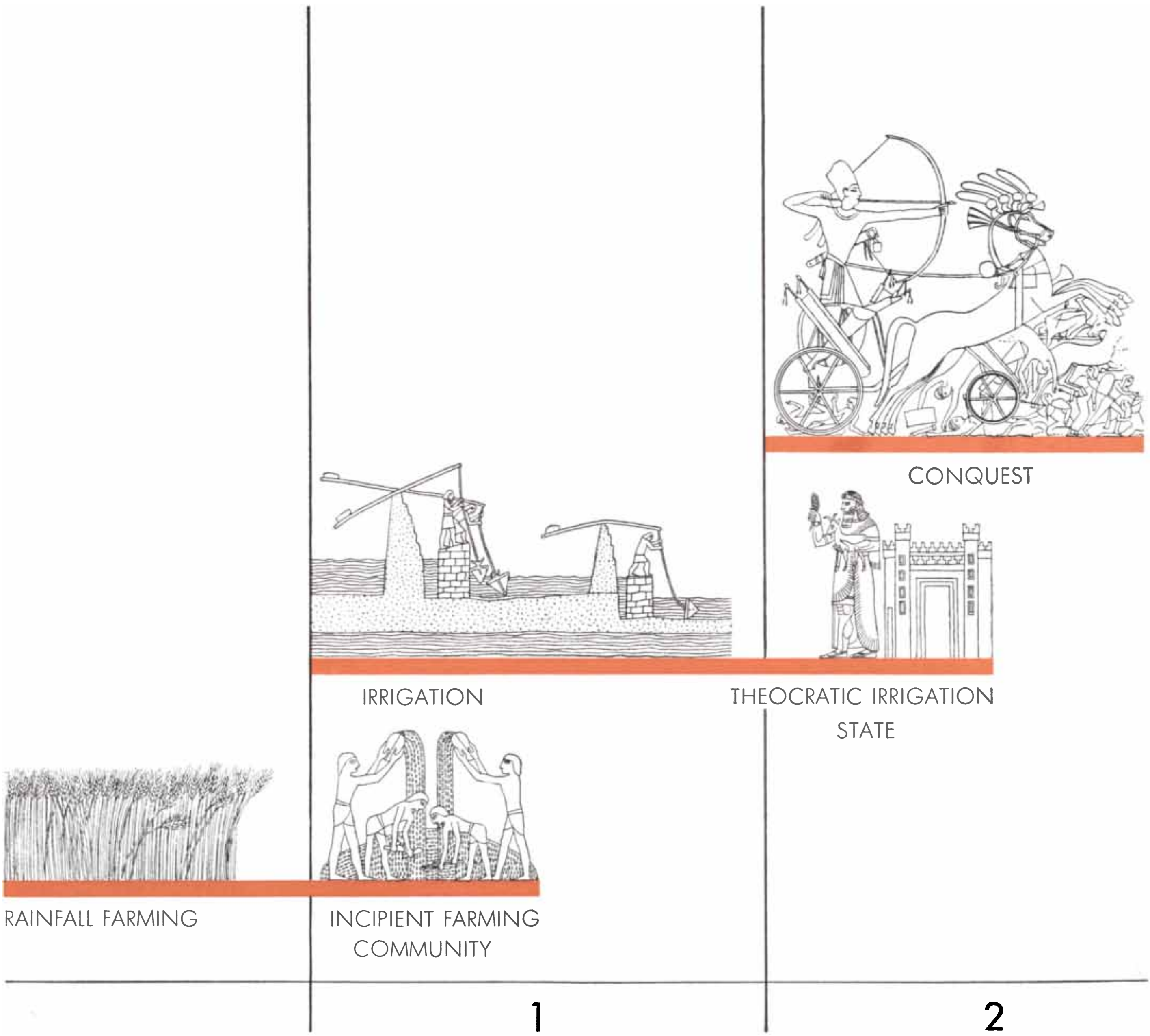
ticated dog, techniques and forms of basketry, the spear and spear thrower, head-hunting, polyandrous marriage, feather headgear, the penis sheath, initiation ceremonies for boys, tie-dyeing techniques for coloring textiles, the blowgun, use of a stick to scratch the head during periods of religious taboo, irrigation agriculture, shamanistic use of a sweat bath, transportation of the head of state on a litter, proving one's fortitude by submitting to ant bites, speaking to one's mother-in-law through a third party, making an arrowhead with side notches, marrying one's mother's brother's daughter. Students of the development of culture sought to learn the origin of such customs, their distribution and how they were combined in the "culture content" of each society.

Eventually this approach led to an attempt to find an over-all pattern in each society's way of life—a view which is well expressed in Ruth Benedict's *Patterns of Culture*. She contrasted, for example, the placid, smoothly functioning, nonaggressive behavior of the Pueblo Indians with the somewhat frenzied, warlike behavior of certain Plains Indians, aptly drawing on Greek mythology to designate the first as an Apollonian pattern and the second as Dionysian. The implication is that the pattern is formed by the ethos, value system or world view. During the past decade and a half it has become popular to translate pattern into more psychological terms. But description of a culture in terms either of elements, ethos or personality type does not explain how it originated. Those who seek to understand how cultures evolved must look for longer-range causes and explanations.

Multilinear Evolution

One must keep in mind Herbert Spencer's distinction between man as a biological organism and his functioning on the superorganic or cultural level, which also has distinctive qualities. We must distinguish man's needs and capacity for culture—his superior brain and ability to speak and use tools—from the particular cultures he has evolved. A specific invention is not explained by saying that man is creative. Cultural activities meet various biological needs, but the existence of the latter does not explain the character of the former. While all men must eat, the choice of particular foods and of how they are obtained and prepared can be explained only on a superorganic level. Thanks to his jaw and tongue structure and to the speech and auditory centers of his brain, man is capable of speech, but these facts do not explain the origin of a single one of the thousands of languages that have developed in the world. The family is a basic human institution, but families in different cultures differ profoundly in the nature of their food-getting activities, in the division of labor between the sexes and in the socialization of the children.

The failure to distinguish the biological basis of all cultural development from the explanation of particular forms of culture accounts for a good deal of the controversy and confusion about "free will" and "determinism" in human behavior. The biological evolutionist George Gaylord Simpson considers that, because man has purposes and makes plans, he may exercise conscious control over cultural evolution. On the other

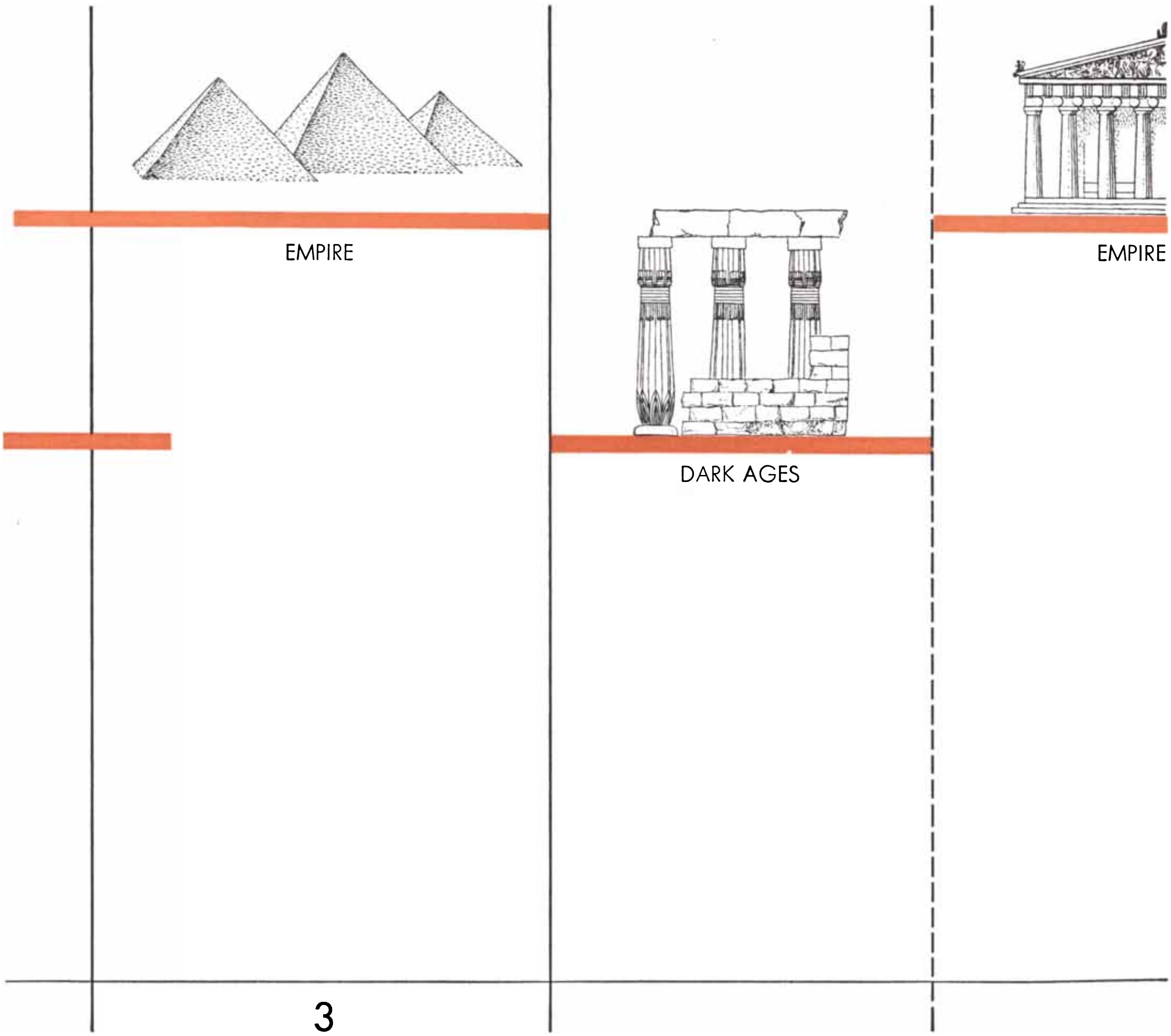


MODERN THEORY of cultural evolution is depicted for the special case of cultures in Egypt, Mesopotamia, China, Meso-America and Peru. In these cultures rainfall farming led to the incipient farming community. Such communities made possible irrigation hand, the cultural evolutionist Leslie A. White takes the deterministic position that culture develops according to its own laws. Simpson is correct in making a biological statement, that is, in describing man's capacity. White is correct in making a cultural statement, that is, in describing the origin of any particular culture.

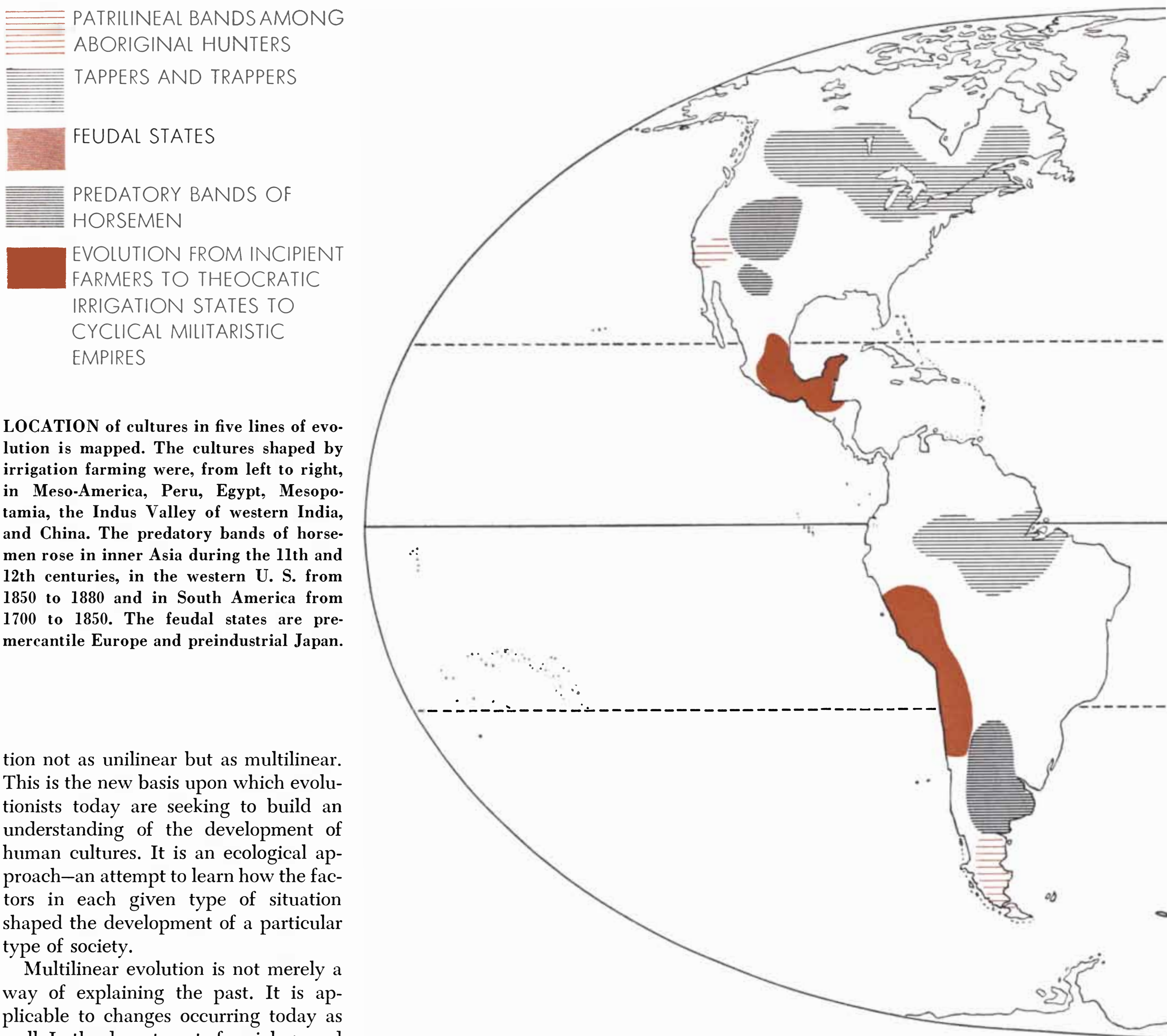
All men, it is true, have the biological basis for making rational solutions, and specific features of culture may develop from the application of reason. But since circumstances differ (*e.g.*, in the conditions for hunting), solutions take many forms. Moreover, much culture develops gradually and imperceptibly without deliberate thought. The growth of settlements, kinship groups, beliefs in shamanism and magic, types of warfare and the like are not planned.

This does not mean that there is no rhyme or reason in the development of culture, or that history is random and haphazard. It is possible to trace causes and order in the seeming chaos. In the early irrigation civilizations of the Middle East, Asia and America the inventions were remarkably similar and ran extraordinarily parallel courses through several thousand years. There was clearly a close connection between large-scale irrigation agriculture, population increase, the growth of permanent communities and cities, the rise of specialists supported by agricultural workers, the appearance of unprecedented skills in technology, the need for a managerial class or bureaucracy and the rise of states.

There have been other patterns in the development of man's institutions, each adapted at different times and places to the specific circumstances of a specific society. The facts now accumulated indicate that human culture evolved along a number of different lines; we must think of cultural evolu-



farming, which culminated in the theocratic irrigation state. When the state outstripped its resources, it turned to conquest and empire. Periodic revolutions then caused oscillations of empires and dark ages. The horizontal bars depict the overlap of these various stages.



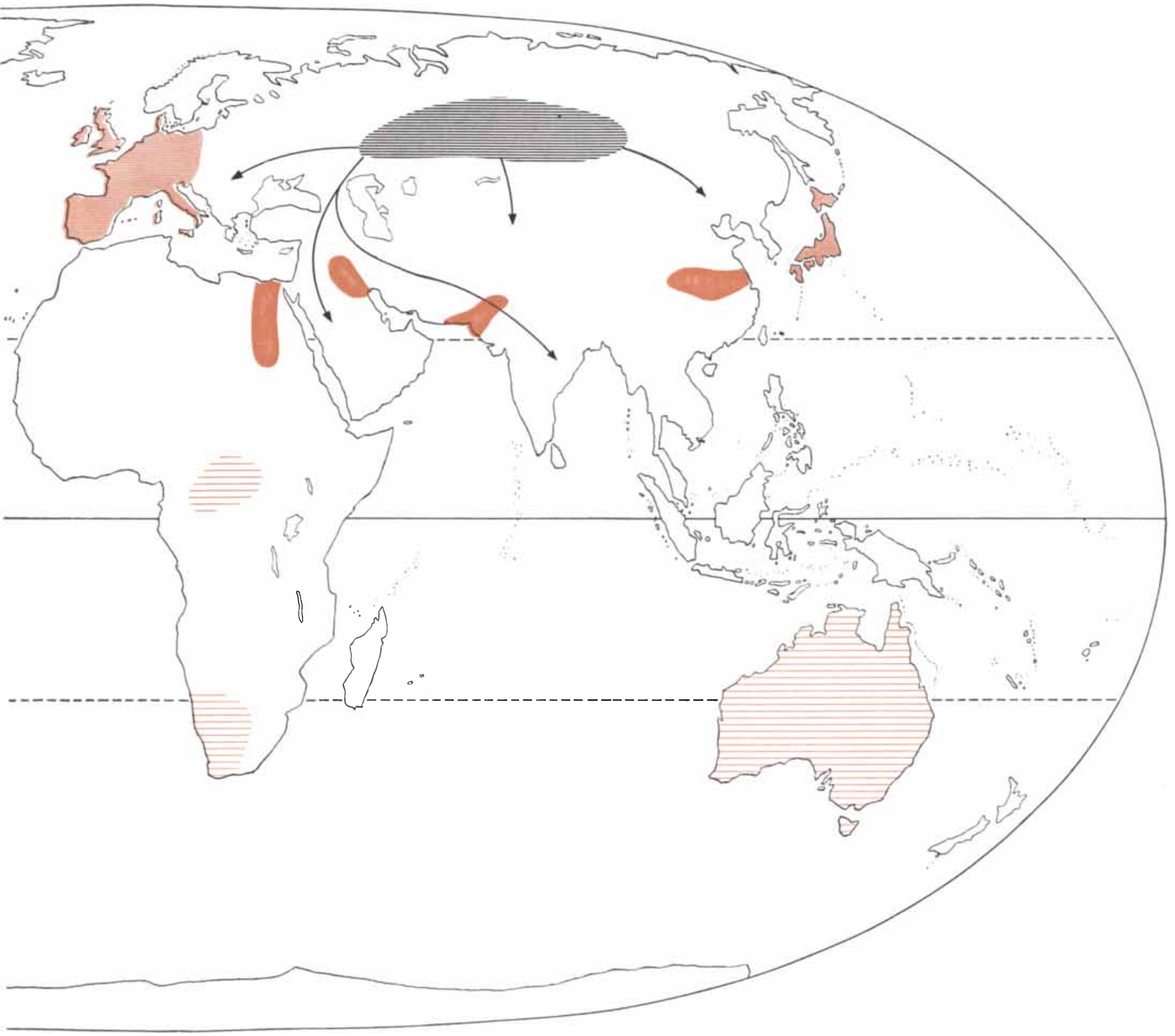
LOCATION of cultures in five lines of evolution is mapped. The cultures shaped by irrigation farming were, from left to right, in Meso-America, Peru, Egypt, Mesopotamia, the Indus Valley of western India, and China. The predatory bands of horsemen rose in inner Asia during the 11th and 12th centuries, in the western U. S. from 1850 to 1880 and in South America from 1700 to 1850. The feudal states are premercantile Europe and preindustrial Japan.

tion not as unilinear but as multilinear. This is the new basis upon which evolutionists today are seeking to build an understanding of the development of human cultures. It is an ecological approach—an attempt to learn how the factors in each given type of situation shaped the development of a particular type of society.

Multilinear evolution is not merely a way of explaining the past. It is applicable to changes occurring today as well. In the department of sociology and anthropology of the University of Illinois my colleagues and I are studying current changes in the ways of rural populations in underdeveloped areas of the world: it is called "The Project to Study Cross-Cultural Regularities." During the past three years my colleagues—Eric Wolf, Robert F. Murphy, F. K. Lehman, Ben Zimmerman, Charles Erasmus, Louis Faron—and I have constructed research models to be tested by investigations in the field. These models consist of several types of populations—peasants, small farmers, wage workers on plantations and in mines and factories, primitive tribes. The objective is to learn how the several types of societies evolved and how their customs are being changed by economic or political factors introduced from the modern industrial world. Such studies should obviously have practical value in guiding programs of technical aid for these peoples.

Hunters, Trappers, Farmers

To illustrate the ecological approach let us consider very briefly several different types of societies, using the ways in which they made their living as the frame of reference. The first example is the form of society consisting of a patrilineal band of hunters. This type of organization was found among many primitive tribes all over the world, including the Bushmen of the deserts in South Africa, the Negritos of the tropical rain forest in the Congo, the aborigines of the steppes and deserts in Australia, the now extinct aboriginal islanders in Tasmania, the Indians of the cold pampas on the islands of Tierra del Fuego and Shoshoni Indians of the mountains in Southern California. Although their climates and environments differed greatly, all of these tribes had one important thing in common: they hunted cooperatively for sparsely scattered, nonmigratory game. In each case the cooperating band usually consisted of about 50 or 60 persons who occupied an area of some 400 square miles and claimed exclusive hunting rights to it. Since men could hunt more efficiently in familiar terrain, they remained throughout life in the territory of their birth. The band consequently consisted of persons related through the male line of



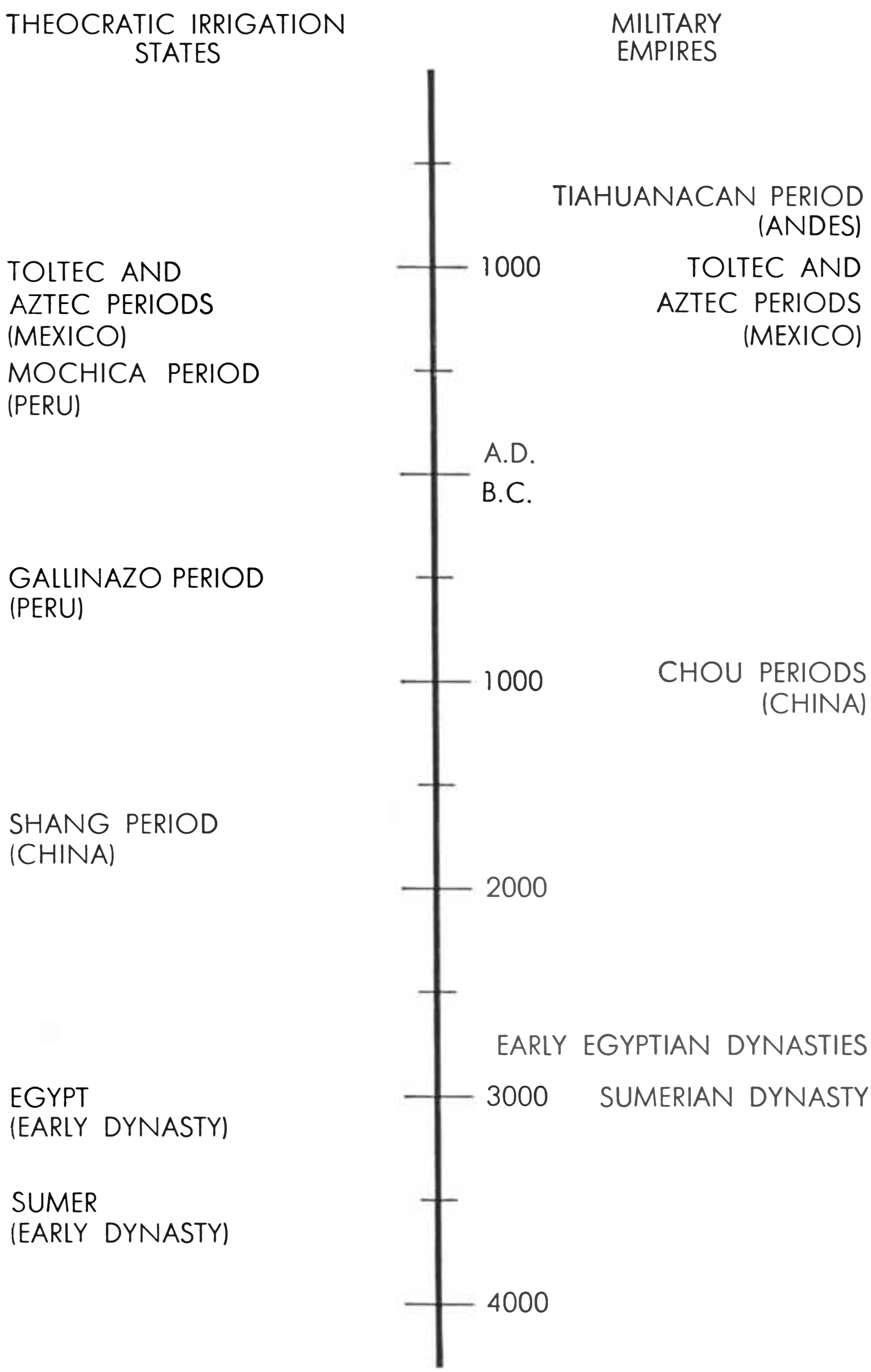
descent, and it was required that wives be taken from other bands. In sum, the cultural effects of this line of evolution were band localization, descent in the male line, marriage outside the group, residence of the wife with the husband's band and control by the band of the food resources within its territory.

Another line of evolution is exemplified by rubber-farming Mundurucú Indians in the Amazon Valley and fur-trapping Algonquian Indians in eastern Canada, of whom Murphy and I recently made a comparative study. The common feature in these two groups is that both were transformed by contact with an outside economy from simple farmers or hunters to barterers for manufactured goods. Although the aboriginal Mundurucú villagers and the Algonquian bands had had very different forms of social organization, both converged to the same form after they began to pursue similar ways of making a living. As the Indians came to depend on manufactured goods, such as steel axes and metal utensils, obtained from traders, they gradually gave up their independent means of subsistence and spent all their time tapping rubber trees and trapping beaver, respectively, eventually depending upon the trader for clothing and food as well as for hardware. Since tapping and trapping are occupations best carried out by small groups on separate territories, the Indians' villages and bands broke down into individual families which lived in isolation on fairly small, delimited areas. The family became part of the larger Canadian or Brazilian national society, to which it was linked through the trader. Its only relations with other families were the loose social contacts created by dealing with the same trader.

Irrigation Civilizations

Irrigation farming is the major organizing factor of another line of evolution, which covered a considerable span of the early prehistory and history of China, Mesopotamia, Egypt, the north coast of Peru, probably the Indus Valley and possibly the Valley of Mexico. This line had three stages. In the first period primitive groups apparently began to cultivate food plants along the moist banks of the rivers or in the higher terrain where rainfall was sufficient for crops. They occupied small but permanent villages. The second stage started when the people learned to divert the river waters by means of canals to irrigate large tracts of land. Irrigation farming made possible a larger population and freed the farmers from the need to spend all their time on basic food production. Part of the new-found time was put into enlarging the system of canals and ditches and part into developing crafts. This period brought the invention of loom weaving, metallurgy, the wheel, mathematics, the calendar, writing, monumental and religious architecture, and extremely fine art products.

When the irrigation works expanded so that the canals served many communities, a coordinating and managerial control became necessary. This need was met by a ruling class or a bureaucracy whose authority had mainly religious sanctions, for men looked to the gods for the rainfall on which their agriculture depended. Centralization of authority over a large territory marked the emergence of a state.



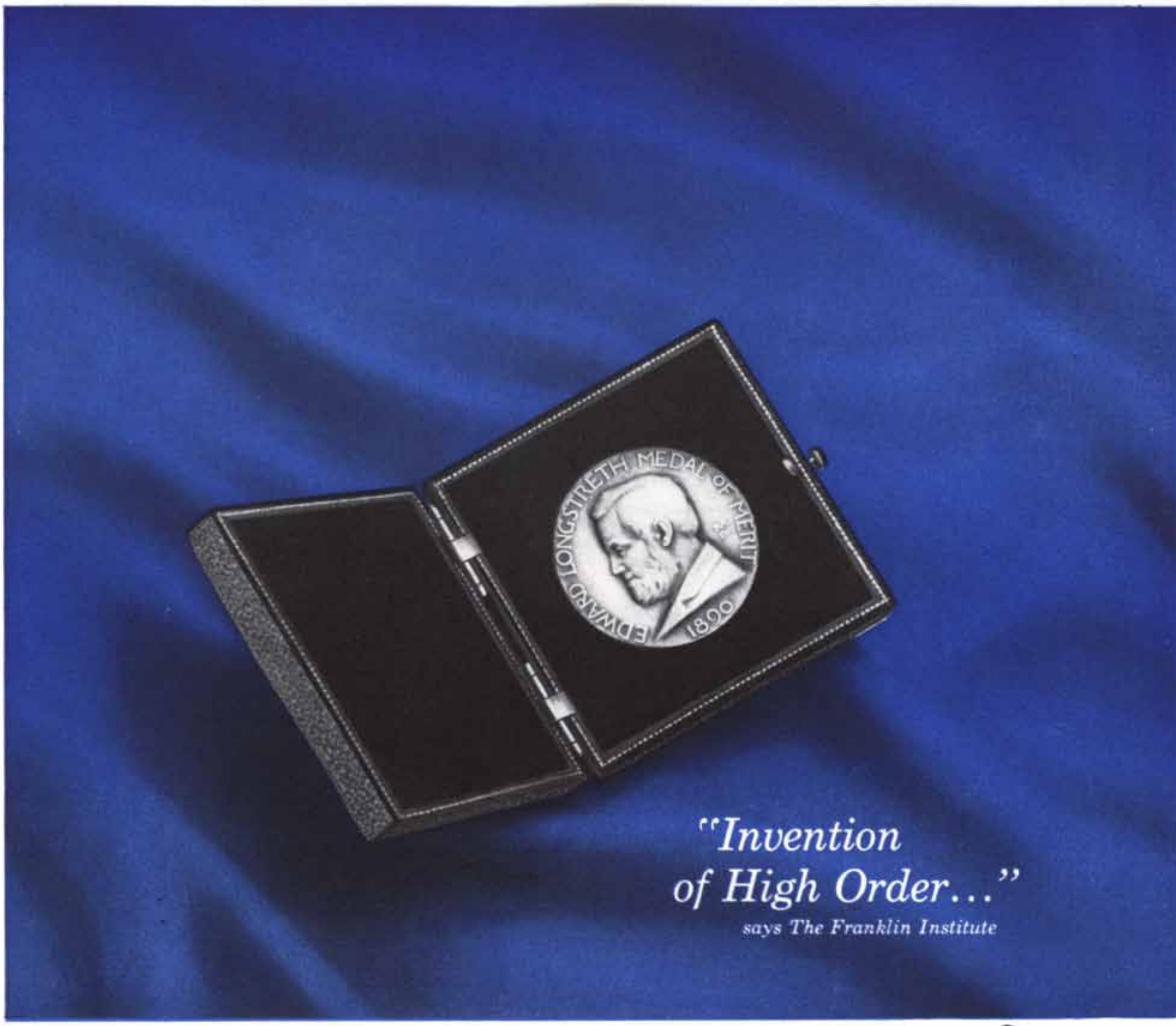
TIME SCALE of theocratic irrigation states and of military empires is compared in this chart. In general the theocratic irrigation states appeared before the military empires.

That a state developed in these irrigation centers by no means signifies that all states originated in this way. Many different lines of cultural evolution could have led from kinship groups up to multicommunity states. For example, feudal Europe and Japan developed small states very different from the theocratic irrigation states.

The irrigation state reached its florescence in Mesopotamia between 3000 and 4000 B.C., in Egypt a little later, in China about 1500 or 2000 B.C., in northern Peru between 500 B.C. and 500 A.D., in the Valley of Mexico a little later than in Peru. Then, in each case, a third stage of expansion followed. When the theocratic states had reached the limits of available water and production had leveled off, they began to raid and conquer their neighbors to exact tribute. The states grew into empires. The empire was not only larger than the state but differed qualitatively in the ways it regimented and controlled its large and diversified population. Laws were codified; a bureaucracy was developed; a powerful military establishment, rather than the priesthood, was made the basis of authority. The militaristic empires began with the Sumerian Dynasty in Mesopotamia, the pyramid-building Early Dynasty in Egypt, the Chou periods in China, the Toltec and Aztec periods in Mexico and the Tiahuanacan period in the Andes.

Since the wealth of these empires was based on forced tribute rather than on increased production, they contained the seeds of their own undoing. Excessive taxation, regimentation of civil life and imposition of the imperial religious cult over the local ones led the subject peoples eventually to rebel. The great empires were destroyed; the irrigation works were neglected; production declined; the population decreased. A "dark age" ensued. But in each center the process of empire building later began anew, and the cycle was repeated. Cyclical conquests succeeded one another in Mesopotamia, Egypt and China for nearly 2,000 years. Peru had gone through at least two cycles and was at the peak of the Inca Empire when the Spaniards came. Mexico also probably had experienced two cycles prior to the Spanish Conquest.

Our final example of a specific line of evolution is taken from more recent times. When the colonists in America pre-empted the Indians' lands, some of


EDWARD LONGSTRETH MEDAL OF MERIT
1890
"Invention
of High Order..."
says The Franklin Institute

the Indian clans formed a new type of organization. The Ute, Western Shoshoni and Northern Paiute Indians, who had lived by hunting and gathering in small groups of wandering families, united in aggressive bands. With horses stolen from the white settlers, they raided the colonists' livestock and occasionally their settlements.

Similar predatory bands developed among some of the mounted Apaches, who had formerly lived in semipermanent encampments consisting of extended kinship groups. Many of these bands were the scourge of the Southwest for years. Some of the Apaches, on the other hand, yielded to the blandishments of the U. S. Government and settled peacefully on reservations; as a result, there were Apache peace factions who rallied around chiefs such as Cochise, and predatory factions that followed belligerent leaders such as Geronimo.

The predatory bands of North America were broken up by the U. S. Army within a few years. But this type of evolution, although transitory, was not unique. In the pampas of South America similar raiding bands arose after the Indians obtained horses. On an infinitely larger scale and making a far greater impression on history were the Mongol hordes of Asia. The armies of Genghis Khan and his successors were essentially huge mounted bands that raided entire continents.

Biology and Culture

Human evolution, then, is not merely a matter of biology but of the interaction of man's physical and cultural characteristics, each influencing the other. Man is capable of devising rational solutions to life, especially in the realm of technical problems, and also of transmitting learned solutions to his offspring and other members of his society. His capacity for speech gives him the ability to package vastly complicated ideas into sound symbols and to pass on most of what he has learned. This human potential resulted in the accumulation and social transmission of an incalculable number of learned modes of behavior. It meant the perpetuation of established patterns, often when they were inappropriate in a changed situation.

The biological requirements for cultural evolution were an erect posture, specialized hands, a mouth structure permitting speech, stereoscopic vision, and areas in the brain for the functions of speech and association. Since culture speeded the development of these re-

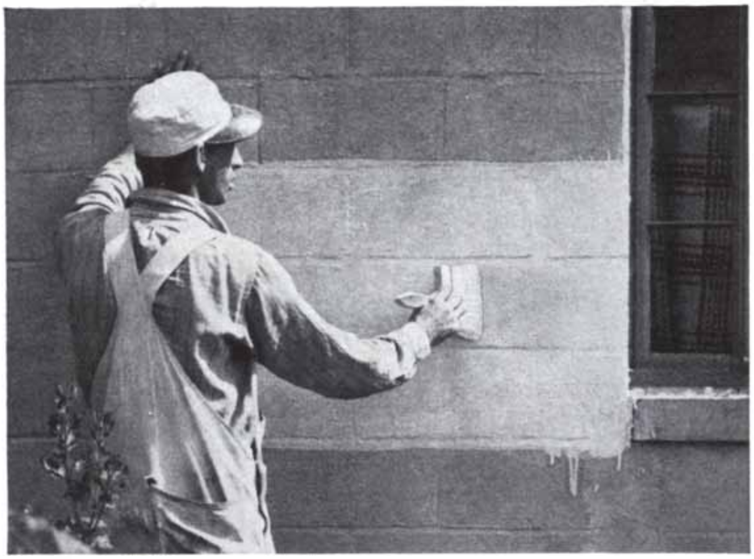
quirements, it would be difficult to say which came first.

The first step toward human culture may have come when manlike animals began to substitute tools for body parts. It has been suggested, for example, that there may have been an intimate relation between the development of a flint weapon held in the hand and the receding of the apelike jaw and protruding canine teeth. An ape, somewhat like a dog, deals with objects by means of its mouth. When the hands, assisted by tools, took over this task, the prognathous jaw began to recede. There were other consequences of this development. The brain centers that register the experiences of the hands grew larger, and this in turn gave the hands greater sensitivity and skill. The reduction of the jaw, especially the elimination of the "simian shelf," gave the tongue freer movement and thus helped create the potentiality for speech.

Darwin called attention to the fact that man is in effect a domesticated animal; as such he depends upon culture and cannot well survive in a state of nature. Man's self-domestication furthered his biological evolution in those characteristics that make culture possible. Until perhaps 25,000 years ago he steadily developed a progressively larger brain, a more erect posture, a more vertical face and better developed speech, auditory and associational centers in the brain. His physical evolution is unquestionably still going on, but there is no clear evidence that recent changes have increased his inherent potential for cultural activities. However, the rate of his cultural development became independent of his biological evolution. In addition to devising tools as substitutes for body parts in the struggle for survival, he evolved wholly new kinds of tools which served other purposes: stone scrapers for preparing skin clothing, baskets for gathering wild foods, axes for building houses and canoes. As cultural experience accumulated, the innovations multiplied, and old inventions were used in new ways. During the last 25,000 years the rate of culture change has accelerated.

The many kinds of human culture today are understandable only as particular lines of evolution. Even if men of the future develop an I.Q. that is incredibly high by modern standards, their specific behavior will nonetheless be determined not by their reason or psychological characteristics but by their special line of cultural evolution, that is, by the fundamental processes that shape cultures in particular ways.

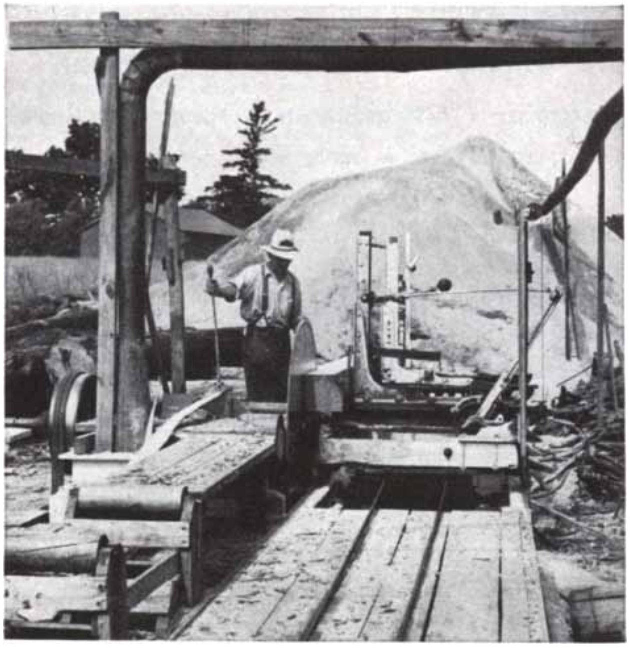
Life on the Chemical Newsfront



HE'S APPLYING TINY CHEMICAL "SHINGLES" to waterproof concrete. The spreading of water on a solid surface and the degree of wetting are determined by the contact angle between water and surface. Metallic stearates give large contact angles, causing water to be drawn up in drops, preventing wetting. AERO* Zinc Stearate, for example, forms very small leaflike plates or layers of adhering plates that repel water like shingles. To waterproof concrete, small amounts of zinc or other metallic stearate are added to cement clinker before grinding, to the concrete mix at time of hydration or are used in cement-water paints or sprays for coating concrete surfaces. **(Industrial Chemicals Division, Department A)**

***Trademark**

THEY USED TO BURN IT, but now even the saw mill waste pile can be used. With Cyanamid's new MELURAC® Resin 304, wood-waste chips and sawdust can be converted to hardboard at a low temperature cure and short cure cycle. This melamine-urea-formaldehyde resin gives high flexural strength, high moisture and water resistance, and imparts no color to the board. The hardboard can be used for furniture cores, veneer bases and attractively textured wall panels, table tops and flooring. **(Plastics and Resins Division)**



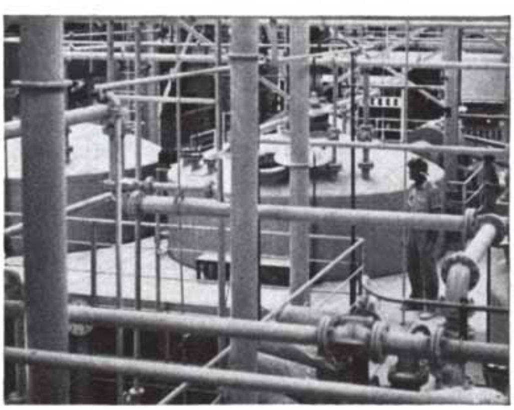
VERSATILE THICKENER for aqueous systems, Cyanamid's water-soluble polymer, Polyacrylamide, is now available from new semi-commercial facilities. Polyacrylamide offers high thickening action and suspending power, excellent stability, uniform bulk density and particle size for rubber and paint latices, ceramic slips, metal cleaners, paper coating compounds, cements and adhesives. A white, free-flowing powder, Polyacrylamide is odorless and readily soluble in cold water to form solutions stable over a wide pH range. **(New Product Development Department A)**

Chemistry Makes Fashion News

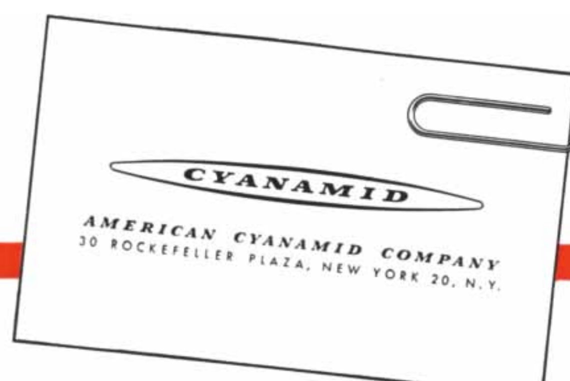
Jacket courtesy Leather Industries of America

WHITE AND PASTEL LEATHERS are in fashion. They owe much of their favor to many fine quality features made possible by such chemicals as Cyanamid's new Leather Product 612. This new re-tanning agent, used for elk type and semisoft leathers, tightens the leather grain surface, and produces a fine low-grained leather with an excellent "break." It also adds fullness and roundness, building up loose-textured open areas in the skin. Leather Product 612 is one of many Cyanamid Dyes Department chemicals used by the leather industry. **(Organic Chemicals Division)**

MORE THAN THE DESIGNER'S SKILL goes into the graceful drape of modern fashions. It takes chemistry, too. CYANATEX® SB-100 Softener, for example, is a new specialty product that gives unusual softness and a smooth, silky "hand" to cotton and synthetic fibers. This softener is compatible with anionic and nonionic agents, starches and salts commonly used in textile finishing. It is extremely resistant to yellowing and scorching. In tightly woven or harsh fabrics, it imparts the lubricity needed for good sewing properties. CYANATEX SB-100 Softener is suggested for knit goods, starch finishes, broadcloth, dyed yarns, tufted spreads, percale sheeting, pillow tubing and all fabrics requiring good drape. **(Organic Chemicals Division)**



THIS MAZE OF PIPE and processing equipment is part of Cyanamid's new plant at Savannah, Georgia, which produces UNITANE® Titanium Dioxide. Twenty-two separate manufacturing steps are necessary to convert black ilmenite to brilliant white titanium dioxide. The whitest pigment yet developed commercially, titanium dioxide is whiter than snow and almost as white as pure magnesium oxide, the common standard used to rate whiteness. Made up of exceedingly fine crystals that reflect light, UNITANE Titanium Dioxide confers exceptional opacity as well as whiteness to paints, fine papers, white wall tires, plastics, vitreous enamels and dozens of other products of beauty and usefulness. **(Pigments Division)**



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

Building for the Future Through Chemistry

Lavoisier

This 18th-century Frenchman is best known as the founder of modern chemistry. He was also a remarkable biologist, farmer, technologist, financier, economist and politician

by Denis I. Duveen

Antoine Laurent Lavoisier is universally known as the founder of modern chemistry, but this achievement tells only a small part of the story of his life. Had Lavoisier never performed a chemical experiment, he would still deserve a prominent place in history. He was a many-sided genius who pioneered not only in chemistry but also in physiology, scientific agriculture and technology, and at the same time was a leading figure of his era in finance, economics, public education and government. Few men in history have busied themselves in so many fields with such powerful effect as this brilliant and charming Frenchman.

Lavoisier was born in Paris on August 26, 1743, the only son of well-to-do parents. His mother died while he was still young, and he was brought up with loving care by his father and a maiden aunt. His father wanted him to become a lawyer; Antoine dutifully completed his legal education and obtained a license to practice, but he had shown his predilection for science by choosing to do his undergraduate work at the Collège Mazarin, where he studied astronomy, botany, chemistry and geology with famous masters. After law school he quickly turned to science again. Within three years, at the age of 25, he was elected to the Royal Academy of Sciences, as a result of his work in helping to prepare a geological atlas of France, his chemical research on plaster of Paris and his recognition with a special gold medal for plans submitted in a royal competition to improve the street lighting of Paris.

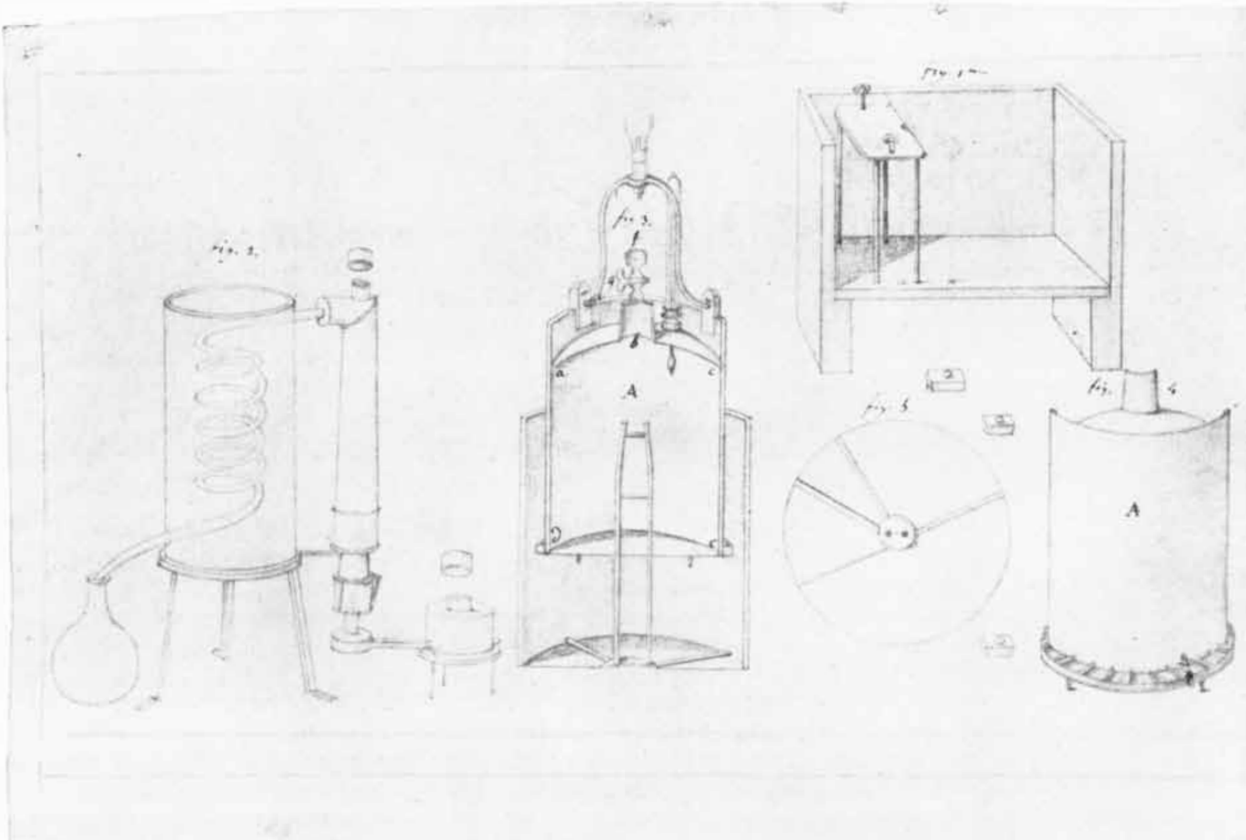
ENGRAVING OF LAVOISIER was based on a painting made in 1788 by Jacques Louis David. On the ledge below the oval frame is some of Lavoisier's chemical apparatus.

Now resolved on a career of scientific research, Lavoisier first arranged to assure himself of sufficient financial means. He bought a share of the *Ferme Générale,* the private company that collected taxes for the King. This association was highly profitable to Lavoisier throughout his life, but it was to bring him to the guillotine.

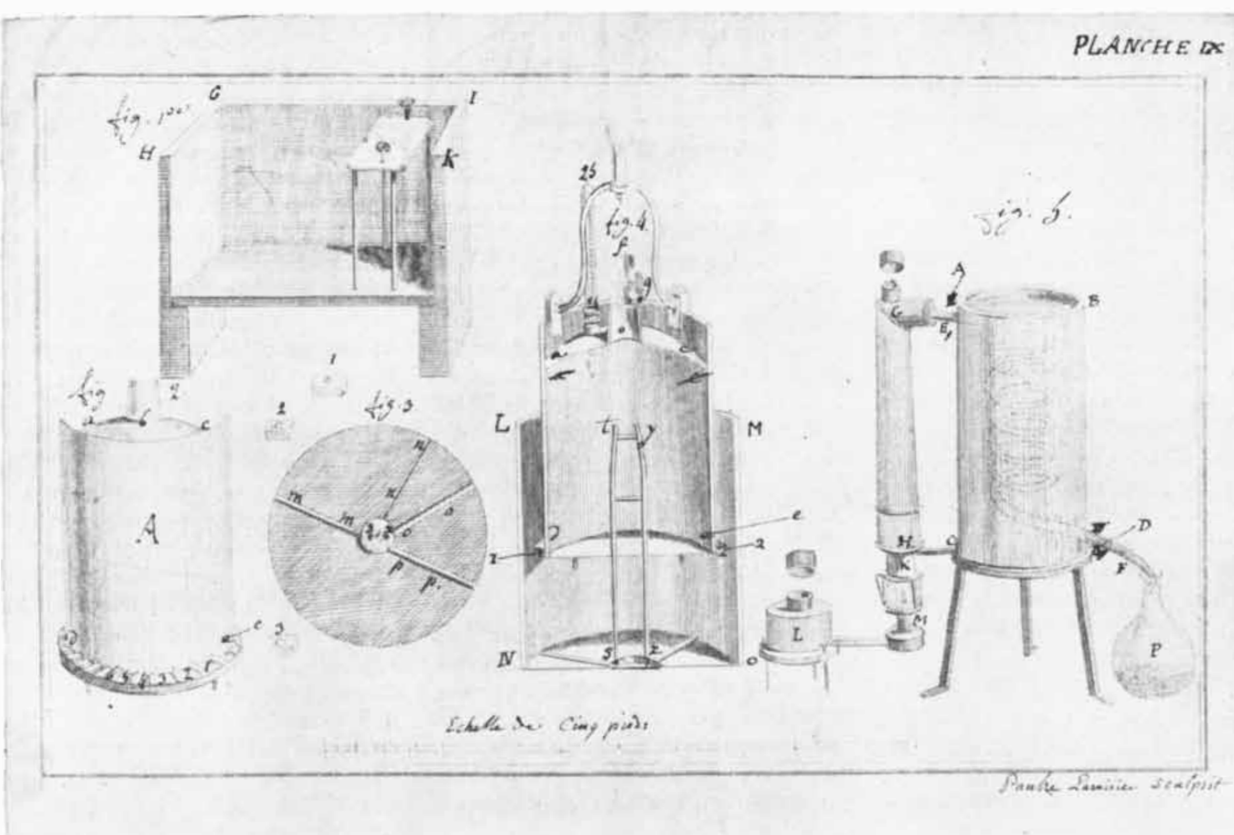
At 28 Lavoisier married Marie Anne Pierrette Paulze, the 14-year-old daughter of a leading member of the *Ferme.* Although it was a marriage of convenience, arranged by the father to save his daughter from pressure in high places to marry an elderly and dissolute count, the union between Lavoisier and his child bride was to prove a happy success. Marie set about learning Latin and English to translate scientific works for her husband, who had little knowledge of foreign languages. She translated two important books by the Irish chemist Richard Kirwan and supplied Lavoisier with résumés of papers published by Joseph Priestley, Henry Cavendish and other contemporary British chemists. Her translations and footnotes show that she herself achieved more than a superficial knowledge of chemistry. As a hostess Marie made the Lavoisier home a popular meeting place for French and foreign scientists; as an accomplished artist she sketched and engraved plates for his books; she helped him in the laboratory as his secretary, taking notes on many of his experiments. After Lavoisier's execution she edited and printed for private circulation his last, uncompleted work, compiled in prison, *Mémoires de Chimie.* It seems a poor reward that her life after Lavoisier was made bitter by an unhappy, short marriage to Count Rumford, who was a renowned scientist and inventor but also a careerist and adventurer.

Lavoisier's work in chemistry is a textbook classic which can be quickly reviewed. In 1772, at the age of 29, he began to study combustion and the "calcination" (oxidation) of metals. He observed that sulfur and phosphorus gained weight when they burned, and he supposed that they absorbed air. The key to explanation of his own observations came when Joseph Priestley discovered "dephlogisticated air" (oxygen). Lavoisier soon showed that it was this substance, to which he gave the name oxygen, that was absorbed by metals when they formed "calces," *i.e.*, oxides. He proceeded to replace the century-old "phlogiston" theory (that substances burned because of an escape of phlogiston) with the correct view that combustion is a chemical combination of the combustible substance with oxygen. Lavoisier could not explain the production of fire, and he introduced the term *calorique* to describe the *element imponderable*—heat. The complete explanation of combustion and heat was not to come until the theory of entropy was developed in the 19th century. Nonetheless Lavoisier, in collaboration with the great physicist Pierre Simon de Laplace, made studies of the heat evolved in combustion which laid the foundation of thermochemistry.

Lavoisier's theory at first failed to account for the combustion of "inflammable air" (hydrogen), evolved when metals were dissolved in acids. Here it was a discovery by Cavendish that gave Lavoisier the clue he needed. Cavendish learned that the burning of inflammable air produced pure water. Lavoisier extended his experiments and concluded that water was a compound of



MADAME LAVOISIER'S DRAWING of some of her husband's chemical apparatus is shown above. At left is a device for condensing and collecting water formed during the combustion of alcohol. In the center is a gasometer. At upper right is a pneumatic trough. Shown below is a proof of the engraving made from the drawing. The objects are reversed by printing. The proof is corrected in Madame Lavoisier's hand. At the lower right it bears her signature: Paulze Lavoisier *sculpsit*.

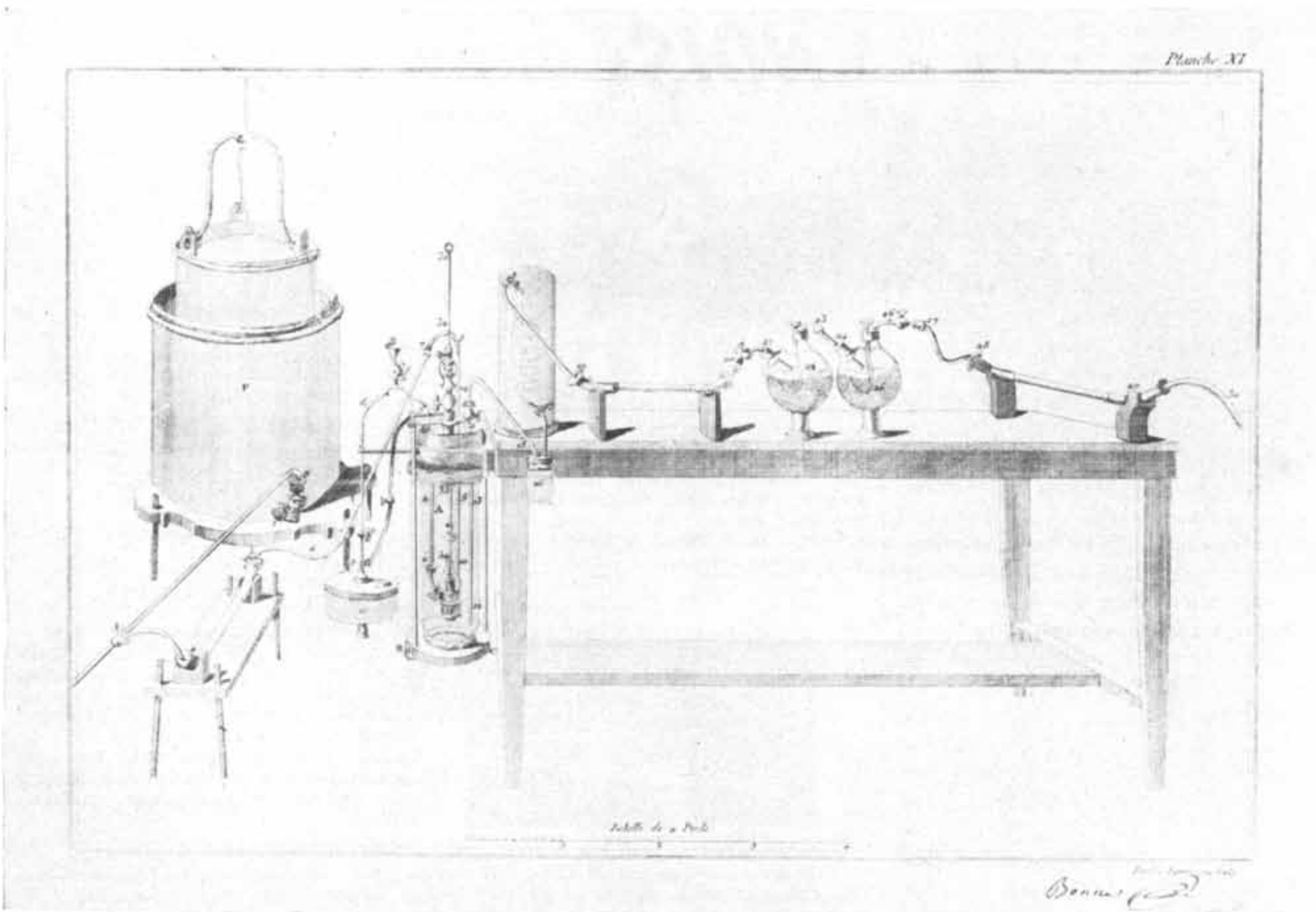


the two gases we now call oxygen and hydrogen. He recognized immediately that this fact supplied a keystone for the building of a whole new edifice of chemistry.

The new chemistry was quite readily accepted. It called for revision of the list of elements and a new system for naming substances; Lavoisier, with other leading French chemists, composed a new terminology, and with minor revisions it is still used today.

Lavoisier's keen interest in combustion led him naturally to respiration. There are those who say that his work in this field justifies his being called the founder of physiology and biochemistry. Certainly he brought order out of chaos. Many had guessed that all life depended on a vital ingredient in the atmosphere; Priestley and others had demonstrated by experiment that breathing animals exhausted the air of a necessary factor. It was left to Lavoisier to show the purely chemical nature of the role played by oxygen, or as it was first called, vital air, in respiration and combustion. He was the first to show that animal heat is produced by a slow process continually occurring in the body and consisting of a form of slow combustion. To demonstrate this experimentally, he planned and carried out with Laplace a series of elegant experiments. They worked with guinea pigs. By accurately measuring the animals' intake of oxygen and output of carbon dioxide and heat—the latter with an ice calorimeter they invented—they laid the foundation of the science of calorimetry. As an extension of this work Lavoisier later collaborated with Armand Seguin in a program of research which established the facts of basal metabolism. The apparatus he designed for this work is the direct ancestor of the equipment used today in determining basal metabolism.

Lavoisier's scientific research was frequently interrupted by calls for technical assistance from the government. One of these was to remedy a shortage of gunpowder. France was suffering from a scarcity of saltpeter, an essential constituent of gunpowder, which was produced by an inefficient licensed monopoly. Called upon for advice by the comptroller general of finance, Lavoisier suggested the formation of a government-owned *Régie des Poudres.* He was appointed as one of the four administrators of this agency and proceeded to institute new and efficient methods of production. Within three years he raised France's annual production of gunpow-



LAVOISIER'S APPARATUS for burning various oils in a measured quantity of oxygen and collecting the products of combustion are depicted in this plate from his *Elements of Chemistry*. Madame Lavoisier approved the plate by writing *Bonne* at lower right.

der from 714 tons to 1,686 tons. It can be said that Lavoisier's efforts contributed to the success of the American Revolution, for without the gunpowder supplied the colonists by France the outcome might have been different.

The *Régie des Poudres* provided Lavoisier with a home and a scientific laboratory at the Arsenal, where he spent his happiest and most productive years. But two episodes in this experience illustrate the hazards to which a scientist may be exposed in government service. On one occasion Lavoisier, his wife and three associates undertook to experiment with potassium chlorate as a possible new explosive. The experiments produced a laboratory explosion which killed two of the party, but the Lavoisiers escaped unharmed. Lavoisier reported the affair to the King's Minister in lofty terms which well illustrate his character: "If you will deign, Sir, to engage the King's attention for a moment with an account of this sad accident and the dangers I faced, please take the opportunity to assure His Majesty that my life belongs to him and to the state, and that I shall always be ready to risk it whenever such action may be to his advantage, either by a resumption of the same work on the new explosive, work which I believe to be necessary, or in any other manner."

The second exposure was political. In 1789, when the Revolutionists had taken control of Paris, the Administration of Powders decided to ship 10,000 pounds of low-quality industrial gunpowder out of the city and replace it with better-quality musket powder. The move alarmed the populace; Lafayette, who was in charge of munitions and had not been informed of the shipment, ordered it returned to the Arsenal. The local commune investigated the powder administrators on charges of treason, and although the inquiry exonerated them, public clamor for Lavoisier's arrest did not abate until the powder was restored to the Arsenal.

Like Thomas Jefferson, whom he resembled in many ways, Lavoisier had a keen and personal interest in agriculture. He inherited from his father a farm at Le Bourget, and soon afterward he also acquired a large agricultural estate near the town of Orléans. Here he himself farmed about 370 acres and leased 865 acres to sharecroppers. It was his habit to spend the sowing and harvest seasons at the farm, and to keep close account of the crop yields and costs by double-entry bookkeeping. Farmer Lavoisier soon decided that crop yields were intimately connected with the amount of manure used on the fields. He then carefully calculated the optimum balance of cattle to acreage of pasture and cultivated land for a mixed farm. His studies of the requirements of various cash crops and of cattle were highly practical and successful. He was able to record with satisfaction that in 14 years he had doubled his yield of wheat and quintupled the size of his herd of cattle.

Lavoisier was active in the Agricultural Society of Paris and in the official Administration of Agriculture, of which he was one of the five original members and the guiding light. He represented the third estate in the Provincial Parliament of Orléans, where he was the prime mover of almost all the subjects discussed and decisions taken. His reports, which dominate the printed proceedings of the Parliament, dealt not only with matters strictly agricultural but also with such varied subjects as public assistance

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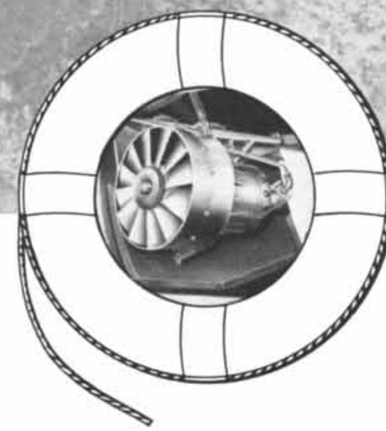

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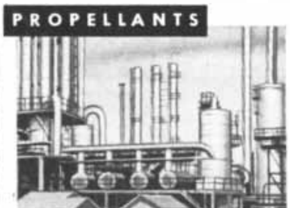

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for orphans and widows, steps to found a savings bank in Orléans, the abolition of the hated *corvée* (the obligation to repair the roads of a parish), tax reforms, the preparation of a mineralogical map of the district and the establishment of workhouses for the poor. He expressed his social creed in these words: "Happiness should not be limited to a small number of men; it belongs to all." Lavoisier was a physiocrat—devoted to the belief that all wealth stemmed from the land and that individual liberty was the most sacred right of man.

Scientifically a pioneer, politically a liberal, sociologically a reformer, Lavoisier was orthodox in his views on finance. In the new republic of 1789 he was elected to the presidency of the Discount Bank which was eventually to become the Bank of France. In a lucid and discerning address he noted with disquiet that inflation had set in. Three years later Lavoisier presented a report to the National Assembly on the lamentable state of the finances of the country. A recent appraisal of Lavoisier's exposition by an expert calls it superb. This report was printed by Lavoisier's friend Pierre S. Du Pont, whom he had financed in the publishing business and whose young son, Irénée, was an apprentice bookkeeper under Lavoisier at the Arsenal. When Irénée, after the Du Pont family's emigration to the U. S., established the great gunpowder works in Delaware, he wanted to name the factory Lavoisier Mills, but the family finally settled on E. I. Du Pont de Nemours.

Lavoisier's famous treatise on political economy, *On the Land Wealth of the Kingdom of France*, is an important one in the history of economics. He had started it before the Revolution, but the National Assembly considered it so useful afterward that it ordered the paper


PASSEPORT.

LA NATION, LA LOI & ~~LE ROI~~.

MUNICIPALITÉ DE PARIS.

LAISSEZ *paſſer* Mr Lavoisier *dénommé, qualifié & déſigné dans le Certificat du Commiſſaire de Police de l'autre part, & prêtez lui aide & aſſiſtance en cas de beſoin.*

Délivré en la Maiſon commune de Paris, le [illegible] *mil ſept-cent quatre-vingt-douze, l'an quatrième de la Liberté.*

No 217 Deltroit
Officier Municipal.
Secrétaire-greffier.

REVOLUTIONARY PASSPORT was issued to Lavoisier in 1792 to enable him to travel to his farm near Blois. On the opposite side Lavoisier is described as 49 years old, five feet four inches, brown hair and eyes, long nose, small mouth, round chin, ordinary forehead and thin face. The words *le Roi* in the second line of the document have been crossed out.

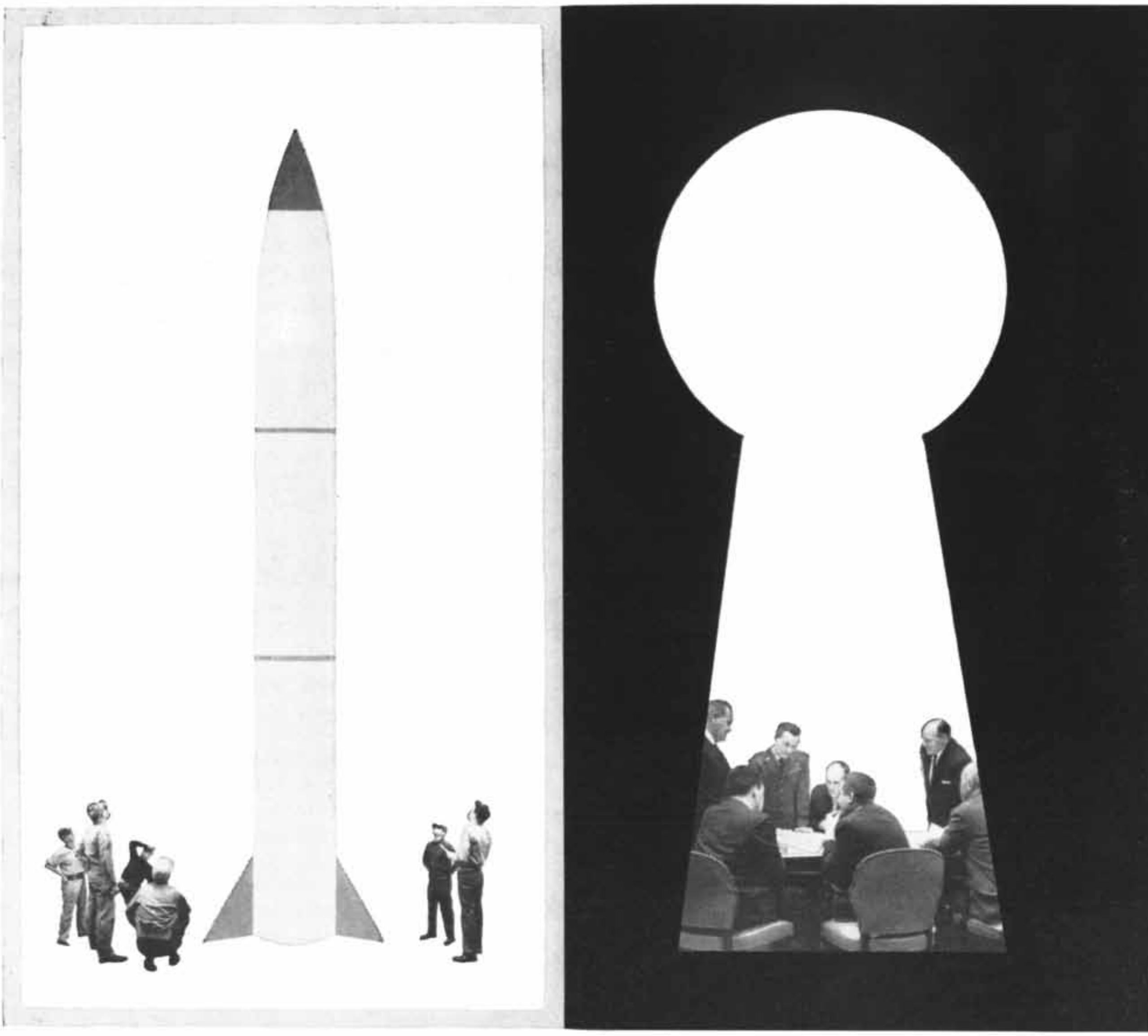
printed in 1791. Lavoisier argued that a sound system of taxation could be founded only on exact knowledge of the country's agricultural production, and he collected data from all the provinces of France. His figures on production, consumption and population were the first reliable national statistics ever made available. Lavoisier recommended that France found an institution to gather and study all forms of economic data—not only on agriculture, but also on industry, population, capital and so on.

As a member of a committee established by the National Assembly in 1791 to advise the government on important questions concerning trades and crafts, Lavoisier proposed a national system of public education. He stressed that education of the people was a good investment from the state's point of view, and that free education should rightfully be available to all irrespective of sex and social position. He proposed the establishment of four kinds of schools: primary, elementary arts, institutes, and 12 national high schools, located in the 12 largest cities of France. He also suggested the creation of four national societies, to advance mathematics and the physical sciences, technical applications of science, the moral and political sciences, and literature and the fine arts.

Lavoisier took an active part in a little-known French attempt to establish an ambitious system of higher education in the new U. S. republic in 1788. The moving spirit of this project was Alexandre Marie Quesnay de Beaurepaire, grandson of a famous French philosopher, economist and court physician. Quesnay proposed a college, to be located in Richmond, the new capital of Virginia, which would be international in scope. The French Academy appointed a commission, which included Lavoisier, to study the question, and the commissioners made a favorable report, which it is reasonable to assume Lavoisier wrote, considering his propensity for taking the responsibility of drafting reports in all such situations.

Quesnay's academy was actually built in Richmond, but it never got a real start, probably because of the revolutionary overturn of France in the following year. It was in this very building that the Constitution of the U. S. was formally ratified. It later became a theater, burned down in 1811, was rebuilt, and today is in use as a church.

One of the first targets of the French Revolution—after the royal family—was the tax-collecting *Ferme Générale*,

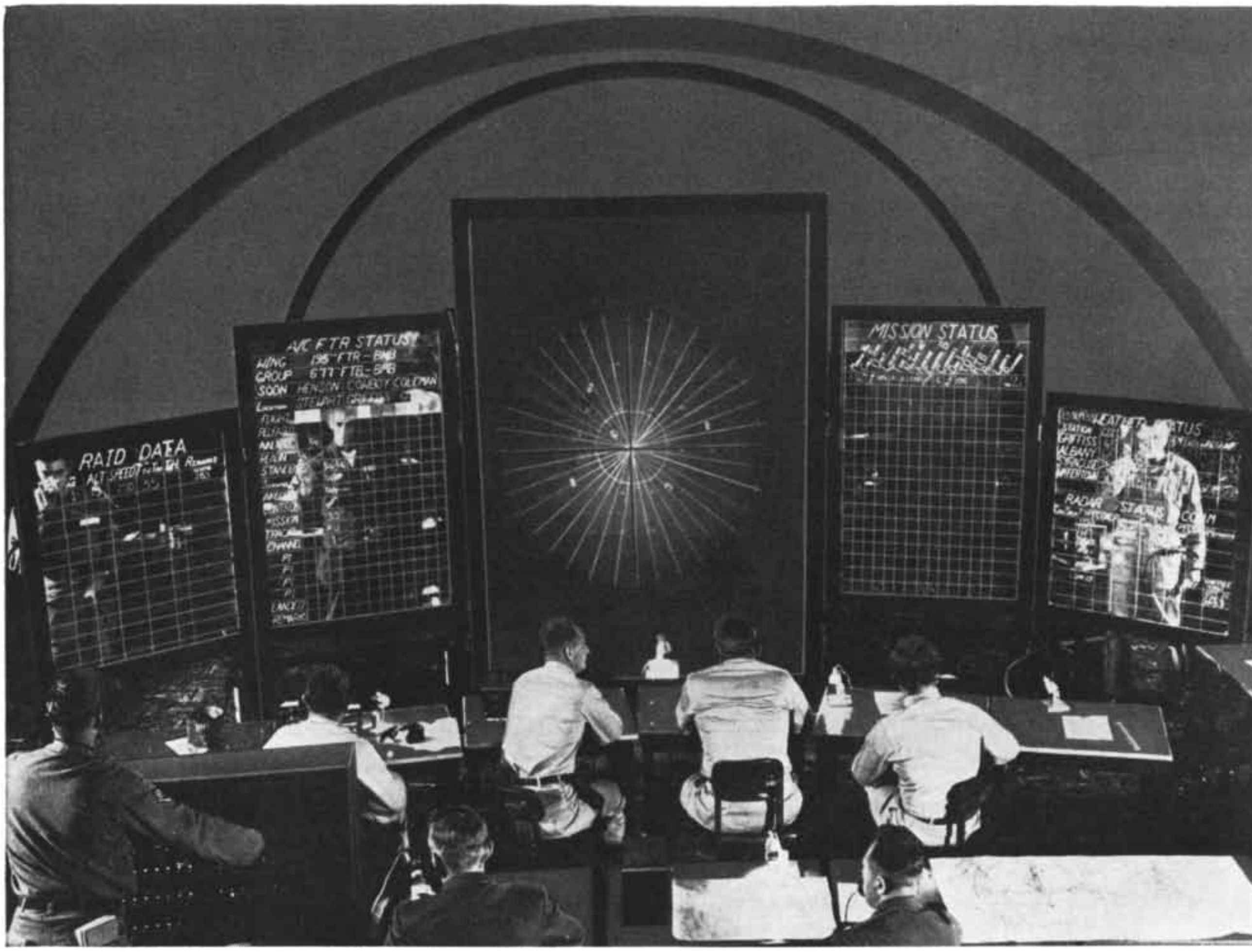


whose members had always borne odium as bloodsuckers who battened on the people. In 1791 the National Assembly finally suppressed the *Ferme* and ordered a detailed statement of its accounts. Delays in producing these accounts inflamed the Revolutionary Committee, and on November 14, 1793, arrest of all the Farmers-General was ordered. When Lavoisier heard of the decree, he went into hiding and tried to have the order reversed, on the grounds of his valuable scientific work for his country. But these attempts were fruitless, and after a few days he surrendered himself.

The Farmers-General were locked up in their former offices, where they finished the rendering of a final accounting in January, 1794. Their accounts showed quite clearly that the tax gatherers had acted throughout in complete conformity with the law.

The Terror, however, was entering upon its most extreme phase, and the Farmers-General were not to escape. New charges were preferred, accusing them of various abuses—levying excessive rates of interest, adulterating tobacco with excessive moisture (thus undermining smokers' health), and the like. In the heated atmosphere of the times the Farmers' accusers had no difficulty in getting a decree ordering their trial before the Revolutionary Tribunal. This was tantamount to a death sentence. At one o'clock in the morning of May 8, 1794, each of the prisoners was handed an almost illegible copy of the charges against him, and at 10 o'clock the same morning they were brought before the Tribunal for trial. Here a difficulty arose, for the Tribunal had jurisdiction only over counterrevolutionary activity, of which the Farmers-General had not been accused. But the Tribunal president, Jean Baptiste Coffinhal, disposed of the difficulty by charging the jury to ask themselves whether it had been shown that the Farmers had taken part in a plot against the people by various misdeeds, including supplying the enemies of the Republic with money illegally withheld from the Treasury—a charge which had not been mentioned in the indictment or supported by any evidence during the trial. The jury unanimously returned a verdict of guilty, and the convicted men were duly guillotined before nightfall.

So died France's greatest scientist. Joseph Louis Lagrange, the great mathematician, said the next day: "It required only a moment to sever that head, and perhaps a century will not be sufficient to produce another like it."



Official U.S. Air Force Photograph

Friend or foe? Tactical defense officers in MINK control center watch movements of aircraft as reported from radar warning sites. This is equipment developed under the direction of Rome Air Development Center.

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84

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The Growth of Mushrooms

The sudden appearance of mushrooms after a summer rain is one of the more impressive spectacles of the plant world. How does the mushroom achieve this remarkably fast growth?

by John Tyler Bonner

There are many ways to study how living things grow, and the study of mushrooms may seem at first thought one of the least promising. I had always been dimly aware that mushrooms grow, but the idea that they might be a suitable subject for investigation of the growth process never crossed my mind until I encountered an unusual instance at Woods Hole, Mass., where we were spending the summer. I used to walk our dog every morning over an abandoned asphalt road, and one day I noticed some round bulges the size of a butter plate in the asphalt. A few mornings later I saw to my utter amazement that one of the mounds had erupted and a mushroom had pushed up through the pavement. My first thought was: What a remarkable feat of strength for a delicate mushroom! A good friend politely informed me that it was not only strength but also persistence, for asphalt is actually a liquid, and a steady force will move it. It turned out that I had by no means been the first to observe such a phenomenon: in fact, I found in a U.S.S.R. journal a paper describing a similar eruption on the floor of a Soviet factory—which I suspect must have

THREE ADULT MUSHROOMS record their own pattern of growth. When the mushrooms first appeared above ground, a row of dots the same size and the same distance apart was painted on their stems and from the center to the edge of their caps. The fact that there are no dots at the tops of the stems shows that these parts grew the most. Some dots are elongated by the growth of the stem.

INITIAL STAGES of mushroom growth in the laboratory are shown in these three photographs. In the first and second photographs the dots are close together; in the third they have begun to pull apart. The dots at the edge of the cap have expanded.

kept the NKVD busy for quite some time.

It is surprising how little literature there is on the details of mushroom growth. As is often the case, the earliest accounts are the most comprehensive. Few facts have been added to the classic report by the 19th-century Strasbourg botanist Anton de Bary. Teachers of botany today have a great deal to say about the growth of the onion root tip and other advanced members of the plant kingdom, but they ignore the mushroom—it "just grows."

Mushrooms are encountered by most people only as a garnish for steaks. The kind you buy at the supermarket is a cultivated variety of the common field mushroom *Agaricus campestris.* Whether you are a housewife who has washed it for cooking, or a consumer who has poked at it with a fork, you know that a mushroom is composed of an umbrella-shaped dome capping a thick stalk. If you have ever taken one apart, you probably also know that, smooth and sleek as the object seems, the mushroom is actually a compacted mass of minute, cotton-like threads, and that its roots are delicate filaments spread widely through the soil.

The mushroom is in essence a spore-bearing and spore-distributing structure. Cells on the fluted undersurface of the cap shed tiny spores which are carried off by the wind. The spore output of a single mushroom is staggering—as many as half a million spores per minute for a period of three or four days. Break the cap off the stem, place it on a sheet of paper and you will be rewarded with a pretty showered pattern of spores outlining the fluted gills of the undersurface. A botanist identifies the species of mushroom by the color of the spores.

In a suitable environment—soil, compost, rotten wood or any other nourishing medium—the spores will send out filaments that invade every nook and cranny. Like the spores themselves, these young filaments contain half the number of chromosomes of adult mushroom cells. In essence they are gametes, like sperm and egg. To develop they must meet and fuse. We cannot, however, call them male and female, for most mushroom varieties have four "sexes." Among the four there are only two possible cross-matings—*i.e.,* one and three, two and four.

After a pair of filaments has fused, combining in the cell nuclei the normal double complement of chromosomes, it continues to sop up food, to elongate, advance and invade. The thread grows at its tip, and as the nuclei divide, trans-

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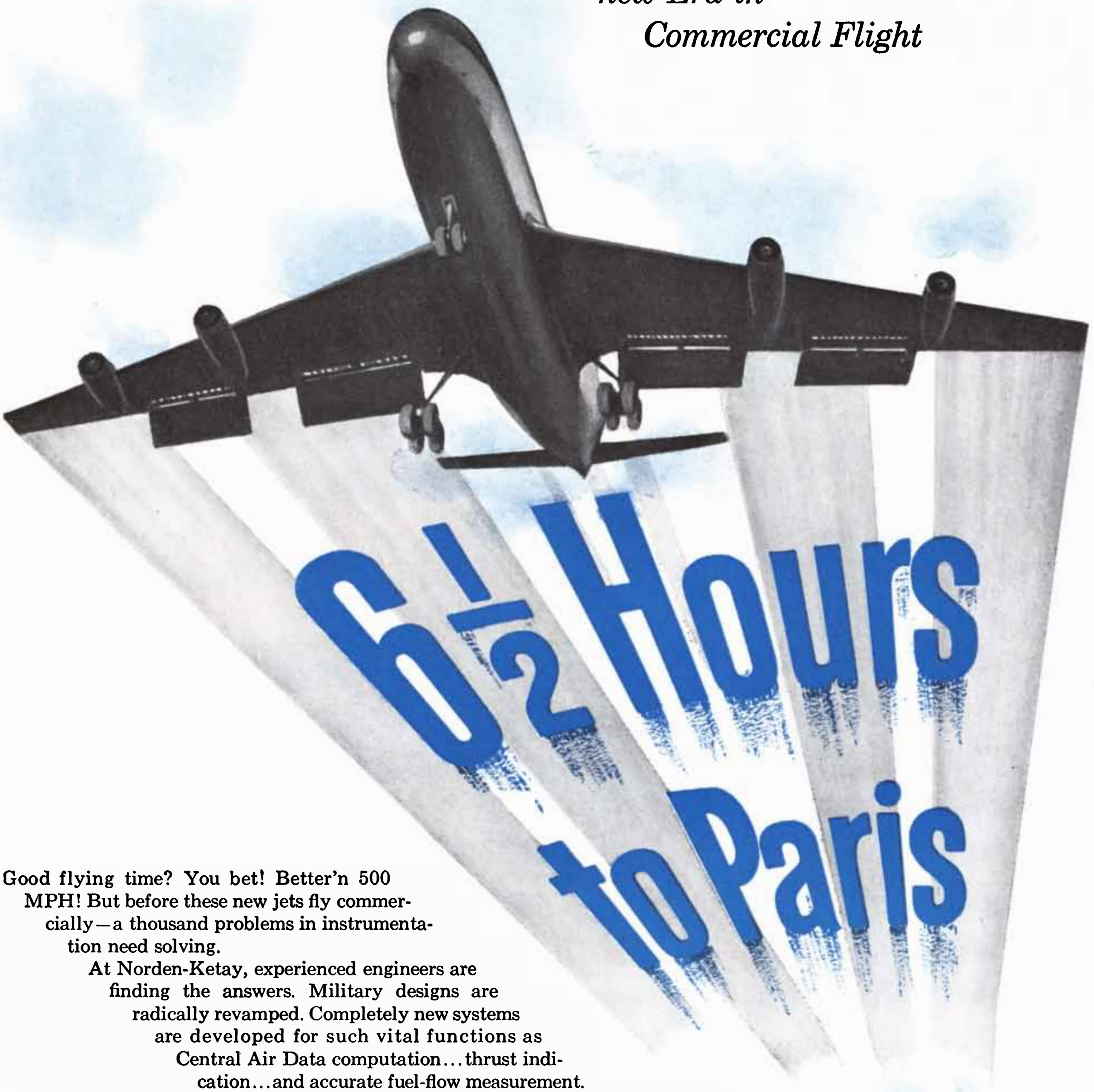

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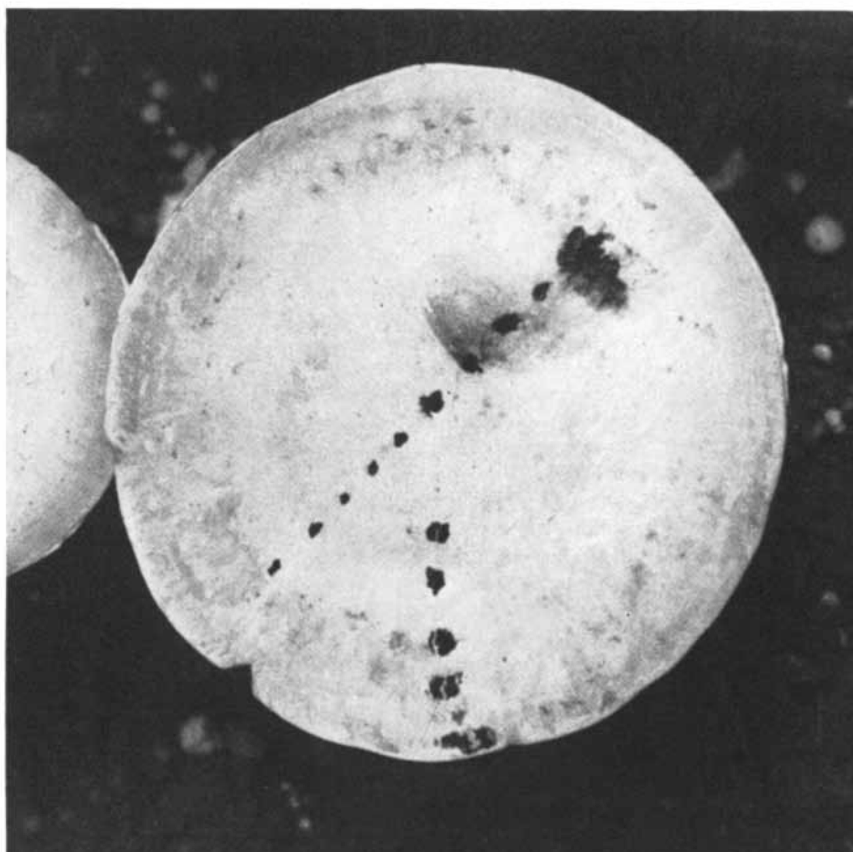
SERVOMECHANISM COMPONENTS • PRESSURE GAGES • AIRCRAFT INSTRUMENTS • AUTOMATIC CONTROL SYSTEMS • RADAR • COMPUTORS verse walls are formed across the filament. In the end, however, the cross walls are perforated with holes that form a passage along the length of the thread, through which protoplasm and even nuclei can pass freely from one cell to the next. This flow was studied carefully by the late Reginald Buller, a distinguished Canadian botanist, and was found to be important for the growth of the mushroom.

A network of growing filaments, called a mycelium, spreads through the soil like the ripples from a stone dropped into a quiet pond. As I sit writing, I can see in the lawn below my fourth-story window a circular patch about six feet across in which the grass has a slightly fresher, greener appearance. I know that the area is underlain by a mushroom mycelium. Last fall the patch was ringed by a perfect circle of mushrooms—what is known as a "fairy ring." Such a ring starts at the center; as the plant's roots deplete the soil of mushroom food, the mushrooms move outward in an ever expanding circle, forming a perfect ring so long as the weather conditions satisfy the fruiting and growth requirements. John Ramsbottom, former Keeper of Botany at the British Museum in London, has a chapter on fairy rings in his delightful book *Mushrooms and Toadstools*. In one year the ring of the "fairy-ring mushroom" (*Marasmius oreades*) will advance five to 19 inches, and from this it can be calculated that certain large patches must be from 400 to 600 years old. Ramsbottom caps this bit of information with a remarkable aerial photograph of plainly visible fairy rings surrounding the famous Stonehenge ruins.

Cultivated mushrooms are grown in a rich compost of soil and horse manure. Many seed companies offer spawn (young mycelia) for planting with fairly complete directions. A tray of compost with spawn should be kept in a damp, quiet place at a temperature near 65 degrees Fahrenheit. A cave or old-fashioned cellar makes an admirable mushroom-growing chamber. In a matter of a few months the flat will be completely interlaced with the white mycelium. The first inkling of fruiting will be the appearance of small white pinpoints all over the surface. Some of these begin



MUSHROOM CAP was painted with two rows of dots. The dots in the vertical row were originally larger than those in the diagonal row. Those nearest the edge became still larger during growth, demonstrating that the edge of the cap grows slightly more than the center.

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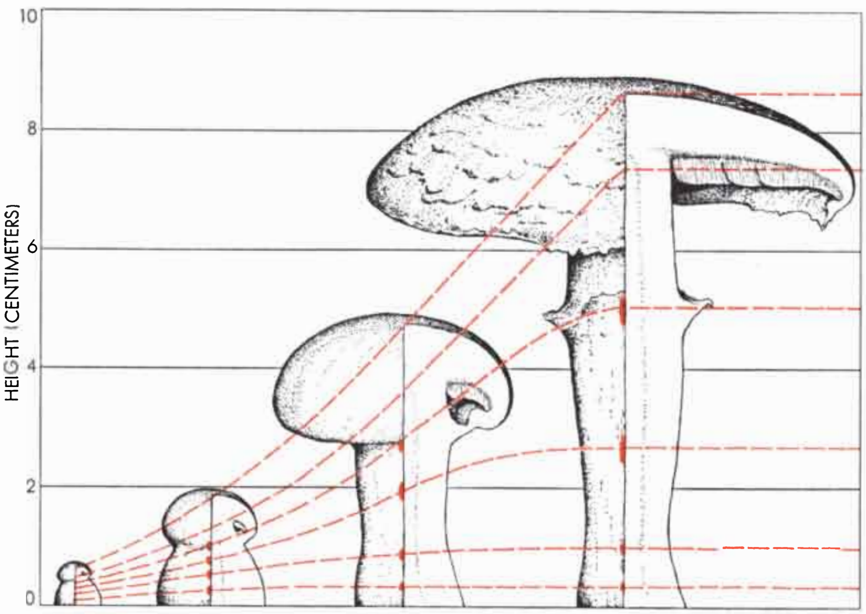
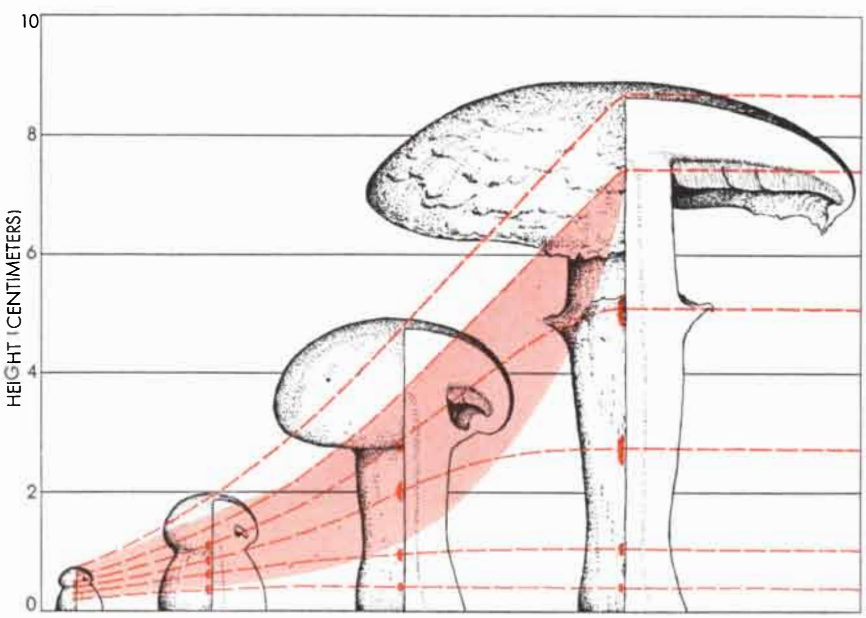
to enlarge (the rest appear to be inhibited by the faster growing ones). When a shoot has grown to a height of about five millimeters, the mushroom cap and stalk begin to be distinguishable. The mushroom expands in both thickness and height until it is 15 to 20 millimeters tall; thereafter it grows in height only. As it shoots up, the cap eventually unfolds from the stem like the opening of an umbrella.

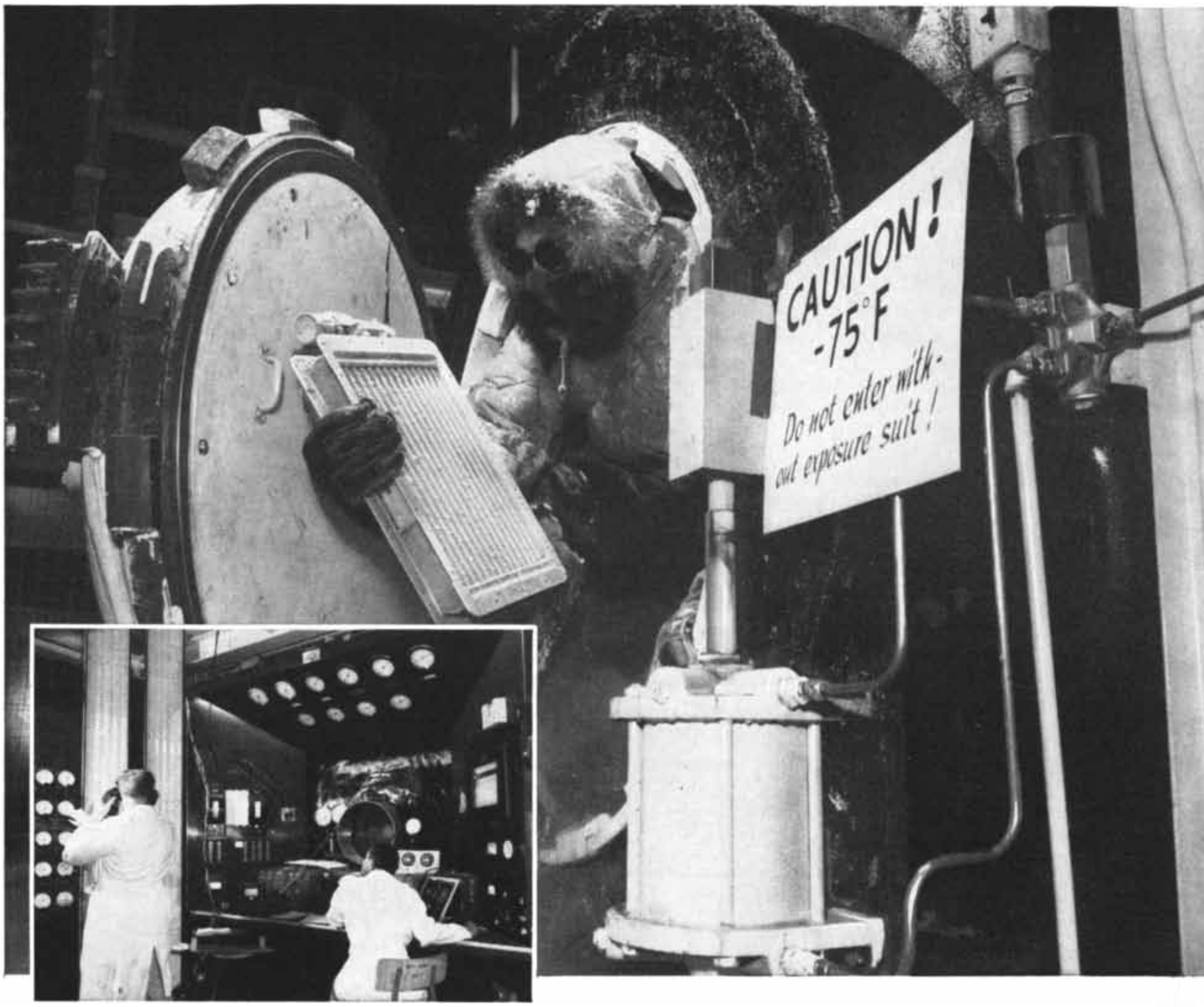
When I embarked on the project of studying this process in more detail at Princeton University about a year ago, two seniors, Raphael H. Levey and K. Kent Kane, decided that they would like to take part, and they energetically set out to find a source of supply. Before long they had located a mushroom grower, Karl Knaust of Catskill, N. Y., who generously agreed to supply us with all the material we needed. It seemed to me a rather distant source, but then I discovered that its proximity to Vassar



GROWTH CURVES trace the position of spots on the stem of a mushroom. The right-hand side of the mushroom has been cut away at each stage to show the change in its internal structure. The stem has already reached its full diameter in the second stage.



ACTIVE ELONGATION of the stem occurs in the zone outlined by the colored tone. The depth of the area indicates that the maximum elongation took place in third stage.



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College made it attractive to my associates. They made frequent week-end trips and returned with prepared flats of compost. It was then a matter of finding a suitable place for lodging the flats, and we ended up by placing them under various laboratory tables in cool rooms.

The first step was to measure the relative growth of different parts of the young mushroom. We marked the stalk at equal intervals up its length with dots of vivid red carmine dye—an old trick—and then periodically photographed and measured the developments. Any student of mushroom growth knows that the stalk grows in a peculiar preferential manner: its elongation takes place mainly in a region just below the cap. We were interested in measuring the exact extent of growth in this and other zones at different stages.

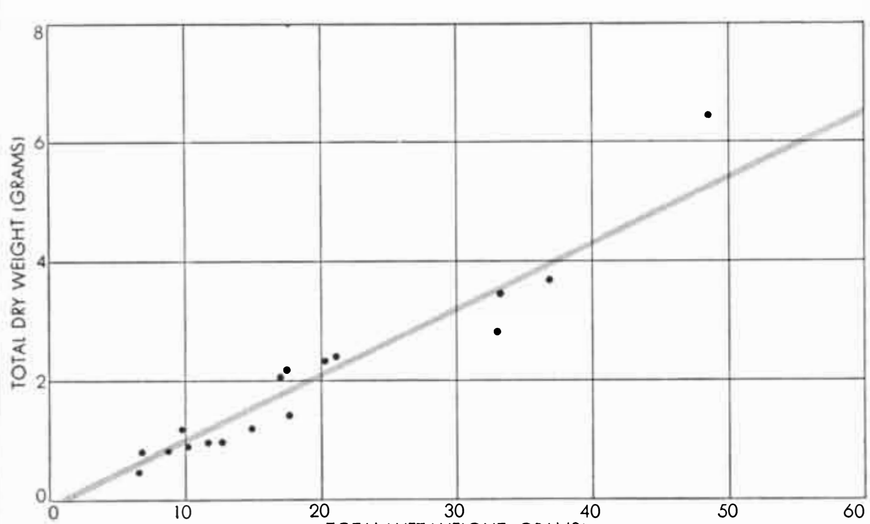
The dye spots told a graphic story. Along most of the stalk the spots remained round, but a spot placed within a certain sharply defined zone next to the cap would stretch out into a vertical line—here the stalk grew. The cap also grew somewhat unevenly, but not in any such abrupt fashion: it grew fastest at the edge and gradually slower toward the center.

So from these carmine experiments it is clear that once a mushroom 15 to 20 millimeters high begins to expand, the stalk does so only at a restricted zone below the cap and the cap does so in a gradient, highest at the edge. Before the incipient mushroom has reached that height, all parts of it expand at a uniform rate.

We put some marked young mushrooms in a moist chamber without soil, and we sliced others vertically through the cap and stalk, as one might slice them for cooking: these, too, expanded in the same regions where growth occurred in mushrooms growing normally in soil—though their expansion was quite limited. We even found that the stalk's growth zone alone, dissected from the stalk and placed on moist agar jelly, expanded appreciably.

It soon became obvious that to make any progress in understanding the growth mechanics we would have to study the development of the filaments that make up the mushroom. We took mushrooms at different stages of growth, treated them in the usual way for tissue examination under the microscope, cut them into thin sections after embedding them in paraffin wax, and then put them on slides, stained them with suitable dyes and examined the filaments through the microscope. We did not discover any startling new facts, but we did find it possible to correlate the mushroom's external expansion with changes in the arrangement of its internal threads.

Until the button is about four millimeters high, the filaments are bunched in a most irregular tangle. As it grows slightly taller, some orientation begins to appear in the stalk just below the cap: the filaments here start to line up parallel to one another. By the time the button has reached 10 millimeters in height, this orientation in the upper stalk region



RATIO OF WET WEIGHT TO DRY WEIGHT of a mushroom remains constant (*straight line among points*) during growth. This indicates that water alone cannot account for the rapid growth of mushrooms. The mushroom acquires both food and water during growth.

Honeywell control instrumentation for the first privately owned reactor, at North Carolina State College.

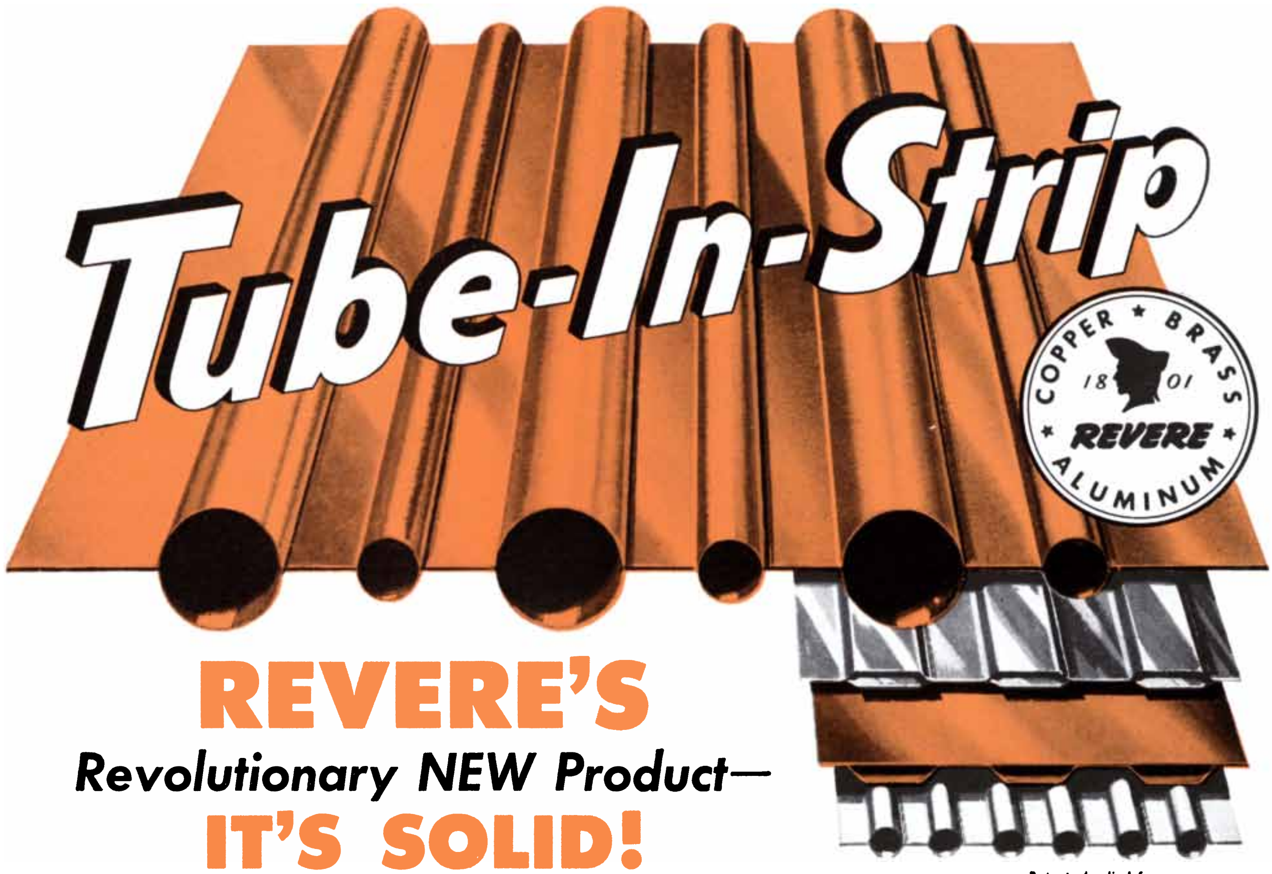
385-MEV cyclotron at Columbia University's Nevis laboratory is controlled from this panel.

is complete. The rest of the stalk remains a tangled mass of threads, and the cap also looks tangled, although occasionally one can see some radial orientation.

We have good evidence that after the mushroom has reached a height of 15 to 20 millimeters the cells of the stalk cease dividing and the filaments stop increasing in number. Thereafter, it appears, all the further rapid growth in height of the mushroom is due to mere elongation of the cells themselves. One evidence of this is given by comparative measurements of changes in height and thickness; another by measurements of weight. The height of the stalk increases in direct proportion to the weight, which shows that all the increase of substance must go into the elongation of filaments.

What intake feeds the elongation of the cells: is it merely water or is it other material from the soil as well? This question was tested simply by comparing the wet with the dry weights of a whole series of mushrooms at different stages. It was found that the dry weight increased in direct proportion to the wet weight, so the cells must be swelled by solid materials along with the water. This fact undoubtedly accounts for the relatively slight expansion found in isolated pieces of mushroom placed in a moist chamber, where only water intake is possible.

From all this one can see that the shape and future of a mushroom are mapped in the very early stages of its growth. Its intertwining threads are sorted out in the stalk in their proper locations and even in the correct number—all ready for the big push of growth. Then if the external conditions are favorable, there will be a sudden surge of materials from the soil mycelia upward into the mushroom, and its cells will elongate so that the mushroom can shoot into the air. There is then in the button a preformed pattern which, like an unfilled balloon, merely needs the proper filling substance to blow it up. This undoubtedly accounts for the proverbial fact that many kinds of mushrooms pop up suddenly. The buttons are often hidden below the grass or leaves, and as soon as the temperature and moisture conditions are just right, the final process of the upward movement of materials inside the threads can take place with dramatic speed. The gun, to change the metaphor, is carefully loaded, and all parts of the primordium are arranged in their proper number and place. Then the rains and the temperature pull the trigger that sets the mushroom off on its final spurt of growth.



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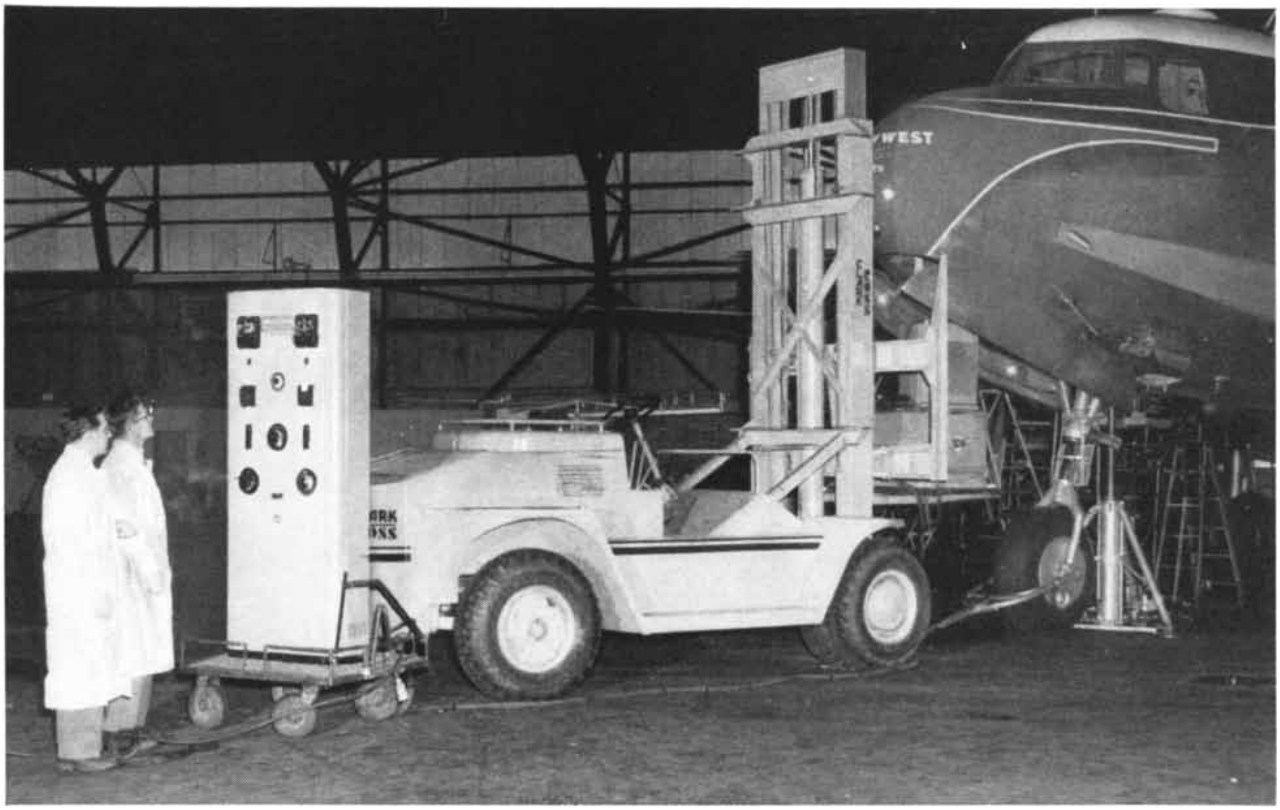

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Stick and Slip

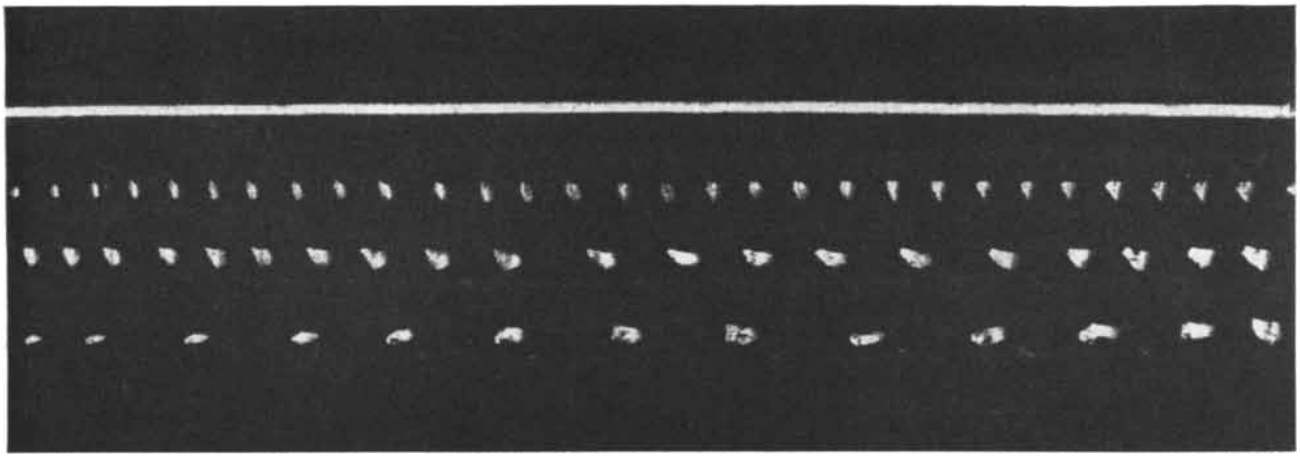
When two substances rub against each other, they frequently stick and then slip. The phenomenon accounts for the squeak of bearings, the music of violins and many other sounds of our daily experience

by Ernest Rabinowicz

The two types of force that are met most frequently in mechanics are gravity and friction. The former has been studied by great men of science in every age. The latter has been largely neglected, it being assumed that the sliding process holds little intrinsic interest and that three simple laws, all discovered before 1800, adequately describe the force of friction. However, the advent of modern machinery, working with very close tolerances under new and widely varying conditions, has shown up the inadequacy of our knowledge of the sliding process. To give but two examples, jet engines and heat-exchanger pumps in nuclear power plants present lubrication problems never before encountered. Consequently the laws of friction have recently been restudied, and new facts discovered. This article will deal with the stick-slip phenomenon, an important by-product of sliding which produces most of the creaking, squealing, chattering and squeaking we hear in our everyday lives.

The three laws describing the force of friction say that when one solid body slides over another, the frictional force (1) is proportional to the load, or pressure of one against the other, (2) is independent of the area of contact, and (3) is independent of the sliding velocity. The first two laws were stated by Leonardo da Vinci and rediscovered in the 1690s by Guillaume Amontons, a French engineer working under the sponsorship of the French Royal Academy of Sciences. The third law was first expressed in 1785 by Charles Augustin de Coulomb, the French physicist better known for his researches in electrostatics.

If the three laws are correct, friction depends only on the applied load, and the coefficient of friction (the ratio friction-force-to-load) for any given materials should be constant under all conditions. The first two laws generally hold true, with no more than 10 per cent deviation. But it has been known for some time that friction is not independent of sliding speed. The coefficient of friction between two bodies may vary as much as 30 to 50 per cent according to the speed of motion. In 1835 A. Morin of France proposed that, since the frictional force resisting the start of sliding for two bodies at rest was obviously greater than the resistance after they were in motion, there should be two coefficients of friction: a static one, for surfaces at rest, and a kinetic one, for surfaces in motion. Today, as a result of work by a number of investigators, we know that both the static and the kinetic coefficients themselves vary. The kinetic coefficient drops off as the sliding speed increases. And the static coefficient depends to some extent on the length of time the surfaces have been in contact—a fact which can be attested by anyone who has ever had occasion to loosen a stubborn screw or nut that has been in place for a considerable period. Thus the only satisfactory way to represent the friction coefficient for any pair of surfaces is by two plots, one of the static



CHALK MARKS on a blackboard demonstrate stick-slip. The top mark was made by a piece of chalk held at an acute angle to the direction of motion; the marks below it, by pieces of chalk held at an obtuse angle to this direction. In the latter marks the chalk stuck to the blackboard, then slipped, then stuck again and so on. The more tightly the chalk is held, the smaller the distance of slip.

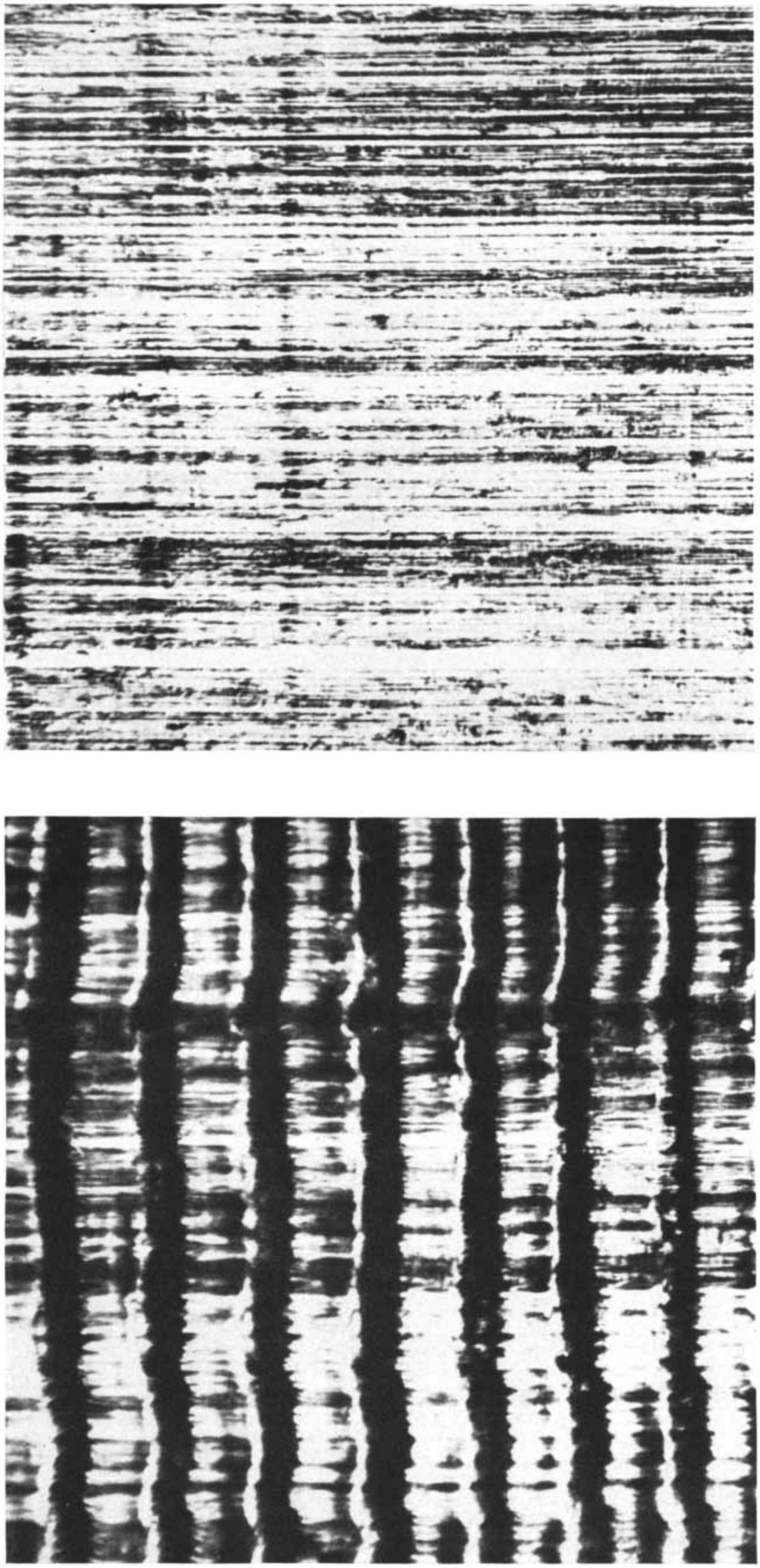
coefficient as a function of time of contact, the other of the kinetic coefficient as a function of sliding velocity.

It is the breakdown of the third "law" of friction—the variation of frictional force with velocity—that is responsible for stick-slip, the phenomenon we shall now consider. Suppose we attach a block to an anchored spring and place it on a longer slab which we set in motion at a slow speed. At first the block is dragged along on the moving slab: it will not be held back by the spring, *i.e.*, slide on the slab, until the spring's pull is equal to the static coefficient of friction. The pull of the stretched spring reaches that value when the block arrives at the point *A* [*see drawing at bottom of page 114*]. Now the block begins to slip on the moving surface. As soon as it does, the lower kinetic coefficient of friction takes over, and the block slides rapidly toward the left. When it has moved back to point *C*, it comes to rest. Here the higher static coefficient takes charge, and the block again sticks to the surface and is dragged to *A*. Then it slips back to *C*. This is a simple laboratory demonstration of the stick-slip phenomenon, so named in 1939 by F. P. Bowden and L. L. Leben, physical chemists at the University of Cambridge, who built an apparatus to study the process.

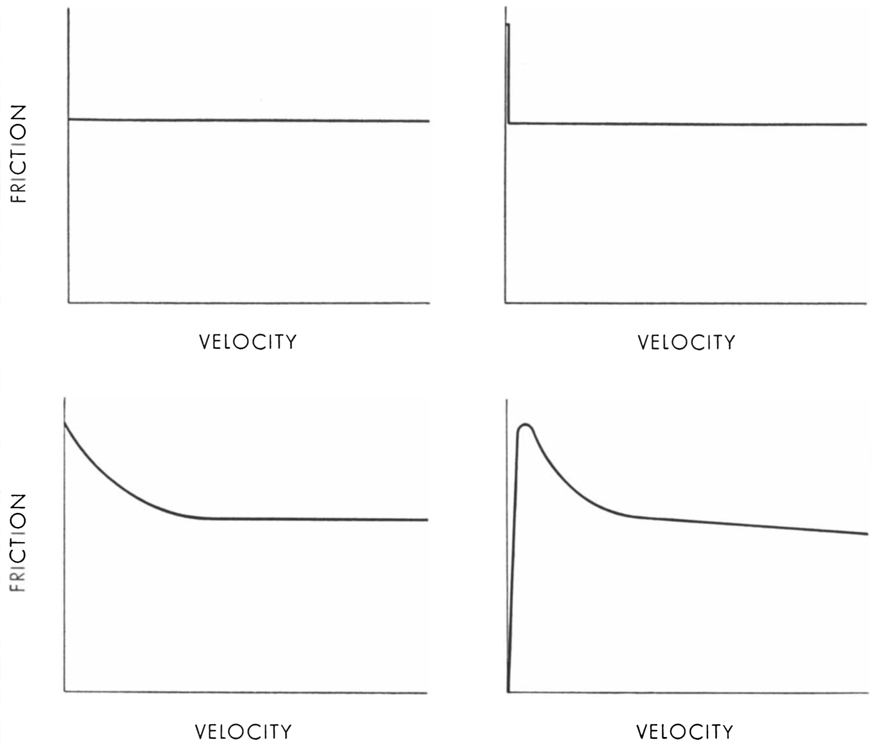
At the point *B* on the scale, halfway between points *A* and *C*, the pull of the spring is equal to the kinetic coefficient of friction. If the static coefficient were the same as the kinetic, the block would be dragged to this point and then stay there, sliding on the moving slab beneath it. As it is, the block oscillates about this position, sticking and slipping by turns. The situation is complicated by the fact that during motion the friction coefficient varies with changes in the sliding velocity, but whether stick-slip may occur can be determined in any given situation simply from the direction in which this relation is changing [*see chart at lower right on page 112*].

What does all this have to do with machinery? Few mechanisms in common use contain sliding surfaces attached to springs. The answer is that whenever solid bodies are pressed together, there is some elastic displacement or deformation of the material, resulting in an effect like the operation of the spring in the foregoing laboratory demonstration.

Common examples of stick-slip are the creaking of doors, the chattering of window sashes, the violent shuddering



METAL SURFACES cut by a machine tool are enlarged. At top is aluminum with the smooth finish of steady cutting. At bottom is titanium with a poor finish due to stick-slip.



EVOLUTION OF THE FRICTION CONCEPT is illustrated. In the late 18th century it was thought that the coefficient of friction remained constant as the relative velocity of the sliding substances was increased (*upper left*). In the early 19th century it was postulated that there were two kinds of friction: static and kinetic (*upper right*). Friction was greatest when two substances were moved from a state of rest, and fell off immediately when they began to slide. Around 1940 it was shown that friction fell off gradually with the increase of velocity (*lower left*). Today it is known that friction first increases with velocity and then falls off (*lower right*). When the changing relationship between friction and velocity has the slope to the left of the peak in this curve, substances slide steadily. When it has the form of the steeper part of the slope to the right of the peak, stick-slip occurs.

of drawbridges, the squeaking of bicycle wheels and the squealing of automobile tires. Stick-slip has its uses. Without it a violinist could produce no music, and he takes good care to promote it by rosining his bow. But in most situations stick-slip is a nuisance or worse. A tool cutting metal should slide smoothly into the material; when its slide is interrupted by stick-slip the cut will be rough and uneven [*see photographs on page 110*]. In the driving mechanism of a phonograph turntable stick-slip would ruin the sound. And during World War II the problem of stick-slip in one delicate situation was a matter of life and death. The turning of a submarine's propeller shaft produces stick-slip noise which can be detected with sonic listening gear. Since the war the Office of Naval Research has sponsored research on stick-slip at the Massachusetts Institute of Technology.

Friction, most investigators now agree, arises from the adhesion of molecules in the surfaces in contact with each other. The bond between the surfaces may be so strong at some points that tiny fragments are torn off one and stick to the other. Experiments with radioactive tracer material have proved this. If the end of a radioactive rod is rubbed along a flat surface, small particles are transferred and make the surface radioactive. This is an excellent experiment for showing the stick-slip phenomenon. A piece of photographic film is laid on the surface that has been rubbed with the rod. After it has been exposed for several hours to the radioactive track left by the rod, the film is developed. The image of the track turns out to be not a continuous line but a series of spots [*see photograph on page 118*]. The sliding rod end stuck and slipped, leaving considerable material where it stuck and very little where it slipped. Exactly the same thing happens when you rub a piece of chalk, tilted in the direction of motion, over a blackboard: you will get a stuttering line of dots.

In any adhesive process the bond becomes stronger the longer it is left undisturbed. This is why the static coefficient of friction increases with time of

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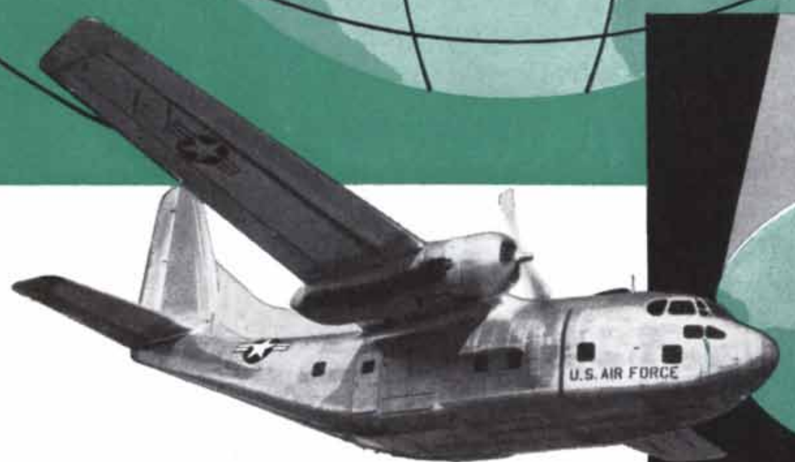

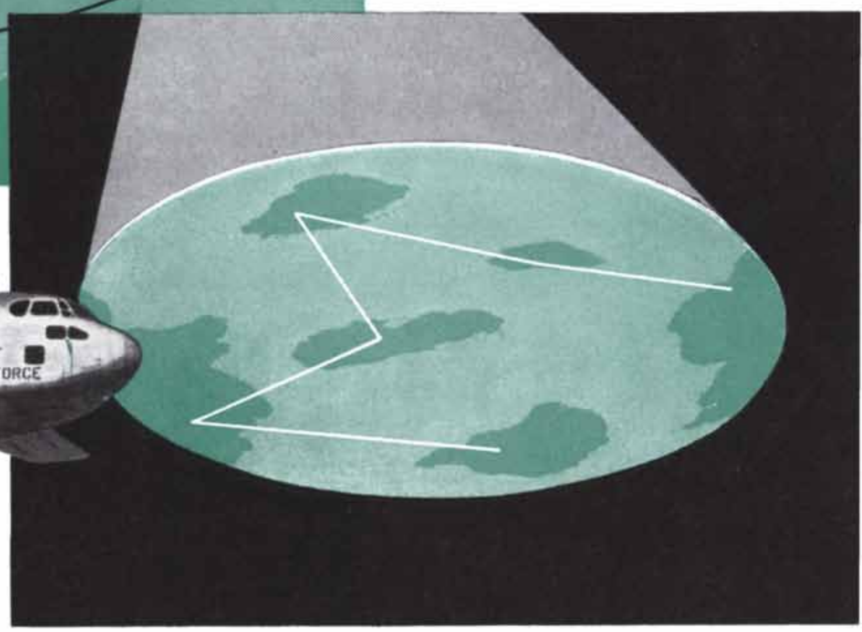

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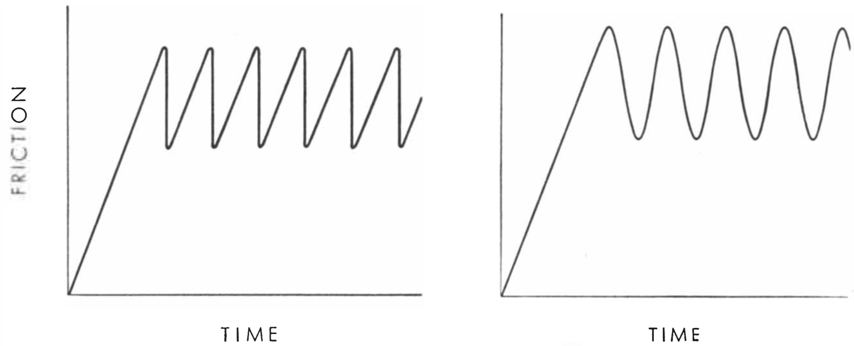


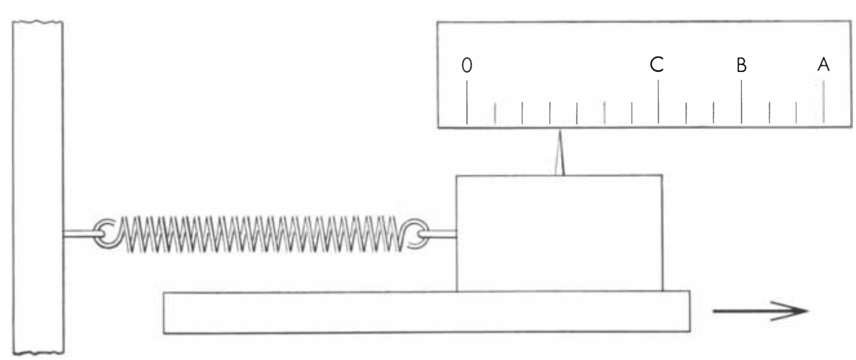
STICK-SLIP at low speed traces the curve at left. The sloping sections of the curve are stick; the vertical sections, slip. At high speed stick-slip traces the sinusoidal curve at right.

contact. In the case of sliding surfaces, the period of contact between points on the two surfaces is, of course, longer when the surfaces slide slowly than when they move rapidly. Consequently if the slide of one surface over another slows down, friction increases. This is the situation that favors stick-slip. However, laboratory tests have developed the unexpected finding that at extremely slow speeds the situation is reversed: as friction increases the sliding velocity also increases. The most plausible explanation seems to lie in the phenomenon called creep. All materials slowly change shape ("creep") even under moderate forces. An increase in force will increase the rate of creep. Thus in the case of surfaces sliding very slowly over each other, an increase in frictional force may produce a perceptible acceleration of the slide in the form of creep of one surface past the other. The limit of speed attained by the creep mechanism varies with the material, because soft materials creep faster than hard ones. The creep of steel is so slight that it cannot be observed. Lead can be made to slide by creep at speeds up to a millionth of a centimeter per second (about one foot per year); soap up to 10 centimeters per second.

These considerations present us with the paradoxical conclusion that there is really no such thing as a static coefficient of friction for most materials. Any frictional force applied to them will produce some creep, *i.e.*, motion.

Studies of sliding at very low speeds are important because they yield systematic information on friction-velocity relations which will enable designers of machines to select materials that will be immune from stick-slip over the range of speeds at which the mechanism is to operate. We also need a great deal more data on the friction coefficients of metals. It seems odd that in this age of metals, tables of coefficients listed in handbooks still have little to say about metals and apply largely to various woods, leather and stones—engineering materials of long ago.

Three main methods are available for curing stick-slip where it is not wanted. Firstly, we can alter the sliding speed. Sometimes this means slowing



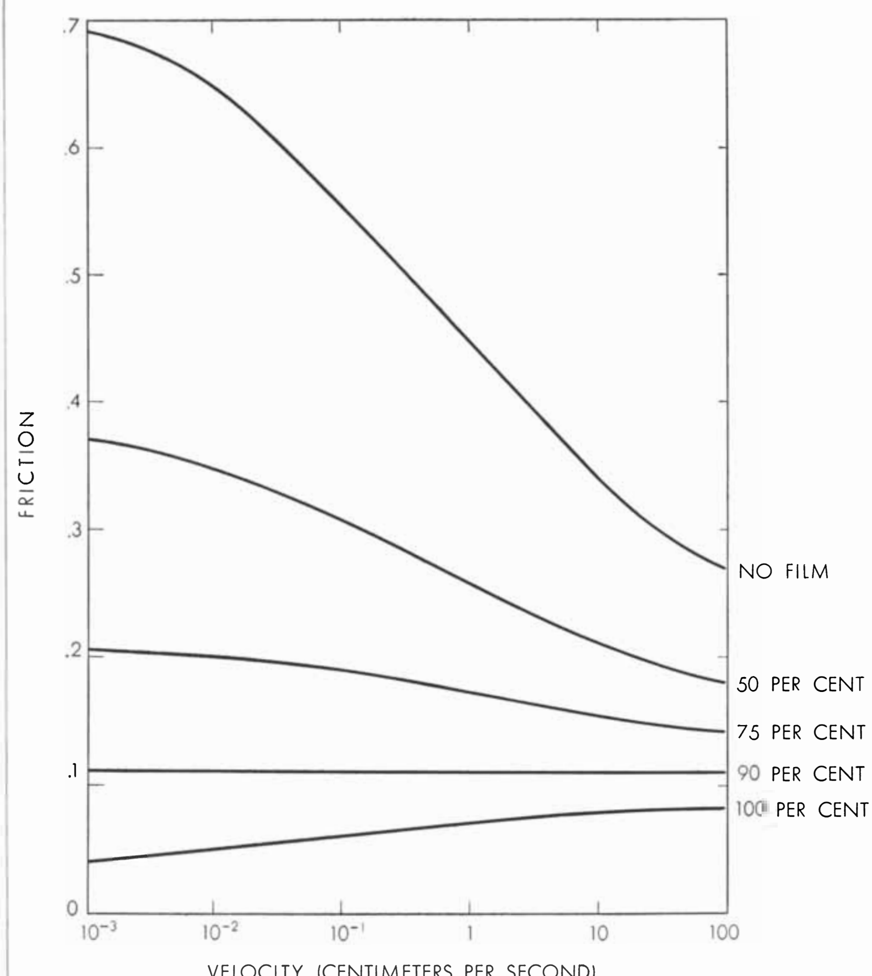
EXPERIMENTAL APPARATUS is used to show the principle of stick-slip. A block is attached to a spring. The slab on which the block rests is moved (*arrow*). If the static coefficient of friction were the same as the kinetic coefficient of friction, the block would simply move with the slab from O to B and stay there. Because the static coefficient is greater than the kinetic, the block moves with the slab to A and then slips back to C. If the movement of the slab were continued at the same speed, the block would oscillate between A and C.

down, in other cases speeding up. For example, a car's tires squeal if it rounds a corner rapidly but not if the turn is slow; on the other hand, a door that creaks when opened slowly may be silent when swung rapidly. Secondly, we may reduce the stored energy (*e.g.*, in the spring) whose intermittent release is responsible for stick-slip. Stiffening the spring will accomplish this end; similarly, stiffening a toolholder will make the tool cut more smoothly. Or we may damp the stored energy by immersing some part of the vibrating system in a bath of viscous oil.

The third and most common method is to lubricate the sliding surfaces. A lubricant forms a soft film which has far less frictional resistance than a metal's surface. The problem here is to maintain the film over the whole interface. As the surfaces slide, the lubricant is gradually worn off, so that parts of the metal surfaces come into contact with each other. So long as the lubricant coverage is 90 per cent or better, stick-slip cannot occur. But when coverage has fallen to 75 per cent, stick-slip becomes very possible [*see chart below*]. At this stage its squeaky protest is a boon, for it serves as a warning that the lubricant must be replenished. The quality of the lubricant is important; some poor lubricants never give even 90 per cent coverage, no matter how much is applied.

External factors, such as humidity, also may play a part. Squeaks in an automobile are apt to be silenced on a wet day—and, perversely, almost invariably when the car is taken to a garage to have the squeaks located and removed. Demonstrations of stick-slip during public lectures are likewise hazardous undertakings.

Friction in a machine brings a train of unhappy events. The sliding surfaces



LUBRICATED SURFACES may be subject to stick-slip. This chart represents one piece of steel slid over another with a film of lubricant between them. When the lubricant is first applied, it covers 100 per cent of the area between the two surfaces. This area is steadily reduced as the surfaces are rubbed together. When 90 per cent of the film remains, the curve is still almost horizontal and no stick-slip occurs. When only 75 per cent remains, the slope of curve is down (*see curve at lower right on page 112*) and stick-slip can begin.

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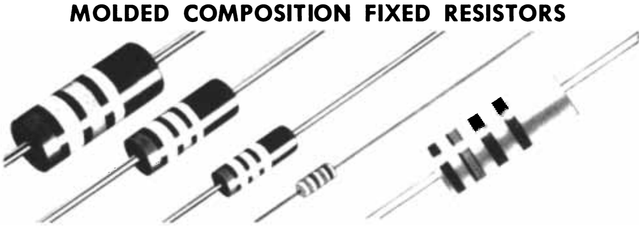

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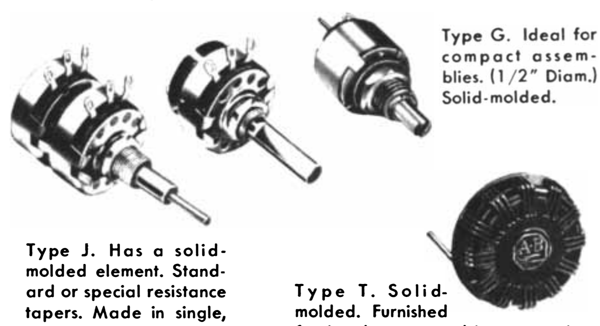

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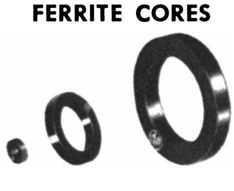

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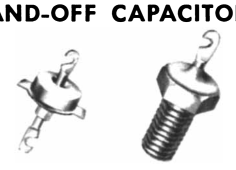

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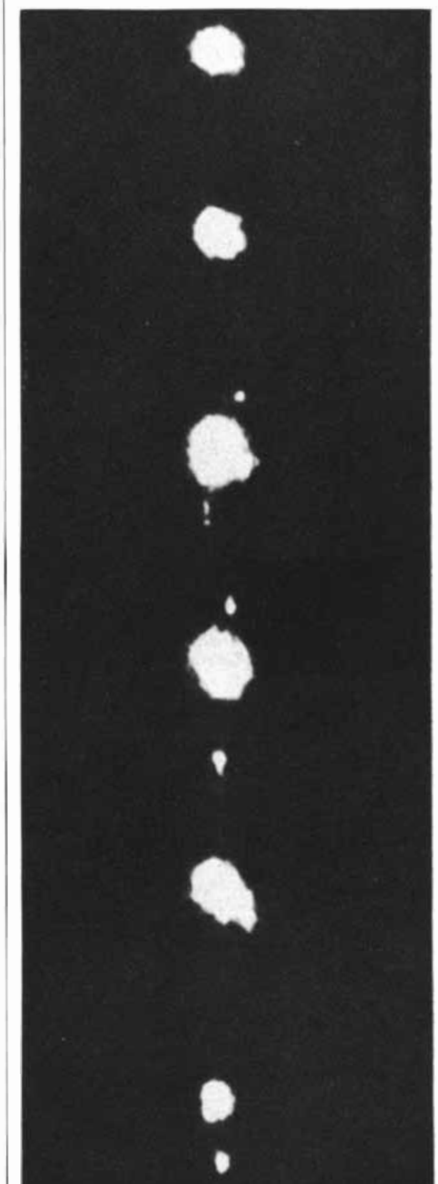
QUALITY

are scarred; the loose particles worn off them act as abrasives and produce more wear; the increasing friction generates heat and robs the machine's mechanical energy. Expensive systems are sometimes installed to warn when more lubricant is needed. But stick-slip itself supplies its own admonitory voice, without which our machine age would soon grind to a shuddering breakdown. It performs the warning function automatically, cheaply and effectively.



RADIOAUTOGRAPH shows stick-slip between two pieces of copper. One piece had been made artificially radioactive in a nuclear reactor. When it was slid over the other piece, some of it was transferred. When the second piece was placed in contact with a sheet of photographic film, the radioactive copper was made visible. Most of the transfer had occurred at the "stick." Only a few fragments were transferred in "slip."

HEART SOUNDS

For more than a century physicians have listened to the slapping of the valves in the heart with the stethoscope. Now these sounds can be subjected to refined analysis with modern electronic gear

by Victor A. McKusick

I have been able to hear very plainly the beating of a Man's Heart. . . . Who knows, I say, but that it may be possible to discover the Motions of the Internal Parts of Bodies . . . by the sound they make, that one may discover the Works performed in the several Offices and Shops of a Man's Body, and thereby discover what Instrument or Engine is out of order.

Not many prophecies in the history of science have been more interestingly fulfilled than this entertaining speculation by Robert Hooke, the versatile 17th-century experimental philosopher [see "Robert Hooke," by E. N. daC. Andrade; SCIENTIFIC AMERICAN, December, 1954]. He was one of the first to take note of the sounds generated by the human heart, but formal study of them did not begin until the 19th century. The distinction of initiating that study goes to a Paris physician named René Théophile Hyacinthe Laënnec, who is immortalized as the inventor of the stethoscope.

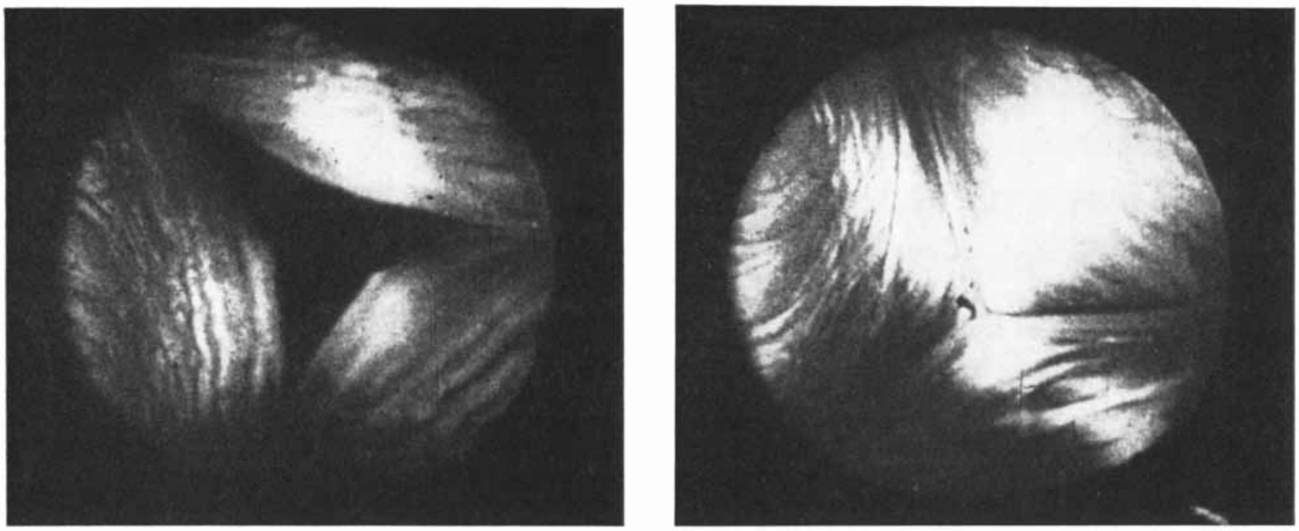
As other physicians no doubt had done before him, Laënnec made a practice of listening to the heart by applying his ear to the front of the chest. He was constrained to observe about the procedure: "As inconvenient for the physician as for the patient, distaste alone renders it almost impracticable in the hospital; it cannot even be proposed to most women and in most of these the volume of the breasts is a physical obstacle to its use." Laënnec's account of the invention of the stethoscope is probably the most famous passage in all medical literature: "I was consulted in 1816 by a young lady who presented the general symptoms of heart disease but in whom palpation and percussion gave little information on account of the patient's obesity. Her age and sex forbade direct examination. Then I recalled a well-known acoustic fact: that if the ear be applied to one end of a timber, it is easy to hear a pin's scratching at the other end. I conceived the possibility of making use of this property of matter in the case at hand. I took a quire of paper, rolled it very tight and applied one end of the roll to the precordial region. Then leaning my ear to the other end, I was pleasantly surprised to hear the beating of the heart much more clearly than if I had applied my ear directly to the chest."

Laënnec was a true son of the Romantic Age. His valuable invention, his battles with conservative contemporaries, the romance of his life and his premature death (in 1825) from pulmonary tuberculosis captivated the public imagination. As recently as 1949 a biographical film, *Docteur Laënnec*, was a hit feature in Paris theaters. Rudyard Kipling's slightly anachronistic short story about him, *Marklake Witches*, has Laënnec captured by the British in the Napoleonic Wars and billeted in a rural English village. One day the heroine comes upon Laënnec and Jerry, the local medico, "playing with toy trumpets. They were not real trumpets because Jerry . . . put his trumpet against René's collar and listened while René breathed and coughed. Said Jerry: ''Tis wonderfully like hearing a man's soul whispering in his inwards; but unless I've a buzzin' in my ears, you make about the same kind o' noise as old Goffer Marklin—but not quite so loud as young Cooper. It sounds like the breakers in a reef—a long way off. Comprenny?' 'Perfectly,' answered René. He knew the significance of these sounds in his chest, and in his soul he said, 'I drive on the breakers. But before I strike, I shall save hundreds, thousands, millions perhaps, by my little trumpets.'"

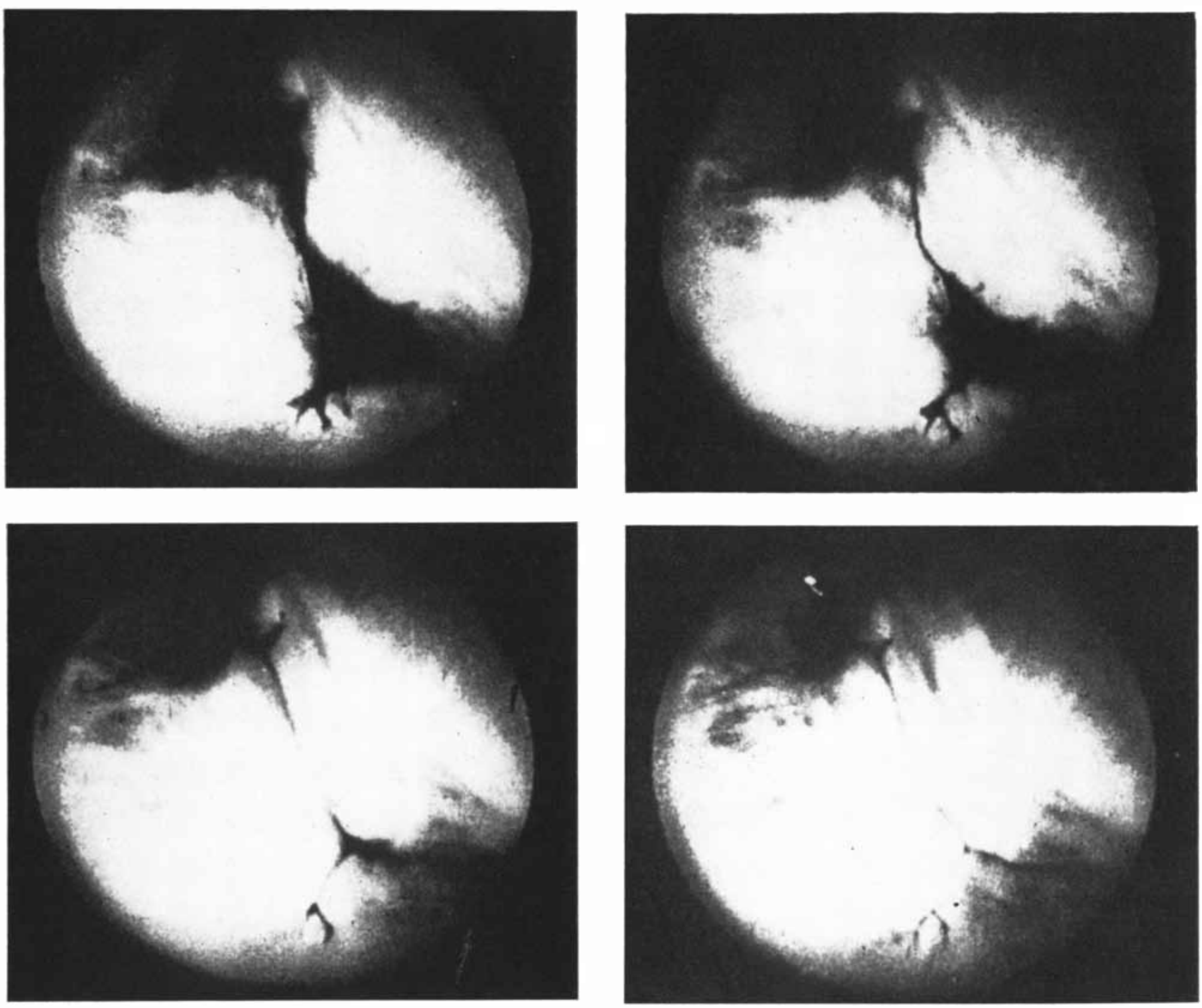
Laënnec's little trumpet was simply a wooden cylinder about 10 inches long, through which he listened with one ear. The refinements came much later—flexible tubing, two snugly fitting earpieces, a flat chest piece with a stiff diaphragm to filter the sound and bring out the high-frequency components. Understanding of the heart sounds also came later. Laënnec himself misinterpreted them: his main interest was the sounds of breathing and lung disease.

The normal heart sounds, as we now know, come from the closing of valves—first the valves between the auricles and the ventricles, then the valves between the ventricles and the great arteries. In 1835 a commission was appointed by the British Association for the Advancement of Science to study the origin of the "first" and "second" sounds. The American Medical Association awarded prizes for essays on the subject. Interest in normal and abnormal cardiovascular sounds grew rapidly. A writer in the latter part of the 19th century said of a typical French enthusiast: "Bruits were to him sweet music; he listened to them in the chest, surprised them in the back, pursued them into the neck and even into the thigh." The French school enriched the medical literature with onomatopoetic and picturesque terminology—*bruit de galop* (a heart rhythm with a galloping cadence), *bruit de scie* (murmurs like wood-sawing), *fou-ta-ta-rou* (a sign of obstruction of the valve between the left auricle and left ventricle) and so on.

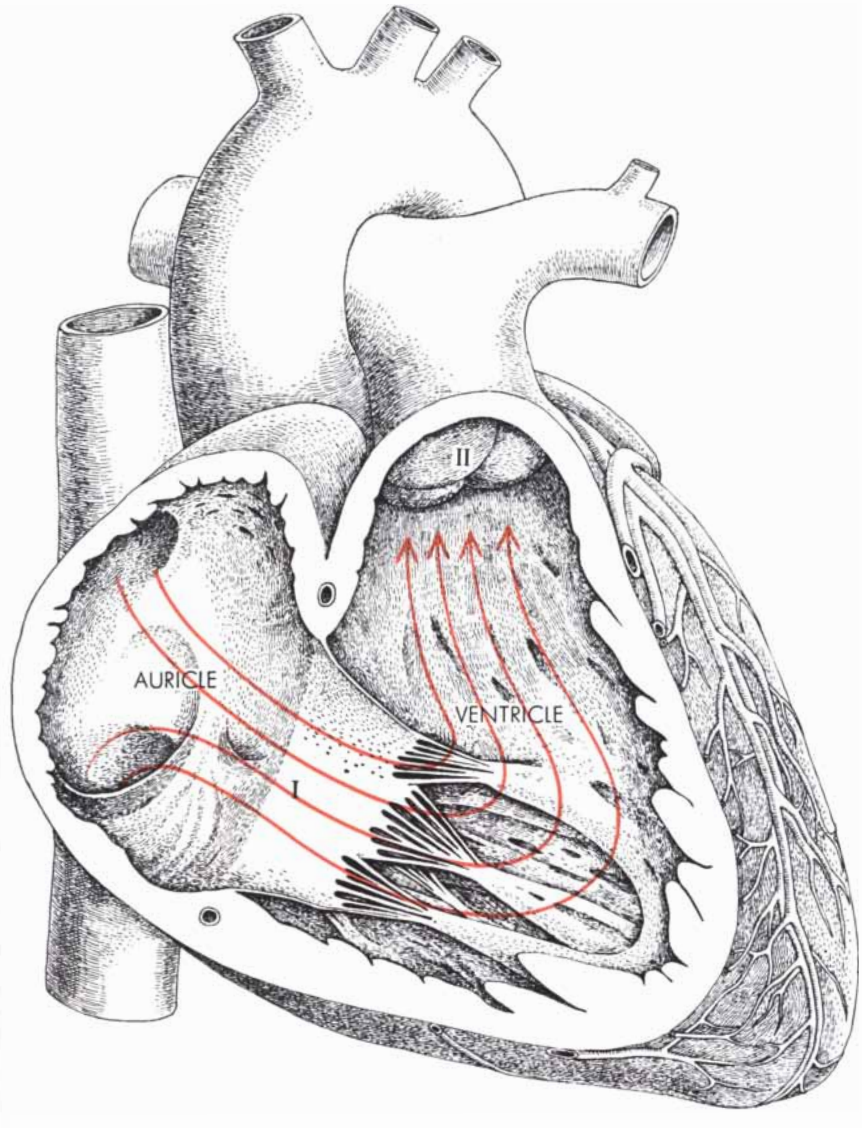
About 1854 the French veterinarian Auguste Chauveau began an attempt to correlate the sounds with mechanical events within the heart. He recorded the



PULMONARY VALVE, which lies between the right ventricle and the pulmonary artery, is photographed from the arterial side in an isolated but beating beef heart. The photographs are successive frames in a sequence made at 24 frames per second. At left the valve is partly closed; at right it is closed. The closing of the pulmonary and aortic valves causes the second of the two main heart sounds.



RIGHT AURICULOVENTRICULAR VALVE, which lies between the right auricle and the right ventricle, is photographed from the auricular side in the same beef heart. The photographs are again successive frames in a sequence made at 24 frames per second, and again show the closing of the valve. The closing of the two auriculoventricular valves causes the first of the heart sounds.

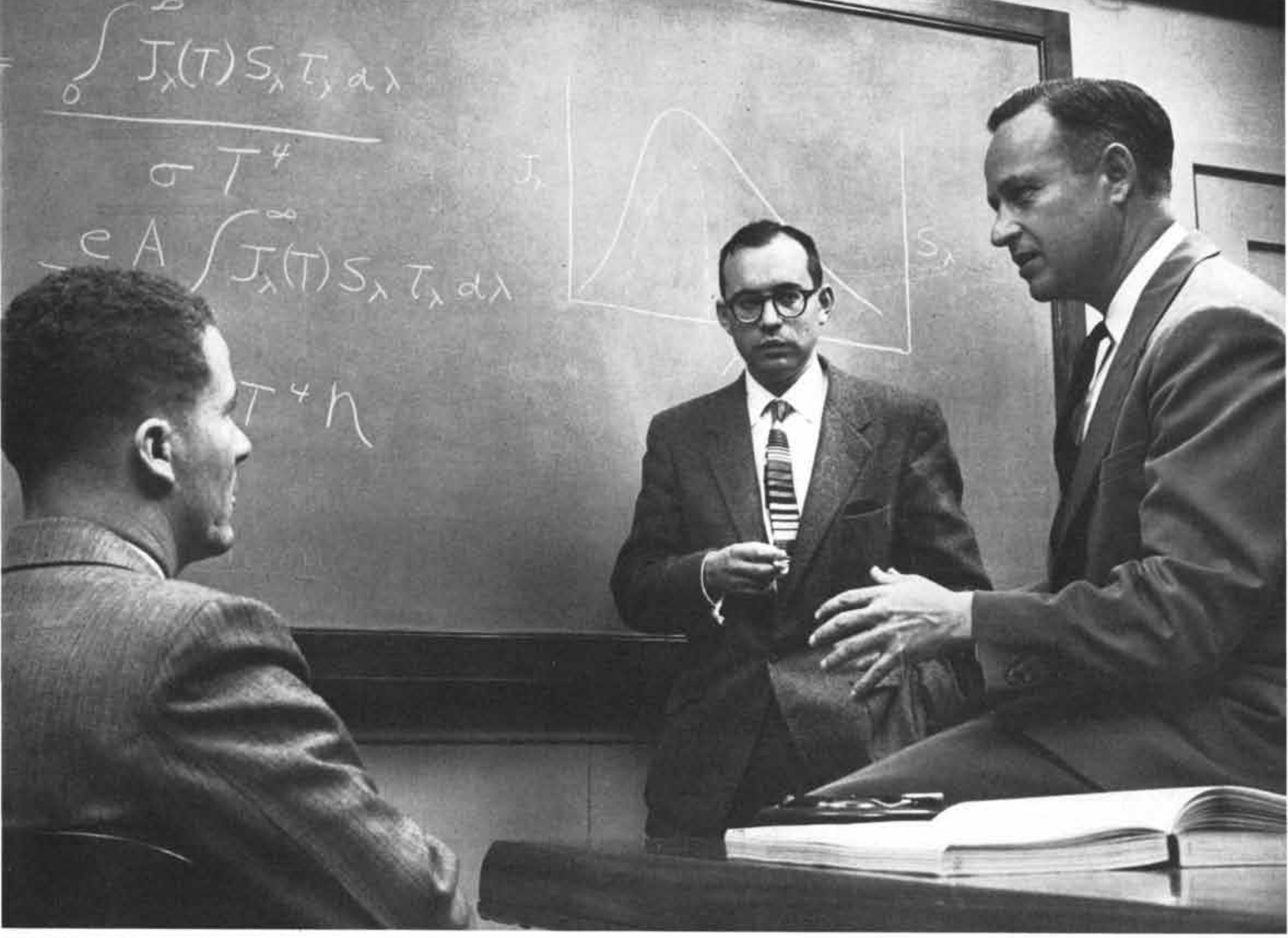


RIGHT AURICLE AND RIGHT VENTRICLE are shown in this cutaway view of the normal human heart. The auricle is filled through two openings by the inferior vena cava (*below the auricle*) and the superior vena cava (*above the left side of the auricle*). Here the ventricle is relaxed. The auriculoventricular valve (I) is open, the pulmonary valve (II) is closed, and blood flows from the auricle to the ventricle. The tendon-like cords at bottom center moor the edges of the auriculoventricular valve. When the ventricle contracts, the auriculoventricular valve is closed, the pulmonary valve is opened, and blood flows through the pulmonary artery into the lungs. The big arched vessel at the top is the aorta.

rise and fall of blood pressure inside the heart of an animal by means of catheters inserted through the veins, at the same time listening to the heart sounds. Visitors to his laboratory at Lyon reported seeing a horse munching hay peacefully outside the window of the laboratory while an instrument inside, via tubes from its body, was recording the curves of pressures from the interior of its heart!

In their enthusiasm physicians overextended themselves and attached grave significance to all unusual variations in heart sounds—whose meaning they were actually in no position to interpret. Near the end of the century Sir James MacKenzie in effect brought an end (in the English-speaking world, at least) to the feverish study of heart sounds by deflating their medical importance. He insisted that the sounds were deceptive, and that disease of the heart muscle was a problem of greater concern than disorders of the valves.

In recent decades there has been a reawakening of interest in the subject, partly because new methods of analyzing heart sounds have become available and partly because surgeons are now able to repair defects of the valves. Details of cardiovascular sound which pre-



Dr. Lewis Larmore (right) discusses fundamental problems of radiation transfer in infrared detection with Dr. T. Teichmann (center) and Experimental Physicist Freeman Hall.

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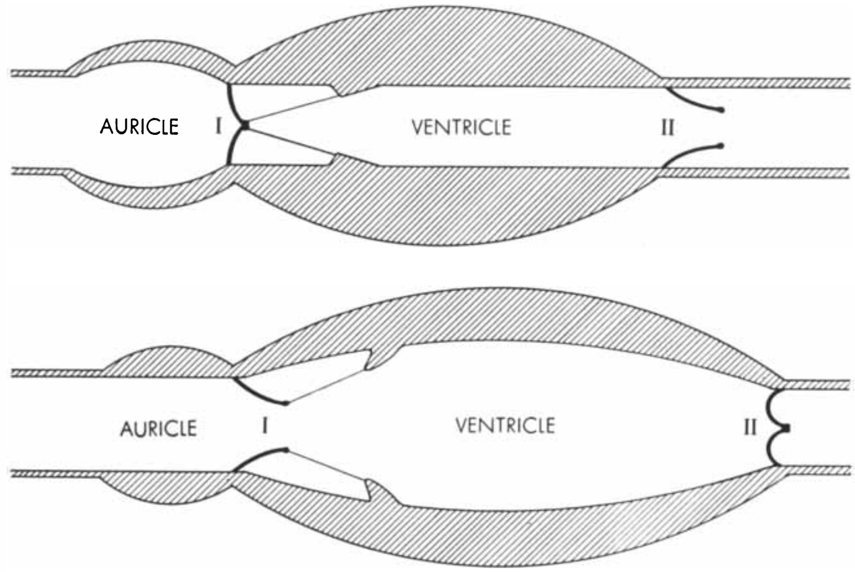
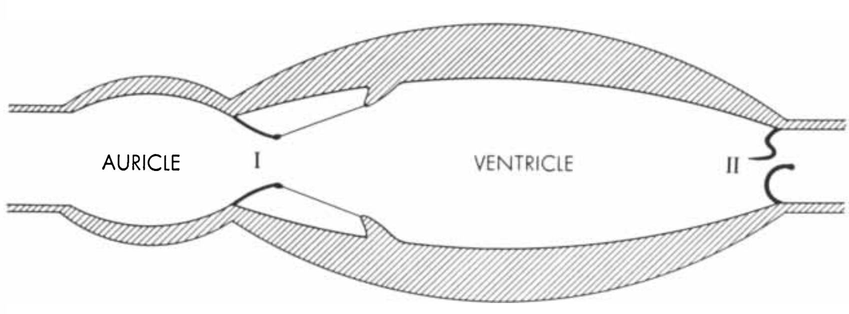


AURICLE AND VENTRICLE are depicted in diagrammatic form. At the top the ventricle contracts; at the bottom it relaxes. At left is the auriculoventricular valve, two of which cause the first heart sound; at right is the arterial valve, two of which cause the second heart sound. The cords that moor the edges of the auriculoventricular valve are to its right.

viously would have been considered useless minutiae are now important guides for the surgeon's hand.

The heart is a pair of pumps operating in parallel. The right ventricle pumps blood to the lungs; the left ventricle pumps oxygenated blood into the aorta, from which it is distributed to the rest of the body. Each ventricle is supplied from an auricle, respectively the right and left, which serves as a reservoir. The ventricle first relaxes and receives blood from its auricle through the opened valve between them. When the ventricle has been filled, it contracts and the valve bangs shut—the first heart sound. Both sides of the heart operate simultaneously, so that the banging of the right and left valves together usually make one sound. Each ventricle now propels blood through an opened valve into a great artery—the right into the pulmonary artery to the lungs, the left into the aorta. When the ventricles have ejected their loads, these valves snap shut—the second heart sound. The left valve (to the aorta) often closes slightly before the right, and the two components of the sound can be distinguished.

The architecture of the heart valves is marvelously suited for their function of preventing backflow of the blood with a minimum of obstruction to the forward flow. Leonardo da Vinci, one of the first to study the mechanics of the heart, was fascinated by the valves' design and sketched their details. Each valve is made up of three hinged leaflets, or cusps, except for the valve between the left auricle and ventricle, which has only two leaflets and is called mitral because of its resemblance to the two-peaked ecclesiastical miter. The valves between the heart chambers operate quite differently, however, from those opening to the arteries. The auricle-ventricle openings are larger, permitting the necessary volume of flow under low pressure from the auricles. To prevent these valves from being pushed back into the auricles



RETROVERTED AORTIC CUSP is depicted at upper right in the same representation. When the ventricle relaxes, the blood leaks back past this cusp and makes it vibrate musically.

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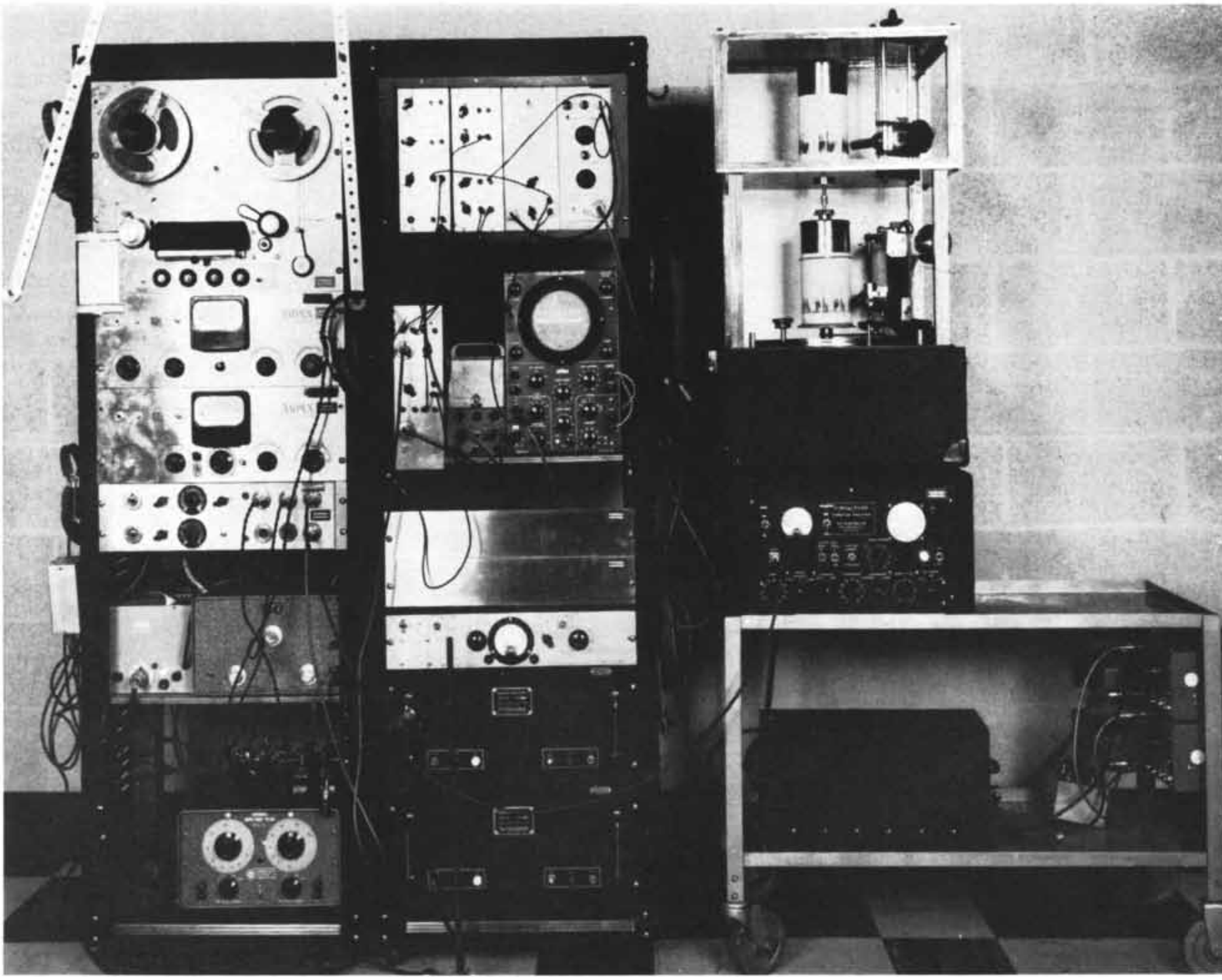


SOUND SPECTROGRAPH, developed to separate the constituent frequencies of speech in visible form, is arrayed to analyze heart sounds. The sound spectrum is recorded photographically on the drum at upper right and by direct writing on the drum below it.

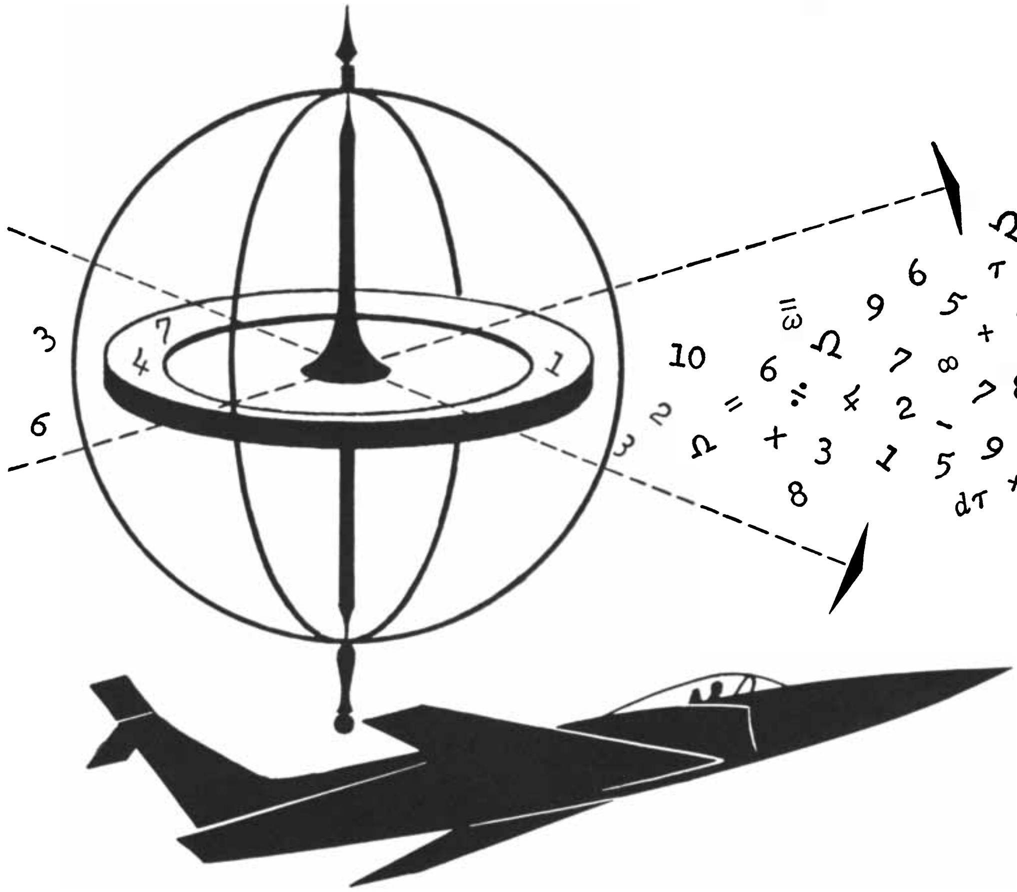
when pressure builds up in the ventricles, there are tendon-like cords from the walls of the ventricles which are attached to the edges of the valves and act as guy wires to hold them closed. At the base of each guy wire is an extension of the ventricular muscle that contracts when the rest of the ventricle contracts and pulls the guy wire tight. The noted British heart surgeon Sir Russell Brock has compared the beautiful structure of this system of cords to the fan tracery of an English cathedral.

The opening (almost noiseless) and closing of each valve is mainly the result of pressure differences on the valve's opposite sides. When the ventricle relaxes, after ejecting its blood into the artery, the valve from its auricle opens. As the ventricle is filled and its walls contract to eject blood again, the build-up of pressure within it closes the auricle valve. The closing is facilitated by a contraction of the muscular valve seat, which narrows the opening that the valve leaflets must cover. The built-up pressure in the ventricle, having shut this valve to prevent backflow, opens the valve to the artery (aorta or pulmonary artery) and pumps blood forward into that vessel.

The ventricles eject blood into the arteries under considerably higher pressure than they receive it from the auricles; consequently the valved openings to the arteries need not be and are not as large as those between the heart chambers. The arterial valves require no guy wires. They are closed simply by the pressure due to the resistance to stretching of the elastic artery walls when the arteries are filled with blood from the ventricles. The closing of these valves is a more rapid process than closure of those between the heart chambers; this may account for the fact that the second heart sound is often shorter and "snappier" than the first.

Heart murmurs usually arise from defective operations of the valves—either a backflow due to leaks (often called "regurgitation") or an obstruction of forward flow (stenosis). For the peace of mind of readers who may have murmurs, I must point out at once that many circumstances other than valvular leaks or obstructions may produce turbulent blood flow, and resultant murmurs, in the cardiovascular system. Such murmurs are common and often of no significance.

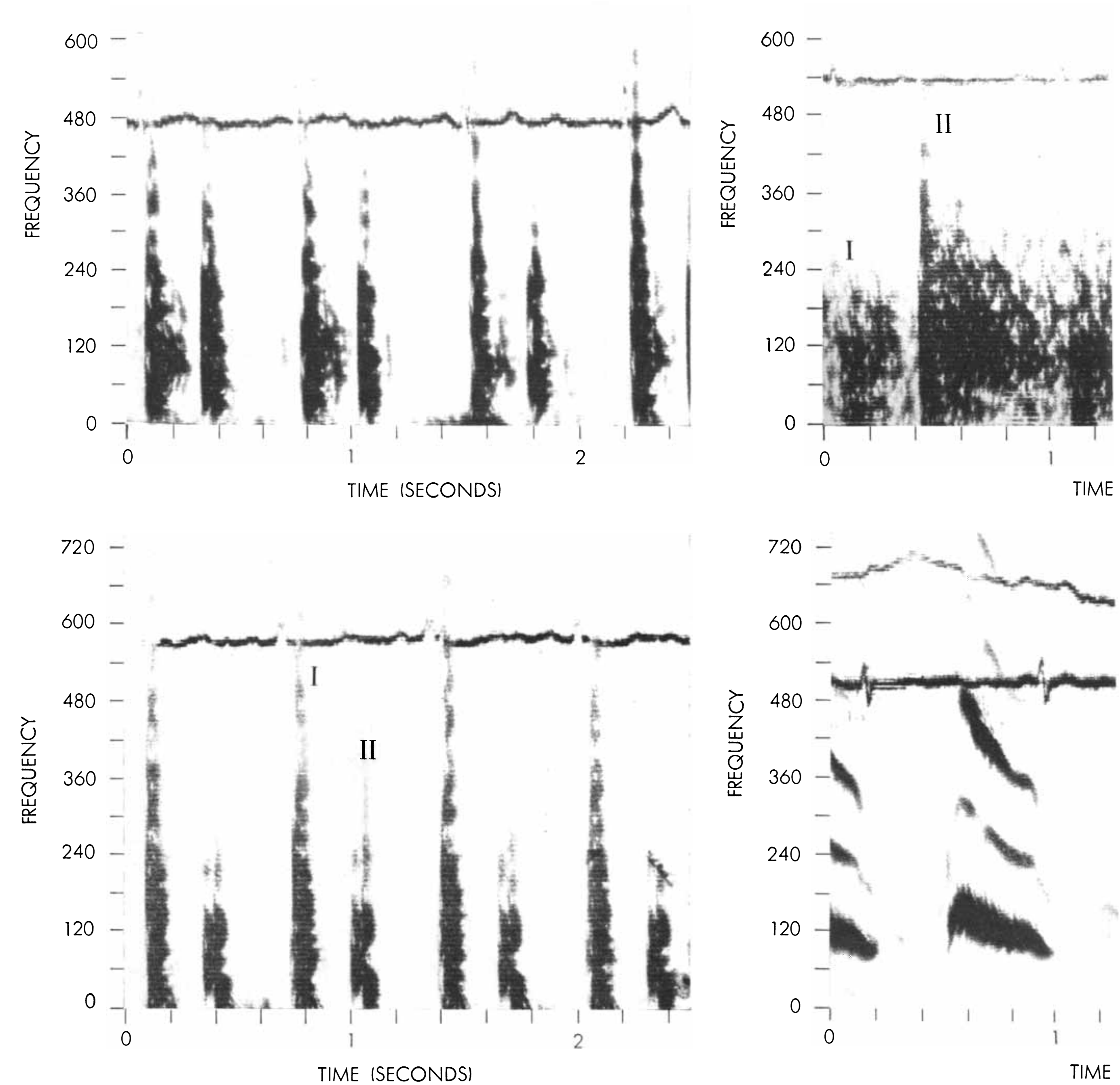
Detailed analysis of the heart sounds, as well as their association with other records of the cardiovascular system's behavior, was first made feasible by Willem Einthoven's invention of the phonocardiograph in 1893. This device translates the heart sounds into a visual recording; it is not to be confused with the electrocardiograph, also invented by Einthoven, which records electrical waves that accompany the heartbeat. A phonocardiogram is a curve showing the peaks and silences of the heart sound cycle. The Einthoven device has been used mainly for timing murmurs and normal valve sounds in relation to other



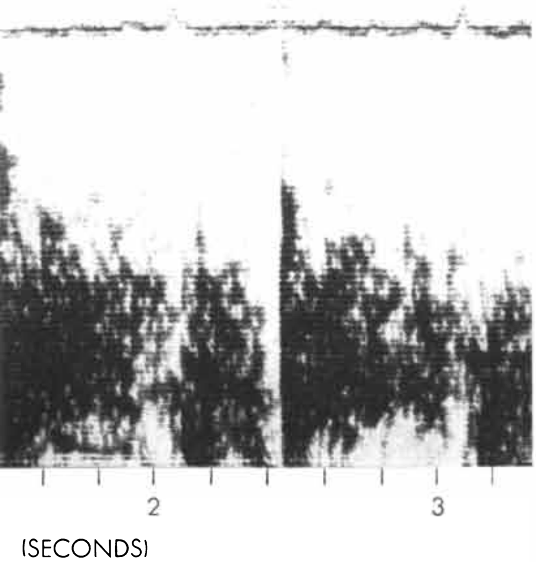
events in the cycle of the heart's activity.

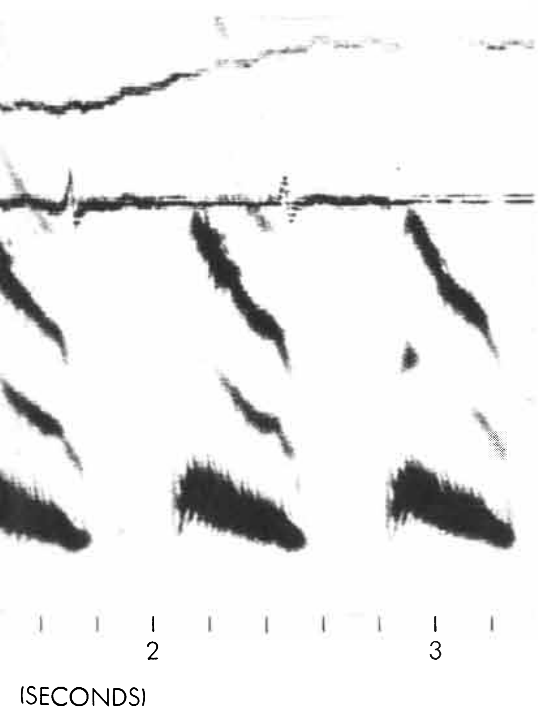
Within the last few years a new instrument has permitted a more refined analysis of heart sounds. It is the "visible speech" machine, developed for quite another purpose by Ralph K. Potter and his colleagues at the Bell Telephone Laboratories. The machine displays the spectrum of component frequencies in speech sounds [see "Ears for Computers," by Edward E. David, Jr.; SCIENTIFIC AMERICAN, February, 1955]. Reading these spectral patterns, one can recognize differences in the speech of individuals and minor differences in dialects. This finding, and the fact that sound analyzers have been useful in diagnosing troubles in complex machines such as airplane engines, encouraged the thought that the instrument might be employed to read the sounds of the heart—just as the imagination of Robert Hooke proposed 250 years ago.

A small microphone placed on the subject's chest picks up the sound vibrations of the heart and translates them into an electrical form. The oscillations are



SPECTROGRAMS of various heart sounds are displayed on these two pages. The vertical dimension of each spectrogram is frequency in cycles per second; the horizontal dimension is timed in seconds. At upper left is the spectrogram of a healthy teen-age subject. Each pair of vertical markings represents the first (I) and second (II) heart sounds. The horizontal trace at the top of the spectrogram is a simultaneous record of the subject's electrocardiogram. At upper right is the spectrogram of a subject suffering from partial destruction of the aortic valve. The second sound is followed by a prolonged murmur of blood regurgitating through the valve. At lower left is the spectrogram of a subject with a congenital heart defect in which the right ventricle must pump much more blood than the left. The emptying of the right ventricle and the closing of the pulmonary valve is thus delayed; the second sound is split. At lower then amplified and passed through a bank of filters which separates the component frequencies. The energy, or loudness, at each frequency is now translated into light by means of tiny light bulbs actuated by the signals. A bank of lights plays on a moving photographic film, producing a tracing which shows both the rhythm of the heart





right is the spectrogram of a subject with a retroverted aortic cusp (*see diagram on page 124*). This produces a musical sound which is vertically split into harmonics. The sound is so loud that the first and second sounds are lost. The line at top of this spectrogram is a record of the subject's breathing.

sounds and the spectral analysis of the sounds. While a record of the sounds is being made, one can make a simultaneous and parallel recording of the subject's pulse beat, breathing cycle, electrocardiogram and any other physiological phenomenon that can be translated into an electrical signal.

Pictures of the heart sounds of four subjects, with their electrocardiograms, are shown on the two preceding pages. Each sharp spike in the electrocardiogram represents an electrical discharge which triggers the contraction of the ventricular muscle. Immediately afterward comes sound I—the banging shut of the valves between the auricles and ventricles. While the ventricles are ejecting their content of blood into the arteries, the sound record of a normal subject is relatively quiet, showing only the sounds due to normal turbulence in the blood flow. Then comes sound II—the closure of the arterial valves.

It is noteworthy that the heart sounds are at low frequency. Most of the energy content is concentrated below 256 cycles—middle C of the musical scale. The normal tracing here, recording a teenager's heart, has components of higher frequency than most adult heart sounds: young people have "snappier" heart sounds than their elders. Notice further that the normal heart sounds are in fact noises, *i.e.*, their frequency content is diffusely distributed over a relatively wide span. Murmurs, on the other hand, are sometimes musical.

One type of musical murmur, whose mode of production is not unlike that of certain musical instruments, is illustrated by the last record on the preceding pages. In this subject the valve at the base of the aorta has a weakened cusp which turns back into the ventricle when the valve should be tightly closed. The leaking back of blood past the lip of the flappy cusp produces a long murmur, louder than the normal first and second sounds. To the ear this murmur sounds like the sawing of wood, the cry of a sea gull, the groan of the bull fiddle or the croak of a bullfrog, depending on the particular case.

The examples given illustrate the new approach that spectral phonocardiography has made possible in the study of heart sounds. Obviously, however, the stethoscope is in no danger of being supplanted. Anyone who had such a notion would quickly be disabused of it by a glance at the roomful of equipment necessary for this method of listening in on the heart.

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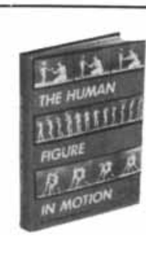

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BOOKS

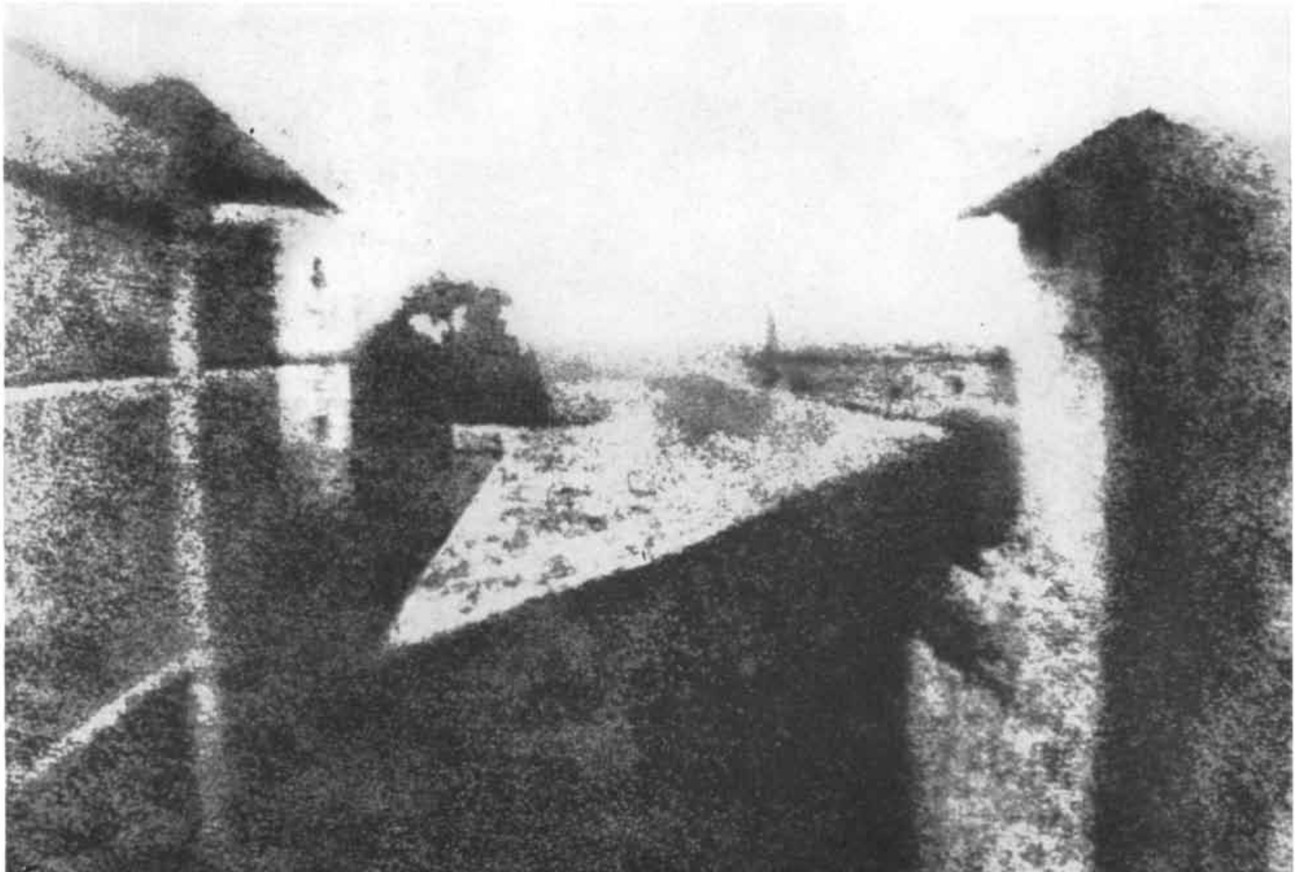
Photography: From its antecedents in the 11th century up to the 20th

by James R. Newman

THE HISTORY OF PHOTOGRAPHY, by Helmut and Alison Gernsheim. Oxford University Press ($16.50).

This elegantly tailored, richly illustrated volume surveys photography from the earliest use of the camera obscura up to 1914. It is more of a treatise than a popular account, but even a box-camera amateur—if, indeed, there are any box-camera users left—will enjoy dipping into the fact-laden text and examining the excellent photographs. The senior author comes well equipped to his task. Helmut Gernsheim is a photographer, a collector of old photographs and instruments, a student of early British photography and the author of several monographs on notable practitioners of the art, including Louis Daguerre, Roger Fenton (remembered for his pictures of the Crimean War), Julia Margaret Cameron (distinguished for her portraits) and the strange, gifted Oxford don, Lewis Carroll, who broke the monotony of his cloistered life by taking pictures of famous men and women and of little girls in the nude. Gernsheim's wife collaborated with him on the book as she did on some of these monographs.

The emphasis of their book is on the British contribution to photography, though they do not neglect important developments in other countries. They explain the scientific, technical, esthetic and social aspects of picturemaking. Apart from the interest of this material and the intriguing byways it opens for the reader, the survey fills a major gap in the history of photography, for until now British accomplishments in the field have received scant attention. In the 19th century Great Britain played a



The first photograph was made by Joseph Nicéphore Niepce, probably in 1826 leading part in the evolution of the camera, the chemistry of photography and the art of taking pictures. The British have long been fierce travelers, and they have relentlessly photographed the cities of Europe and the African jungles, the Alps and the pyramids, Egypt, Palestine, Syria and Turkey, India, China, Java and Japan. Many thousands of such pictures were taken before 1865 and form a record whose quality has never been surpassed.

The story of photography begins in the 11th century, when an Arabian scholar called Ibn Al-Haitham (better known by his Latin name Alhazen) invented the camera obscura—literally "dark room." If light enters a darkened room through a tiny hole in the wall, an inverted image of the view outside appears on the opposite wall. Alhazen suggested an effective use of this arrangement to capture the image of the sun at the time of a partial eclipse; the image, he said, would be crescent-shaped. He also discussed the effect of changing the size of the aperture. Most historians have overlooked Alhazen's description of the camera obscura, which is preserved in manuscript in the India Office Library in London. This may explain why the invention has been erroneously ascribed to various others, including Roger Bacon, Leon Battista Alberti and Leonardo da Vinci. The historical point is perhaps minor, but the invention itself is important, for it embodies the concept from which the photographic camera was derived.

For seven centuries men played with the camera obscura, were fascinated by it and improved it. Astronomers, physicists, painters, soldiers and travelers found various ways to turn it to serious use and pleasure. At first the camera lived up to its name and was a room; gradually it grew smaller. The 16th-century physician and mathematician Jerome Cardan appears to have been the earliest to suggest using a convex lens instead of a minute peephole for transmitting the light. Later a diaphragm was added to sharpen the image, and the camera became portable, being transferred to a sedan chair. Then it assumed form as a tent. Journeying through Austria in 1620, Sir Henry Wotton, diplomat, poet and pamphleteer, had a memorable encounter which he described in a letter to his friend, Sir Francis Bacon.

"Let me tell your Lordship a pretty thing which I saw coming down the Danuby, though more remarkable for the Application, than for the Theory. I lay a night at Lintz, the metropolis of the higher Austria. . . . There I found Keplar [*sic*], a man famous in the Sciences, as your Lordship knowes, to whom I purpose to convey from hence one of your Books, that he may see we have some of our own that can honour our

The first successful daguerreotype was made by Louis Jacques Mandé Daguerre in 1837

King, as well as he hath done with his *Harmanica*. In this mans study, I was much taken with the draught of a Landskip on a piece of paper, methoughts masterly done: Whereof enquiring the Author, he bewrayed with a smile it was himself, adding he had done it *non tanquam Pictor sed tanquam Mathematicus*. This set me on fire: at last he told me how. He hath a little black tent (of what stuffe is not much importing) which he can suddenly set up where he will in a field; . . . it is exactly close and dark save at one hole, about an inch and an half in the Diameter, to which he applies a long perspective-trunke [Kepler's telescope], with the convex glasse fitted to the said hole, and the concave taken out at the other end, which extendeth to about the middle of this erected Tent, through which the visible radiations of all the objects without are intromitted, falling upon a paper, which is accommodated to receive them; and so he traceth them with his Pen in their natural appearance, turning his little Tent round by degrees till he hath designed the whole aspect of the field. . . ."

Here obviously was a valuable instrument for topographers, but otherwise, as Sir Henry observed, "to make Landskips by it were illiberall: though surely no Painter can do them so precisely." Still, even painters could not afford to obstruct progress, and an 18th-century essayist on painting devoted a chapter to the camera and remarked that "the best modern painters among the Italians have availed themselves greatly of this contrivance."

Like Alice in Wonderland, the camera obscura kept shrinking. It diminished to a large box; then the box was cut down so that it could be carried under a cloak; later several boxes were nested and could be extended like a telescope. Robert Boyle constructed his version of a "portable darkened room," and Robert Hooke, never gladly left behind, made a "perspective box" to illustrate the laws of vision. Looking somewhat like a megaphone, it had a lens, a ball-and-socket handle and a set of diaphragms of different sizes to represent the expansion and contraction of the pupil of the eye. The versatility of this portable camera was extended by a reflex arrangement which combined a mirror that reflected the image right side up onto a piece of stretched oiled paper, with a hood to improve visibility.

By the 18th century the camera obscura had become a craze. It enraptured spectators and was discussed in medical treatises, novels and Goethe's writings. No one who traveled for pleasure would take a step without it. Cameras found lodgment in charming rococo tables and in the heads of walking sticks, in goblets and in hollow books. Tristram Shandy railed against historians who

The Cathedral of the Resurrection in the Kremlin was photographed by Roger Fenton in 1852 portrayed their subjects as in a camera drawing, where "you are sure to be represented in some of your most ridiculous attitudes."

And yet there was no photography. There were various ingenious contraptions for reducing, defining, projecting and dramatizing outside scenes. It was thrilling to see the sky, churches, valleys, mountains, human figures reflected by a mirror, in full color, onto a small, opaque glass screen. But the image, for all its lifelike beauty, was like a shadow, a momentary creature of light and circumstance, which vanished without a trace once the light faded.

The great objective was a method for trapping the image. That light left its mark had long been known: the ancients had observed that sunlight turns leaves green, that it bleaches many substances, from bones to togas. Some chemists had vague notions about a relation between silver salts and light, but the matter had not been explored. In 1727 came the first breakthrough. Johann Heinrick Schulze, a German professor of anatomy, was experimenting one bright day at an open window with nitric acid which happened to contain a little silver. He noticed that a part of the precipitate in his flask which was directly exposed to the light turned purple. At first he was uncertain as to the cause, but further experiments proved that silver was responsible for the change in color. In communicating his results to the Imperial Academy at Nürnberg he marked the paradox that light brings darkness.

The way was open to further progress. Jean Hellot found that a solution of silver nitrate could be used for invisible writing. His *"encre sympathetique"* (a boon to duplicitous wives and diplomats), when applied to paper, turned slate color in the sun. Giacomo Beccaria made the useful discovery that silver chloride was sensitive to light. The eminent Swedish chemist, Carl Scheele, observed that, after blackening, silver chloride became insoluble in ammonia; thus he discovered the first crude fixing agent. Scheele also learned that violet rays are chemically the most active, and other investigators, including the Geneva librarian Jean Senebier and the astronomer William Herschel, added considerably to the knowledge of the solar spectrum and the effect of different colored rays on silver chloride. On the basis of the facts established by the end of the 18th century, picturemaking was possible. But, as on other occasions in the history of science, the putting together of two and two was delayed.

The first to perform the addition, according to Gernsheim, was not a scientist but a writer of science fiction. Tiphaigne de la Roche, a forerunnner of Jules Verne, in 1760 made "a remarkable forecast of photography" in his fantasy *Giphantie*. He conceived of pictures being formed on a piece of canvas coated with "a subtle matter, very viscous and quick to harden and dry." This prophecy does not seem to me impressive: obviously de la Roche had no more idea of how to make a picture than Bishop Wilkins of how to fly to the moon. A far more helpful contribution came from the gifted Tom Wedgwood, son of the noted potter and lover of science, Josiah Wedgwood. Young Wedgwood had made the acquaintance of the chemist

Portrait of a young couple beside Niagara Falls was made around 1875

Humphry Davy while he was serving an apothecary's apprenticeship. Both, being fond of experimenting, attacked the problem of printing camera obscura images, Wedgwood on surfaces coated with silver nitrate and Davy on silver chloride. Both failed, though they would have succeeded if they had been more patient and exposed their "plates" longer. Wedgwood fell back on the simpler method of superposing objects—leaves, insect wings, paintings on glass—directly on sensitive paper or white leather moistened with silver nitrate. After exposure to light he obtained imprinted images of outlines of the objects, and more detailed figures in the case of the glass paintings. Davy, by similar experiments using a solar microscope, got enlarged images of microscopic objects. Unfortunately the outline images soon faded for lack of a fixative. Wedgwood and Davy knew about Scheele's discovery of the fixing properties of ammonia, but neither had the imagination to make use of this knowledge.

The decisive advance was made by a Frenchman, Joseph Nicéphore Niepce, the son of a King's Counselor. Joseph and his brother Claude, both of inventive turns of mind, had patented in 1807 an ingenious little steam engine which propelled a boat on the Saône and the Seine. Joseph turned to experiments with the camera obscura, and in 1816 he succeeded in projecting images on paper sensitized with silver chloride, using long exposures. He immediately tried to make a positive print from the negative—a procedure which no one else had even tried. However, this attempt failed, nor was he able to fix permanently the image on the negative.

For years he continued his researches without making notable progress. Then about 1826—the date is by no means certain—he made what Gernsheim calls the world's first photograph. On a small pewter plate (now in Gernsheim's collection) Niepce captured the view from an upper-story window of his home. A pigeon house, a pear tree with a patch of sky showing through the branches, a slanting barn roof, a bakehouse, a chimney—these compose the first permanently fixed image from nature. Gernsheim visited Niepce's home in 1952 and found that some of the features of the photograph could still be clearly seen.

Niepce's camera, manufactured for him by a firm of Paris opticians, was equipped with a meniscus prism (*i.e.*, of crescent-shaped section) which corrected the lateral transposition of the image. As in earlier successful experiments in photoengraving, he coated his pewter plate with "bitumen of Judea" (a kind of asphalt), which hardens in two or three hours under the influence of light. He washed away the soft unexposed portion with a solvent consisting of oil of lavender and white petroleum, and had an asphalt image which remained unalterable by light. The exposure for this classic shot was long—some eight hours. In the picture the sun "seems to be shining on both sides of the courtyard."

Niepce was so secretive about his process that he derived little benefit from it. On a trip to England in 1827 he got in touch with officials of the Royal Society. They were properly impressed with what he had accomplished, but be-

Alfred Stieglitz' famous photograph "The Terminal" was made in 1893 cause he was willing to discuss his invention only in general terms the Society could not take cognizance of it and no record of any kind appears in the Council minutes.

Meanwhile another Frenchman was performing experiments which were destined completely to overshadow Niepce's. Louis Jacques Mandé Daguerre had already gained a reputation from his "diorama"—a picture show with changing light effects which, "by its perfect illusion of reality," had thrown the whole of Paris into ecstasy. So lifelike were the pictures, painted by Daguerre's partner Charles Bouton on both sides of a transparent screen, that when a young son of King Louis-Philippe asked him at a command performance, "Papa, is the goat real?" the King is said to have replied, "I don't know, my boy, you will have to ask M. Daguerre himself."

But Daguerre sought an even higher level of fidelity. On hearing of Niepce's work, he wrote to him offering to collaborate. Niepce after a time succumbed to Daguerre's persistence, and in 1829 they became partners. It is uncertain whether they ever actually joined forces in experimenting—Niepce died in 1833 and his son Isidore took his place in the partnership—but Daguerre made remarkable progress on his own. In 1831 he discovered the light sensitivity of silver iodide, which he produced by exposing a silvered copper plate to iodine vapor. Still, the arrangement was not sensitive enough to yield an image. Then in 1835, quite by accident, he uncovered a fact of the first importance. The circumstances were strikingly similar to those which 60 years later were to lead to Henri Becquerel's discovery of radioactivity.

Daguerre had put into his cupboard an unsuccessfully exposed plate, intending to repolish and reuse it. On taking it out of the cupboard a few days later he was astounded to see the plate impressed with a picture. Immediately he exposed a few other of his silver iodide plates and put them back into the magic cupboard. Again they emerged with pictures. A painstaking examination of the chemicals in the cupboard at last established that the vapor from a few drops of mercury spilled from a broken thermometer had worked the "miracle." The mercury had developed the latent image; it was necessary only to expose a plate for 20 minutes to a half-hour and then the image could be made to appear by the "after-process." By 1837 Daguerre had learned how to fix the image permanently, using a solution of common salt in hot water. Later the same year he presented the first successful daguerreotype, a still life, to the curator of the Louvre. The picture is preserved, and a reproduction of it is included in Gernsheim's book.

Daguerre had a nose for publicity and an energetic determination to capitalize on his success. He made plans to organize a company and float shares. He drove around Paris with his apparatus on a truck, photographing monuments and public buildings and attracting great crowds. A number of leading scientists interested themselves in daguerreotyping, among them the influential physicist and politician François Dominique Arago. Thanks to Arago's patronage, a pension for Daguerre was proposed, and in return his process was to be published to the world so that anyone, "by observing a few very simple directions . . . may succeed with the same certainty and perform as well as the author of the invention." Newspaper reporters, no less imaginative in 1838 than today, added to the excitement by circulating stories that the Emperor of Russia had offered Daguerre 500,000 francs for his "secret," but that he had declined, preferring to share it with mankind. As the hour approached for the Chamber of Deputies to vote on the pension, the deputies emitted torrents of eloquence. Joseph Louis Gay-Lussac proclaimed the invention the beginning of a new era in civilization. The pension bill was passed unanimously. At a joint meeting of the Academies of Sciences and Fine Arts, before an audience that overflowed into the courtyard and to the banks of the Seine, Arago disclosed the details of Daguerre's process. "There was as much excitement," said an eyewitness, "as after a victorious battle. . . . The crowd was like an electric battery sending out sparks." Painters and engravers were equally hysterical but less elated. "From today painting is dead," exclaimed the painter Paul Delaroche on first seeing a daguerreotype.

Many improvements followed on the heels of Daguerre's work. Among the foremost innovators was William Henry Fox Talbot of England, who laid the foundations of modern photography by describing the negative-positive process. He also discovered the latent image and invented the calotype process in which the image was fixed on good-quality writing paper coated with silver iodide. It is interesting to note that he described a method for printing positives in the camera itself in a minute or two after exposing the negative. Another leading figure was Joseph Bancroft Reade, a curate and distinguished amateur scientist. He developed a negative-positive

technique independently, and, more important, was the first to use hyposulfate of soda—"hypo"—as a fixing agent. Reade has been neglected by historians, and credit for work he did has been improperly assigned to Fox Talbot.

The exploitation of the daguerreotype in Great Britain forms an amusing piece of legal, commercial and social history. From the start Daguerre made it litigiously clear that only licensees could use his process. Nevertheless the business flourished. Improved cameras came on the market, and the public flocked to portrait studios to have their likeness captured "by the sacred radiance of the sun." At first pictures were expensive—a guinea or more—and only the rich or members of the rising industrial middle class could afford the sittings. But demand, competition and accelerated processes steadily brought the price down, so that within a few years one could be immortalized for a shilling. Fortunes were made by licensees and sublicensees in the space of a couple of years. One Richard Beard, who had a parlor in Holborn, is said to have cleared 35,000 pounds his second year in business.

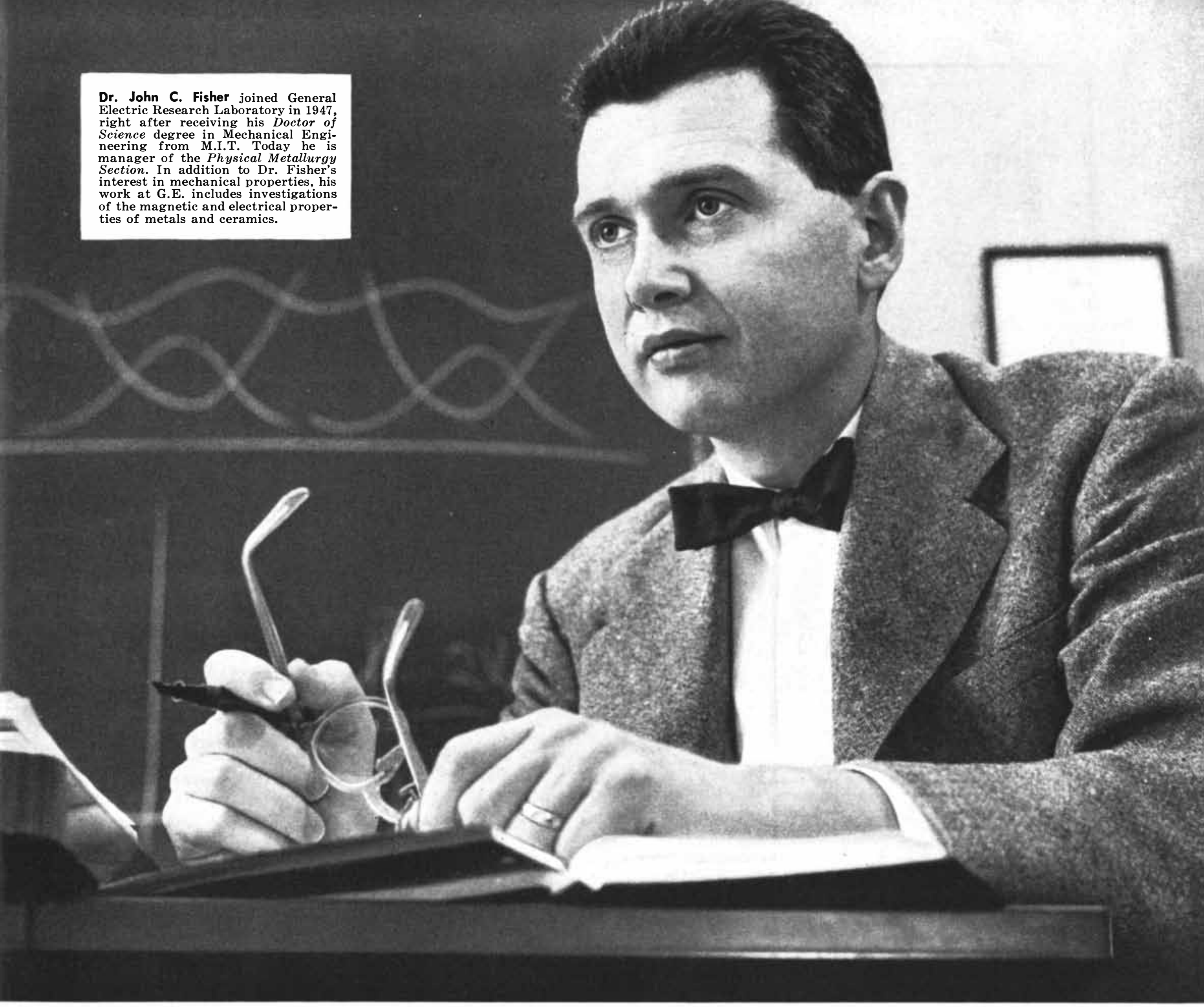
Sitting for a portrait was a painful and ticklish affair. Ladies were advised what color dress to wear, what flowers to carry, how to brush their hair, how to look relaxed. So that the mouth would not look like a steel trap, they were given a recipe for a "pretty expression": pucker the mouth as if you were going to say "prunes." As the photography craze grew and cameras became easier to get, many persons entered the business as a profitable sideline. Ice-cream and roast-chestnut vendors, barbers and tobacconists, tea-and-shrimp rooms combined the sale of their regular wares with services in portraiture. A Londoner could get his "likeness and a cigar" or "a shave and his shape" or "an eel-pie and his likeness" for sixpence. The new industry was evidently on a firm footing when a blacksmith could shoe horses in one corner of his smithy while his apprentice, taking time off from the bellows, posed the customers for daguerreotypes in the other corner.

Gernsheim's account moves through the "collodion period," the advent of stereoscopic photography, the "*carte de visite*" era, the beginnings of snap-shot and news photography and the evolution of dry plates. He discusses the work of the great war photographers Roger Fenton and Mathew Brady, the first aeronautical photographer Felix Nadar (who in 1855 took bird's-eye views of Paris from a balloon), the pioneer news picture of the Hamburg fire of 1842 and the brilliant portrait artists, including Brady, Thomas Annan, Julia Cameron, Lewis Carroll, David Octavius Hill and Robert Adamson. The "gelatine period"—gelatine silver-bromide paper—began about 1870, and soon there was mass production printing. Flexible film marked another advance, followed by hand, pocket and detective cameras and push-button photography. In 1850 there were 50 amateur photographers in Britain—by 1910 there were 19,000. The corresponding U. S. figures are 900 and 32,000. The survey concludes with chapters on flash pictures, the photography of movement and photomechanical printing processes.

Gernsheim's emphasis on British photography leads to some surprising omissions. American picturemakers, in particular, get the short end of the stick. Alfred Stieglitz receives a few encomia, but there is no serious appraisal of his work. William Henry Jackson, the famous Frontier photographer whose Yellowstone pictures were primarily responsible for Congress' decision to make the area a national park, is not mentioned. The great documentary photographer, Lewis Hine, whose pictures are among the most powerful pieces of social criticism to appear before the First World War, is overlooked, as is Jacob Riis. T. H. O'Sullivan's awe-inspiring pictures of the Canyon de Chelly in Arizona and his superb survey photographs, as well as A. J. Russell's memorable Union Pacific Railroad scenes, are among the many other items for which no place was found in these pages. And a number of the pictures selected by the author do not, in my opinion, do justice to the best style of their makers. Nonetheless Gernsheim has written an excellent history of the art, craft and science of photography, which has effected greater changes in society than even Arago or Gay-Lussac could have imagined.

Short Reviews

I AM A MATHEMATICIAN, by Norbert Wiener. Doubleday & Company ($5.00). In the first volume of his autobiography, *Ex-Prodigy*, Professor Wiener discussed his childhood and youth; in the second he covers his mature years and scientific career. Since 1919, when he was 24, he has been on the staff of the Massachusetts Institute of Technology, a post which has afforded him the opportunity not only to engage in researches in pure mathematics but to apply his exceptional imaginative powers



Dr. John C. Fisher joined General Electric Research Laboratory in 1947, right after receiving his *Doctor of Science* degree in Mechanical Engineering from M.I.T. Today he is manager of the *Physical Metallurgy Section.* In addition to Dr. Fisher's interest in mechanical properties, his work at G.E. includes investigations of the magnetic and electrical properties of metals and ceramics.

Secrets of alloy strength

General Electric's Dr. John C. Fisher discovers how atomic order influences ability of alloys to resist deformation under load

One important factor in the strength of alloys is the local arrangement of the different kinds of atoms in them. Large atoms tend to pair off with small ones, because they fit into the alloy crystals better that way. Dr. John C. Fisher of the General Electric Research Laboratory has shown that this type of structure exhibits greater resistance to deformation than pure metals, in which the atoms are all of the same size.

According to this concept, plastic deformation separates some of the atomic pairs, and their resistance to separation causes the strength. It is now known that many alloys of commercial importance owe their strength, at least in part, to this cause. Thus the study of solid-state physics, directed toward understanding the strength — as well as electrical and magnetic properties — of metals and alloys, is today laying the groundwork for the development of new materials to meet the needs of the times.

• • •

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

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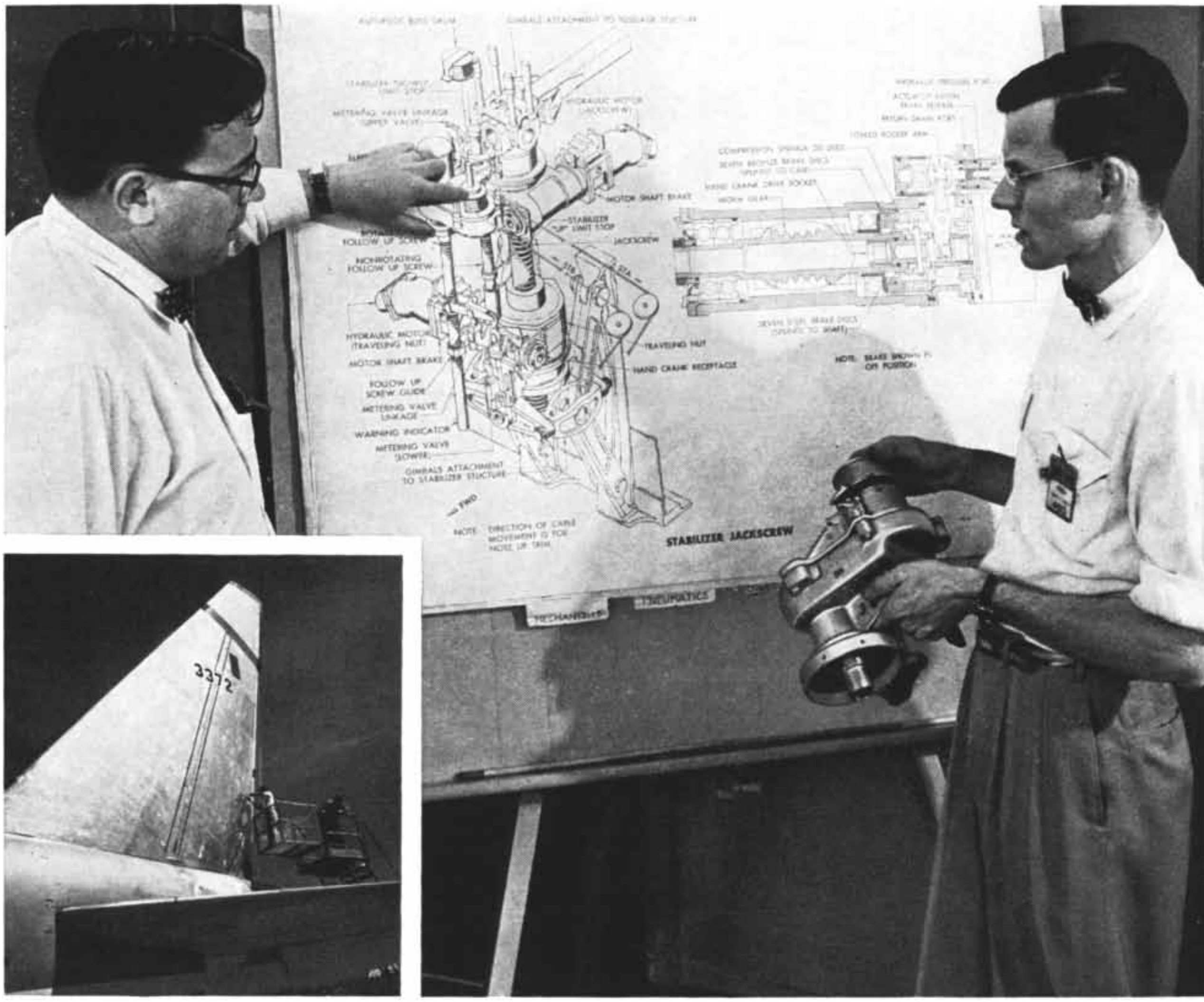
to problems ranging from engineering and theoretical physics to physiology and the social sciences. A large portion of his effort has been concentrated on harmonic analysis—a mathematical tool for breaking down complex motions into sums of simple oscillations. By generalizing and extending a method whose foundations were laid in the 19th century by Joseph Fourier, Wiener has found new approaches to the understanding and control of many diverse physical phenomena. He is of course better known to the general public for his innovations in the field he has named cybernetics. Whether this branch of knowledge has the universal implications which he seems to attach to it remains to be seen, but at any rate it has drawn the lively attention of a wide group of scientists who see in feedback and information theory a magic key to a myriad of baffling questions. The book tells of his friendships, his family life and his many trips abroad, his joint researches with other scientists, his experiences as a visiting lecturer around the world. It also offers Wiener's views on social and political matters. These are the memoirs of a gifted, courageous, independent, self-admiring man, not the least of whose achievements is that he made a life and career for himself despite the fact that he was a prodigy and that he had a driving father who did his best to ruin him.

THE BIOLOGY OF THE SPIRIT, by Edmund W. Sinnott. The Viking Press ($3.50). Dean Sinnott's book is an attempt to solve certain ancient philosophical difficulties—the body-mind dualism—and to find a rational basis for religious and ethical values in the facts of modern biology. His main thesis is that all protoplasm possesses a "self-regulating and goal-seeking" property; that mental activity, though vastly more complex than "bodily development," is rooted in protoplasm and is ruled by the same purposive principle; that body and mind are not essentially unlike but rather two aspects of a "fundamental unity"; that it is not only possible but obligatory for man to establish and strive for the attainment of goals which "magnify" life, further "material and intellectual progress" and enrich "spiritual understanding." Thus "his spirit will grow into completer harmony with the Universal Spirit and he may truly prove himself a child of God." Neither in conception nor in argument, as many readers will realize, is this a very original essay. Running through it are strands of the thought of Hans Driesch, of Henri Bergson, of William James and of others. Sinnott is not more successful than they were in presenting a watertight case for "goal-seeking," for a link between body and mind or for a scientific basis for justice, kindliness or other ethical values. Those who are initially disposed to adopt Sinnott's faith will find his book both comforting and compelling, the testament of a cultivated man; but those who approach it with skepticism will find little in the notion of the biology of the spirit to transform them into believers.

THE EQUATORIE OF THE PLANETS, edited by D. J. Price. Cambridge University Press ($10.00). In 1951, while collecting data for a history of scientific instruments, Dr. Price found in the library of Peterhouse College at Cambridge an extraordinarily interesting Middle English manuscript. Its subject was a medieval astronomical instrument called an equatorie, which was used to calculate the position of the planets and was a complement to the better-known astrolabe, designed to assist all calculations of the apparent position in the heavens of the sun and the stars and for the casting of horoscopes. The manuscript, as Price soon came to realize, had an importance beyond its subject matter, for there was evidence that its author was Geoffrey Chaucer and that it was written in his own hand. In his famous *Treatise on the Astrolabe*, thought to be the earliest genuinely scientific work in English, which Chaucer composed for the education of his 10-year-old son "litel Lowis," the prologue referred to some sections which have never been found. The newly discovered manuscript covers some of the topics he mentioned in that prologue; moreover, it was written, as internal evidence shows, in 1392, soon after the *Astrolabe*. But the most dramatic clue is the appearance of Chaucer's name in connection with a table for converting any number of years to the equivalent number of days, at the rate of 365¼ days to the year. When this autograph showed striking similarities to at least one other specimen of Chaucer's signature in the British Public Record Office, Price enlisted the aid of experts in various fields to try to establish whether the manuscript could be firmly ascribed to Chaucer. Thus far the issue is in doubt, but with the help of many different techniques, including ultraviolet and infrared photography, a good deal of supporting evidence has been assembled. This elegant quarto volume presents the manuscript in facsimile, together with a translation, notes and a linguistic analysis by R. M. Wilson. It is



B-52 jack screw—a typical Boeing design challenge

On Boeing B-52 bombers, the horizontal tail surface has more area than the wing of a standard twin-engine airliner. Yet it can be moved in flight, up or down, to trim the aircraft.

The device that performs this function is a jack screw, which, though it weighs only 255 pounds, can exert a force of approximately 225 *tons!*

Many kinds of engineering skills went into designing and developing a jack screw so precise that it automatically compensates for stretch and compression under load. Civil, electrical, mechanical and aeronautical engineers, and mathematicians and physicists—all find challenging work on Boeing design projects for the B-52 global jet bomber, and for the 707 jet tanker-transport, the BOMARC IM-99 pilotless interceptor, and aircraft of the future.

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a fascinating exercise in historical scholarship.

CANCER AND COMMON SENSE, by George Crile, Jr. The Viking Press ($2.75). This short book is neither cheerful nor very enlightening, but it makes some sensible points. Dr. Crile asserts that there is a nationwide cancer phobia which is justified neither by the incidence of the disease nor by the advantages to be gained from periodic examinations. The multiplication of cancer clinics in the last 20 years has failed altogether, he says, to reduce the rate of death from cancer. In the case of a fast-growing cancer, it is apt to make very little difference, according to Crile, whether it is detected "early" or "late"; only if the cancer grows slowly is surgery, radiation or chemotherapy likely to benefit the patient. He criticizes "professional perfectionism" which leads to "overdiagnosis and overtreatment"; the profligate use of radical techniques in surgery; the instillment of hope that a universal cancer cure is imminent. And he is quite emphatic on the point that no one can tell how long a person can live who has an "incurable" cancer. Crile's opinions are a counterweight to popular misconceptions and professional dogmas, but he evidently has his own prejudices, and the plain reader will not always find it easy to discover them.

THE HUMAN FIGURE IN MOTION, by Eadweard Muybridge. Dover Publications, Inc. ($10.00). This book reproduces 196 of Muybridge's famous photographic sequences of the figure in action. The plates are chosen from thousands made by Muybridge in an extensive program of photographic research at the University of Pennsylvania. Muybridge was a talented eccentric. Born in England in 1830, he was christened Edward James Muggeridge. It was not a pretty name, and he fiddled with it until he achieved what was certainly an unusual result. In 1850 he came to the U. S. and became a well-known photographer on the Pacific Coast. The noted railroad builder Leland Stanford, who was interested in the scientific training of race horses, employed him to photograph various phases of their gait. Muybridge used 24 cameras, "drop shutters actuated by springs and rubber bands" and improved wet plates which registered exposures of two thousandths of a second. The running horse tripped the shutter of each camera by breaking a thread as it passed in front of the lens. With this rig Muybridge made thousands of pictures of the horse in motion. A quarrel with Stanford broke up their arrangement and Muybridge moved to Philadelphia, where in 1883 he was retained by the University of Pennsylvania to pursue his studies of figures in motion. Many of the sequences in this book are as enthralling—and of the same esthetic tendency—as the views through a magnascope in a 1910 penny arcade ("What the Butler Saw"). But when looked at in their historical context they make an impressive and valuable collection.

DREAMS AND NIGHTMARES, by J. A. Hadfield. Penguin Books (65 cents). Men have probed their dreams ever since they began to probe themselves. Primitive people, philosophers, charlatans, old wives, sophisticates, simpletons, psychologists—in short, everyman has had and continues to have theories on the meaning of dreams. The subject is surveyed in this book by an experienced British practitioner of psychological medicine. Dr. Hadfield describes first the contributions of Sigmund Freud, whose main tenets are that the dream is a wish fulfillment of sexual desires and that the mechanism of the dream is designed to transform unconscious desires into an enigmatic form which is acceptable and therefore permits the dreamer to continue his slumber. Among the important modifications of this theory is Carl Jung's idea that dreams represent not merely the exercise of repressed wishes but the expression of needs which must be met to fulfill our lives. Jung also asserted that in dreaming we draw not only upon our own experiences but also upon a racial memory or collective unconscious composed of the archaeological remains of all human experience since the beginning. After examining the various criticisms raised against the views of Freud, Jung and others, Dr. Hadfield presents his own "biological theory." This is not the "heavy-supper" theory—which suggests that a midnight repast of lobster breeds nocturnal monsters—but rather the notion that dreams serve as a testing ground where the dreamer examines the worrisome problems of his daily life and tries to solve them. This effort is, of course, noncommittal and cost free, so that one can try again and again to master a difficulty or adapt himself to circumstances without worsening the real predicament. The dream process, then, is simply a continuation during sleep of the thinking and adaptive process of waking hours. If a serious breakdown of the individual's capacity to adapt occurs, he becomes mentally ill; in this case the interpretation of dreams

is of considerable medical value because it affords access to the unconscious reasons for nonadaptation. This is a clearly written, unpretentious book which, with the help of innumerable interesting examples drawn from Hadfield's practice and wide reading, offers any dreamer the opportunity to judge for himself the nature and purpose of the phantoms and winged buttonhooks that chase through his head at night.

HISTORY OF THE RISE AND INFLUENCE OF THE SPIRIT OF RATIONALISM IN EUROPE, by W. E. H. Lecky. HISTORY OF EUROPEAN MORALS, by W. E. H. Lecky. George Braziller, Inc. ($5.00 each). Readers are in debt to this discriminating publisher for making available at reasonable prices a series of valuable books out of print and hard to get. These two recent additions to the Braziller reprints are highly readable surveys by a great 19th-century Irish historian and philosopher of history. Lecky, as C. Wright Mills observes in his introduction, was a "man full of human sanity." His moral view, his estimate of economic matters, his political outlook may no longer excite us; yet he is one of the men "off whose work we have been living"—and from whom we still have much to learn.

RELATIVITY: THE SPECIAL THEORY, by J. L. Synge. Interscience Publishers, Inc. ($10.50). Professor Synge presents the essentials of relativity "from the Minkowskian point of view, that is, in terms of the geometry of space-time." This is an unusually thorough and interesting presentation, which keeps in focus at all times the physical significance of the theory. The author promises a second volume on the general theory.

Notes

MATHEMATICAL THEORY OF ELASTICITY, by I. S. Sokolnikoff. McGraw-Hill Book Company, Inc. ($9.50). The second, substantially revised edition of a comprehensive treatise on elasticity.

SCEPTICISM AND ANIMAL FAITH, by George Santayana. Dover Publications, Inc. ($3.50). A reissue of Santayana's well-known and attractive introduction to his system of philosophy.

THE ANALYTICAL THEORY OF HEAT, by Joseph Fourier. Dover Publications, Inc. (Paperbound, $1.95). A reissue of a famous treatise by the 19th-century French mathematician and physicist, remembered for his work on heat and on numerical equations.

YOU AND THE ATOM, by Gerald Wendt. Whiteside, Inc., and William Morrow & Company ($1.95). While it cannot be said that there is a grave shortage of popularizations of atomic energy, this book makes its place because it is concise, plainly written and inexpensive.

THE MATHEMATICS OF PHYSICS AND CHEMISTRY, by Henry Margenau and George Moseley Murphy. D. Van Nostrand Company, Inc. ($7.95). The second edition of this established handbook of applied mathematics has been thoroughly revised.

NIELS BOHR AND THE DEVELOPMENT OF PHYSICS, edited by W. Pauli, L. Rosenfeld, V. Weisskopf. McGraw-Hill Book Company, Inc. ($4.50). Essays on 20th-century physics in honor of Niels Bohr's 70th birthday. Among the contributors are C. G. Darwin, W. Heisenberg, L. D. Landau, J. A. Wheeler, F. L. Friedman and the three editors.

COMPARATIVE PHYSIOLOGY OF REPRODUCTION, edited by I. Chester Jones and P. Eckstein. Cambridge University Press ($8.50). Proceedings of a 1954 University of Liverpool symposium on the endocrinology of vertebrates.

RESEARCH REACTORS, prepared by the U. S. Atomic Energy Commission. McGraw-Hill Book Company, Inc. ($6.50). Detailed descriptions of six types of reactors. Many photographs and design drawings.

LEONARDO DA VINCI, by Sigmund Freud. Random House (95 cents). A Modern Library paperback of Freud's celebrated study of psychosexuality.

THE LIFE AND ART OF ALBRECHT DÜRER, by Erwin Panofsky. Princeton University Press ($10.00). The publishers, without sacrifice of text or illustrations, have reissued this admirable biography in one volume at a reasonable price. It presents Dürer's achievements as a painter, illustrator, mathematician and scientific thinker.

LOUIS AGASSIZ FUERTES, by Mary Fuertes Boynton. Oxford University Press ($7.50). A brief biography and selection from the correspondence of a rarely gifted painter of birds and ornithologist who died in 1927. Illustrated by a number of superb half-tones.

Lockheed diversification in action...

Below: Engineers and scientists at work on some of the 44 major projects in progress at Lockheed

Operations Research discussion on passenger transport routes

Operations Research openings

Electronics Specialists
Fire Control and Guidance Specialists
Aerodynamics Engineers
Physicists

Fatigue test on Super Constellation skin

Structural Engineering openings

Research Specialists
Structures Engineers
Stress Analysts
Weight Engineers

Design study on hydraulic requirements of new transport

Design openings

Design positions are open at all levels in controls, electrical, hydraulics, mechanical, power plant and structures fields.

Hot-air cyclic de-icing test on radar search plane

Thermodynamics openings

Research Specialists
Thermodynamics Engineers
Thermodynamicists

Fuel system test on advanced jet trainer

Flight Test Engineering openings

Flight Test Engineers
Flight Test Analysts
Instrumentation Engineers
Electrical Research Engineers

Aerodynamic meeting on high-speed fighter

Aerodynamics openings

Aerodynamics Engineers
Aerodynamicists
Dynamics Engineers
Wind Tunnel Test Engineers

Why Lockheed offers engineers more opportunity for promotion

Lockheed's policy of aircraft diversification is the answer. Twelve different models are in production – passenger and cargo transports, world's fastest jet fighter, jet trainers, patrol bombers, radar search planes. Aircraft in development are equally diversified.

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This simply means there are more high echelon positions at Lockheed to be filled – because there are more projects in motion year-in, year-out. In brief, there are more projects in progress than at virtually any other company, more technical management positions to be filled, more opportunity for promotion for career-conscious engineers.

Naturally, there are related career benefits such as the varied assignments possible in a diversified company . . . and the fact that diversified activities create a working atmosphere in which fresh thinking, new ideas are welcomed and rewarded.

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THE AMATEUR SCIENTIST

Mostly about the collection and study of fossilized seeds

In the Rawhide Creek country of southeastern Wyoming, where you drive 50 dusty miles to post a letter, Charles and Mabel Bass are engaged in what they describe as "the hazardous occupation of dry farming." Their ranch, near Jay Em, Wyo., produces wheat, wool and mutton. For the Basses the dry Wyoming steppes yield another product that absorbs all their free time—fossil plants. For a number of years they have been pursuing paleobotany at a level that has earned them world-wide recognition among professionals. Last July *Earth Science*, official publication of the Midwest Federation of Mineralogical Societies, told about their work and credited them with many unique finds.

Their hobby got its start when Mr. Bass took to reading geological books and bulletins to beguile the time on the range while herding sheep. He thus learned something about the ground beneath his feet and developed a watchful eye for geologists, with whom he formed a quick and enduring friendship whenever any came to the region. Mrs. Bass joined him in his hobby after she exchanged the career of rural schoolteacher for that of housewife, mother and part-time farmhand.

The Basses now have an impressive collection of minerals and petrified woods such as are prized by "rock hounds" everywhere. But what particularly attracts the interest of scientists is their remarkable collection of fossil seeds. An account of their work follows, in their own words.

"To put seeds in the ground," they write, "is supposed to be the principal interest of farmers. We are farmers, but for some time we have been interested in taking seeds out of the ground. The seeds that merit this unique attention are not ordinary seeds of wheat or turnips or apples that you can buy at the store or find listed in the seed catalog. They are seeds that have turned to stone—petrified, or what we prefer to call fossil, seeds. Our study of fossil plants and our pleasant work of collecting them is simply a hobby. Our collection includes petrified wood cut in cross sections three fourths of an inch thick and polished on one side, and lovely little limb casts showing bark structure. In the collection also are many beautiful fossil leaf-imprints of early plants and trees. Our first love, however, is the fossil seeds, which are the most interesting finds we have made in our region.

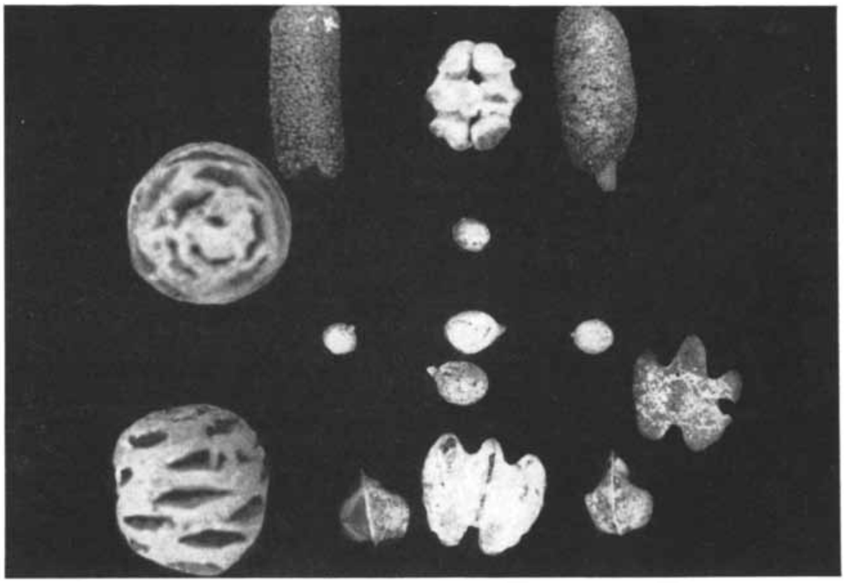
"Seeds are the final product of the flower. They are the most variable of all structures produced by plants, differing widely in surface markings, size, color and internal anatomy. These variations help botanists to classify and identify seeds even though they have been fossilized for millions of years. All seeds consist basically of two parts: the seed coat and the enclosed embryo. Some fossil seeds are still intact, and upon being broken apart or cross-sectioned show these parts very distinctly. Other fossils are merely the casts left in stone by the original seed, and they can be identified only by the seed's surface structure and markings. The complex structure of the seed parts is best studied with the aid of a microscope.

"Plants can be preserved as fossils only if they are made up, at least in part, of fibrous or woody material. All higher plants have bundles of tough, hollow, interlacing fibers, known as vascular bundles, which serve as conducting channels for food and as supporting skeletons of the plants. It is this tough substance that enables a leaf or a piece of wood to leave its imprint in rock. In the case of seeds, the hard or crustaceous outer coat is what preserves the seed in the fossilizing process.

"Organic material such as a seed is preserved from decay when it is suddenly and completely entombed beyond the reach of oxygen—by volcanic ashes, wind-blown sands, flood waters, deposits in a lake or river, peat in a bog, or some other covering material. Obviously only a very small proportion of the plants or animals which existed during any period would have been subjected to conditions that fossilized them.

"The material covering the entombed organic matter, say a seed, gradually hardens under pressure and turns to stone. Ground waters, carrying mineral

Fossilized seeds collected by Charles and Mabel Bass of Jay Em, Wyo.



An assortment of fossil seeds and fossil fruits

matter in solution, percolate through this rock mass and remove the organic matter from the buried seed, replacing it molecule by molecule with mineral compounds. Thus the seed's exact form and minute cellular structure are preserved. In some cases the organic matter decays first and leaves a cavity in the rock the precise size and shape of the seed. Mineral-bearing ground waters then precipitate their sediments into the cavity until it is filled or partly filled with stone. This is called a cast.

"Fossil seeds are among the rarest fossils available. Reasons for their rarity are numerous. Seeds are only a short-lived stage of plant life: they normally sprout and turn into plants. Many are eaten by animals and insects. We have fossil walnut kernels showing rounded holes where worms ate into them [*see photograph on page 152*]. Further, seeds are less likely than leaves or branches to become petrified, because of their smallness: they are more easily crushed, decay more readily, and so on. Finally, their smallness makes them extremely difficult to find.

"In order to locate an area where fossil seeds may be found we must first know or learn something of the geologic history of the area. The first clue is the finding of some petrified wood. This may be a petrified forest or it may be only a fragment of wood eroded from a sandy bank. If the petrified forest is made up of tree trunks and branches washed into a deposit by flood waters, as is the case of the Triassic petrified forests of central Arizona, there is little use to look for fossil fruits, for they would have been lost on the journey. But if the petrified forest stands where it grew, as in some coal beds and in rock of Yellowstone Park, fossil seeds and cones are likely to be found. One of the best places to look is in stratified rock which has been eroded into cuts and gullies, exposing the strata.

"Our hunt for fossil flora takes us on many exhausting trips. Some areas are so rugged that after we have penetrated them as far as possible with a jeep or horse, the last few miles must be covered on foot. Here, and in other localities somewhat more accessible, we spend strenuous hours on hands and knees searching for tiny seeds. Some are so small they must be hunted with a magnifying glass. Some seeds, such as the walnut kernels, are found free of matrix and are ready to be brought home and immediately placed in the display case. Others, such as the pine cones, may be surrounded with hardened volcanic ash which must be tediously removed by using a small sharp instrument. The Miocene hackberry seeds, which are merely sand casts, are so soft and delicate that a chunk of the surrounding sandstone matrix must be chopped out of the cliff with a fossil pick, after which the delicate seeds are carefully removed and treated with a preservative to prevent shattering.

"For the sake of clarity and order we will group the descriptions of our fossil seeds according to the three major geologic eras in which fossil flora occur—the Paleozoic, the Mesozoic and the Cenozoic.

"We begin with the Carboniferous division of the Paleozoic era. The plants of that time are preserved today as the well-known coal-measure fossils of the Pennsylvanian, Mississippian and Permian periods. Among them we find rush-like calamites, ancient ferns and lycopods. These all reproduced by spores developed in cases on the undersides or bases of the leaves or in spore-bearing cones. The waxy and resinous outer coating of the spores helped to preserve these microscopic fossils. They are valuable to the paleobotanist in his attempt to learn about the propagation of plant life in the distant past. From this era also come evergreen relatives of our present-day conifers. Our specimens include seeds of the Cordaite trees, whose woody trunks were much like those of the modern pines. The seed, about 24 millimeters long, was developed in a husk or coat, the outer layer being fleshy.

"The principal plants of the early Mesozoic era were rushes, early conifers, ferns and cycads. This is often called the age of cycads. They were the most numerous and interesting plants of this era and served as food for the dinosaurs. They had genuine flowers which developed into a seed-bearing fruit. Our collection includes several lovely fossil cycad buds, one of which is free of matrix. Cycads were dominant until the close of the period, when the flowering plants, angiosperms, began to rise and spread. The cycads are of great scientific interest. Their series has been traced in almost continuous line from the ancient extinct species to the subtropical, palm-like plants of today.

"Our work in the Mesozoic era has been mostly among rocks of Cretaceous age. We have found objects, which a prominent paleobotanist says may be cycad seeds, within spherical rock concretions along with fragments of fossil wood and marine life, indicating a shoreline deposit. The seeds are globular, about 24 millimeters in diameter, and show cell structure.

"From the Cretaceous also we find the small cones of the redwood tree, the largest and oldest cone-bearing evergreen. The cones are dark brown (from iron in the fossil), nearly round and from 21 to 27 millimeters in diameter. They are identified on the basis of having an average of 30 scales to a cone [*see specimen at lower left in photograph on this page*].

"In the Upper Cretaceous rocks of Wyoming we find cones of the Araucarian pines. The ovoid female cones, when broken in cross section, plainly show the seeds and the cells in which they are located. The rocks have also yielded casts of the fossil fig *Ceratops*. The specimens are remarkably figlike in

appearance, and some show regular striations around the neck.

"We have in our collection seeds of the ancient ginkgo tree, *Carpolithus ginkgoites fultoni*. The seed is slightly obovate (with the narrow instead of the broad end at the base). It is 9 to 12 millimeters long and has longitudinal ridges. Fossil ginkgo is rare. The only species of the ginkgo tree surviving today is *Ginkgo biloba*, a native of Japan and China.

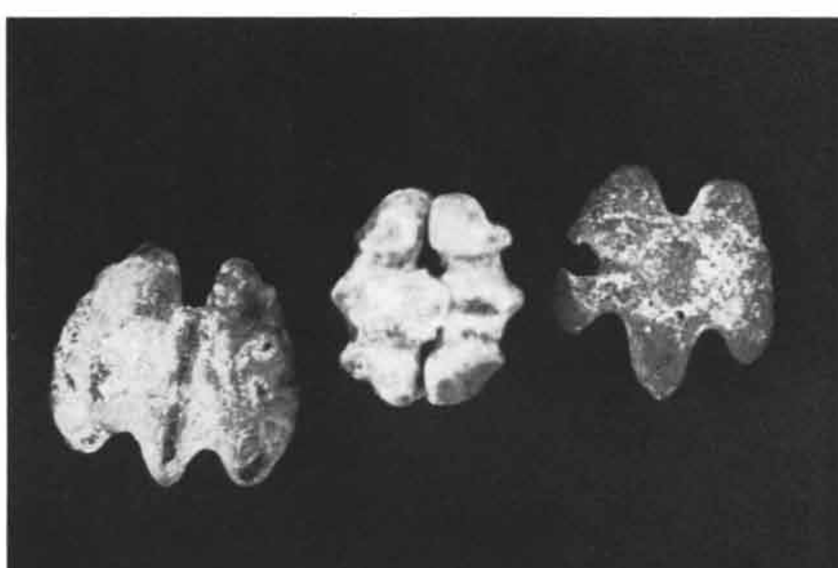
"In the Cenozoic era the plants begin to take on a more modern aspect. The most common seeds are those of the hackberry tree, which is found in strata all the way through the Tertiary period. This tough, adaptable tree has met the challenge of the elements down through the ages in Wyoming, South Dakota and Nebraska. It must have been a prominent tree in the Cenozoic forests. Its solitary seed is cherry-like, slightly obovoid and four to six millimeters in diameter. Only the seed or pit is fossilized; the pulpy fruit has disappeared. Hackberry seeds from the Eocene stage of the Tertiary period are well preserved, but the smaller seeds of the later Oligocene are in a less perfect state, and the still later Miocene seeds are very fragile and poorly preserved in this locality. The Miocene specimens are not unlike present-day hackberry seeds.

"The very first fossil seeds we found were the kernels of Oligocene walnuts, *Juglans siouxensis*, which were described many years ago by the late Edward W. Berry. The Oligocene deposits in Nebraska remain our most prolific source of fossil seeds, although of course there is no such thing as an actual abundance of any fossil seed or fruit; all are scarce, and some are more scarce than others. The walnut kernels are from 15 to 18 millimeters in diameter, a golden brown in color and perfectly silicified. They look quite edible. They show well-developed secondary lobing characteristics. We find broken pieces, quarters, halves and complete nuts, some showing part of the shell [*see specimens at lower right in photograph on page 150*].

"From the Eocene beds of the Clarno district in Oregon we have fossil seeds of walnuts, hickory, grapes and a member of the moonseed family. Other finds from the early Tertiary period, in Wyoming, Colorado and Montana, are fossil fruits of the genus *Cercidiphyllum*, of which the only surviving member today is the katsura tree of Japan and China. The fossil fruits are small blunted pods with seeds slightly resembling the winged seeds of a conifer.

"One of our most noteworthy finds is seeds of the *Iodes*, a genus of plants which still has some living members growing in the tropical regions of southeast Asia and Africa. A well-known paleobotanist informed us that *Iodes* fossils had never before been found in North America or in beds younger than the Eocene; we found our specimens in Oligocene formations. The beautifully silicified seeds are broadly oval and lens-shaped, and their surface is ornamented with shallow concave areas.

"A number of our choice fossils are unidentified, which means that they have not been studied and given scientific names by professional paleobotanists. We, as amateur collectors, are not



Fossilized walnut kernels are perforated with worm holes

qualified to identify unknown specimens; consequently, no matter how closely a fossil may resemble its present-day counterpart, we must still class it as unidentified.

"Perhaps our favorite unidentified specimens are the agatized objects from the Oligocene formation of northwestern Wyoming, which look like pine cones [*see object at top center of photograph on page 149*]. They are distinctly marked with the diamond-shaped apex of the thickened cone scales, including the spots left by the recurved spines. They vary considerably in size. From the same locality we have found small unattached seeds, which we believe to be from some of these cones.

"We have some tiny, globular, pealike seeds, plainly showing the embryo, which doubtless belong to the bean family [*specimens at left in middle row in photograph on page 149*]. When placed beside present-day pea seeds they are as 'alike as peas in a pod.' In the Oligocene also we have found some nearly round, cherry-like seeds with the attached stem and five sepals of the persistent star-shaped calyx, as well as larger, cherry-like seeds without the calyx. Other unidentified specimens are burrlike objects which may be burrs of a chestnut or chinquapin and some lovely, perfectly preserved catkins [*at top in photograph on page 150*]. We suspect that some, if not all, of the unidentified finds are new to science and are deserving of description in scientific literature.

"As long as there are more fossil seeds, woods or leaves to be found, we intend to keep on looking for them. We would love to find an acorn or a cone or fruit different from any other ever found, and this we will do unless old age overtakes us too soon. We sometimes wonder if paleobotany has been given its rightful place in the study of the science of living things. Extensive searches have been carried on for fossil animals, but plants are just as important, for without plants there would have been no animals.

"We have never regretted choosing this hobby—or perhaps we should say that it chose us. If you ever begin to pay attention to fossil flora, you will find the interest growing on you like a coat of tan on a summer day. Once you have found the specimen that is one in a million, once you have seen through a magnifying glass the intricate perfection of a tiny agate seed or the delicate cell structure of a piece of replaced wood, you will give your heart to this fascinating pastime. Such a hobby, like beauty, is its own excuse for being. It is pregnant with the diligence of study, the dignity of labor, the thrill of discovery, the pride of possession and the pleasure of sharing.

"Trees of the ancients,
plants of the past,
Fruit of the gods, leaves
that will last,
Catkins of agate, flowers
of stone,
Silica walnuts, agate pine
cone,
Seeds of the *Iodes*,
tropical vine,
Have lain in the mud
through ages of time.
Seeds of the hackberry,
others I've found,
Lie in my case on velvet
background.
These are the essence of
nature's springtime,
God has preserved them,
now they are mine."

Roger Hayward, whose drawings regularly adorn this department, enjoys tinkering with devices for demonstrating basic mechanical principles. Recently he confected two versions of a rubber-band heat engine, with the object of showing how a system becomes increasingly sensitive to external forces as it approaches the condition of instability.

"One easy way to demonstrate this," he writes, "is to consider the case of two cylinders of unequal diameter standing on end. It takes less force to push over the thinner cylinder. The narrower the cylinder, the closer it comes to the condition of instability.

"With a few rubber bands, a needle, some thread and other household objects, you can devise heat engines for demonstrating this principle in more interesting ways. I propose to illustrate two systems here.

"The first [*illustration on page 156*] is based on a classical seismometer scheme. From a bracket, which can be a laboratory glassware holder, a piece of aluminum foil is suspended on a thread. The foil, or bob, can pivot around its midpoint, which is attached to a stretched rubber band. The aluminum foil is curled up at the edge to shade the rubber band from a desk lamp that shines on it.

"Turn the bob to the left. The left side of the rubber band is now unshaded. Warmed by the lamp, this part of the rubber shrinks, *i.e.*, contracts. The pivot point accordingly moves slightly to the left. As a result the pendulum now

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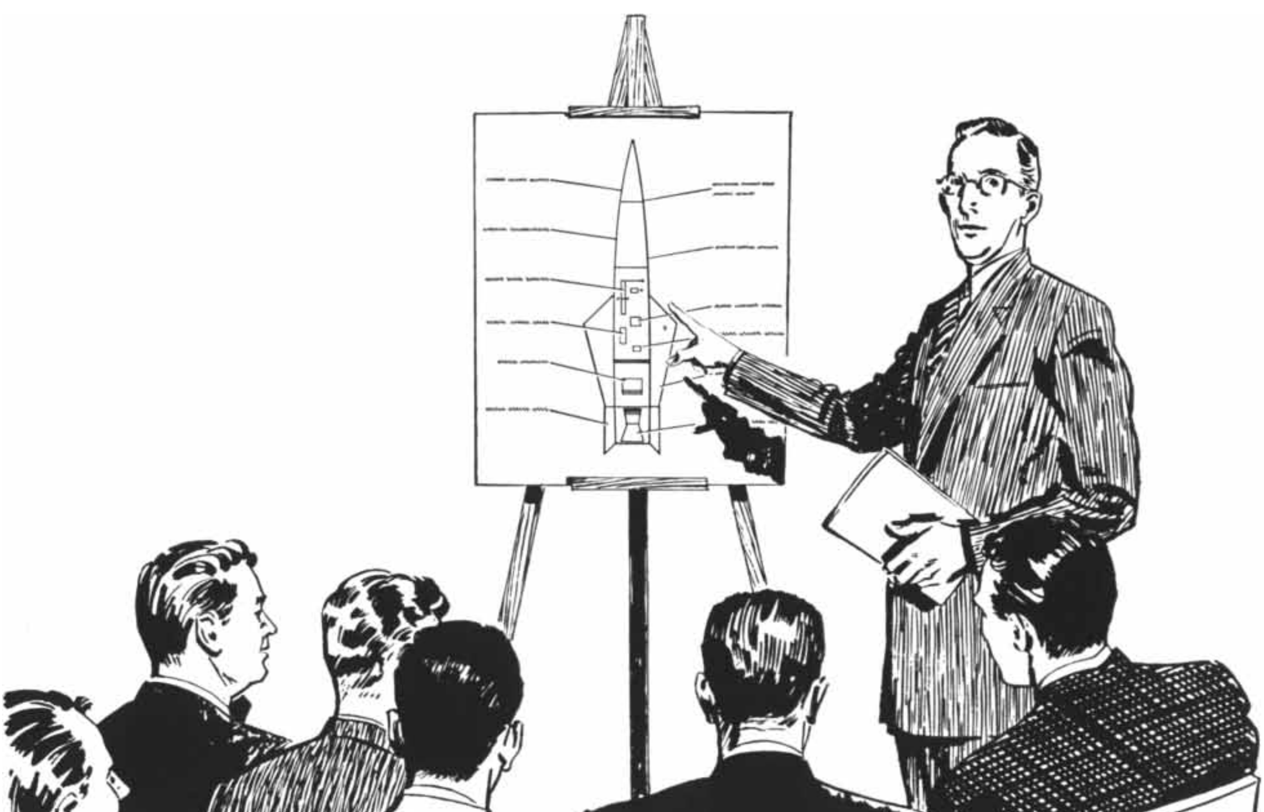
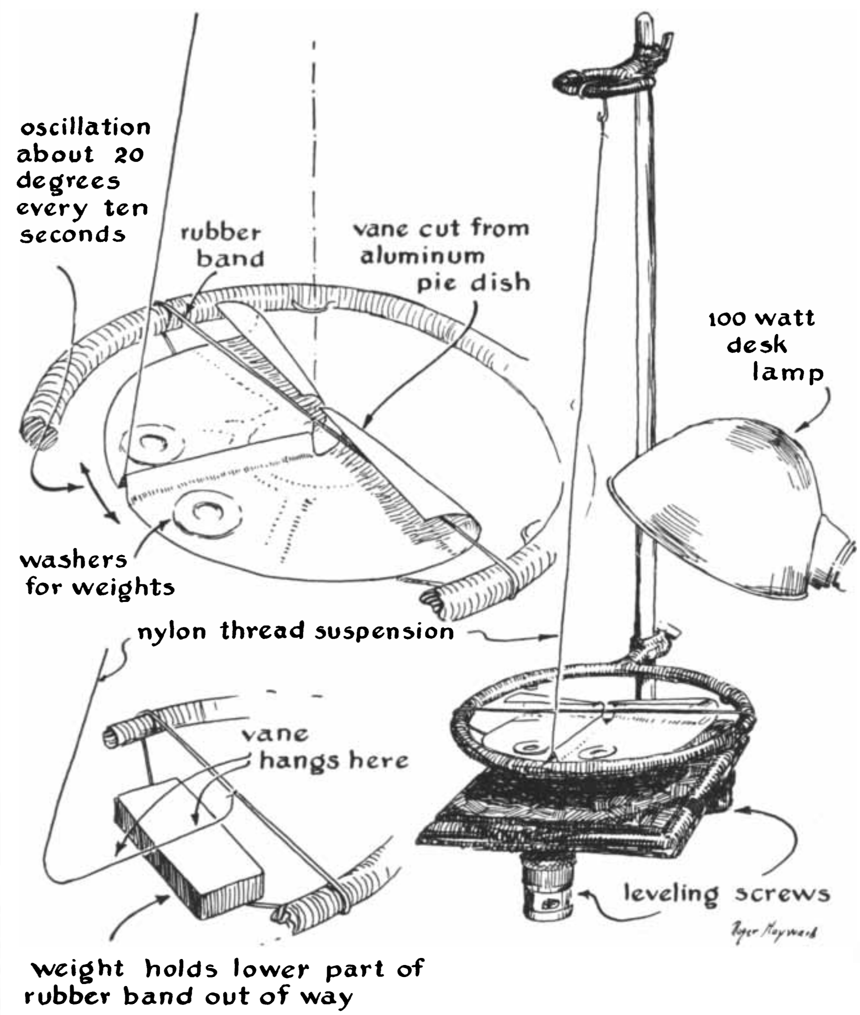


swings to the right. The curled portion of the bob then shades the warmed portion of the band and exposes the other half to the lamp. The opposite half of the cycle then begins. The apparatus, as here proportioned, will vibrate about 16 cycles per minute over an amplitude of about 10 degrees. I tried observing the shift of the bottom pivot with a small telescope. The motion must be less than a thousandth of an inch, because it was not perceptible.

"Save for the leveling screws, which must be capable of exquisite adjustment, the rest of the apparatus is easy to make. Aluminum foil for the bob is easy to cut with ordinary scissors. The 24-gauge weight of foil used for bakery pie-plates is handy. The vane or bob is balanced on the thread by sliding the washers toward or away from the thread. This is quite easy. A wooden structure can be substituted for the lab stand. The thread is N.Y.M.O. sewing thread size A, 300 yards per spool.

"Aside from the stability effects, I suppose the two lessons to be learned from this experiment have to do, first, with the phase relationships of the system, and second, with the surprising behavior of rubber when subjected to changes in temperature. The driving force for any oscillator must be out of phase with the displacement, preferably by 90 degrees. In the case of the 'figure 4' seismometer suspension, the inertia of the pendulum plus the time lag in warming the rubber combine to approximate 90 degrees. As for the behavior of warmed rubber, one would suppose that it should expand with increasing temperature like almost everything else. It does—*except when under tension.* I discussed this with Linus Pauling some years ago and he said that you should picture rubber, when under tension, as a bundle of stretched chains, with heat shaking the chains. The harder the chains are shaken (by thermal agitation) the more they pull on the fastenings at their ends. Thus the rubber can have either a positive or negative temperature coefficient, de-



An apparatus to demonstrate the effects of near-instability

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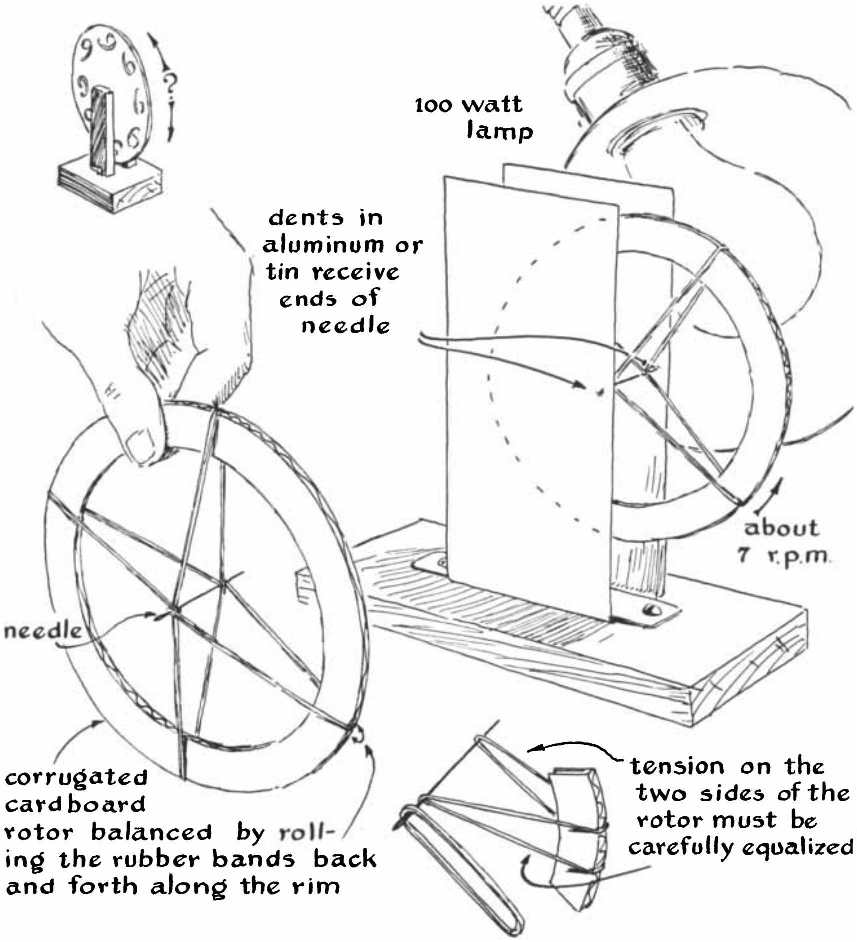

A heat engine driven by warmed rubber bands

pending on how you use it—a property which suggests endless experiments.

"As far as I know this peculiar form of pendulum, as driven by rubber, is new; at least I worked it out myself last night after I went to bed. It might be used as a thermometer, and measure temperature mixed with earthquakes. Moral: It is easy to make any device sensitive if you don't care how many things you measure simultaneously. But if the gadget is to unscramble the mixture, then it is harder to make.

"The second system [*see illustration above*] shows the same principle applied to a gadget which converts heat into rotary motion. The rim of the wheel is cut from corrugated cardboard with a sharply pointed knife. The rim supports spokes made of rubber bands, and they in turn hold a needle shaft in alignment. You mount this assembly between two plates of thin tin or aluminum. I had the engine running in about an hour, the first 40 minutes being spent in getting the needle to stay in proper alignment. Equalizing the tension on the two sides of the wheel is quite a chore. The needle tends to turn sideways and dump off the bands. Then you start all over. You must next adjust the bands until the wheel balances perfectly when in its bearings. The balancing act, however, is not too difficult. If the wheel persists in coming to rest with an unbalanced section down, you move the outer tips of the bands until it is balanced all around. Now you shine a 50-watt lamp close to one side of the shield. The wheel will start rotating at seven revolutions per minute. The gadget ran all evening.

"For the upcoming generation who would like a wheel intended to run forever without an external source of power, we submit the classical perpetual motion machine shown in the upper-left corner of the drawing. The principle: Sixes become nines as the wheel turns. Whether this numerical increase can generate counterclockwise rotation I leave to you."

Many readers have called our attention to an error in the legend of the circuit diagram which appeared at the top of page 134 in the February issue. The resistance value should have been 560,000 ohms, not 560.

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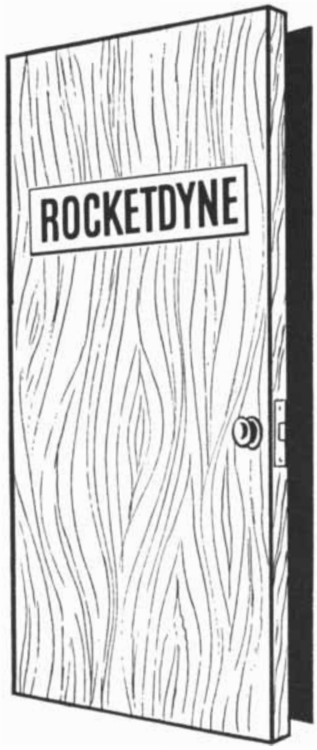

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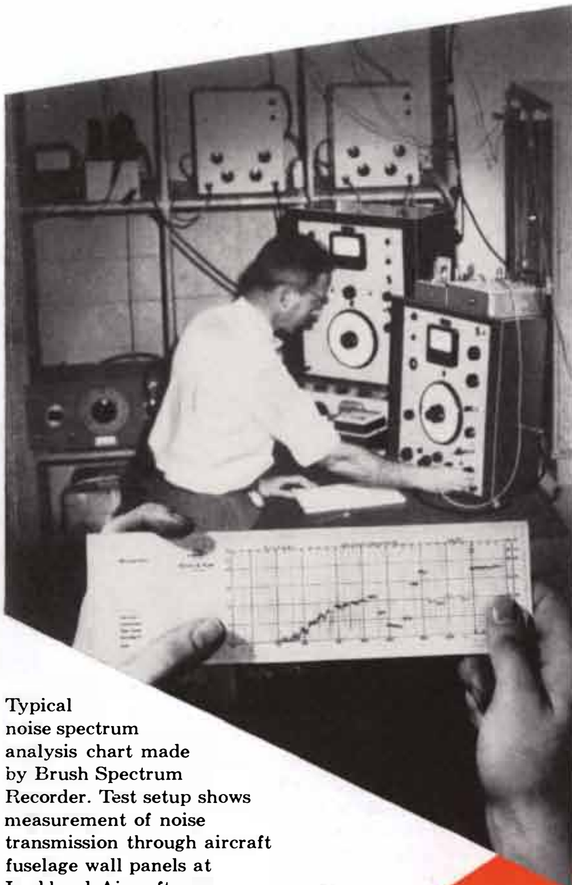
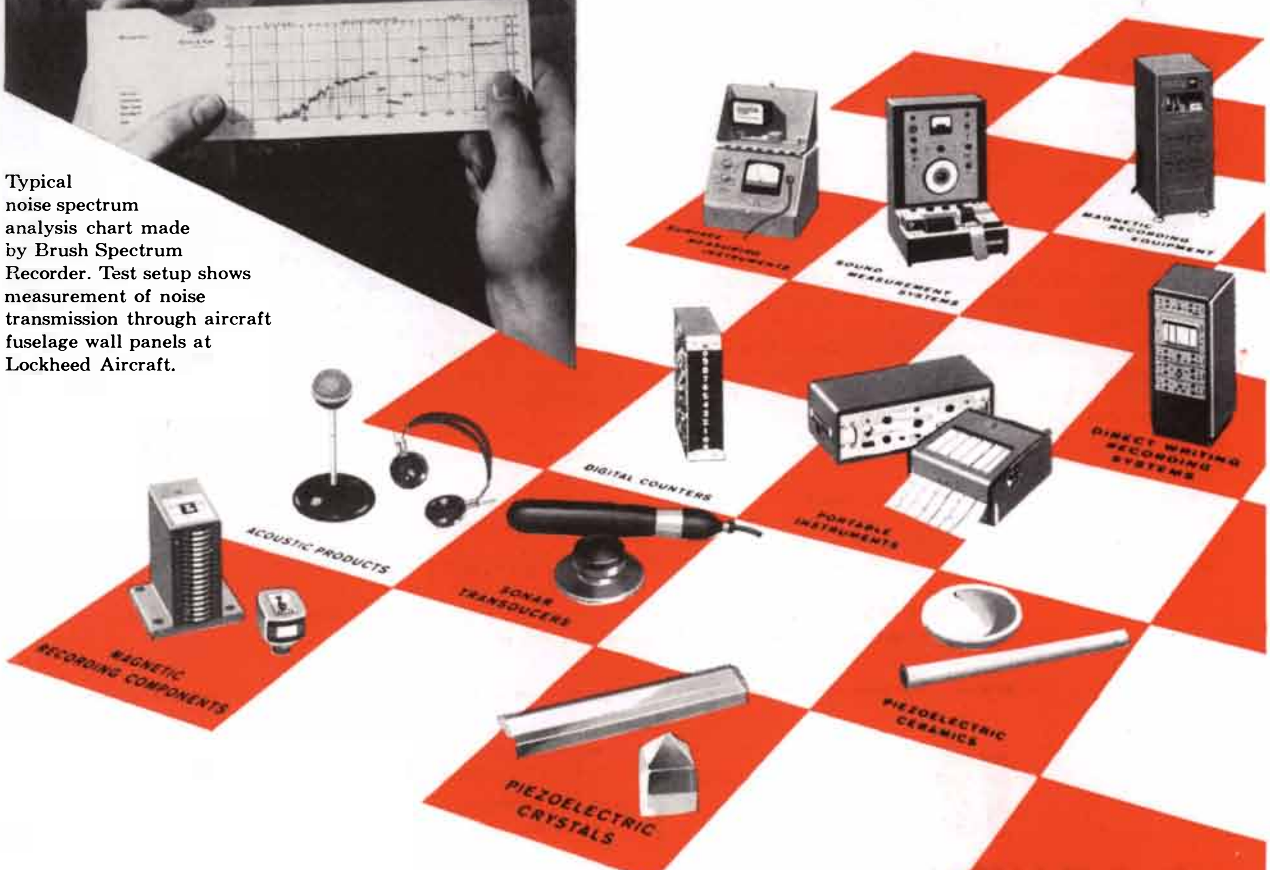


Typical noise spectrum analysis chart made by Brush Spectrum Recorder. Test setup shows measurement of noise transmission through aircraft fuselage wall panels at Lockheed Aircraft.

The first step in noise and vibration analysis is to *get the facts*. Here instrumentation, manufactured in Denmark by Bruel & Kjaer, has won international acceptance as the best equipment to use for some solid reasons:

Measurements are made in one-third octave steps, to positively identify frequencies . . . all sounds from 14 to 36,000 cycles per second are automatically scanned to eliminate laborious data plotting . . . and a complete amplitude vs. frequency record can be made in just 21 seconds! Brush offers a complete line of sound measurement equipment — thus we can help you in system application.

For complete information on sound, noise and vibration measurements call your Brush representative. Or write Brush Electronics Company, Dept. B-5, 3405 Perkins Avenue, Cleveland 14, Ohio.



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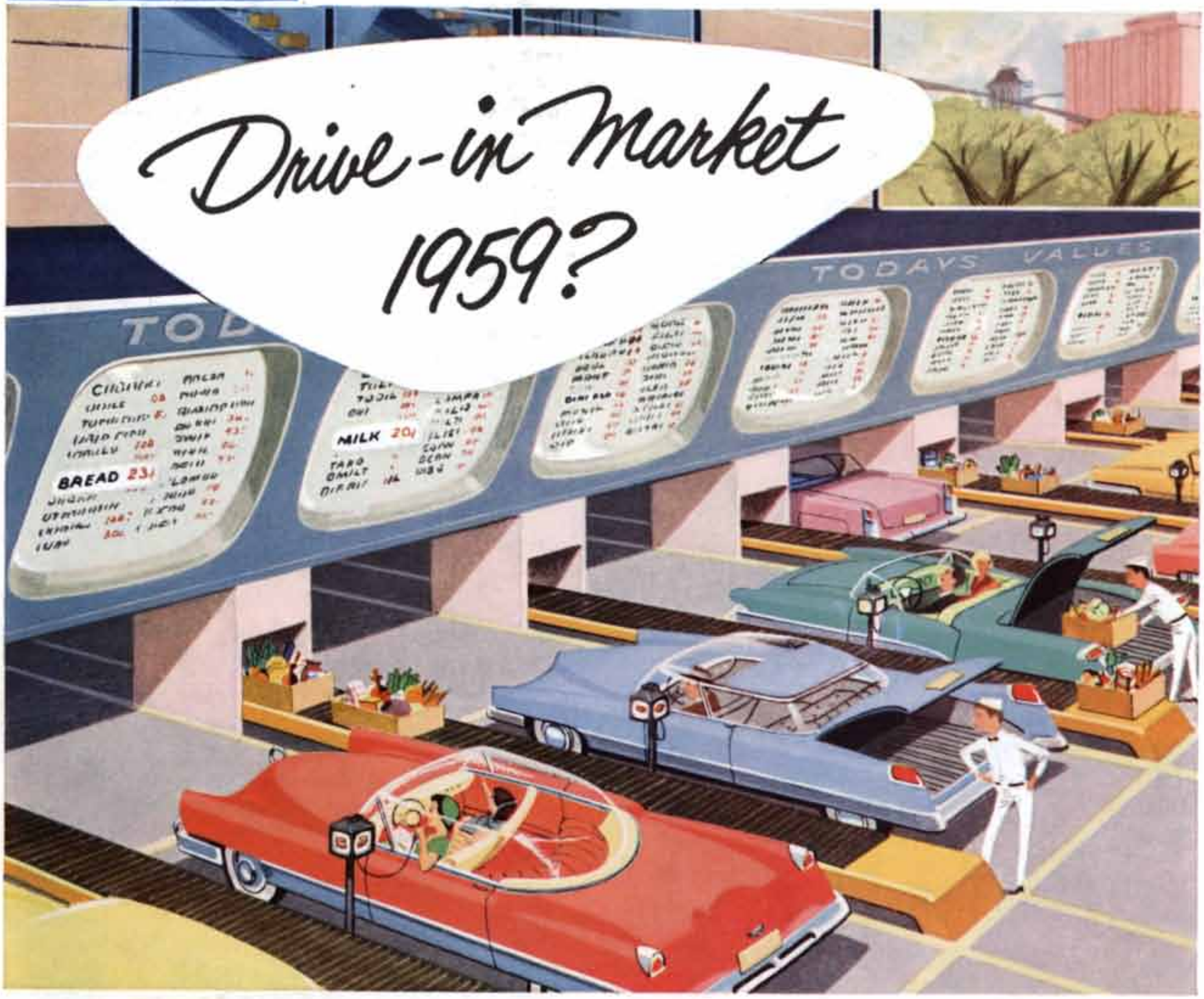

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