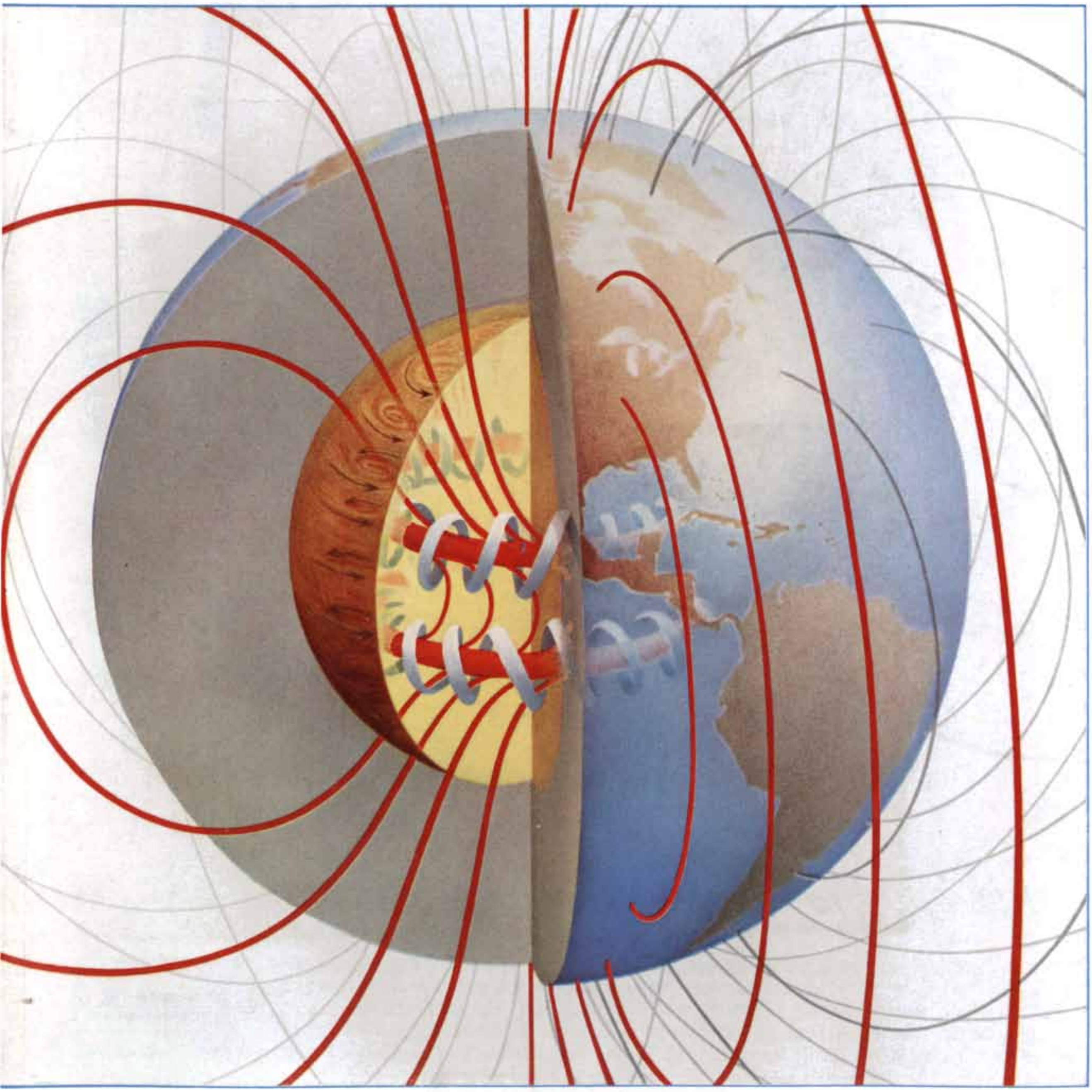
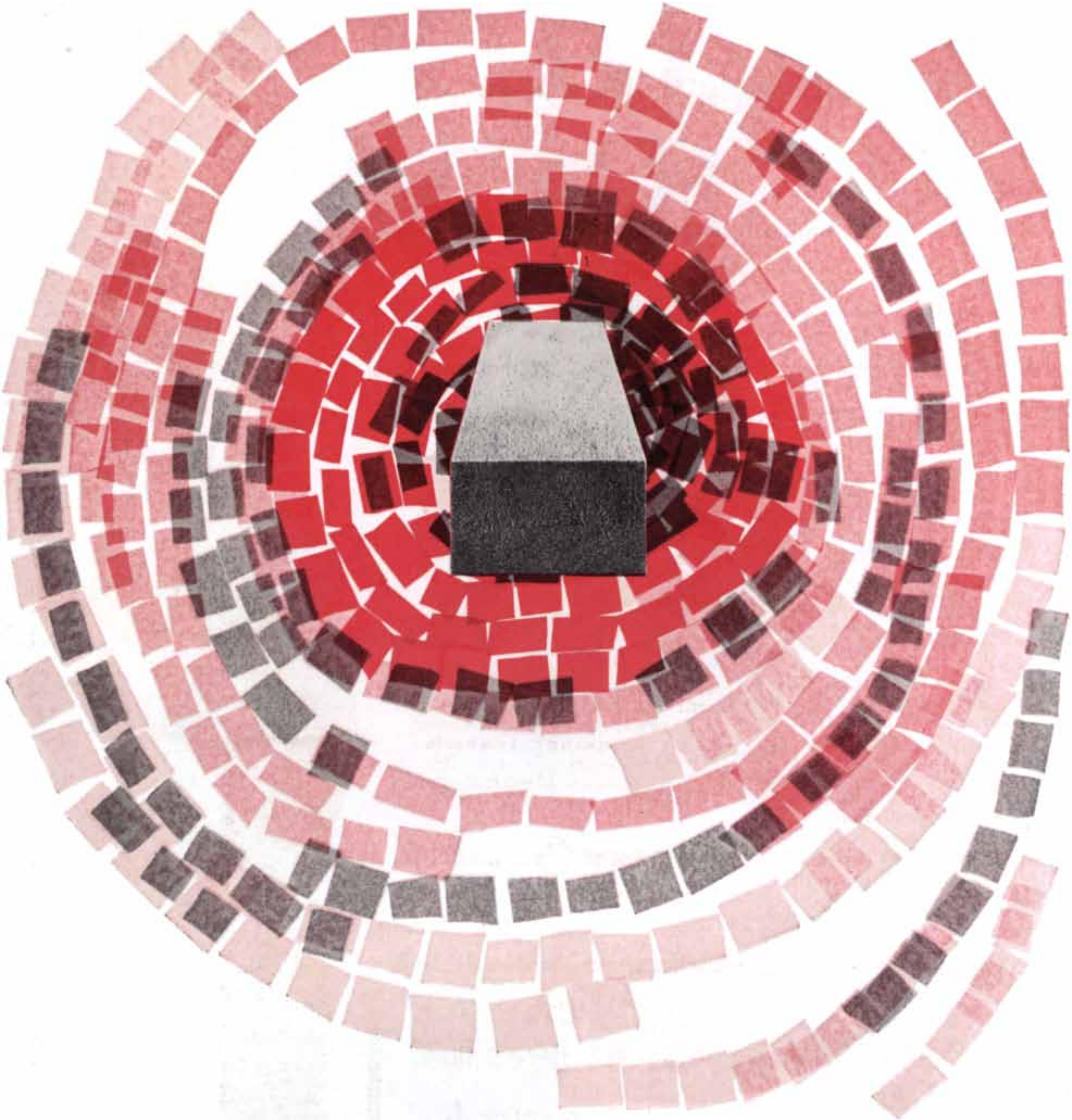
SCIENTIFIC AMERICAN



THE EARTH AS A DYNAMO

FIFTY CENTS

May 1958



mix imagination with Alcoa Aluminas

and get refractories or refractory castables that work hardest, longest! Refractories are vital to production in almost every industry. To give industry the best refractories possible, more and more refractory manufacturers have turned to Alcoa® Aluminas. They've found that refractoriness and durability increase in direct proportion to the amount of alumina they use. They know it pays to mix imagination and engineering with Alcoa Aluminas . . . for the best in refractory performance at reasonable cost.

Alcoa is not a source for finished refractories, but does supply aluminas to manufacturers of the best refractories. For their names, write: Aluminum Company of America, Chemicals Division, 706-E Alcoa Building, Pittsburgh 19, Pennsylvania.

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ALCOA CHEMICALS
ALUMINUM COMPANY OF AMERICA

"ALCOA THEATRE"
Exciting Adventure
Alternate Monday Evenings

Boon to equipment designers and "problem liquid" pumpers

Sealless plastic pump eliminates corrosion, leakage, contamination, cuts maintenance to bone!

Sometimes the answer to a problem lies not in further improvements along an existing avenue of development, but rather in creative thinking that finds a completely *new approach* to the problem. That's what Cooper Alloy has done with its Vanton Plastic Sealless Pump (mfd. by Vanton Pump Div). Where other companies have sought to *improve* shaft seals to minimize leakage and maintenance, Cooper Alloy has worked out a design that *eliminates* the shaft seals (see panels below).

Practical results are outstanding. Product contamination is eliminated, since pumping chamber is completely sealed, and no metal touches the liquid. Leakage and scoring of pump parts are eliminated; maintenance is reduced to infrequent replacement of liners. Body blocks and liners can be fabricated from a wide variety of plastic materials, to handle any corrosive, abrasive, or pharmaceutical fluid pumped in industry today.

Currently in use in thousands of "problem-pumping" situations the nation over, the Vanton Pump will soon appear in two new important applications:

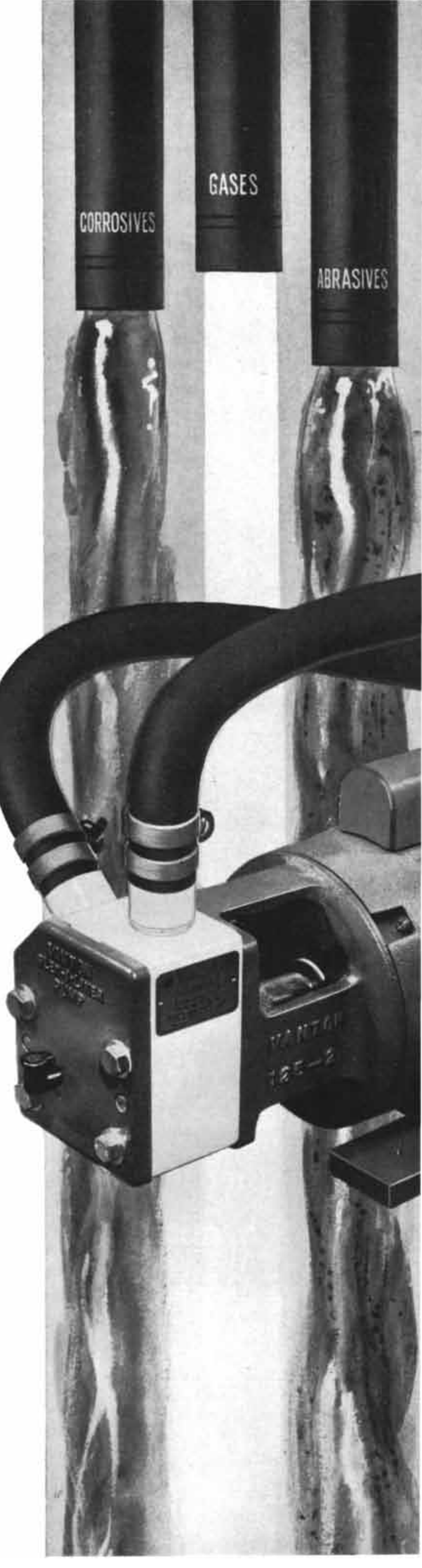
Close-Coupled Motor-Pump Unit, for versatile, all-purpose pumping in "run-of-mill" plant situations;

Original Equipment Model, with long trouble-free working life, and *no maintenance schedule needed,* styled *and priced* to meet the needs of original equipment manufacturers in all fields, from industrial to aircraft to home appliances.

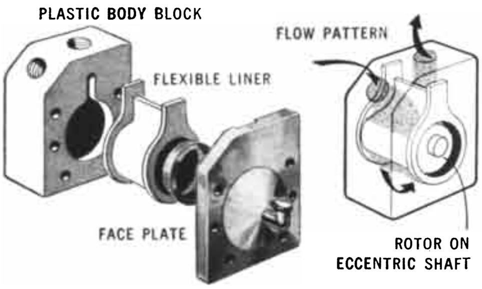
Where can you use this simple, trouble-free, leak-free pump design?—or this kind of pioneering, problem-solving Cooper Alloy thinking? Inquiries welcomed, especially from Original Equipment Manufacturers. Write today, won't you?

COOPER ALLOY

Corporation • Hillside, New Jersey



New Cooper Alloy pump design outflanks shaft seal problems by eliminating seals. Here's how:



Conventional Pump. Seals and packing are needed to seal off fluid pumping chamber where impeller shaft, powered from outside, enters casing. Seals require constant maintenance and attention, to prevent leakage, and depending on product, contamination and scoring of pump shaft. Vanton Pump, having no shaft seals, avoids these problems.

Vanton Design Is Simple. Minimizes Maintenance: Liquid flows in channel between molded plastic body and synthetic liner. No liquid touches metal. Liner flanges are secured to body block by bolted face plates. Pumping mechanism is rotor on eccentric shaft. All bearings are located outside of fluid area. At each revolution rotor pushes liner against body block and sweeps a "slug" of liquid around track from inlet to outlet. Resilient liners, replaceable in minutes, absorb "grind" of abrasive slurries. Wide choice of plastic materials gives easy handling of all industrial corrosive and abrasive liquids, with minimal maintenance. Self-priming, high vacuum, capacities ⅓-40 gpm. FOR ALL THE FACTS, WRITE FOR BULLETIN SA50.

F *FOR*

Y *YOUR*

I *INFORMATION*

Allied Chemical

NEW USES FOR POLYETHYLENE

Polyethylene, as we all know, is pretty versatile stuff. By varying its molecular weight, it can be made soft and fluid—or so hard that even its manufacturer doesn't know what to do with it! (More about this from us in future articles.) Right now, a word about the low-molecular types, of especial interest to molders and textile people.

Textile finishes: Polyethylene is now emulsifiable—and that's good news for the textile industry, already the largest consumer of chemicals. A-C polyethylene emulsions can be used either by themselves or with other finishes to impart a variety of desirable characteristics to both natural and synthetic fibers, such as soft "hand," and better wearing qualities through increased tear strength and abrasion resistance.

Slush molding: Molders are well aware of the advantages of this process—low pressures, short runs, inexpensive molds. But, they may not be as aware as they should be of the advantages of polyethylene for slush molding. Here's an entirely new material for the process—one which "gives the properties without the problems." A mixture of A-C polyethylene with conventional types permits viscosity control. Polyethylene and slush molding are opening up a whole new concept of plastics manufacture—from small toys to 50-ounce parts—all with fine detail and warm "lifelike" feel. *Write for our latest bulletins on these polyethylene developments.*

A new concept of plastics manufacture—slush molding with A-C polyethylene. (Decoys at left are from mold above.)

REPORT ON ROCKET PROPELLANTS

A few years from now, if somebody tells you his vacation is going to be "out of this world," he may mean it quite literally. He may be planning a jaunt to Mars—or the moon. Chances are he'll go "by rocket." And what will make the rocket go? That's a question which is absorbing the attention of many of our rocket-minded citizenry today —and for purposes far more pressing than space travel.

Nitrogen Tetroxide may prove to be one of the answers. It's certainly worth a long look into. N_2O_4 offers some decided advantages over liquid oxygen and hydrogen peroxide as an oxidizer. Compared to liquid oxygen, for instance, it is strikingly better on a density basis (1.45 vs. 1.14). It gives 12% greater range and is far easier to handle, needing no refrigeration. More than an oxidizer, its energy content contributes thrust as well. Availability? Sources are now adequate and potential availability is practically unlimited. The cost is slightly greater, but all things considered, it may be cheaper to use—as a first-stage, dependable oxidizer.

Of course, there's nothing exactly "new" about Nitrogen Tetroxide as a chemical. It became available in pilot plant quantities 'way back in the early 1940's. Today's demands for the ideal rocket propellant give it new and pertinent interest. *A new bulletin is available.*

NEW FOREST-FARMING BIBLIOGRAPHY

"Forest Fertilization," a 300-page bibliography, with abstracts, on the use of fertilizers and soil amendments in forestry, has been published by the State University College of Forestry, Syracuse University. This book, first of its kind, is the result of a two-year study sponsored by Allied's Nitrogen Division. It is now available to the public at a $3.00 cost-of-printing charge. Also available, and without charge, are two booklets translated from German and Japanese sources describing fertilization practices in those countries. *Write us for any or all.*

* * *

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Established 1845 SCIENTIFIC AMERICAN May, 1958 Volume 198 Number 5

ARTICLES

DEPARTMENTS

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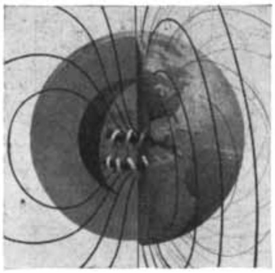

THE COVER

In the painting on the cover the earth is partly cut away to show how eddies in its fluid core (*yellow sphere*) may give rise to the earth's magnetic field. The lines of force in the field are represented by the large loops. These loops may be the result of electric currents (*helixes*) which are in turn generated by eddies (*small arrows*) in the core.

THE ILLUSTRATIONS

Cover painting by Irving Geis

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Take a New Look at

TITANIUM

Wonder metal? Restricted supply? Not today. Titanium is daily *proving* its economic advantages in more and more industrial applications.

And Mallory-Sharon... world's largest integrated producer of special metals... is ready *now* to assist you in designing with titanium. We can supply your requirements for titanium and titanium alloy sheet, strip, rod, bar, plate and other mill products... many of them from stock.

Check below for ways titanium and its alloys can serve you now! Then write us about your requirements, or contact our nearest sales office.

For availability — *Delivery time on titanium has been cut by Mallory-Sharon's ingot inventory in certain grades and analyses. Here, orders can be started in the ingot stage, saving time for fabricators. In addition, a wide range of sheet and bar sizes can be shipped direct from stock.*

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For technical facts *write for "Titanium Fact File"—giving advantages, metallurgy, corrosion properties, information on machining, welding, forming. Our Service Engineering group is ready to assist you.*

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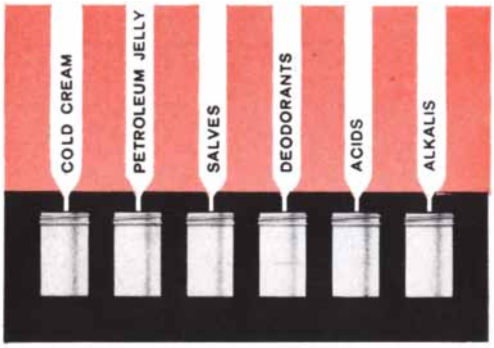
CELANESE FORTIFLEX MAKES POSSIBLE A

A Word About Celanese Fortiflex . . .

Fortiflex is a linear type polyolefin with a specific gravity less than water. Its rigidity combined with toughness makes possible a host of packaging applications—from thinwall blown bottles and injection molded jars to transparent film for bags and wraps. Its heat resistance and resistance to chemical attack mean that Fortiflex containers can be subjected to post-packaging sterilization, and can be used for packaging many chemically reactive liquids, semi-solids and solids. Fortiflex has the sanction of the Food and Drug Administration.

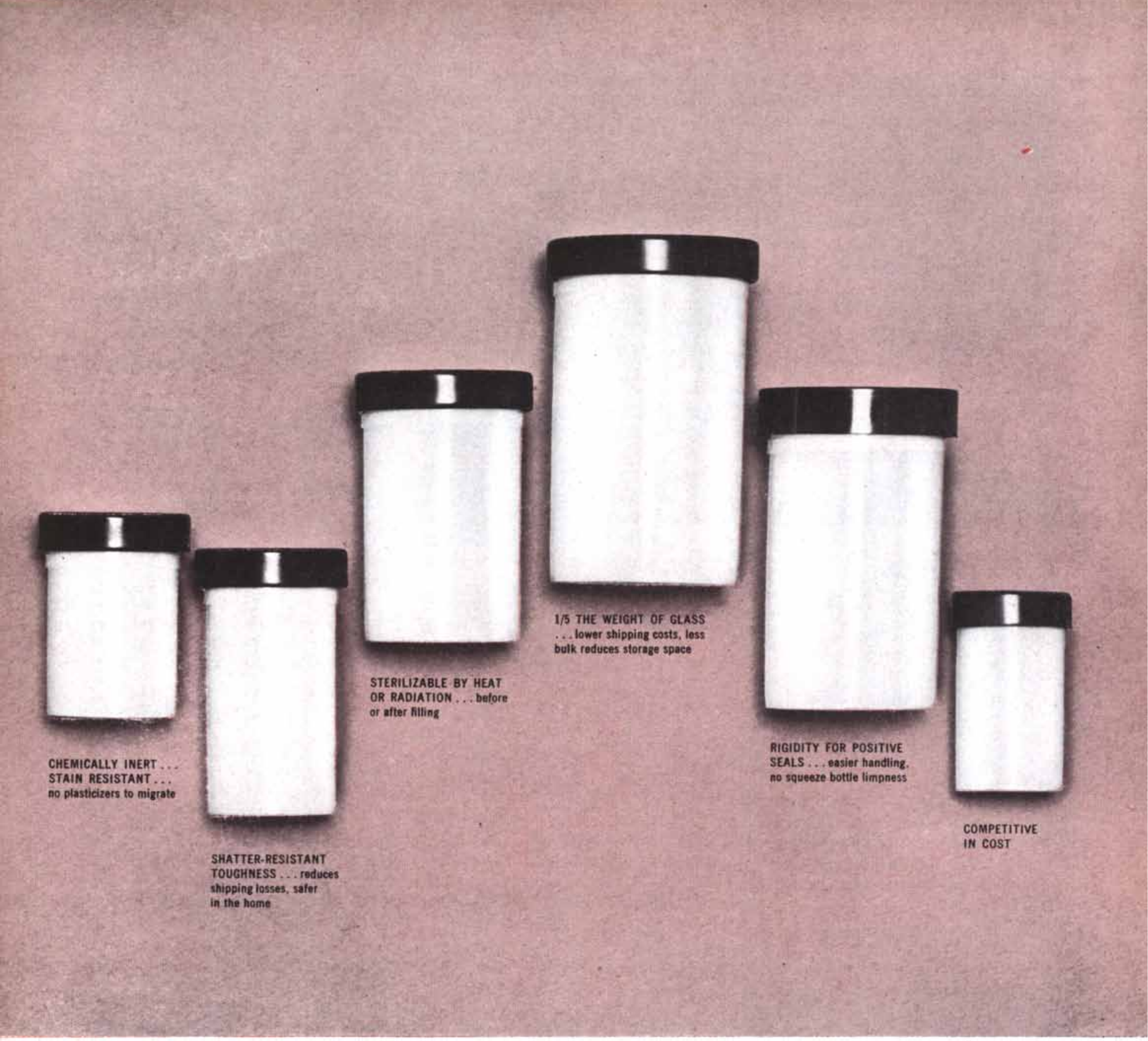
If you have a packaging problem that calls for something special in a packaging material, write to: Celanese Corporation of America, Plastics Division, Dept. 192-E, 744 Broad Street, Newark 2, N. J. Canadian Affiliate: Canadian Chemical Co., Limited, Montreal, Toronto, Vancouver. Export Sales: Amcel Co., Inc., and Pan Amcel Co., Inc., 180 Madison Avenue, New York 16, N. Y.

Celanese® Fortiflex®



A THOUSAND PACKAGING POSSIBILITIES

Celanese Fortiflex is basically a simple polymer of ethylene. However, its ordered molecular arrangement provides the combination of rigidity, toughness, and chemical and heat resistance needed for almost any type of container packaging.



SIGNIFICANT ADVANCE IN JAR PACKAGING

Lermer Plastics, Incorporated offers immediate shipment on a complete line of Poly-Opal drug, cosmetic and ointment jars in the popular slim line shape

Taking advantage of the unique properties of Celanese Fortiflex, Lermer Plastics, Incorporated have developed a line of rigid-type containers that promise to revolutionize the packaging of drugs, cosmetics, chemical specialties and other products. Called Poly-Opal, the jars now in production are made in six sizes—from ½ oz. to 4 oz. They are designed for standard threaded closures, and can be hermetically sealed with cellulose type seals.

Poly-Opal jars are also available in a full range of colors. Other special shapes, sizes and colors can be created for exclusive use of industrial users.

For more information about Poly-Opal Fortiflex plastic jars, you are invited to get in touch with Lermer Plastics, Incorporated, Garwood, N. J. Address your inquiry to Dept. CF500 for prompt response.

Fortiflex...a Celanese linear polyolefin

LETTERS

Sirs:

John Bardeen's letter ["Letters," SCIENTIFIC AMERICAN, January] criticizing B. T. Matthias's article on superconductivity requires some comment from a theoretician's point of view. Professor Bardeen's contentions are that the Bardeen-Cooper-Schrieffer (B.C.S.) theory gives a sound and essentially complete explanation of all major effects in superconductivity, and that no valid objections have been raised against it.

Actually several objections, involving more than just points of mathematical rigor, have been raised by various people, *e.g.*, at the International Conference on Low Temperature Physics at Madison, Wis., in August, 1957.

The perhaps most serious objection raised concerns the very derivation of the Meissner effect, the most fundamental phenomenon of superconductivity. It has been demonstrated that by the use of certain identities (which follow from the law of conservation of charge alone and are thus universally true) the "Meissner effect" of the B.C.S. theory can be transformed away. So clearly the B.C.S. derivation of the Meissner effect is not consistent with the conservation law of charge. This point is glossed over in the B.C.S. paper in a footnote reference to other influences which, however, are not calculated. There is, thus, no valid theory of the Meissner effect given, nor of the vanishing of resistance.

Many of the other results of the B.C.S. theory, which seem to show such remarkable agreement with experiment, are secondary consequences of only one quantity, a gap in the possible energies of electron excitations, which is an adjustable parameter of the theory. Thus only this one quantity is under test. Its derivation, incidentally, is also open to doubt.

It would seem that Dr. Matthias's original caution was well justified.

M. R. SCHAFROTH

University of Sydney
Sydney, Australia

Sirs:

This is not the place to answer Dr. Schafroth's comments in detail. Nothing has occurred to change the views expressed in my letter. This letter should not have implied that the theory has been developed so far that there is no room for reasonable skepticism about its ultimate success.

JOHN BARDEEN

Department of Physics
University of Illinois
Urbana, Ill.

Sirs:

The entertaining and provocative article on symmetry by Martin Gardner ["Mathematical Games"; SCIENTIFIC AMERICAN, March] recalled for your readers the tantalizing question: "Why does a mirror reverse left and right and not up and down?" Despite the comprehensive descriptions of light paths and optical principles which are usually marshaled in answer to this query, there seems to be an even more fundamental basis, which, the writers of this letter propose, lies primarily within the province of psychophysiology.

Humans are superficially and grossly bilaterally symmetrical, but subjectively and behaviorally they are relatively asymmetrical. The very fact that we can distinguish our right from our left side implies an asymmetry of the perceiving system, as noted by Ernst Mach in 1900. We are thus, to a certain extent, an asymmetrical mind dwelling in a bilaterally symmetrical body, at least with respect to casual visual inspection of our external form. Here the term symmetry is used in an informational context, and indicates that the observer can make no distinction, other than sense, between

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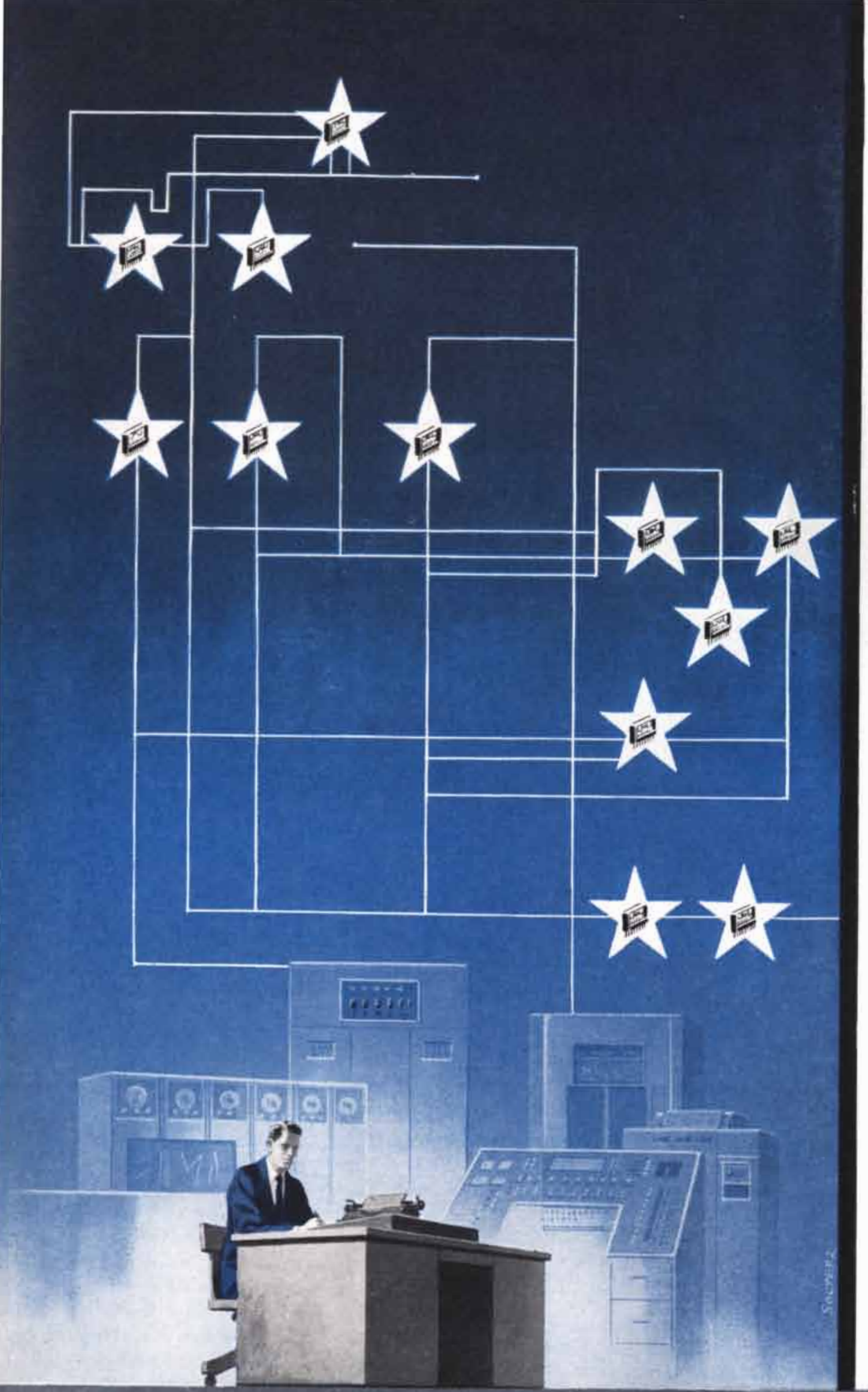

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And the smaller computer they make possible can be used in hundreds of new ways . . . in industry and for defense. Avco 'building blocks' are already in production for a U. S. Army-U. S. Air Force *portable* computer.

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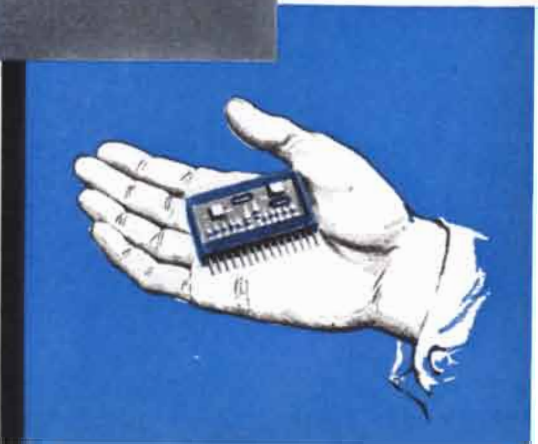

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two or more elements of his perceptive field. Of course by refining his observations he may gain information of other dissimilarities, at which time the system under consideration ceases to be symmetrical.

When we stand before a mirror, we see reflected a superficially bilaterally symmetrical structure, and we are misled by this apparent symmetry into treating the system as if ourselves and our reflection were identities rather than enantiomorphs (entities of opposite "handedness"). Therefore, by psychological projection, we seem to be able to rotate our body image 180 degrees in three-dimensional space around a vertical axis and to translate it a distance equal to twice the distance to the mirror, thereby achieving a coincidence between our body and its reflection. By this process we have imagined the identical central-nervous-system perceptive machinery which is in ourselves, rather than its enantiomorph, to exist within our mirror image. We are consequently led to the erroneous statement that when we move our right hand, our mirror image moves its left hand. If we, more correctly, imagine our enantiomorphic selves within our mirror image, then we realize that its definition of right and left would be reversed, and when we move our defined right hand, it moves its defined right hand. We must endow our reflection not with our own coordinate system, but with a mirror-image coordinate system. This can easily be illustrated by placing a paper bag over one hand and re-defining the major body axes as "head-feet," "front-back," and "hand-bag" (instead of right-left). Now stand before a mirror and observe that when you move head, mirror image moves head; when you move feet, mirror image moves feet; when you move hand, mirror image moves hand; and when you move bag, mirror image moves bag. What has become of right-left reversal? It has been dispelled, as the chimera it was, by the simple procedure of making our superficial structure obviously not bilaterally symmetrical. It is no longer possible to produce essential coincidence between ourselves and our mirror image by 180-degree rotation around our vertical axis, any more than around any other axis, and we recognize the enantiomorphic nature of our reflection.

To illustrate how the convention of rotation about a vertical axis imposes the concept of right-left mirror reversal on objects other than ourselves, consider a map of the U. S. oriented in the customary manner of North headward and East to the right. To observe the mirror

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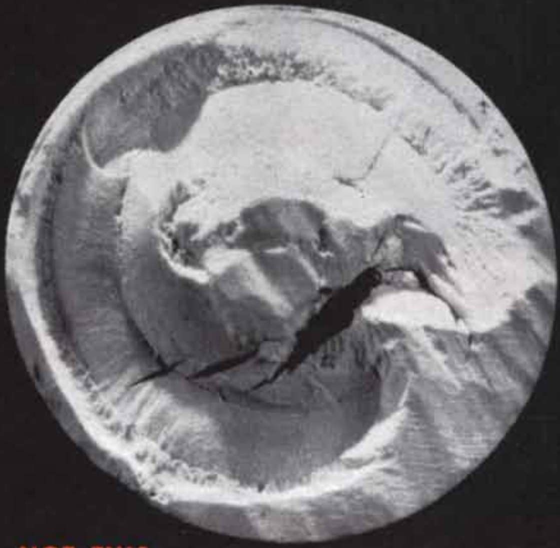

NOT THIS

This is an unretouched photo of a broken 3" thick section of high alumina ceramic, formed by the conventional wet process. It clearly shows typical voids and hidden stress patterns inherent in all conventionally made, wet process ceramic parts.

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Outside of the spark plug field, Coors has pioneered in isostatically forming high alumina ceramics. In this forming technique, blanks are initially produced by pressing dry, unfired powder in a rubber mold under high hydraulic pressure. An accurate inside contour can be formed by pressing the powder around a metal arbor. The uniform pressure from all directions provides uniform compactness and complete homogeneity. The final outside shape is formed by machining the blanks.

In a wet process, the ceramic parts, once formed, must be dried. This drying action causes hidden stresses to develop. And finally, the volume occupied by the water is replaced by air, forming hidden voids and weak spots.

Since the powdered ceramic material used in the *Isostatic Process* is dry before it is formed, the machined blanks go directly into the high temperature kilns. Unpredictable drying necessary in wet processes is thus eliminated.

With Coors Alumina Ceramic parts made by the *Isostatic Process*, the engineer can accurately design for mechanical and electrical properties—an impossibility with any ordinary methods of forming ceramic. For complete mechanical and electrical properties, send the coupon below. Parts to test your design will be furnished at nominal cost.

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Please send me detailed Bulletin 1055-A on Coors High Strength Alumina Ceramics and Coors manufacturing facilities.

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Company..

Address...

City..............................*State*...................

Please refer to our 12-page catalog in Sweet's Product Design File image of this map, we invariably rotate the map around its North-South axis toward a mirror. This habit undoubtedly derives from the fact that most of our movements designed to inspect our environment involve rotation about our vertical axis. For example, if the map were fixed to a wall opposite a mirror, we would observe the map directly and then rotate ourselves about our vertical axis to view the map's reflection. In either case, East will now appear to our left, but North will remain up. If, however, we rotate the map around its East-West axis to face the mirror, or look at the reflection of the wall map by standing on our head, then East remains to our right, but North becomes footward. It now appears that the mirror has reversed top and bottom rather than right and left.

The only determined coordinate system is that which the observer imposes on his environment, and the axes can be adjusted so that the origin occurs at any point within the observer's perceptive space. When we describe the parts of an object relative to one another, we generally do so by adjusting our coordinate system so that the origin occurs within the object, and it thereby acquires top-bottom, front-back, and right-left axes corresponding to those of the observer. As objects rotate within this system, either through motion of the object or motion of the coordinate system (*i.e.*, the observer), certain of the object's coordinate values will change sign. Rotation of an object around its vertical axis results in change of sign of right-left and front-back loci; around its right-left axis results in change of sign of front-back and top-bottom loci; and around its front-back axis results in change of sign of top-bottom and right-left loci. However, since the observer defines the coordinate system, rotation of the observer does not result in change of sign of the relative parts of the observer. Thus, if we look at our own reflection while standing on our head, we still erroneously interpret the mirror as reversing right and left, because in the process of inverting our body, we have inverted the coordinate system itself.

ROBERT D. TSCHIRGI, M.D., PH.D.

JOHN LANGDON TAYLOR, JR., PH.D.

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Medical Center
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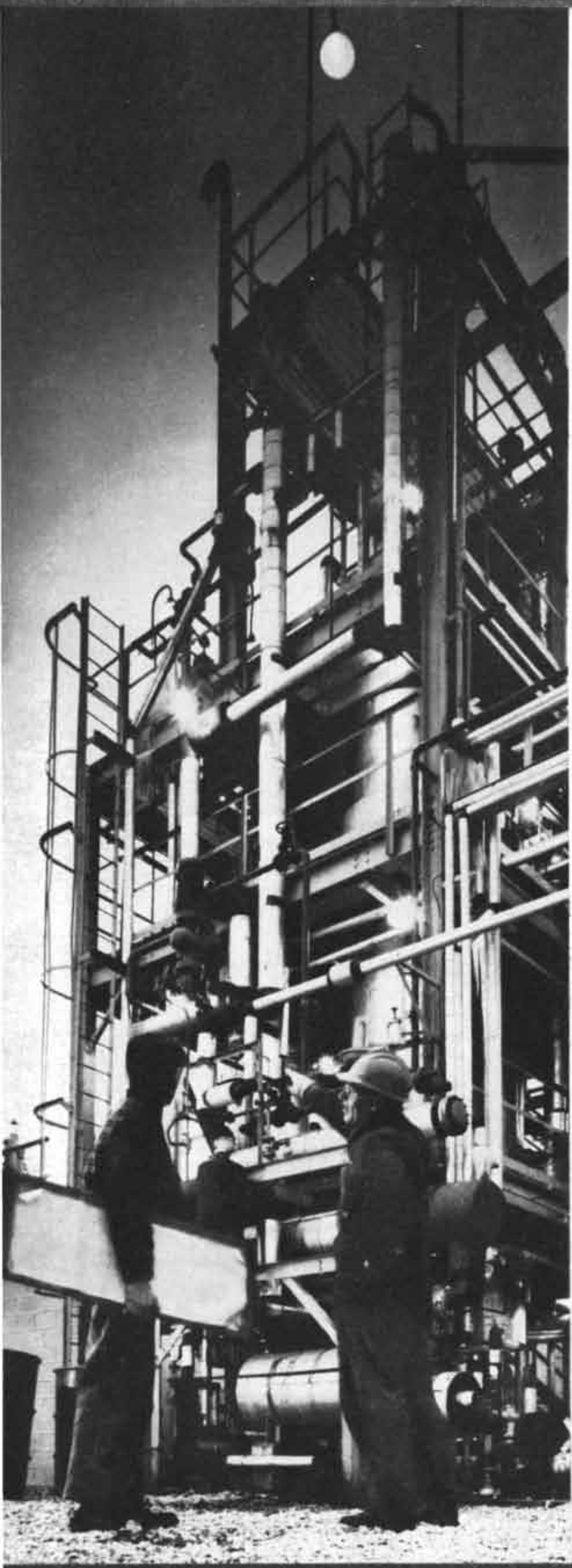

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DispersaGen*—a new soy development designed to perfect water-based paints

DispersaGen is an improved wetting agent for pigments in all types of water based paints. It is non-ionic; helps make smooth, creamy pigment pastes; maintains particle suspension; facilitates spreading. Paints thus formulated are more uniform, give clean cut coverage when applied, provide many other desirable features. DispersaGen is brand new. Be among the first to use DispersaGen to improve your formulations.

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50 AND 100 YEARS AGO

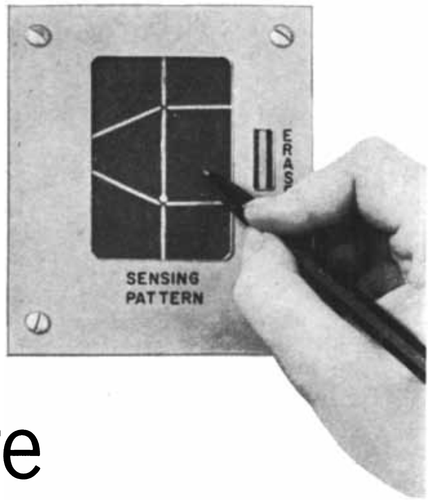
SCIENTIFIC AMERICAN

MAY, 1908: "The view that the atom is a complex system made up of negatively charged corpuscles and positively charged alpha particles has been made the subject of extensive mathematical studies by J. J. Thomson. Thomson's hypothetical atom is a system composed of rings or shells of corpuscles in a uniform sphere of positive electrification. That the corpuscular theory is the last word on the nature of matter, none will contend. Thomson himself writes: 'The theory is not an ultimate one; its object is physical rather than metaphysical. From the point of view of the physicist, a theory of matter is a policy rather than a creed; its object is to connect and coordinate apparently diverse phenomena, and above all to suggest, stimulate and direct experiment.' "

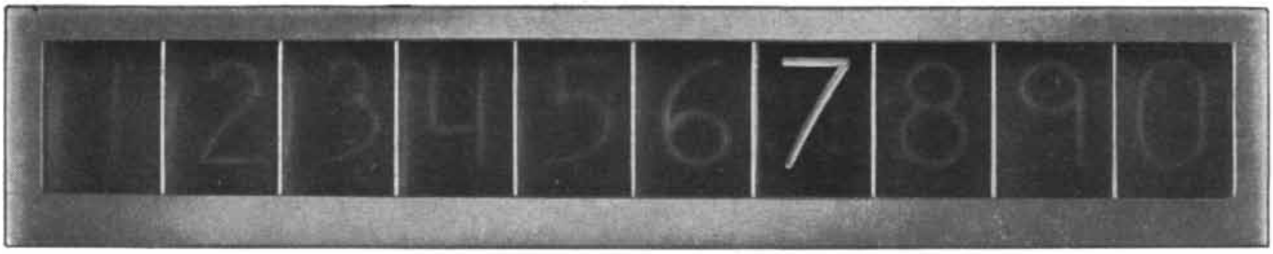
"In 1931 the asteroid Eros will approach the earth within 16,000,000 miles, about half the distance that separated the two planets in 1900. Sir David Gill asserts that it will then be possible to determine the solar parallax to one 10,000th of a second. The magnitude of this undertaking makes it necessary to distribute the work among all the meridian observatories of the world. For this reason Sir David proposed last August that a congress of astronomers be convened without delay for the purpose of considering the work to be done. If the hope of this eminent astronomer is fulfilled, we shall know the sun's distance to within 10,000 miles—little more than the diameter of the earth."

"One of the most interesting discoveries made at Pompeii within recent years was that of the Roman Villa Boscoreale, with its frescoes, mosaics and other antiquities. The collection of silverware which forms the most important of the objects was found in the wine reservoir, and it seems to be clearly indicated that the pieces were carried to this hiding place at the time of the eruption. The Baron de Rothschild bought for $80,000 95 pieces of the silverware, which he presented to the Louvre; the

Write a numeral here



and read it here



on new Bell Labs machine

A new device invented at Bell Laboratories "reads" a numeral while it is being written and instantly converts it into distinctive electric signals. The signals may be employed to make a numeral light up in a display panel, as above, or they may be sent to a computer or to a magnetic "memory" for storage.

The writing is done with a metal stylus on a specially prepared surface. Two dots, one above the other, are used as reference points. Seven sensitized lines extend radially from the dots. Transistorized logic circuits recognize numerals according to which lines are crossed.

The concept of a number-reader has interesting possibilities as a new means of communication from humans to machines. For example, in an adjunct to a telephone, it might provide inexpensive means of converting handwritten data into signals which machines can read. The signals could be transmitted through the regular telephone network to a teletypewriter or computer at a distant point. In this way, a salesman might quickly and easily furnish sales data to headquarters, or a merchant might order goods from a warehouse.

Modern communication involves many more fields of inquiry than the transmission and reception of sound. The experimental number-reader is but one example of Bell Telephone Laboratories work to improve communications service.

Tom Dimond, a B.S. in E.E. from the University of Iowa, demonstrates an experimental model of his number-reading invention. A similar device can also be made to read alphabetical characters. Small size and low power requirements result from transistor circuitry.

BELL TELEPHONE LABORATORIES
World Center of Communications Research and Development

frescoes have been acquired by the Metropolitan Museum of Art in New York City."

"For some months past the British military authorities have been experimenting with a new type of tractor for the haulage of heavy vehicles over rough and unstable ground. This machine, the invention of Mr. David Roberts, M.I.M.E., represents a new development in traction. Briefly, its object is to crawl over the ground, there being a series of feet disposed along the periphery of two heavy side-chains passing over fore and aft wheels. As this chain revolves, the feet are successively brought into contact with the ground, thereby impelling the machine forward or backward. Because of its peculiar movement, the soldiers at the Aldershot military center, where it is in operation, promptly christened it 'the caterpillar.' "

"Upon the return of the newspaper correspondents and photographers from North Carolina, considerably more information was obtainable regarding the recent flights made by the Wright brothers in testing their aeroplane than has hitherto been available. All those who witnessed the flights agree that the performance of the machine was marvelous, and that the speed attained with the small motor of 30 horsepower was remarkable. As already noted in our last issue, the speed in question appears to have been from 45 to 48 miles an hour, although the last flight was timed in seven minutes and 40 seconds, during which the Wright brothers claim that the machine traveled slightly over eight miles. According to report, they made three earlier flights of 18, 24 and 32 miles respectively. Since their trial flights in North Carolina have been witnessed by newspapermen, and photographs of these flights have been secured, there is no longer any doubt of the pre-eminence of America in aviation."

MAY, 1858: "M. St. Claire Deville lately delivered a lecture on aluminium before the Society for the Encouragement of National Industry at Paris; he gave some interesting facts in relation to its properties, and the progress made toward its general introduction. Under the skillful hand of this celebrated manipulator, it has been reduced to a

beautiful white metal with a slight bluish tinge, easily worked, more easily melted than silver, remarkably well adapted for gilding, and, in short, capable of being applied to many manufacturing household purposes."

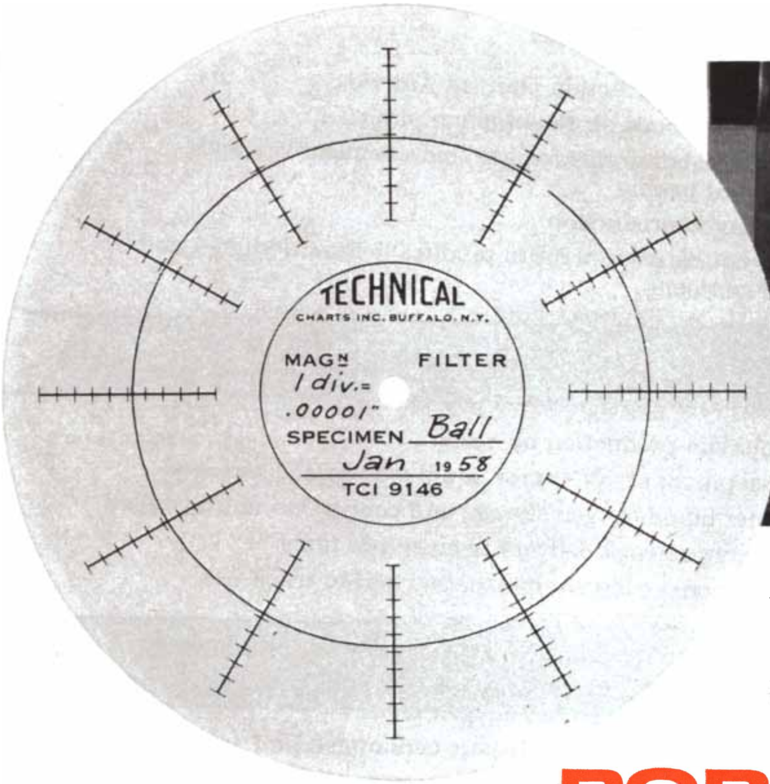
"By the latest news from Europe, we learn that very active preparations are now making for the next effort in laying the Atlantic telegraph cable. Our noble frigate, the *Niagara*, with the British war steamer *Agamemnon*, her former companion, are taking in their shares of the cable, and they will be in readiness to proceed on the expedition about the end of May. Mr. Bright is still chief engineer, and from his former experience it is reasonable to suppose he will neglect no precaution to ensure success. From recent experiments on the coils, as stated in English papers, it would appear that only about eight words per minute can be sent through the cable—very slow work indeed."

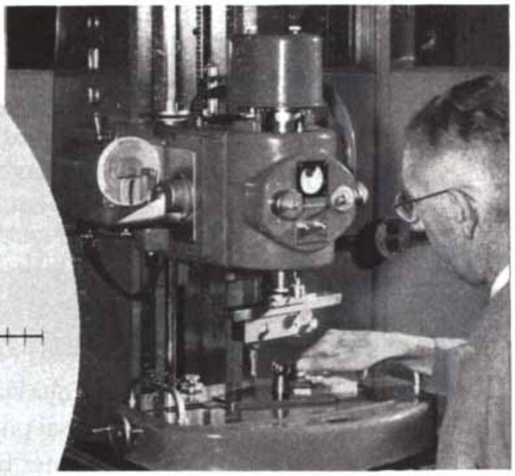
"At the opening of a new street in Paris lately, M. Jules Duboscq's electric light was employed with great success, perfectly illuminating the street and shedding a beam of brilliant white for a great distance."

"There is a hoop skirt manufactory in New York City which weekly turns out 24,000 ladies' skirts, employing for that purpose 500 hands, 180 sewing machines, and not less than a tun of steel. Various materials have been employed to give the required degree of flexibility to the skirts, to enable their wearers to sit upon them, and pack them to the smallness of compass frequently required, without affecting their elasticity and capacity to again spread themselves to the full extent and graceful form when their wearers rise to an erect position. The rotundity of spread is now given to this general favorite of female apparel by very thin steel springs, so prepared, and intertwined with the stiffened fabric of which they are principally composed, as to give them these characteristics."

"A commission appointed in France to consider the claims of Professor Morse for remuneration, because his telegraph was employed in that country, has reported in his favor, and has recommended the payment to him of 400,000 francs. As Professor Morse's telegraph was first patented in France and has been the one mostly used in that country, where all the telegraphs are under government control, the sum is very respectable."

ND FACTS





Accuracy measured in millionths of an inch, made visible to the human eye. Steel balls, the heart of New Departure precision ball bearings, held to 5 millionths of an inch or less in sphericity. Graph at left shows sphericity variation of a ball on the order of one millionth of an inch (.000001") measured by Talyrond Machine. Graph radial divisions are .00001".

PORTRAIT of PRECISION!

The extreme accuracy of New Departure ball bearing component parts is now playing a vital role in successful missiles for the Army, Navy and Air Force. Above —typical bearing parts, less separator —unretouched photograph.

A mechanism is only as accurate and reliable as the bearings supporting its moving parts. For the designer the problem is how to achieve the essential rigidity or *accuracy of location*, yet be assured of extreme *freedom of rotation.*

A "tip-off" to the solution lies in the chart above—super-precise steel balls, the heart of New Departure precision ball bearings. For, with balls held to 5 millionths of an inch or less out-of-roundness and other bearing parts finished with comparable care, such bearings can be mounted and *preloaded* to provide the hairsplitting exactness of location and *ease of rotation* required of the finest precision instruments.

The AChiever-guidance system proved in tests of the Air Force's Thor ballistic missile demands tolerances often measured in millionths of an inch, as is the case with the New Departure ball bearings on which the AChiever's precision gyros turn.

1908–1958
GM
FORWARD FROM FIFTY

NEW DEPARTURE
DIVISION OF GENERAL MOTORS, BRISTOL, CONN.
NOTHING ROLLS LIKE A BALL

CRYOGENIC* KNOW-HOW
...highlights from the Record

*Technology of ultra-low temperatures

1907 LINDE installed first air liquefaction plant in America
1912 Built the first American-made air liquefaction plant
1914 Established scientific laboratories for gas and chemical research, experimentation, and testing
1916 First commercial argon production
1917 First natural gas liquefaction plant to produce helium designed and built for U. S. government
1917 Argon extensively used to fill light bulbs
1917 LINDE became a part of UNION CARBIDE
1918 Operations extended to Canada
1920 Development of rare gas separation processing
1922 Began commercial production of neon
1928 Started development of system for liquid oxygen and nitrogen
1932 First customer liquid oxygen storage and conversion unit installed
1932 First liquid oxygen truck delivery to customer units
1935 High-pressure conversion equipment adapted to truck use
1935 Oxygen converted from liquid to gas on trucks
1937 Powder-vacuum insulation reduced heat leak to contents by a factor of 10
1939 First vacuum-insulated railroad tank car shipment of liquid oxygen
1940 First combination liquid and gaseous oxygen plant
1944 Liquid oxygen producing plants, transport containers, and storage units made for government
1946 Basic patent for powder-vacuum insulation issued
1946 First 25,000,000 cu. ft. liquid storage reservoirs for oxygen, nitrogen, or argon
1948 First 140 ton a day low-purity oxygen-producing unit
1949 First 360 ton a day on-site oxygen-producing unit for chemical industry
1950 First liquid nitrogen equipment for shrink fitting
1951 Heat leak to contents further reduced by a factor of 10
1953 First 450,000 cu. ft. capacity vacuum-insulated trucks
1955 First automatically-operated on-site oxygen plant
1955 First 3000 cu. ft. compact cylinder for storage, transport, and conversion of liquid oxygen
1957 3000 cu. ft. cylinder adapted to shipment of liquid nitrogen, argon, and hydrogen
1957 Continuing progress in decreasing heat leak to contents
1957 Liquid oxygen distribution system requiring no external power source
1957 First automatically-operated 120 ton a day on-site oxygen plant
1957 Single shipment of 10,000 liters of xenon
1958 Continual commercial shipments of liquid hydrogen

Linde
TRADE MARK

UNION CARBIDE

The terms "Linde" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

Some Cold Facts About CRYOGENICS and 'LINDE'

Since installing the first oxygen liquefaction plant in America in 1907, LINDE has continuously expanded its Cryogenics capacity—scientific, engineering, and production. How much? Look!

PRODUCTION

More than 50 plants for producing liquid or gaseous oxygen, nitrogen, argon, hydrogen, and rare gases (neon, krypton and xenon).

Here are the capacities of a few centrally-located plants producing liquid:

Essington, Pennsylvania — **500 tons a day** (12,000,000 cu. ft.)

Fontana, California — **175 tons a day** (4,200,000 cu. ft.)

Ashtabula, Ohio — **500 tons a day**

Others at Kittanning (**700 tons**), Seattle (**20 tons**), Houston (**40 tons**), Birmingham (**20 tons**), East Chicago (**900 tons**), *Etc.* . . .

Most on-site plants operated for single-customer use produce high-purity gaseous oxygen. Capacities range from 10 tons a day to more than 500 tons a day. (One ton equals 24,150 cu. ft., N. T. P.)

DISTRIBUTION

Over 100 storage and distribution installations, plus hundreds of customer units are serviced by a LINDE built fleet of:

More than **500** liquid-carrying railroad box tank cars.
Standard capacity: 1,000,000 cu. ft. (gaseous equivalent)

Over **350** liquid-carrying trucks and trailers:
Capacity: 60,000 to 450,000 cu. ft.

(More than ⅔ of these are equipped to convert liquid to gas at 3000 psi pressure)

STORAGE AND STORAGE-CONVERSION UNITS

Portable

Aircraft storage-conversion—oxygen—
Capacity: 5, 10, 25 liters

Storage-conversion cylinders—liquid oxygen—(Adapted also for liquid nitrogen, argon, neon, hydrogen service) **Capacity: 3,000 cu. ft.**

Special liquefied gas refrigerator containers for biologicals, cryogenic research —
Capacity: 25 and 640 liters

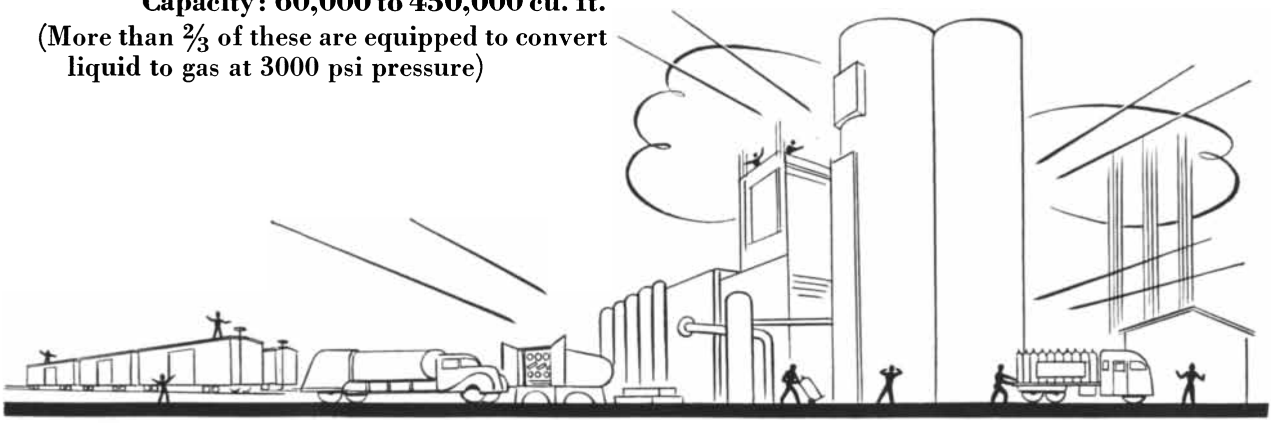
Others with capacities up to 450,000 cu. ft., including mobile pumping units

Stationary

About **650** liquid storage or combination storage and conversion units in service at customer, distributor, or mass-plant locations—
Capacity: 10,000 to 75,000,000 cu. ft.

RESEARCH AND ENGINEERING

Of the combined staff of 1300 at three laboratories, more than 1000 engineers, scientists, and technicians are constantly adding to LINDE's knowledge of Cryogenics and supporting sciences. Years of solving low-temperature problems, plus our up-to-date know-how of Cryogenic engineering, equipment, and liquefied gas applications are yours when LINDE becomes your source for cold facts and materials.



Put LINDE's vast experience in Cryogenics to work for you

Call or write Department R-5, LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd St., New York 17, N. Y.
In Canada: Linde Company, Division of Union Carbide Canada Limited.

THE AUTHORS

MORRIS TEPPER ("Tornadoes") heads the Severe Local Storms Research Unit at the U. S. Weather Bureau. A graduate of Brooklyn College, he was an Air Force weather officer in the Pacific during World War II, then acquired a Ph.D. in meteorology and fluid mechanics from the Johns Hopkins University. Tepper writes: "During my service with the Air Force, I was struck by the pilot's dependence on the weather officer for the completion of his mission. At the same time, I was struck by the inadequacy of weather data and theory on which the forecaster could base a prediction with any degree of confidence. Thus the importance of understanding weather processes as a prerequisite to forecasting them was impressed on me. One of my first investigations upon joining the Weather Bureau after the war was of the 'squall lines' which produce remarkable local weather disturbances—including tornadoes—but which seem to the forecaster to appear and disappear without explanation. I developed the 'pressure-jump theory' which, by analogy to the flow of liquids in a channel, proposed that the squall line behaves as an atmospheric gravity wave." Tepper belongs to the Weather Bureau chess team and also goes in for woodworking and gardening.

P. O'B. MONTGOMERY and W. A. BONNER ("A 'Flying-Spot' Microscope") share the credit for developing the new television microscope built by them at the Southwestern Medical School of the University of Texas. Montgomery, a pathologist, is a graduate of Southern Methodist University and received his M.D. from Columbia University in 1945. He is associate professor of pathology at Southwestern Medical School, and has served as medical examiner of Dallas County in Texas. Bonner is an electronics engineer. He was born in Durham, England, in 1920 and worked on research projects in television engineering before turning to medical electronics.

WALTER M. ELSASSER ("The Earth as a Dynamo") comes from the German Rhineland and studied physics at the universities of Heidelberg, Munich and Göttingen, taking his Ph.D. at the last-named institution under the direction of Max Born. He taught for several years at the Technische Hochschule in Berlin and at the University of Frankfurt, concerning himself mainly with quantum mechanics. From 1933 to 1936 he was a fellow of the Institut Henri Poincaré at the University of Paris. There he developed an early form of the theory of nuclear shell structure now widely used by nuclear physicists. He then joined the staff of the California Institute of Technology. Upon coming to the U. S., Elsasser decided to leave nuclear physics for geophysics, which he declares "leaves more play for work of the imagination." His reasons for this shift were two: first, a life-long interest in astronomy, and second, the personal influence of Robert A. Millikan, who was then pioneering geophysics in the U. S. Elsasser is now professor of theoretical physics at the La Jolla campus of the University of California. He says: "My preoccupation with the basic nature of the earth's magnetic field started around 1937 as a private sideline and continued for many years without public support. It was not until about 1950 that the scientific public began to take an interest."

E. P. ROSENBAUM ("The Teaching of Elementary Mathematics") is a member of the board of editors of SCIENTIFIC AMERICAN. He approaches the subject of his article not only as a journalist but also as a teacher: for several years he taught mathematics and physics at the Milford School, a preparatory school in Connecticut.

SIDNEY M. JOURARD ("A Study of Self-Disclosure") is a clinical psychologist and associate professor of psychology at the University of Florida. A Canadian, he studied psychology at the University of Toronto and the University of Buffalo, where he received his Ph.D. in 1953. Since then he has taught at Emory University and the University of Alabama. His book *Personal Adjustment: An Approach to the Study of Healthy Personality* has just been published by the Macmillan Company.

STANLEY D. BECK ("An Insect and a Plant") comes from Portland, Ore., and studied entomology at the State College of Washington. After Navy service on a minesweeper during the Second World War, he went to the University of Wisconsin, where in 1950 he received his Ph.D. and became assistant professor of zoology. At Wisconsin Beck has developed a program of teaching and research on insect physiology. His own work has dealt mainly with the adaptation of insects to plants—a subject which, he says, "cuts across the fields of physiology, be-

havior, ecology, biochemistry, genetics and applied entomology."

RACHMIEL LEVINE and M. S. GOLDSTEIN ("The Action of Insulin") collaborate on research at Chicago's Michael Reese Hospital, where Levine heads the department of medicine and Goldstein is associate director of the department of metabolic and endocrine research. At the age of 17 Levine left his native Poland for Canada, where he studied philosophy, comparative literature and medicine at McGill University. He has been a physiologist at Michael Reese Hospital since 1936. Goldstein, also from Canada, received his undergraduate and medical training at McGill under Dominion provincial scholarships, winning his M.D. at the age of 23.

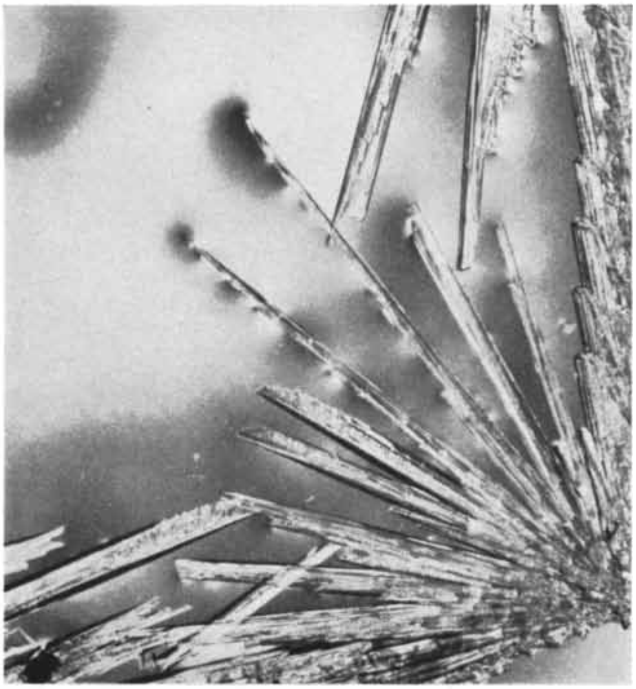
CARL W. BLEGEN ("King Nestor's Palace") is chairman of the classics department at the University of Cincinnati. Born in Minneapolis in 1887, he attended Augsburg Seminary there, then went on to advanced studies in Greek and Latin literature at Yale University. How he became an archaeologist is explained by him as follows: "I was lucky enough to receive a fellowship which was described in the University catalogue in magic words. They stated that the holder would be permitted, if he so desired, to spend a year in Athens at the American School of Classical Studies. It sounded exciting and tempting, so I went to Athens, expecting to stay a year. Instead, I actually stayed 17 years, having a chance to take part in many excavations, wandering freely about the country, and inevitably absorbing some familiarity with Greece, its people and its past. It was the digging that interested me especially. When I went to Cincinnati as professor of classical archaeology, the University gave me leave to spend the second semester each year carrying on research in the field. Professor and Mrs. W. T. Semple of Cincinnati founded and supported the University's Archaeological Expedition, which undertook new excavations on a large scale at Troy from 1932 to 1938, and which has more recently been uncovering the palace of King Nestor."

MORRIS KLINE, who reviews Lancelot Hogben's *Statistical Theory* in this issue, is professor of mathematics at New York University. He is the author of the popular book *Mathematics in Western Culture* and of several other pieces for SCIENTIFIC AMERICAN, the most recent being "The Straight Line" (March, 1956).

BARRETT RESEARCH REPORTS ON:

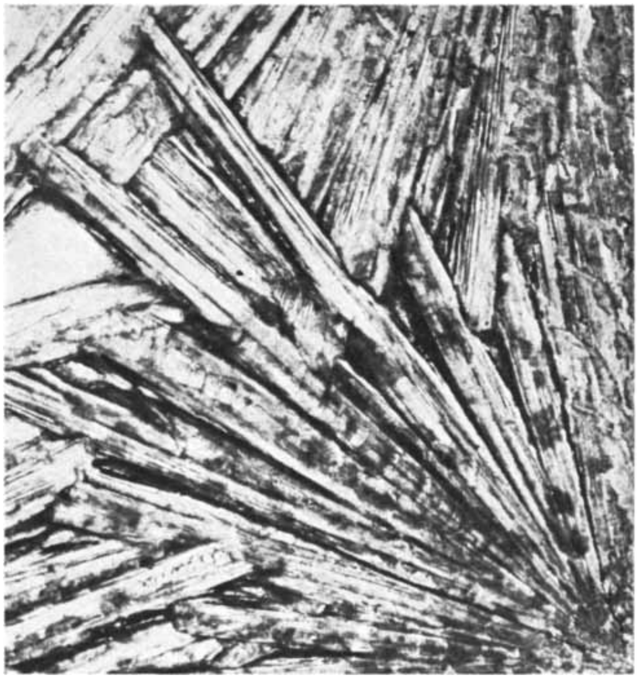
A New Standard of Purity

1. Unusual photomicrographs show the formation of crystal phthalic anhydride from the liquid state—key to Barrett purity measurements. Above, first crystals appear as liquid is cooled to freezing point.



2. Crystals grow rapidly from "root" of first solid formation. Temperature variations are carefully plotted during this phase change to determine freezing point of sample.

3. Crystals have now engulfed 75% of area. When determined, the freezing point is compared with that of 100 mole % phthalic anhydride—permitting accurate calculation of over-all purity.



4. Completely crystallized, phthalic anhydride looks like this, magnified 25 times. By the method of freezing point determination. Barrett commercial phthalic measures 99.7 mole % pure.

for Phthalic Anhydride

SUMMARY: *The Barrett laboratories have established the purity of Barrett Phthalic Anhydride (commercial specifications) at 99.7 mole per cent. To achieve this accuracy, they used a method known to physical chemists as the calorimetric freezing point determination. It involves the indirect measurement of the freezing point of 100 mole per cent phthalic anhydride. When determined, this freezing point becomes the standard of purity against which phthalic samples are measured. Barrett researchers now have set this standard, permitting new accuracy in the purity measurement of phthalic anhydride.*

When you're measuring purity, that extra place beyond the decimal point often seems to be just beyond the reach of your analysis. You turn to mass spectrometry, infra-red spectrophotometry, or chromatography for the analysis of specific impurities. But when it comes to finding the sum of all impurities, you may have to abandon electronic instrumentation and return to the white-coated methods of physical chemistry.

First, find the freezing point

The calorimetric freezing point determination, a method accepted by the U.S. Bureau of Standards, is a real boon to the decimal point chaser. The crux of this method is the extrapolation of the freezing points to 100 mole per cent material. Once you can establish this value for a particular compound, you are well on the way to new accuracy in measuring its purity.

After determining that the method was theoretically applicable to phthalic anhydride, Barrett chemists went to work on the freezing point problem. Though phthalic anhydride (or anything else) of absolute purity is nonexistent, its properties can be arrived at indirectly. Barrett research established the freezing point of 100 mole per cent phthalic anhydride to be 131.11 ± 0.01°C.

With this absolute value now available, the purity of phthalic anhydride can be measured with a new accuracy. The second law of thermodynamics describes the relationship between the mole fraction of a substance and the freezing point depression. Working from there, Barrett researchers have measured the mole fraction of Barrett Phthalic Anhydride (commercial specifications) as 0.997.

Pitfalls of titration

This is a particularly impressive degree of assured purity when you compare it with the vagaries of phthalic purity measured by titration. Say, for instance, a manufacturer quotes a purity of 99.5% by titration. This may sound precise but actually it gives you no firm limit on total impurities.

Phthalic acid, maleic anhydride, maleic acid and benzoic acid are some common impurities which go undetected by titration. These masqueraders are all included in the purity figure determined by titration.

On the other hand, the purity of Barrett Phthalic Anhydride can now be stated positively at 99.7 mole per cent. This gives customers the comforting assurance that Barrett Phthalic Anhydride will react smoothly and contribute its full share to uniformity of end products—be they alkyd resins, polyesters, plasticizers or chemical intermediates.

Microscopic devils

While keeping careful tabs on overall purity, Barrett also pays close attention to special trouble-brewing impurities. Maleic anhydride and other impurities can cause trouble in phthalic anhydride at percentage levels you wouldn't notice in your drinking water. Another report in this series will carry the full story on these elusive devils and how they are exorcised.

If you would like the deep-down details of the Barrett lab's work on phthalic purity, you're welcome to a reprint of the published article, *Calorimetric Determination of the Freezing Point of Phthalic Anhydride.* Drop us a postcard now, while you're thinking of it.

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Allied Chemical

Hermann von Helmholtz...on immortality

"...what arouses our moral feeling at the thought of a future cessation of all living creation on earth, remote as this may be, is above all the question whether all life is but an aimless sport, which will ultimately fall prey to destruction by brute force. In the light of Darwin's great thoughts we begin to see that not only pleasure and joy, but also pain, struggle, and death, are the powerful means by which nature has built up her finer and more perfect forms of life. And we men know that in our intelligence, our civic order, and our morality we are living on the inheritance which our forefathers gathered for us through labor, struggle, and sacrifice; we also know that what we acquire will in like manner ennoble the lives of our descendants. Thus the individual, who works for the ideals of humanity, even if in a modest position and in a limited sphere of activity, can bear without fear the thought that the thread of his own consciousness will one day break."

—Über die Entstehung des Planetensystems, 1871

THE RAND CORPORATION, SANTA MONICA, CALIFORNIA

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

Established 1845 SCIENTIFIC AMERICAN May, 1958 Volume 198 Number 5

Tornadoes

These explosively violent storms are so small and short-lived that they are very hard to study. New meteorological methods now help us to pick out areas where they are likely to strike

by Morris Tepper

"The raider was first reported on the shore of Lake Michigan near Saugatuck about 6:30 p.m. It moved northeastward . . . striking the Hudsonville area, Ottawa County, at 6:58 p.m. Hudsonville was left in ruins, with 14 persons dead. The next locality in the raider's path was the suburban business community of Standale, west of Grand Rapids, which was nearly wiped out at 7:11 p.m., with the loss of four more lives. . . . A total of 18 persons lost their lives [in the raid] and 340 were reported injured. Destroyed or badly damaged were 332 homes, 100 farm buildings and 105 other structures."

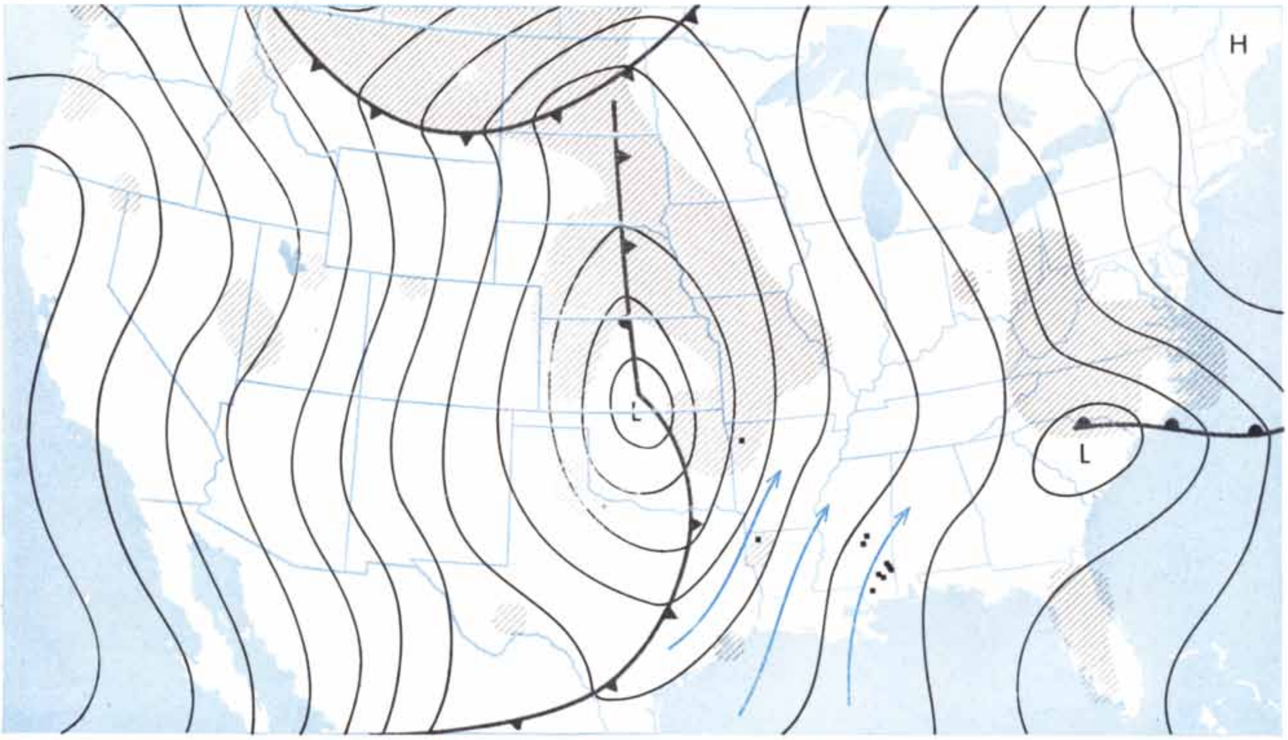
The foregoing is not an account of a bombing raid or a visit by a space ship. It is a U. S. Weather Bureau report of an event of April 3, 1956, to which few people in the U. S. except those immedi-

WHIRLING WINDS of a tornado scored these elliptical marks across a field near Scottsbluff, Neb., on June 27, 1955. Though a tornado may leave a track only a few dozen yards across, the speed of the winds within the funnel may reach 500 miles an hour.

FRAGMENTS OF HOUSES fly in the air as a tornado passes across a group of buildings near Dallas, Tex. The violent winds around the funnel and a sharp drop in atmospheric pressure make frame buildings literally explode. Debris which is spun around and

ately affected paid much note. I have quoted the report verbatim with only one slight change: substituting the word "raider" for the word "tornado." Tornadoes are a frequent and devastating occurrence in the U. S., but such is man's fatalism about acts of nature that these catastrophes usually arouse less general excitement than the escape of a wildcat from the zoo. The fact is that, although the menace of tornadoes has always been with us, only within the last few years has any important effort been made to find out how they arise and what might be done to reduce their toll of life and property.

Last year 924 tornadoes were reported in the U. S. They killed 191 people, injured 2,343 and caused damage amounting to more than $73 million. Since the early decades of this century

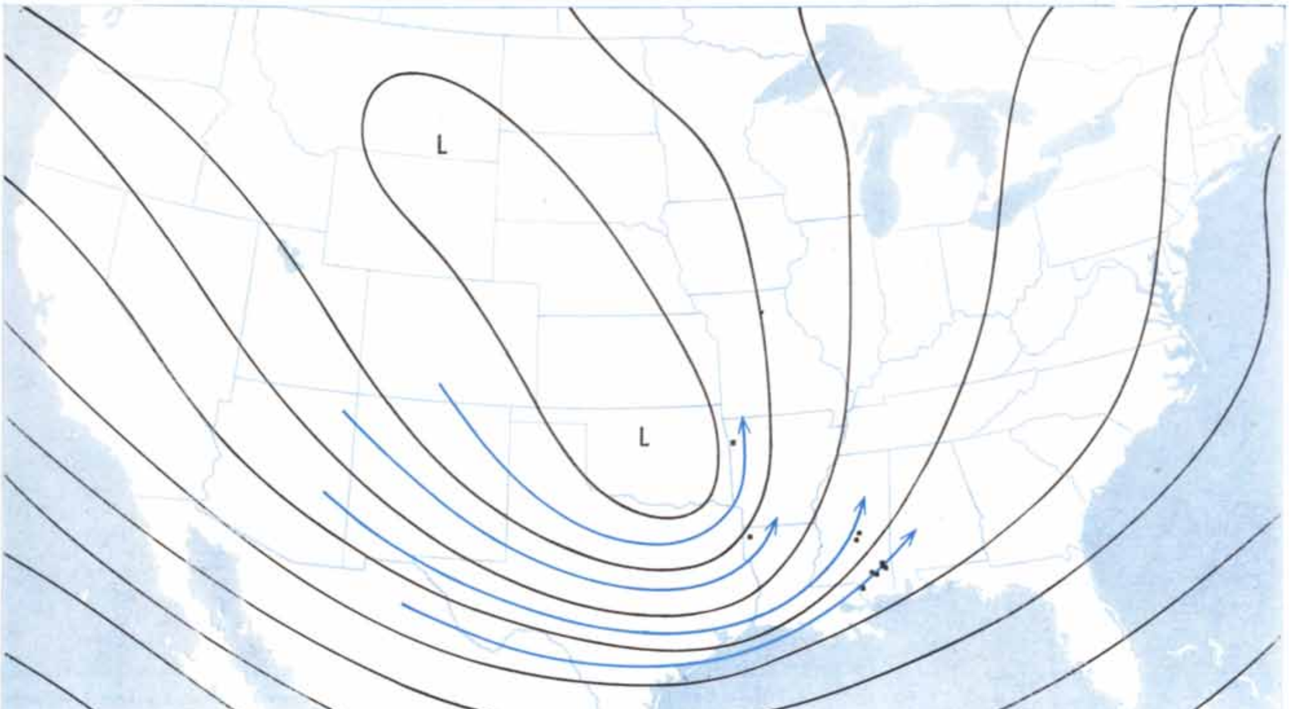


OVER-ALL WEATHER CONDITIONS which set the stage for tornadoes are shown in these maps of pressure and wind patterns on February 26, 1958. At the surface (*left*) southerly winds brought warm, moist air from the Gulf of Mexico. Around 18,000 feet

ejected at high speed does further damage. The base of the cloud to which a tornado is attached is usually about 3,000 feet above the earth, but the tornado's circulating winds may perhaps extend higher. These photographs were made on April 2, 1957.

the average number of tornadoes reported annually has risen more than fivefold. It is unlikely that this increase can be attributed to atomic bomb tests or any real meteorological change in the U. S.; rather it appears that the Weather Bureau has simply been getting a more complete count of the tornadoes actually occurring. In any event, we have come to realize that these vicious storms are much more frequent and more widespread than used to be thought. They are most common in the Midwest, but tornadoes are now known to strike in every part of the country and at every season.

In the nature of things, because a tornado springs up suddenly and usually lasts less than an hour, most of our information about the phenomenon consists of the excited reports of people who



(*right*) radiosonde observations revealed a strong current of cold, dry air from the North Pacific. Tornadoes (*black squares*) occurred in the area where these two currents crossed. The local conditions which set off tornadoes do not show up on these large-scale maps.

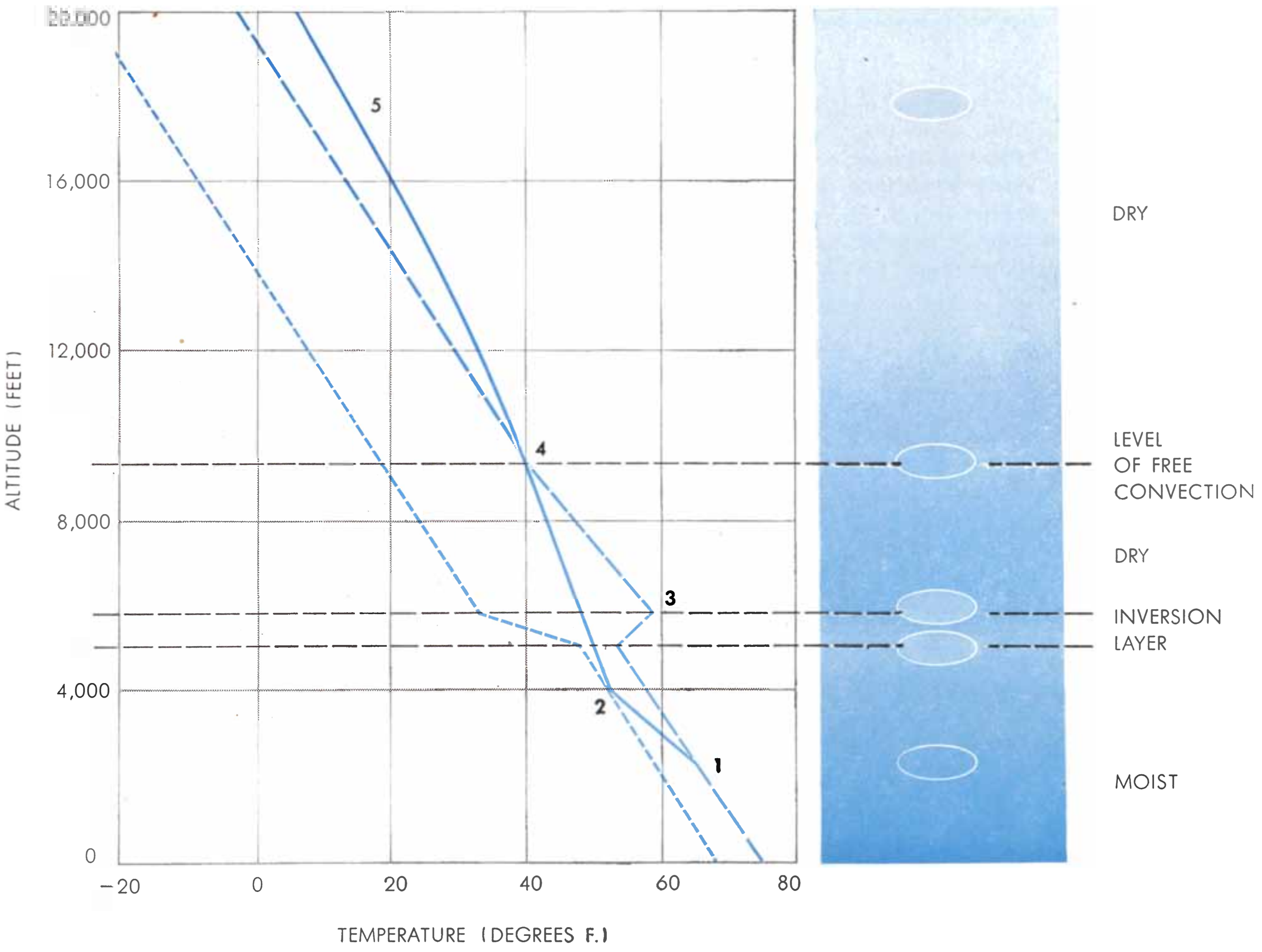
happen to have been in the path of the storm. The accounts of these untrained observers, who have lived through a most violent experience, naturally fall somewhat short of scientific objectivity and completeness. Indeed tornado experts have found that it is often impossible to decide from the witnesses' accounts, or even from inspection of the storm's damage, whether the event was actually a tornado or merely a strong windstorm. But with special networks of observing stations and instruments such as radar the Weather Bureau has recently begun to collect more systematic information on tornadoes. Some have actually been photographed on motion-picture film.

What exactly is a tornado? The general picture is familiar enough. The phenomenon is usually brewed on a hot, sticky day with south winds and an ominous sky. From the base of a thundercloud a funnel-shaped cloud extends a violently twisting spout toward the earth. As it sucks in matter in its path, the twister may turn black, brown or occasionally even white (over snow). The moving cloud shows an almost continuous display of sheet lightning. It lurches along in a meandering path, usually northeastward, at 25 to 40 miles per hour. Sometimes it picks up its finger from the earth for a short distance and then plants it down again. The funnel is very slender: its wake of violence generally averages no more than 400 yards wide. As the tornado approaches, it is heralded by a roar as of hundreds of jet planes or thousands of railroad cars. Its path is a path of total destruction. Buildings literally explode as they are sucked by the tornado's low-pressure vortex (where the pressure drop is as much as 10 per cent) and by its powerful whirling winds (estimated at up to 500 miles per hour). The amount of damage depends mainly on whether the storm happens to hit populated areas. The worst tornado on record in the U. S. was one that ripped across Missouri, lower Illinois and Indiana in three hours on March 18, 1925, and killed 689 people.

The tornado's lifetime is as brief as it is violent. Within a few tens of miles (average: about 16 miles) it spends its force and suddenly disappears.

How a tornado develops its prodigious energy is still a complete mystery. Since we know very little about the specific atmospheric forces that give rise to this type of storm, our theoretical attack on the problem must start from general principles.

One thing we do know is that torna-



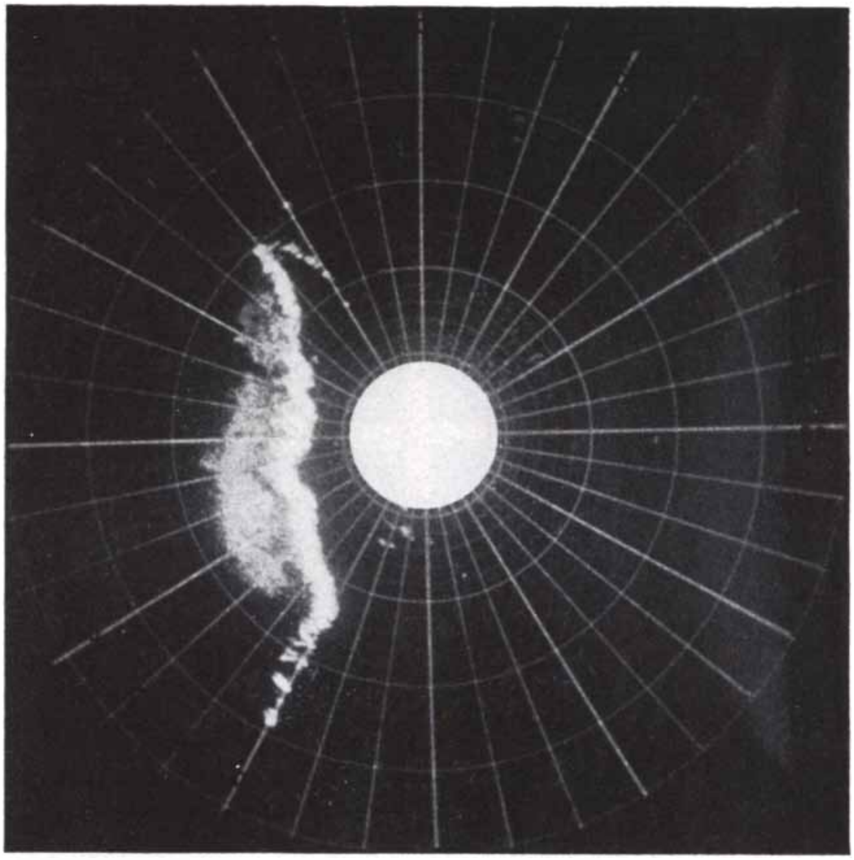
TORNADOES MAY BE SET OFF by a strong updraft. Graph (*left*) and schematic drawing (*right*) show how this develops in the atmospheric structure often found before a tornado. (Color intensity shows temperature.) A parcel (*oval*) of moist air forced upward to its dew point (2) becomes saturated and cools more slowly than the dry air around it. If it is forced past the inversion layer (3) to the level where it becomes warmer than its surroundings (4), it will push upward by itself (5), producing a "chimney" of rapidly rising air.

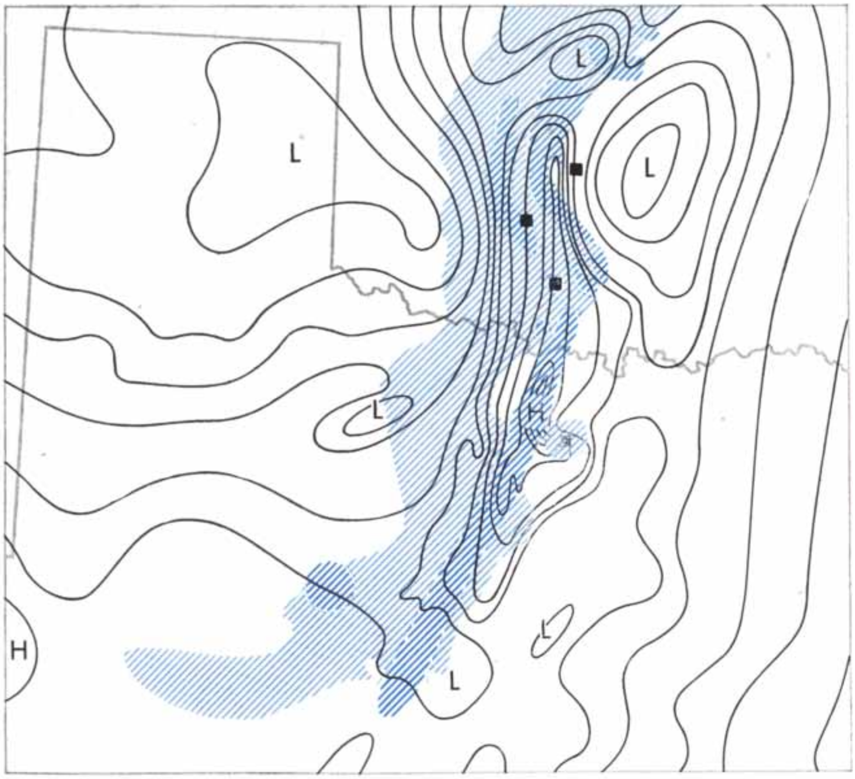
does generally are born in an atmosphere whose structure is potentially unstable. Usually there is an inversion layer, some 5,000 to 6,000 feet up, where the air becomes warmer instead of cooler with increasing height. The soundings show that before the outbreak of a tornado the air below this layer is very moist; above, very dry. This setting suggests how strong local updrafts may develop. Assume that a warm, moist parcel of air near the ground is driven upward (by some force we shall leave unspecified; there are several possible ways this can happen). As it rises the air expands, because of the diminishing pressure at higher altitudes, and the expansion cools it. Eventually the warm parcel of rising air will be cooled to about the same temperature as the cool higher air it is invading. But by this time a warming process has begun to operate in the parcel. Since it carries a good deal of moisture, its air becomes saturated as it cools, and the moisture begins to condense. As the parcel is driven higher, the heat released by the condensation reduces the rate of cooling, and ultimately the parcel becomes warmer than the surrounding air. Consequently it will now rise of its own accord, and its upward motion is accelerated. In short, the process creates a narrow "chimney" of swiftly rising air [*see chart on opposite page*].

Such a mechanism could generate strong vertical currents, but it does not explain how a tornado develops its spin. To account for the tornado's vortex we must look to other processes. Here we fall back on principles of the mechanics and dynamics of rotary motion. For instance, the tornado may attain its extremely rapid rotation by a process of convergence that shrinks its radius—as a skater speeds up her spin by pulling in her arms, or as the water running out of a basin speeds up its rotation when it spirals in toward the drain hole. There are also other possible ways in which a vortex may develop.

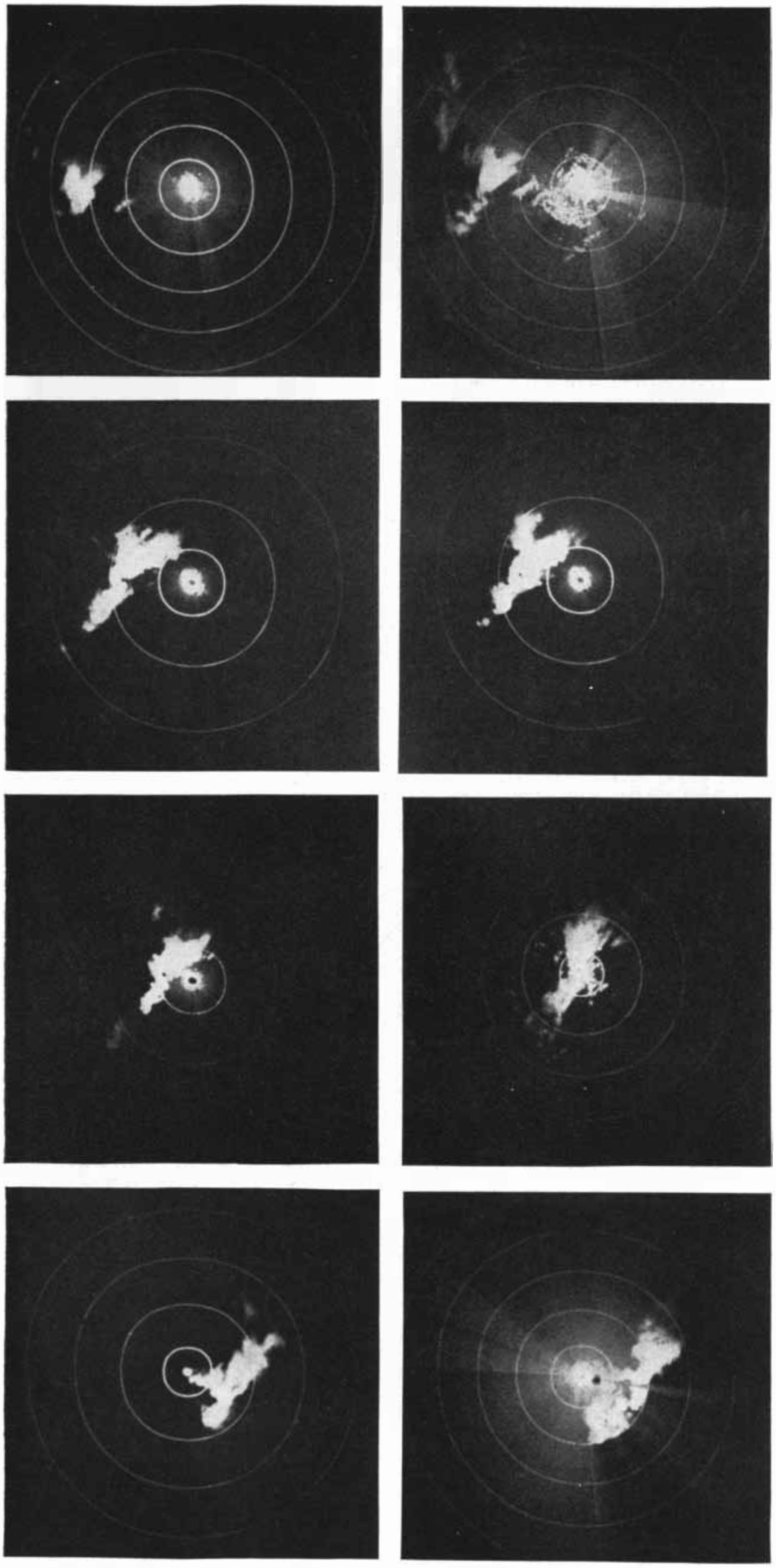
When we have acquired enough information to form a theory as to how atmospheric forces generate tornadoes, we shall probably be able to predict the occurrence of these strange and unexpected storms. Meanwhile the Weather Bureau has set up a forecast center in Kansas City to accumulate information and issue alerts when conditions seem to indicate that tornadoes may develop.

We know in a general way, on a statistical basis, what some of the conditions are. The favorite locale and time





"MESO-SCALE" CONDITIONS which trigger tornadoes are shown on map (*bottom*) which summarizes data from a special network of closely set weather stations. Tornadoes (*black squares*) develop along a "squall line" of sharp pressure rise. Moist air forced aloft produces intense precipitation (*hatching*); this shows up on radar, as in the photograph at top. The map and photograph cover two different areas, each about 500 miles across.



RADAR TRACKS a tornado which passed through Bryan, Tex., on April 5, 1946; the sequence of photographs covers an hour and a half. In the fourth and fifth pictures the funnel shows as a small, dark spot in the light area directly to the left of the center of the screen.

of tornadoes is the Midwest in late spring and early summer. They come most often in the late afternoon or early evening—between 3 and 9 p.m. As I have mentioned, the setting is usually a hot, muggy day with southerly winds. More specifically, four conditions seem to be indispensable: (1) moist, warm air at low levels; (2) cool, dry air at higher levels; (3) a strong southerly wind at the surface plus a strong wind aloft blowing over it from a different direction, usually westerly or southwesterly; and (4) some lifting mechanism, such as a cold front or storm line, which drives the warm air upward. Most commonly this last mechanism—what might be called the trigger that starts a tornado—is a line of thunderstorms, known as a "squall line."

During the past six years the Weather Bureau has been operating a close network of stations in the tornado belt to get a fine-scale picture of atmospheric conditions. The stations, only 25 to 30 miles apart, record pressure, temperature, humidity, rain and wind. This detailed survey has brought to light that tornadoes frequently develop in a squall line or a line of sharp rise in pressure. The "pressure jump" is so ominous as a possible harbinger of tornadoes that the Weather Bureau has installed in about 100 stations an alarm device which sounds a buzzer and flashes a light when the pressure jumps. These stations are monitored 24 hours a day.

The observations I have just described are on what we call the "meso-scale," as distinguished on one hand from large-scale weather maps of the country and on the other from local, on-the-spot conditions. The meso-picture shows us the small-scale structures in which tornadoes arise. So far our observations of these structures have been almost entirely confined to ground level; we need more information about the conditions in the upper air. During the past two tornado seasons a pilot engaged by the Weather Bureau has sounded potential storm areas in an airplane carrying instruments. But a single plane is not enough, and the Bureau is now planning to have flights of many aircraft take simultaneous recordings at many points to show the pattern of atmospheric conditions throughout a critical area.

We have good hopes that we shall eventually be able to detect tornadoes themselves at a distance by means of radar. It is already possible to identify the type of storm that may generate tornadoes by its radar picture. An approaching squall line shows up on the radarscope as a line of intense echoes. A concentrated storm produces a bright image, which can be traced by vertical scanning high into the atmosphere. During the development of a tornado, observers have sometimes seen peculiar patterns on their scopes—hooks, S-shapes, doughnut shapes and so on.

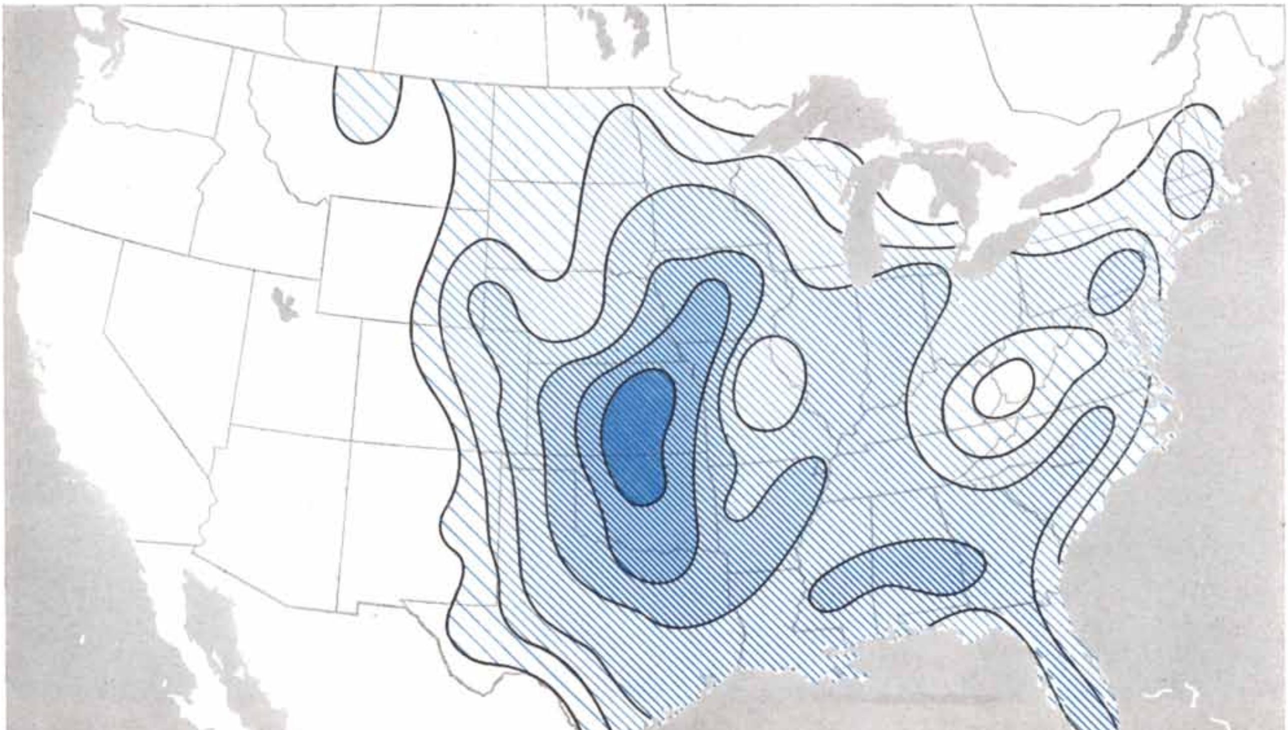
Another possible means of identifying a tornado at a distance is the phenomenon known as "sferics"—radio static produced by atmospheric electricity. We know from the lightning display that the air around a tornado must be charged with a great amount of electricity. With directional antennas and receivers placed some distance apart we should be able to locate the electric center, and it may be possible to distinguish a tornado from an ordinary electric storm by the frequency or intensity of the discharges. Its lightning has a very different appearance—more diffuse and more continuous.

Any effective tornado warning system not only must discover the conditions that threaten to generate such a storm but must pinpoint the area where a tornado is likely to break out. At present the Weather Bureau's alerts usually cover an area about half the size of a Midwestern state. We hope to be able to narrow down the area, and the time, in which tornadoes can be expected to form. To achieve sharper forecasts we shall need much more research on the general setting in which tornadoes are apt to materialize, on the basic principles that underlie their development and on the localized structures from which they are born.

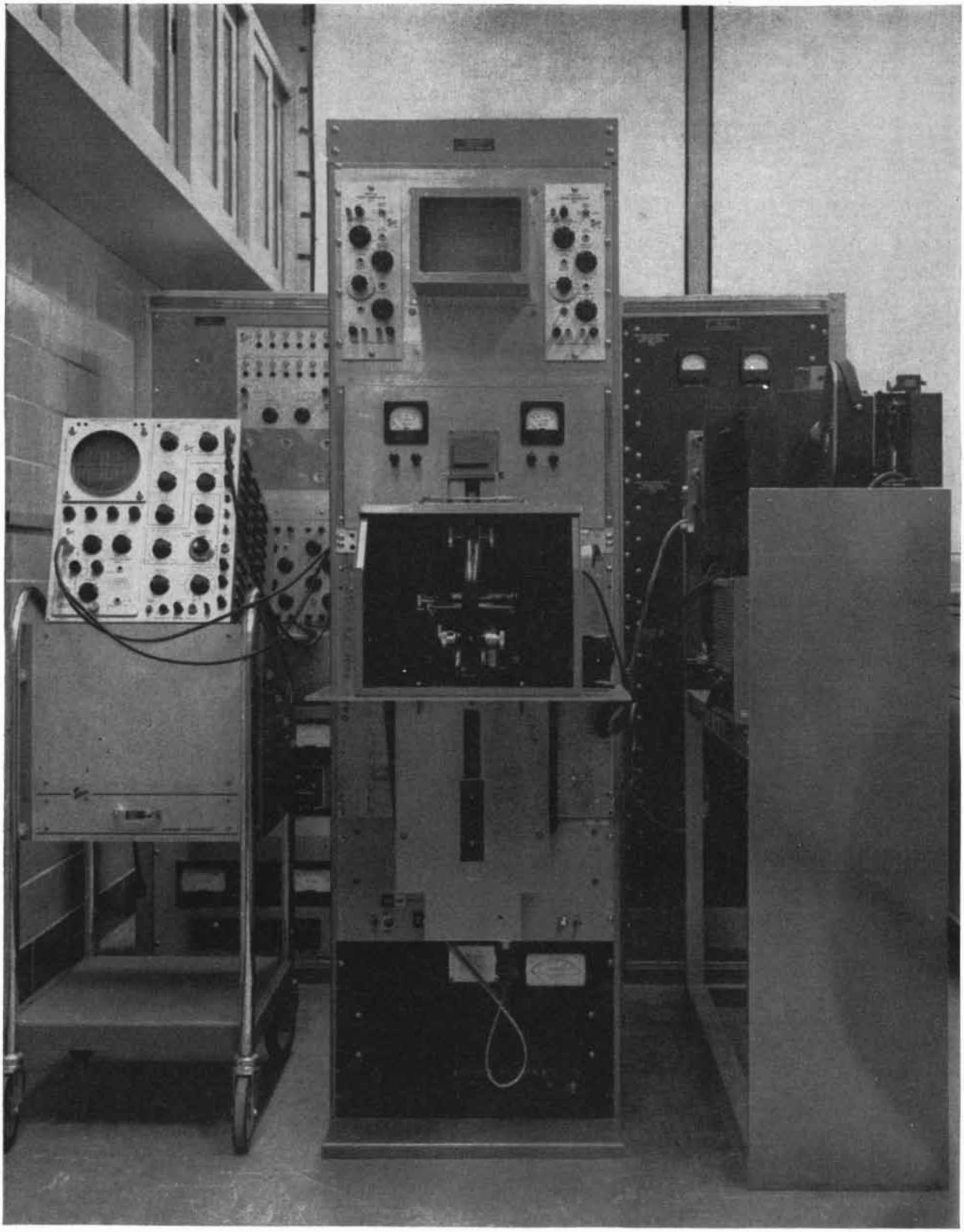
In addition it is necessary to have a system of rapid detection and warning to alert people in the path of a tornado as soon as one actually springs up. There may be only a few minutes to warn them to take shelter—the few minutes that spell the difference between life and death. Radar, sferics and networks of tornado minutemen may help to make these storms less catastrophic than they have been in the past. A number of networks, manned by public-spirited volunteers, have already been organized in metropolitan areas to report tornadoes or threatening conditions to the Weather Bureau.

We have heard so much lately about schemes for controlling weather that it is natural to ask: Should it not be possible to break up a storm as localized and transient as a tornado? Could we prevent one from forming? The latter possibility seems quite remote. Even if we could predict exactly where tornadoes may form, nothing short of a massively energetic intervention (such as huge thermonuclear explosions) could influence the great volume of air involved, which amounts to thousands of cubic miles. And of course such a cure would be worse than the disease—to say nothing of the possibility that our interference might trigger off tornadoes that would not otherwise have started.

It may be within the realm of possibility, however, to soften the fury of a tornado already in being. If we could somehow modify the parent thunderclouds from which the tornado draws its energy, perhaps by artificial cloud-seeding, we might draw some of the twister's sting. But this brings us squarely into the broader problem of searching for a better understanding of the atmospheric forces and mechanisms that rule our weather, of which tornadoes are but one manifestation—albeit the most violent known on the earth.



FREQUENCY OF TORNADOES in the U. S. from 1916 to 1955 is shown on this map. Darkest shading shows the greatest number; in the white areas they are very rare. Tornadoes occur throughout the year, hitting a peak in late spring and early summer.



ULTRAVIOLET FLYING-SPOT MICROSCOPE is photographed in the authors' laboratory at the Southwestern Medical School of the University of Texas. In the center is a reflecting microscope. Behind the small box above the reflecting microscope is an ultraviolet scanner tube. Ultraviolet radiation emitted by the scanner tube is directed into the reflecting microscope by a mirror in the small box. After passing through the reflecting microscope the radiation is converted into electrical impulses by a phototube. The electrical impulses are then used to make an image on a television screen. The viewing screen at the top presents a complete picture of the microscope field. The oscilloscope at left presents the scanning lines one at a time. Apparatus for photography is at right.

A "FLYING-SPOT" MICROSCOPE

In which a thin beam of ultraviolet radiation is used to scan living cells. An advantage of the method is that the cells can be examined at length in this harsh light without killing them

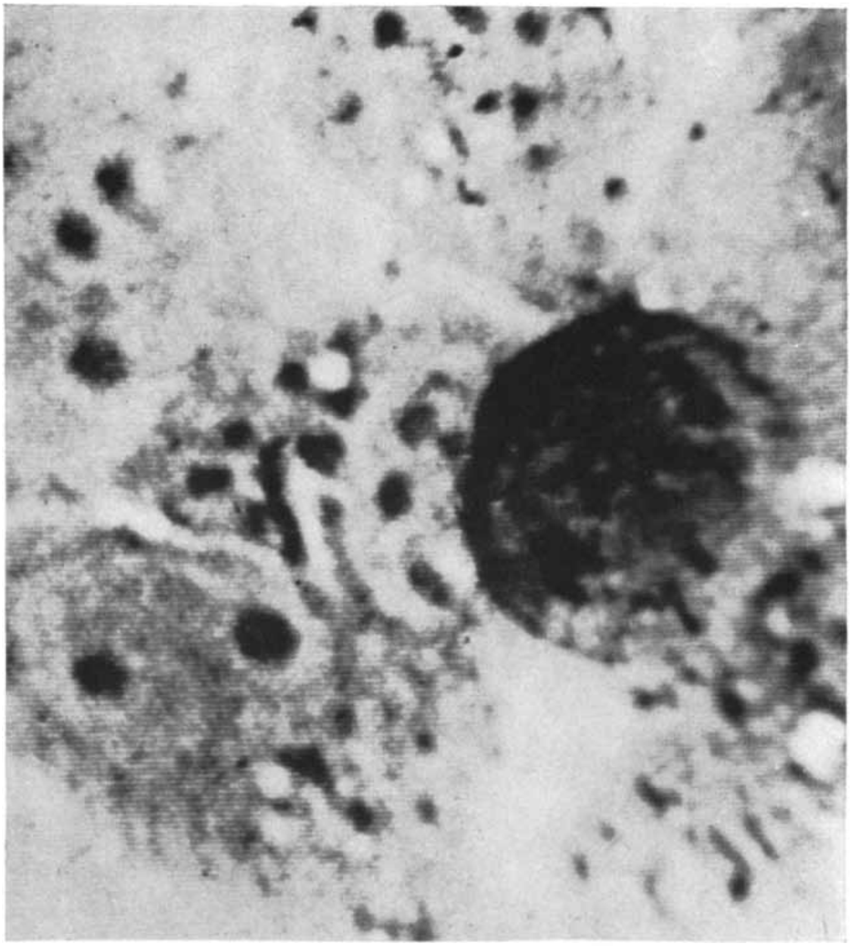
by P. O'B. Montgomery and W. A. Bonner

A biologist who studies life at the cell level, like a physicist studying atoms, is almost a blind groper in the dark. Nearly everything he learns has to come from indirect evidence. He can break up cells and analyze their chemical make-up; he can study their metabolism by measuring their food intake and chemical output; he may even see a fuzzy picture of their anatomy through a microscope. But the basic processes of the living cell are beyond human seeing.

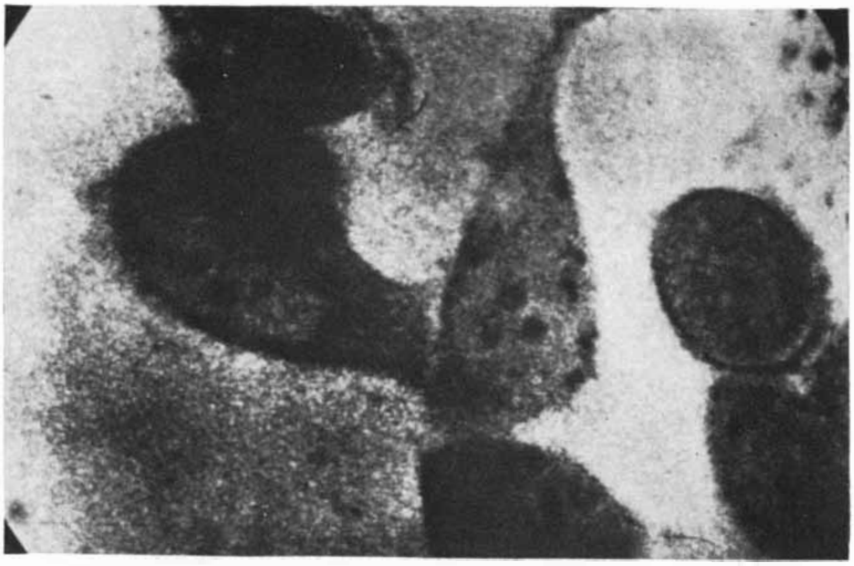
It has been the dream of biologists to find a supermicroscope that could bring this drama into view. An ordinary microscope cannot do so because the waves of visible light are too long to resolve activities at the molecular level. The electron microscope can penetrate to that level, but it captures only a picture of the cell stopped in the stillness of death. We now have a new microscope, however, which takes us a long step toward visualizing the life of a cell. It can make motion pictures of the living cell in the act of growing and dividing to reproduce itself. It tells us something about chemical changes going on within the cell. It shows movements and activities of the tiny cell organs. And it pictures some of the changes that take place when a cell suffers injury or dies.

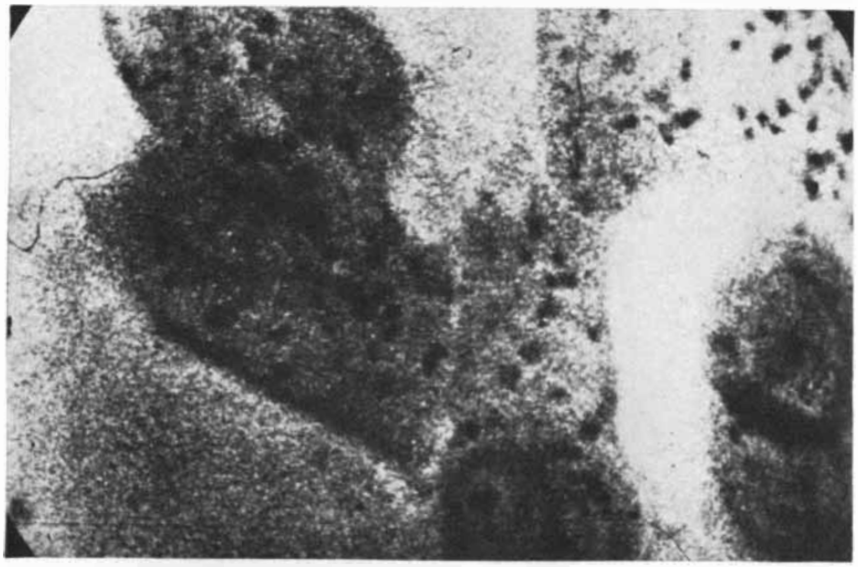
The instrument uses ultraviolet light, whose wavelengths are short enough to give twice as good resolution as visible light. Ultraviolet light, as everyone knows, can be damaging to living tissue. (We would have reason to fear rather than welcome sunlight if the atmosphere of the earth did not shield us from the sun's ultraviolet radiation by absorbing most of it.) But the new microscope, thanks to certain electronic devices, can photograph cells in ultraviolet light for hours without killing them. What is more, the instrument actually turns the damaging effects of ultraviolet to advantage. We can mete out damaging doses to selected parts of the cell and see what happens.

More than 50 years ago A. Köhler of Germany made some pictures of cells in ultraviolet light. He had to use fused quartz instead of glass for the lenses of his microscope, because glass blocks the short ultraviolet wavelengths. He could not, of course, see the specimens on his



HUMAN CELLS of the HeLa cancer strain are enlarged some 2,000 diameters in the ultraviolet flying-spot microscope. The large dark object at right is a nucleolus, a body within the nucleus of a cell. The smaller dark objects are bodies in the cytoplasm, the part of the cell outside the nucleus. The horizontal scanning lines of the picture are faintly visible.





HELA CELLS in this sequence were photographed for hours in the ultraviolet flying-spot microscope. The photographs show how the cells changed shape during the exposure. Faintly visible in the light area near the right side of the bottom photograph is a watery bubble.

slides, ultraviolet rays being invisible to the eye, but he was able to produce images on photographic film, which *is* sensitive to ultraviolet. Köhler got some good pictures of the chromosomes in the cell, and he noted that the chromosomal material (chromatin) absorbed ultraviolet much more strongly than did other parts of the cell.

Köhler's lead was not followed up actively for more than 30 years. Then in 1936 Torbjörn Caspersson of Sweden took up ultraviolet microscopy to study the genetic material of the cell. He found that ultraviolet at the wavelength of 2,600 angstroms was strongly absorbed by the nucleic acids, and the discovery touched off intensive study of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), which has been pursued with growing enthusiasm ever since.

With this ultraviolet technique it has been possible to map the distribution of nucleic acid in chromosomes and to learn other important information about cells. But the method is cumbersome and severely limited when applied to living cells. In the first place, we usually do not photograph fully active cells but only a fixed preparation. Secondly, the business of making the photographs is time-consuming, and particularly awkward because the experimenter, being unable to see the specimen in the ultraviolet light, cannot focus the microscope visually but has to make one picture after another and adjust the microscope after each one until he arrives at the proper focus. In the process, of course, the subjects die, because few cells can stand more than one or two exposures to the ultraviolet radiation.

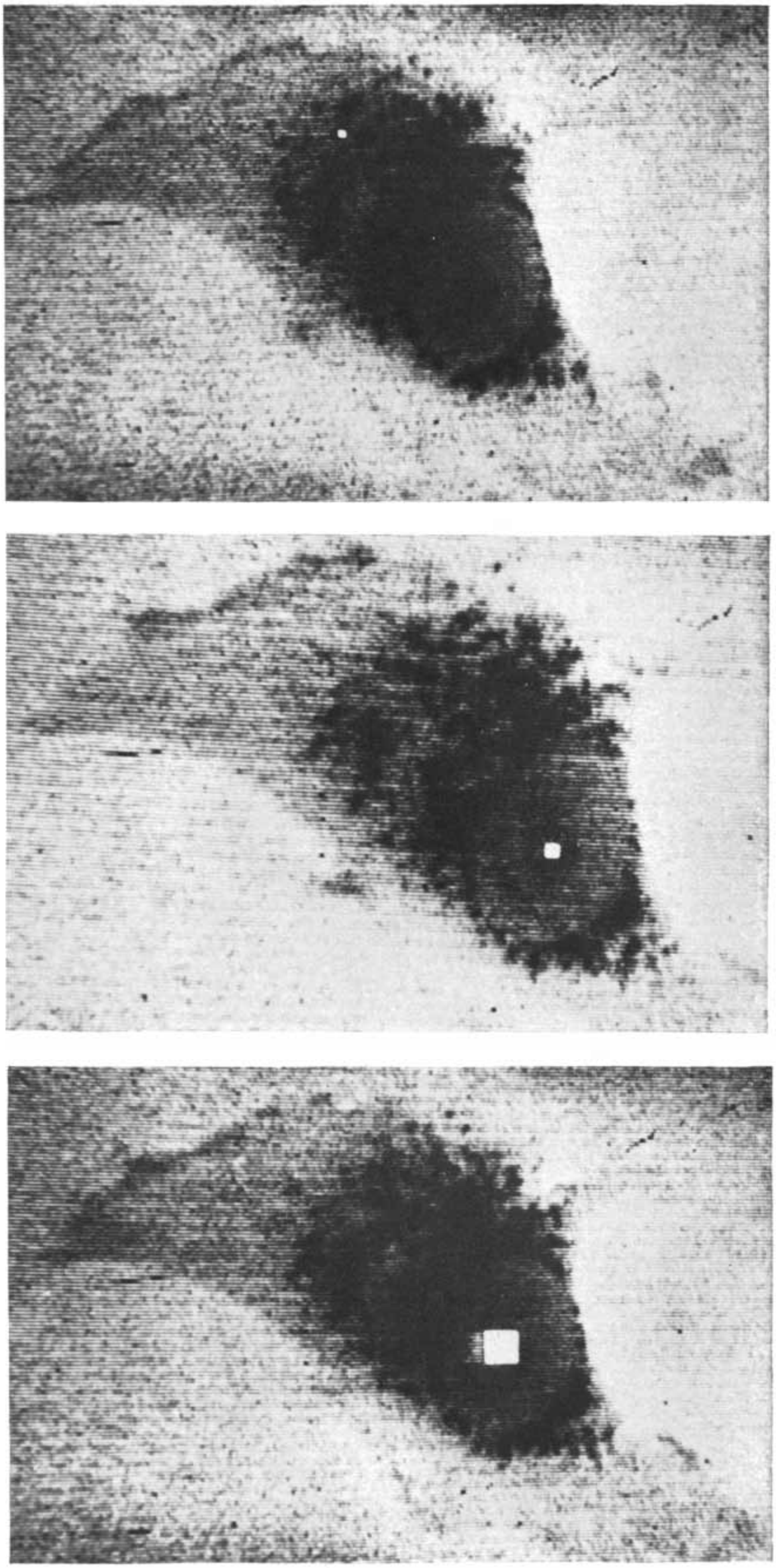
The ultraviolet investigators have tried to follow the life of the cell by making "still pictures" at successive stages of its typical experiences. But to appreciate the shortcomings of this procedure you must imagine what it would be like to attempt to learn the rules and objectives of the game of baseball, say, by photographing one play and destroying all the players in the process, setting up another game with a new set of players, again getting only one play, and so on and on. It is problematical whether we could ever get any understanding of the game on the basis of this type of information.

The new ultraviolet microscope now enables us to study cells in a more sequential fashion. It gives us a complete motion picture of a single game, or at least one or more full innings of a game. The instrument is based essentially on the television idea: an ultraviolet beam scans the subject, and the ultraviolet "image" is eventually translated into a visual picture, which is photographed at certain chosen intervals. The living cells thus photographed escape damage, because (1) the scanning spot of ultraviolet light touches each point of the cell only for an instant, and (2) we can use a very weak beam of the light and amplify the faint image by electronic means.

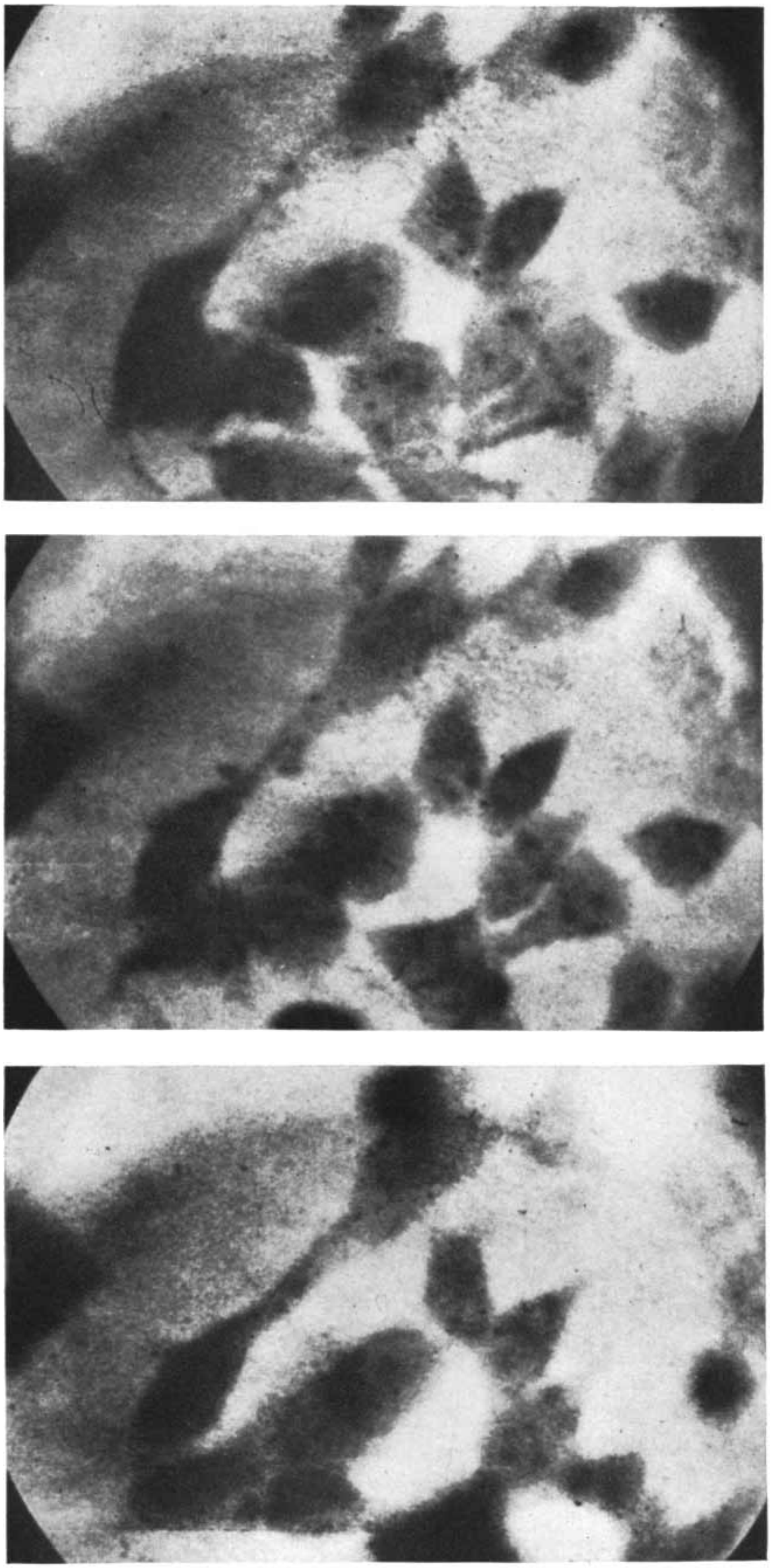
The instrument is called "the ultraviolet flying-spot television microscope." Its operation involves a series of components [*see diagram on page 43*]. First a fine beam of electrons sweeps across the face of a cathode-ray tube line by line, as the flying spot does in a television picture tube. But in this case the tube is coated with a phosphor that emits ultraviolet light instead of visible light. The flying spot of ultraviolet light so generated is reflected in reverse through the microscope. There it "scans" the cells on the slide and produces an image made up of points of varying brightness, the brightness depending on how much of the ultraviolet is absorbed by each area of the cell. Next this image is converted into a pattern of electric current in a photomultiplier tube, which amplifies the energy to make the image stronger. Finally the amplified current feeds into cathode-ray picture tubes, where it paints the picture in visible light, as on a television screen. We use two picture tubes, one to present the picture for visual observation and the other to record the same picture with a camera. The visual tube is coated with an orange phosphor that has a long afterglow, so that we can see the complete picture in each frame even when the flying spot moves at a slow scanning speed. In the tube for the camera we use a blue phosphor, which has less afterglow and is more favorable for photography.

The controls in the instrument make it possible to vary the scanning speed from one twentieth of a second to 10 seconds for a complete frame, and to take successive pictures over a wide range of intervals—10 per second, one every minute or one every 25 hours. Thus we can telescope the cell's activities and speed up the motion picture of its life as much as we wish.

Each point of the cell is exposed to ultraviolet so fleetingly that it either suffers no damage or has time to recover from the brief exposure before the flying



BRIGHT SPOT in each of these photographs indicates an area of intensified ultraviolet irradiation and illustrates how the beam size can be varied. The beam can single out a lipoprotein droplet (*top*), a portion of the nucleolus (*center*) or the whole nucleolus (*bottom*).



DESTRUCTIVE EFFECTS of ultraviolet irradiation can also be observed with the new microscope. HeLa cells exposed to killing doses of ultraviolet die off one by one. They first contract into opaque masses (*middle picture*) and eventually tend to disappear (*bottom*).

spot visits it again. We have made continuous motion pictures of cells for up to nine hours without any evidence of injury to them. One of the great virtues of the instrument is that the destructive effect of ultraviolet can be turned on and off at will at any point in the cell, merely by stepping up or throttling down the strength of the beam at the desired point. We can selectively damage an area as small as one micron in diameter. This means that we can destroy a single tiny body in the cell while leaving the rest undamaged, or we can damage most of the cell but skip some small area, such as the nucleus. Needless to say, an instrument which makes it possible to study the behavior of cells that have been partly crippled at selected points should have a big future in biology.

In our laboratory we have already learned a number of very interesting things about cells with the ultraviolet television microscope. The subjects we have studied so far are three different types of cells: human cancer cells of the so-called HeLa strain, connective-tissue cells of human fetuses and heart cells of the salamander. All these cells show certain common features in the motion pictures. We see them drinking in fluid from their surroundings (pinocytosis); we see dark round bodies moving around actively in the cytoplasm of the cell; we see varying numbers of other bodies (nucleoli) in the nucleus. The cytoplasm of the cell is fairly transparent to ultraviolet light in its outer regions, but it absorbs more and more (*i.e.*, becomes darker) toward the nucleus.

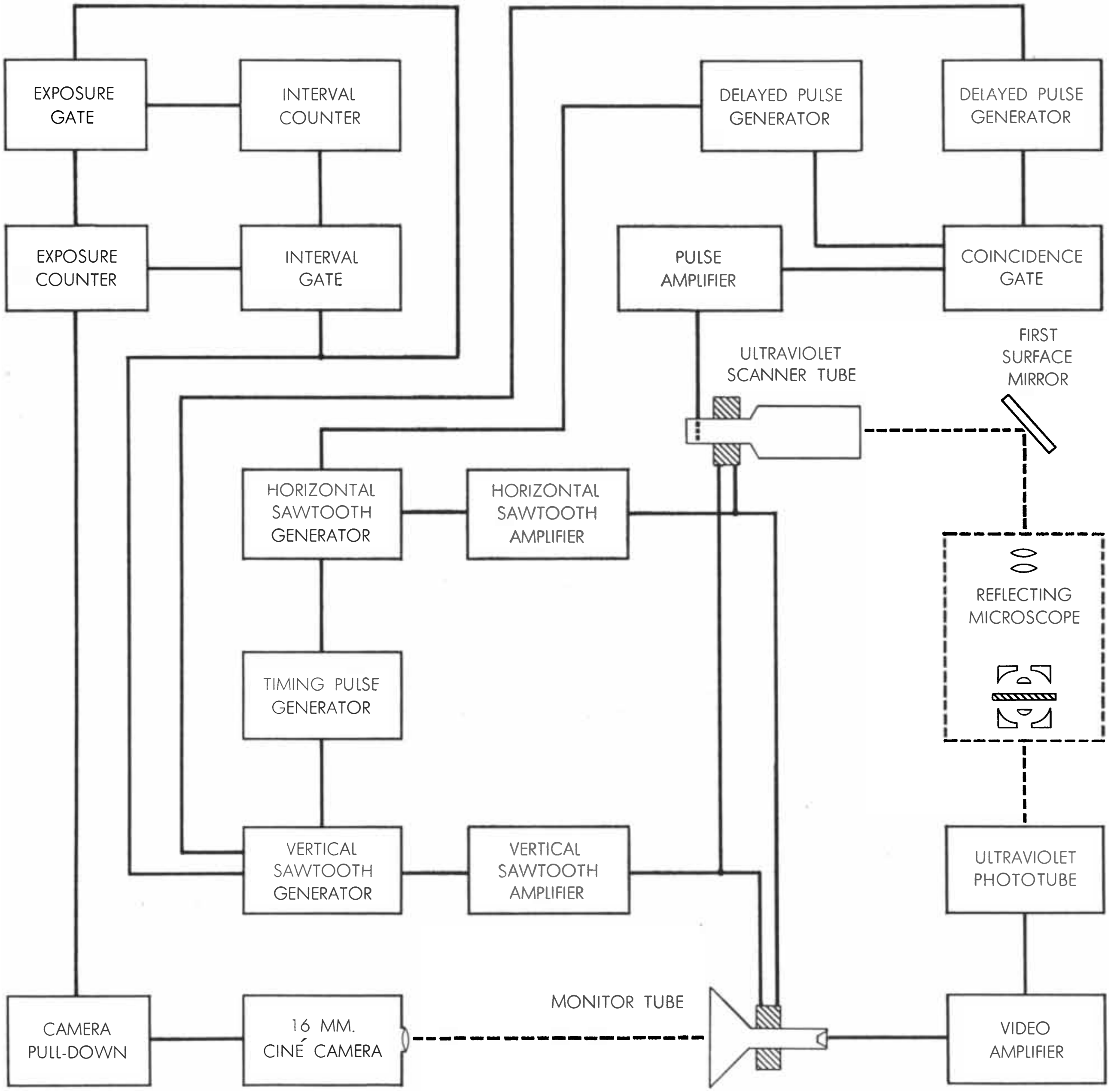
We have seen many cells go through the process of reproductive division (mitosis). Although this is a most sensitive phase of a cell's life cycle, apparently the flying spot of ultraviolet light does not injure it, for some cells carry out a perfectly normal mitosis even after they have been scanned for several hours.

The actual division of the cell usually takes about 60 minutes. Just as it is dividing into two, violent bubbling breaks out on its surface. Our photographs show that there are two kinds of bubbles: small, short-lived bubbles which absorb ultraviolet light, and large, transparent ones which disappear slowly. The latter apparently are bubbles of water squeezed out of the cytoplasm.

What happens when we deliberately damage the cell with the ultraviolet light? (We can apply a graded damaging dose to the whole cell either by stepping up the strength of the current or by increasing the scanning speed, which increases the frequency of attack by the flying spot on each point of the cell.) We find that a moderately punishing dose causes the cell's cytoplasm to gel, as if it were suddenly frozen into immobility. The cell stops drinking at its surface; the tiny round bodies in the cytoplasm stop moving. Otherwise, however, the cell looks exactly as it did before. When this dose catches the cell in the act of dividing, we sometimes see more striking effects. Not only does the division stop abruptly but many big bubbles break out on the surface, so that the cell looks like a Medusa head.

The response of cells to a heavier dose of ultraviolet radiation is dramatic. The cell suddenly becomes completely opaque (*i.e.,* black) and contracts into a small round ball. But interestingly enough each cell reacts as an individual. That is to say, no two cells, even in a group of a single type, show exactly the same vulnerability to the ultraviolet irradiation. If we expose a group together to the same damaging dosage, the cells give up the ghost one by one, each after a different time, and a few survive even after 30 minutes of exposure.

To find such individuality in cells of the same strain is a little unexpected. It is one of the many fascinating new questions to which the new microscope has introduced us in our exploration of the most fundamental of life's mysteries—the nature of the living cell.



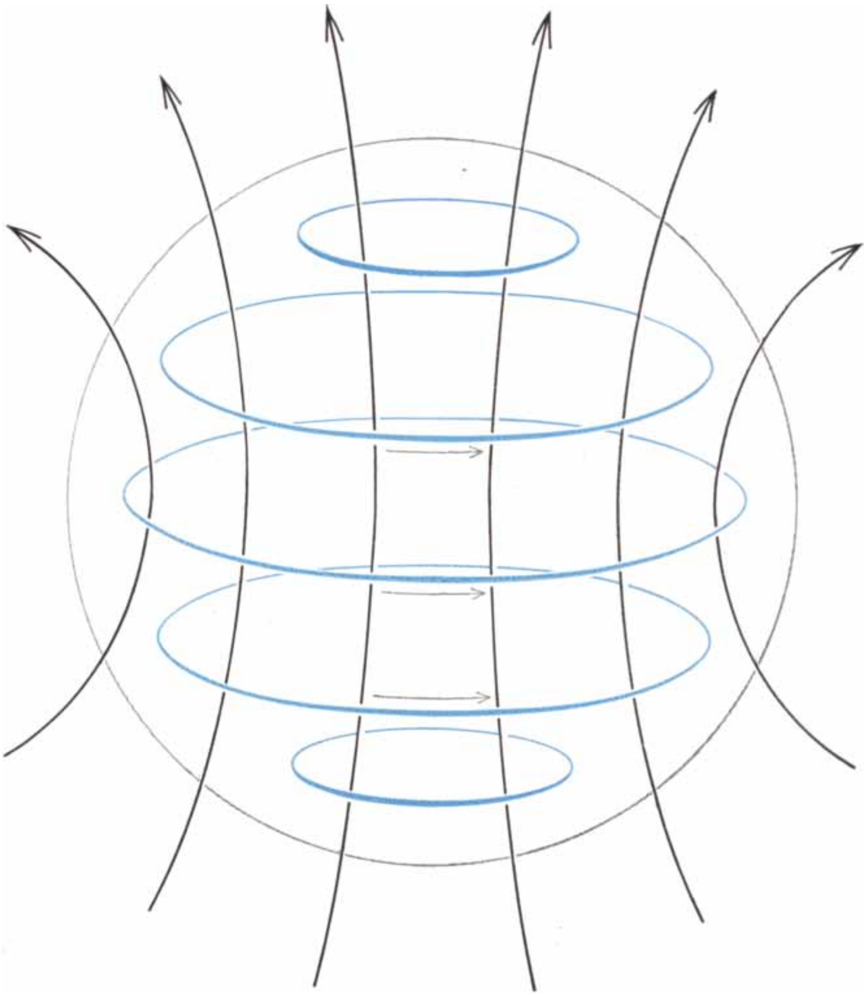
BLOCK DIAGRAM shows the principal parts of the flying-spot microscope. The scanner tube emits ultraviolet light which passes through the quartz eyepiece and reflecting condenser of the microscope to the cells being examined. Rays not absorbed enter the phototube, which translates them into electrical impulses. These are amplified and relayed to the monitor tube (essentially a television picture tube). Apparatus in the center of the diagram controls the timing and dimensions of the scanning beam. Apparatus at top right is used to vary the intensity of irradiation in one portion of the sweep. Other apparatus is used for photography.

The Earth as a Dynamo

Why is the earth a magnet? The best answer at present is that the slow flow of matter in its fluid core generates electric currents, which in turn set up a magnetic field

by Walter M. Elsasser

The problem of explaining the earth's magnetism has been with us ever since William Gilbert, the Elizabethan scientific genius, first showed that the earth as a whole acts as a gigantic magnet. It may continue to be with us for a long time to come, because the main source of the magnetic field undoubtedly lies deep in the interior of the earth, forever beyond reach of our direct investigation. But as we learn more about physics, and about the properties of our planet, we are coming closer and closer to a reasonable theory which rests on established physical principles and fits the known facts. I want to tell of some recent work on the problem that makes us confident we are now on the right track.



SHAPE OF THE EARTH'S MAGNETIC FIELD (*arrows*) strongly suggests that it is produced by circular electric currents (*ellipses*) flowing at right angles to its lines of force.

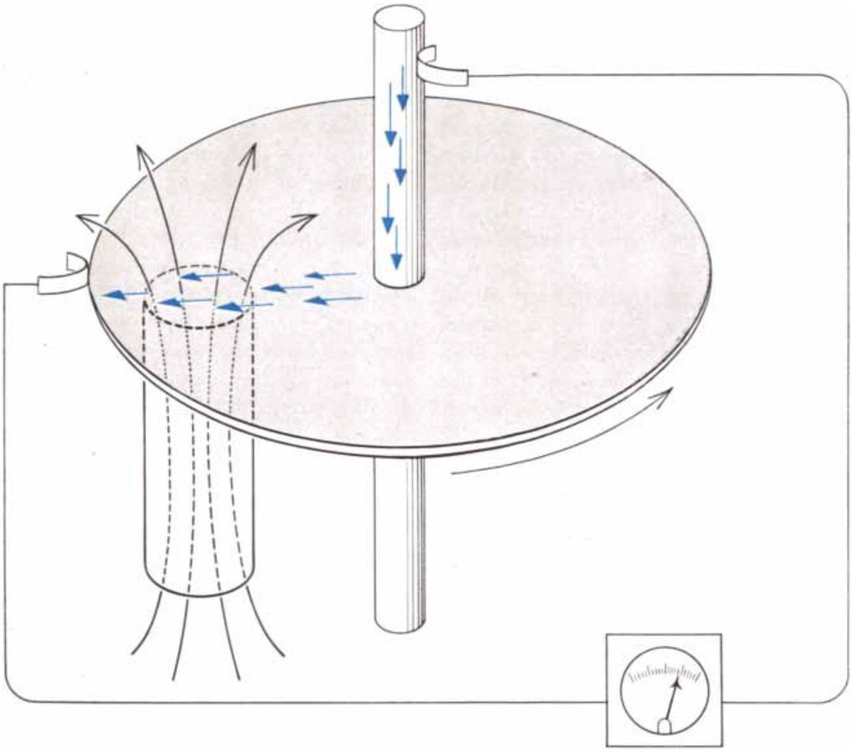
Gilbert thought that the field might be produced by a large body of permanently magnetic material inside the earth. This idea had to be given up a long time ago, when it became plain that the temperature of the earth's interior must be much too high to allow any material to retain magnetism. Physicists were left completely at a loss to explain the earth's field. It became fashionable to look for some new cosmic process for producing magnetism which eluded detection in the laboratory but applied to very large rotating bodies such as planets and stars. The main proponent of this line of thought in modern times has been the famous British physicist P. M. S. Blackett. But Blackett and his school have now abandoned such ideas because astrophysical evidence shows very clearly that the magnetism of stars does not conform to any reasonable scheme involving a new fundamental law.

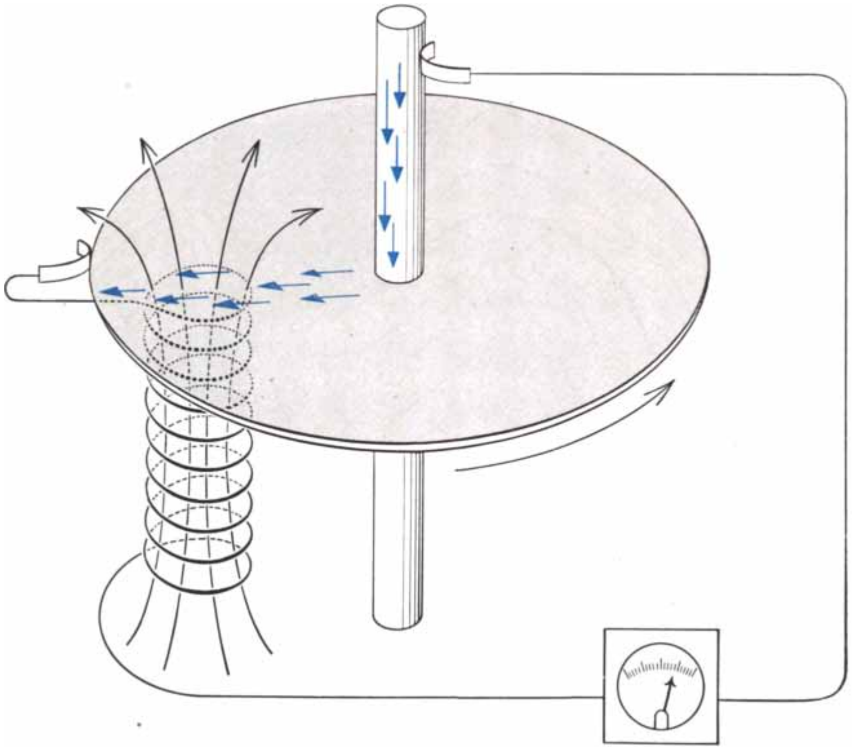
We come back, then, to the simple and familiar process by which we generate magnetic fields every day—namely, by the use of electric currents. An electric current flowing around a bar of iron induces magnetism in the metal. But the magnetized material need not be a solid bar. We know that electricity can produce magnetic fields in a gas or other fluid: such phenomena have lately been much studied under the name of magnetohydrodynamics. Let us see whether magnetohydrodynamics can explain the existence of the earth's magnetic field.

We must assume first of all that there are electric currents in the core of the earth. Possibly they were started originally by chemical irregularities which separated charges and thereby initiated a battery action that generated weak currents. But how the currents originated is less important than the question of how such currents could be built up and perpetuated to maintain the earth's continuing magnetic field. We do not have to look far for a process that could accomplish this: it is the familiar principle of the dynamo.

A dynamo converts the energy of mechanical motion into electric current. The motion may be relative motion between a coil and a ferromagnetic material or between two coils (or other conductors of electricity). The simplest illustration of such a machine is the disk dynamo invented by Michael Faraday. He put a disk of copper on a spindle and spun the disk over a bar magnet set up near the outer edge of the disk [*see diagram at the right*]. The motion of the conductor through the magnetic field of the magnet induced a small current in the disk, as shown in the diagram. Now we can replace the bar magnet with a coil, and this will induce a current in the disk in exactly the same way, provided we start with a current in the coil. And if we feed the current induced in the disk back into the coil, we have a self-contained system for generating current simply by spinning the disk. This is exactly the principle on which power-station generators operate.

The Faraday disk itself could not maintain a current for very long, because the current induced in the disk is so weak that it would soon be dissipated by the resistance of the conductor. If we had a material that could conduct electricity a thousand times better than copper, the system would indeed yield a self-sustained current. We could also make it work by spinning the disk very fast, but here again the solution is only theoretical, because the necessary speed is far beyond feasible limits. There is, however, a third way we could make such a dynamo self-sustaining, and this has a direct bearing on our problem of explaining the earth's magnetism. All we need to do is to increase the size of the system: theory says that the bigger we make such a dynamo, the better it will function. If we could build a coil-and-disk apparatus of this kind on a scale of many miles, we would have no difficulty in making the currents self-sustaining. And the larger we made it, the less speed of rotation we would need. If the disk had the same diameter as the earth, its





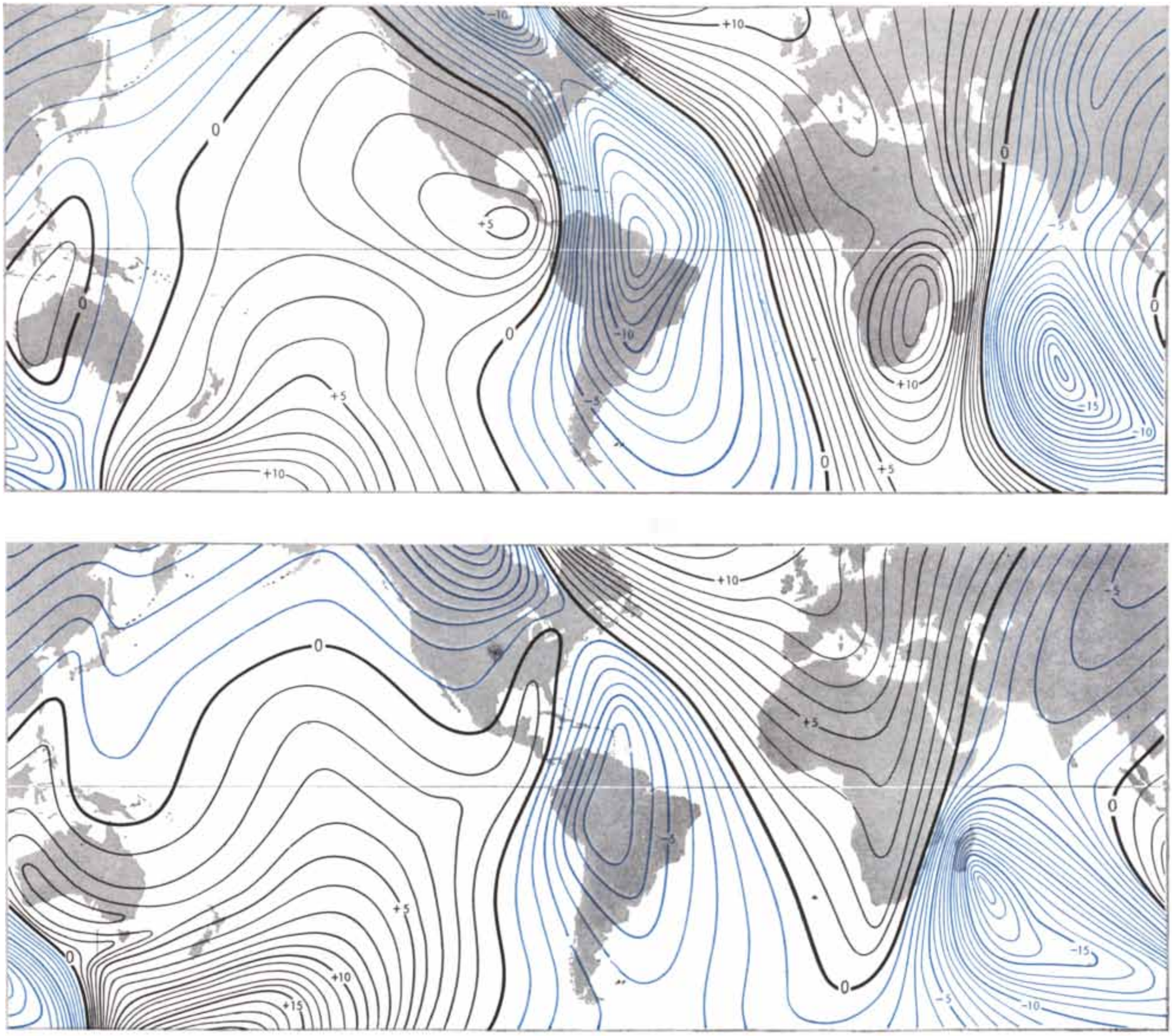
SIMPLE DYNAMO generates electric current (*colored arrows*) when a copper disk is turned through the magnetic lines of force of a bar magnet (*top drawing*) or a coil (*bottom*).

outer edge could rotate at a snail's pace and we would still have a dynamo.

We have a plausible mechanism, then, for maintaining self-sustaining electric currents in the earth's interior. Let us now look at the interior to see whether currents can actually be generated there.

The study of the travel of earthquake waves through the earth has told us some very definite facts about its internal structure and composition. First of all, we know that the earth has a distinct core 4,316 miles in diameter—a little more than half the total diameter of the globe. We know also that this core is fluid. It may therefore be in motion—which is one of the necessary conditions for the dynamo model we have discussed. And finally, we are reasonably sure that the main material of the core is iron: it is probably composed of an iron-nickel alloy with some dissolved impurities. Thus we have a molten metal or alloy filling the inner part of the earth. It is at once a good conductor of electricity and a fluid in which motions can easily take place. In other words, the core is exactly the kind of medium we need for the Faraday type of dynamo. It allows both mechanical motion and the flow of current, and the interaction of these can generate self-sustaining currents and magnetism.

So far, so good, but the most important evidence is yet to come. The nature of the earth's magnetic field itself is the strongest argument for the dynamo theory. For many years geophysicists have known that the magnetic field is irregular and constantly changing [*see maps below*]. The compass needle does not point exactly to the north, and it deviates from true north by different amounts in various parts of the world.



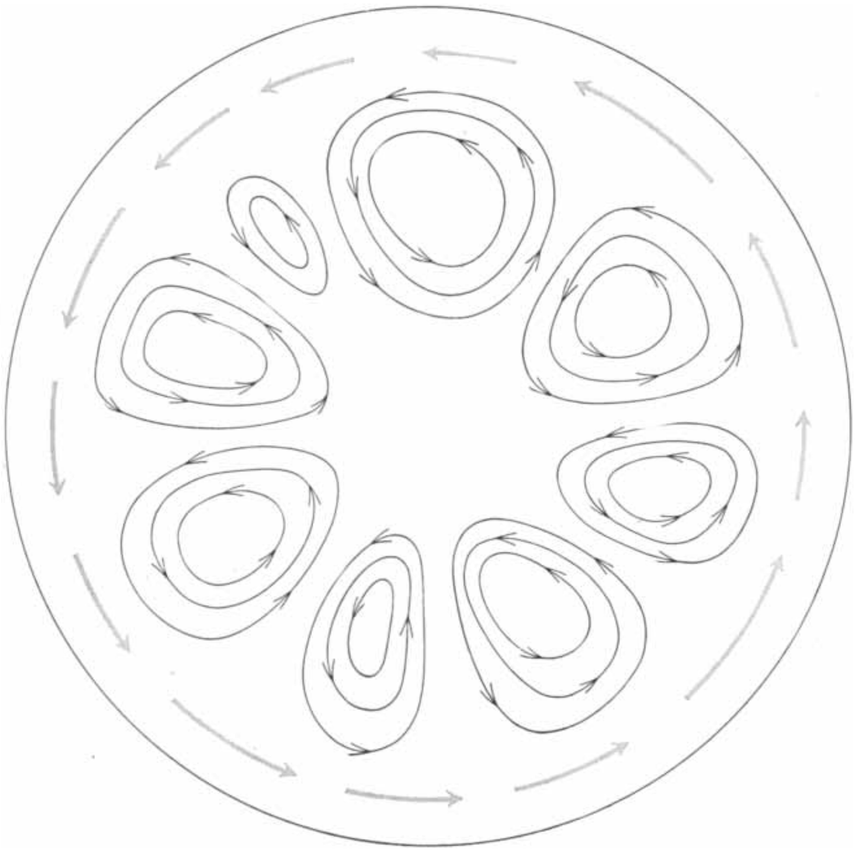
CHANGING EDDIES in the earth's magnetic field are reflected by the differences in the contours on these two maps of the world. The contours plot the rate of change in minutes of arc per year of magnetic declination: the deviation of a compass needle from true north. The map at top shows the contours in 1912; the map at bottom, the contours in 1942. A contour labeled with a positive number (*black*) indicates the rate at which a compass needle on the contour moved away from true north; a contour labeled with a negative number (*color*), the rate at which a needle on the contour moved toward true north. On the North Island of New Zealand in 1942, for example, a compass needle would have moved away from true north at a rate of five minutes of arc (+5) per year.

There are many eddies, as it were, in the field. They are eddies in a literal sense, because they change as time goes on. Seamen and fliers who use magnetic charts for navigation know only too well that the maps must be brought up to date every few years. Not only does the field fluctuate but the rate of change itself varies from time to time.

Moreover, even the over-all strength of the earth's field as a whole is not constant. In the century since accurate measurements of the field began to be made, its strength has declined about 5 per cent. We need not be alarmed into thinking that by the year 4000, say, people will no longer be able to use magnetic compasses for navigation. There is evidence that in the last few years the decline in strength has begun to slow down, and the trend may turn upward in the near future. Finally, we know that the north magnetic pole has been wandering about the Arctic in the course of geological time; it is now just north of Canada near the 70th latitude.

All this is precisely what we should expect on the dynamo theory. It represents overwhelming evidence that the core of the earth is in motion; the variations and changes in the field must reflect these motions. So the pieces of the puzzle fit together. Seismology tells us that the earth's core is fluid; the study of the magnetic field confirms that there are motions in this same core. Indeed, from the measured changes in the field we can compute the speed of these motions. It turns out that matter in the core is moving at the rate of about a hundredth of an inch per second, which means that in the course of a few centuries a particle may travel through a large part of the core. In a very true sense the variations in the magnetic field that we observe on the surface of the earth tell us something about what is going on in the deep interior.

The question arises at once: What is the source of energy for these motions? We do not, as yet, have a conclusive answer. Some scientists believe that heat flowing outward from the center of the earth gives rise to convection currents in the core, as happens when a pot of water is heated at the bottom. Small differences in the chemical constitution of parts of the core also would produce slow movements of the fluid, as differences in salt content do in the oceans. Or it may be, as Harold Urey of the University of Chicago has suggested, that the earth's interior is changing and moving because it has not yet reached a state of equilibrium. In any event, motion there is, and there is one more thing we can say safely. Calculations show that the energy required to maintain motion in the earth's core is surprisingly small.



CIRCULAR ELECTRIC CURRENT (*gray arrows*) which gives rise to the earth's magnetic field may be driven by smaller eddies of current (*closed arrows*). This schematic diagram is a section through the Equator, *i.e.*, the poles are perpendicular to the plane of the page.

The dynamo theory of the earth's magnetic field takes off from the two basic facts that seem well established: the existence of a core composed of molten metal and the presence of motions in this core. It requires no additional assumptions. From these facts we can derive the magnetic field merely by applying laws of classical physics which have been known and uncontested for well over 100 years. But the reasoning is not altogether simple and straightforward: we have some tricky questions to answer.

Suppose we take a fishbowl, say a foot in diameter, fill it with mercury and heat it from below. We will certainly get thermal convection in the mercury. But by no stretch of the imagination can we expect to detect any electric currents or magnetism in the bowl. Now our bowl of mercury is very similar to the earth's liquid core, and we often use scale models satisfactorily to investigate fluid motions: *e.g.*, a ship model in a tank or a model of an airplane in a wind tunnel. What, then, is wrong with our model of the earth's core? Mathematical analysis answers this question. The model fails because electrical processes and mechanical motions do not scale down (or up) in the same way.

If we suddenly shut off a current in a coil in the laboratory and instantly hook up the coil to an oscilloscope which displays what happens immediately thereafter, we find that the current does not stop at once but takes a small fraction of a second to die out. This is known as the decay time. A circular current in the mercury of our fishbowl would have a decay time of about a hundredth of a second. But now as we increase the size of the vessel we discover the striking and surprising fact that the decay time increases out of all proportion: in fact, it goes up as the square of the increase in the vessel's diameter. In a vessel 10 times larger than our first, the current will take 100 times longer to decay. Calculations show that an electric current circulating in the earth's core would require about 10,000 years to decay. Ten thousand years would be ample time for this current and its associated magnetic field to be "pushed around" considerably by motions in the fluid, however sluggish they might be.

We can visualize how this pushing-around process might generate new electric currents and might amplify magnetic fields. Let us consider just the magnetic fields. We can think of the field lines as so many ribbons which are pulled and stretched by the motion of particles in the fluid: this is not merely a fanciful way of speaking but actually a literal description of the way they behave. Let us assume that a group of particles in the fluid, moving at different speeds, pulls laterally on some lines of force which are straight to begin with. The lower part of these ribbons, where the particles are moving faster, will be pulled farther than the upper part, and therefore the ribbons will be stretched. In the process of stretching they gain energy—energy which is imparted by the motion of the particles. This basic process of the conversion of mechanical energy into electrical and magnetic energy —not essentially different from the operation of a dynamo—can be shown mathematically to account satisfactorily for the electric currents and the magnetism of the earth's core.

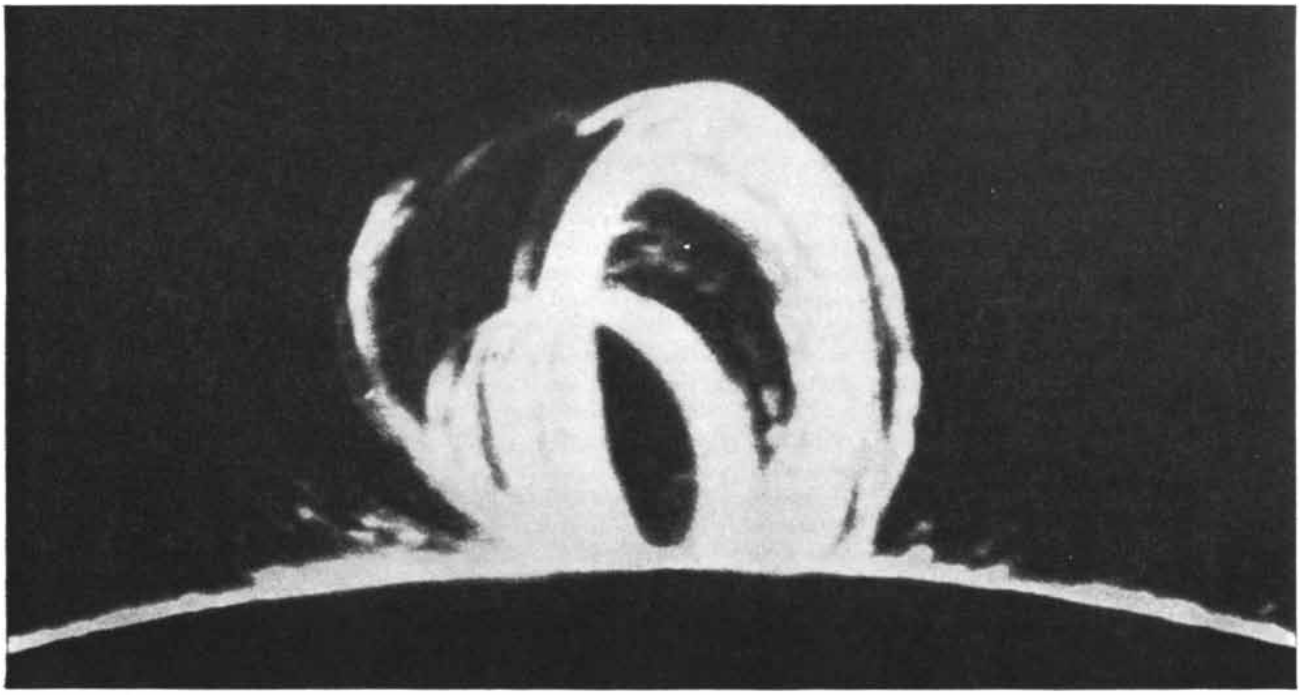
If the core contained no electric currents at the beginning of the earth's history, it could soon have acquired small currents by some chemical battery action. These tiny currents would rapidly be amplified by being pushed around by the fluid motion, and the amplification would go on until an equilibrium state was reached. Thereafter the core would contain self-replenishing electric currents and the earth would have a permanent magnetic field.

One major question remains: Why does the earth have a unified general field? The process I have described would produce only localized eddies, not a general field. But we have a reasonable answer to the question. The stage director that lines up the eddies in some sort of order must be the earth's rotation, for the general field is aligned approximately along the axis of rotation.

The greatest difficulty in all attempts to explain the earth's magnetic field has been the problem of introducing the driving force that produces the general symmetry of the over-all field. We have to assume that the field is generated by circular electric currents closed upon themselves. In such a setup there is no apparent place where we can insert a driving force—either a battery or any other. But the dynamo theory allows the earth's rotation to act as a driving force. The rotation causes the closed currents of the eddies to flow in the same direction [*see diagram on preceding page*]. If we were in the earth's core we would observe only the individual eddies. But at our observation posts outside the core their aggregate effect is nearly equivalent to a single current flowing in a large circle around the whole core, as the diagram indicates. Over-all the field is fairly stable, but, since eddies start, grow and decay in more or less random fashion, the magnetic field is unpredictable in its details.

Of late, strong support for the dynamo theory has come from the camp of the astronomers. They have found that not only our sun but also many other stars possess strong magnetic fields, and we can easily picture dynamo processes operating in the stars. The sun has extremely strong magnetic fields in the sunspots, and its archlike prominences must be formed by magnetic lines of force [*see photograph below*]. So far some 60 other strongly magnetic stars have been identified; no doubt a large proportion of the whole star population, if not all of this population, is more or less magnetic.

The stars rotate; their gaseous matter conducts electricity well; their magnetic fields change rapidly—all this points to a dynamic rather than static explanation of their fields, such as we postulate for the core of the earth. Although our fishbowl of mercury is an inadequate model of what goes on inside the earth, the earth's core seems to be a quite tolerable model for the magnetohydrodynamic processes that fill the universe on the vastest possible scale.



PROMINENCE on the sun was photographed with a coronagraph at the High Altitude Observatory of the University of Colorado. The artificially eclipsed disk of the sun is at bottom. Shape of the prominence suggests that it travels along magnetic lines of force.

Kodak reports on:

the things some people want in front of a television camera tube . . . our desire to be a fountainhead . . . creation and propagation of slides and filmstrips

It will be interesting to see if this picture and the paragraph of type you are now reading succeed in their purpose (and it's a long, long shot) of eliciting even a single letter, wire, or phone call from a party seeking a strong and competent organization to take on the development, design, and/or construction of a complex optical-mechanical system for feeding some sort of image into a television camera tube. The quest for such a contact is suggested by the very satisfactory manner in which our work is progressing on two such projects, the first television bombsight and the first airborne television gunsight. In security-dictated disorder, the photograph suggests the kind of components we make and put together for these affairs. Nor are our talents along these lines newly acquired, even if Ed Sullivan* doesn't stress them on Sunday evenings when discussing our more popular mechanical and optical products. The letter, wire, or phone call goes to Eastman Kodak Company, Military and Special Products Division, Rochester 4, N. Y.

*The fact may little signify, but Ed and most of the other figures of live television reach the magic screen through *Kodak Television Ektanon Lenses* on the studio cameras.

Of tocopherol we sing

Of tocopherol we sing a tune different from that used for Eastman Organic Chemicals as a class. Here the principle of non-specialization is cast off. Here is no place for pleasantries where one Sandmeyer reaction product or another, one nitrite reagent or another, serve as mere illustrations of diversity. The stream of tocopherol that pours into the world economy has one of its main sources in us. To be looked to, likewise, as a fountainhead of tocopherol research suits us. It says so right at the bottom of our advertisements to the pharmaceutical industry: "leaders in research and production of vitamin E." The greater number of disinterested investigators we can incite to scrutinize the role and fate of tocopherol in mammalian and avian physiology, the prouder we shall be.

To facilitate such inquiry we announce our readiness to supply at \$50 per 10 mg d-α-tocopheryl acid succinate bearing a C^{14}-labeled 5-methyl group. Biologically and chemically identical with the crystalline material we regularly sell to pharmaceutical manufacturers, it carries the high specific activity of 1 microcurie per mg.

Because of the slight formality which requires licensing of radioisotope users by the Atomic Energy Commission, Division of Civilian Application, Oak Ridge, Tenn., this material is not handled as an Eastman Organic Chemical or sold through dealers. A photocopy of your AEC authorization must accompany your purchase order. Submit it to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

The powers of semi-darkness

One result of all the efficiency pervading life today has been more time to sit around in semi-darkness listening to speakers draw attention to Worthwhile Matters with the help of slides or filmstrips. You will not deny that this is good.

What, then, can be done to encourage and facilitate the generation of lots more slides and filmstrips? Consider the sources.

There are organizations—some for profit, some non-profit—that produce them for schools. All they need for encouragement is sales. Subjects are of the kind that keep well. Life along the Nile. The circulation of the atmosphere. That sort of thing.

Then there are firms producing films and filmstrips to order for promoters of causes. The need for higher protective tariffs. The need for lower barriers to international trade. How to sell bicycles to people over 40. Here an advertising or public relations agency often acts as intermediary between sponsor and producer.

Outfits that use slides and filmstrips to communicate on a broad and varied scale often maintain their own production facilities for the purpose. This would include large companies, government bureaus, ag colleges.

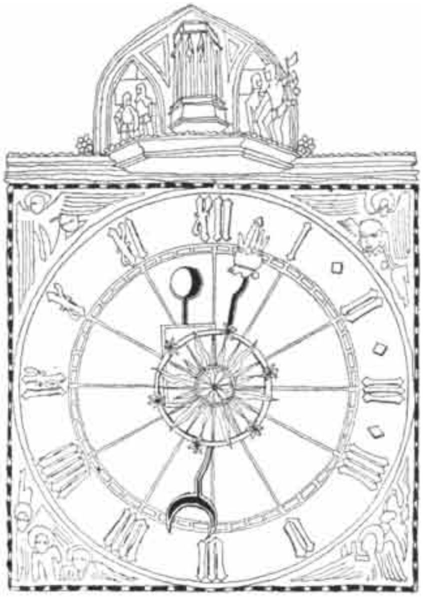
Not to be neglected beyond these large operations, however, is the individual on his own who has an audience to face and to tell of his work and thoughts as vividly as he can. He, too, can make them—slides if he intends to put on the same performance only once or a few times, filmstrips if it is to be given many times in essentially unchanged form.

For his benefit we have published a Kodak Data Book, "Photographic Production of Slides and Filmstrips." Kodak dealers have it for sale or can order it. It is particularly rich in details on attaining good quality color reproduction by the use of masking techniques. The danger that purchase of this 50¢ booklet turns out eventually to have been the first step toward establishment of a slide-and-filmstrip department in the organization with which the reader is affiliated, while slight, is undeniably present.

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

Prices quoted are subject to change without notice.

Kodak
TRADEMARK



SCIENCE AND

Satellites and Beyond

With the launching of Vanguard I and Explorer III in March there were five man-made objects whirling around the earth. Sputnik II, with its dead radio and dead dog, was expected to come down around the middle of April. Explorer I, still sending radio signals on one channel, was thought to be good for several years. Vanguard I may stay up for 100 years, and its accompanying rocket case may orbit as long as 10 years. Explorer II, which began its journey a little off course, is expected to have a lifetime of only a few months.

The Vanguard satellite, launched by the U. S. Navy on March 17, is a sphere 6.4 inches in diameter weighing 3.25 pounds. Its elliptical orbit, which crosses the Equator at an angle of 33 degrees, has a minimum altitude of 404 miles and a maximum of 2,466. Flying much higher than any of the other satellites, Vanguard takes a longer time—134 minutes—to complete each revolution. The sphere contains two transmitters, one powered by conventional batteries and transmitting at 108 megacycles, the other powered by solar batteries, transmitting at 108.03 megacycles. The solar batteries, distributed over the surface of the vehicle, are expected to last for months or years, depending on the rate of erosion by meteors. Vanguard I's transmitters are reporting temperatures inside the vehicle and at its surface. Its signals are also giving some information about the ionosphere; they give a measure of the degree of ionization.

Explorer III was put into orbit by the Army on March 26. It is a 31-pound cylinder six and a half feet long and six inches in diameter. Its orbit, inclined at 34 degrees to the Equator, has a minimum height of 110 miles and a maximum of 1,700; it takes 116 minutes for the trip around the earth. Like Explorer I, it has two transmitters (on the standard frequencies of 108 and 108.03 megacycles) together with instruments for measuring temperatures and detecting cosmic rays and impacts of meteors. Explorer III carries a magnetic tape recorder which stores two hours' worth of cosmic-ray counts and reports the accumulated information on command from a ground station. After each readout the tape is erased and starts recording again.

All the satellites are being tracked continually. Little Vanguard, only the size of a grapefruit, so far has been followed only by the Minitrack radio network, but Moonwatch teams have reported sighting it several times, and it is expected to be picked up eventually by the special satellite cameras, of which six are already in operation in the U. S., Australia, Japan, India, South Africa and Spain.

Only two of the satellites launched so far—the spherical Sputnik I and Vanguard I—could give information about the density of the upper atmosphere and the shape of the earth. The others, being asymmetrical in shape, vary greatly in drag as they tumble along. Sputnik I showed that the upper atmosphere is denser than had been thought. Vanguard I will add more accurate information after its precise orbit has been established visually.

During the remaining months of the International Geophysical Year the Navy plans to launch at least seven full-sized (21-inch) Vanguard satellites and the Army one or more of the Explorer type. More ambitious projects also are under way. The U. S. Department of Defense has directed the Army and the Air Force to shoot four or more "probes" to the moon, and has started off the project with an allocation of $8 million.

Last month the President's Science Advisory Committee, headed by James R. Killian, Jr., recommended a long-range program of space projects which would go on from satellites to unmanned rockets to the moon, then to other planets and eventually to manned vehicles. The Committee estimated that to put the first man on the moon and bring him back would cost "a couple of billion dollars." Its estimate of when manned space flight might become feasible ranged from 10 or 20 years hence to some time in the next century. The Committee saw no urgency for sending up men in rockets, aside from the adventure, because instruments could collect about as much information as human passengers could.

The Committee proposed a list of subjects to be investigated, among them the much-debated question whether clocks would run slower in a space flight.

Parliament of Science

To consider a science policy for the U. S., a "Parliament of Science" was held in Washington last month at the call of the American Association for the Advancement of Science. It was attended by more than 130 leading scientists and representatives of the humanities, the public and the press. After three days of discussion, the group adopted a statement of general principles and more than 50 specific recommendations.

The parliament focused its attention on five areas: support of science, organization of the nation's scientific effort, communication among scientists and between scientists and the public, guidance of the nation's youth and improvement of education. Among the important conclusions reached were:

Basic research must be supported both by government and by private funds. These must be provided in ways which encourage and support creativity and maintain a balance in universities between research and teaching. Grants to universities should be made on the basis of long-range plans and should cover both direct and indirect costs. More money is needed for "large and expensive" research projects in the biological and social sciences. The national tax structure should be altered to increase corporate and private contributions to education and research.

Federal support of education is necessary, and the first priority should go to improving teaching, by raising teachers' salaries and increasing their opportunities for further study. Scholarships and fellowships should be awarded on a merit basis only. Fellowship programs should include the humanities and social sciences as well as the natural sciences. Science teaching in elementary and high schools should be improved by expanding programs for training teachers and revising certification requirements to reduce education courses and increase subject courses.

Efforts must be made to improve communication of science. Scientists should use "clear, vigorous English" in writing professional papers, and should encourage critical and responsible editorial policies in professional journals. Agencies that support research should encourage scientific meetings, support the preparation of monographs, abstracts, bibliographies and the like, and should support research in methods of organizing and circulating scientific information among workers in science.

Scientists have an obligation to communicate their work not only to other scientists but also to the general public; this will require cooperation with science writers. Scientists and their organizations should help to train such writers, and the National Science Foundation and National Institutes of Health should be authorized to give funds for similar training programs. Scientists should also make use of adult education programs, local discussion groups and science fairs to communicate their ideas to the public.

Scientists should work with the American Society of Newspaper Editors and other groups to reduce governmental secrecy and protect the public's right to know. Restrictions on the dissemination of scientific information, unless clearly necessary for national security, are "destructive, wasteful and intolerable."

The delegates were sufficiently enthusiastic about the results of the parliament to ask the A.A.A.S. to hold more such conferences.

Federal Aid to Research

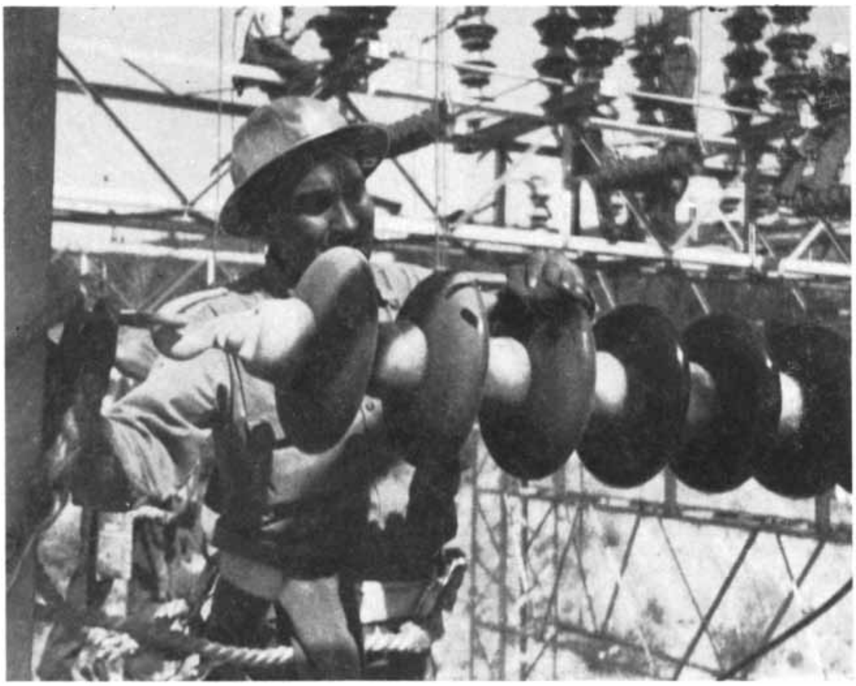
The U. S. Government's vast sponsorship of research in colleges and universities since World War II has brought them benefits which far outweigh the drawbacks, according to a committee of the National Science Foundation which has just completed an exhaustive study of the relationships between the Government and the universities. Government agencies now contribute about two thirds of these institutions' funds for research and development. The committee finds that scientists have had freedom in their choice of projects and that the government support has greatly ex-

SILICONE NEWS

Cost-cutting Silicones

Speed Maintenance, Production

TRIMMING THE TAB ON PLANT EXPENSE — *Every executive knows that rising costs coupled with excessive down-time can swing a healthy net profit to an embarrassing loss. New ways to smooth production flow and cut maintenance hours have been discovered, however . . . with silicones. Here are some salient facts on how Dow Corning Silicones have come to the aid of plant engineers.*

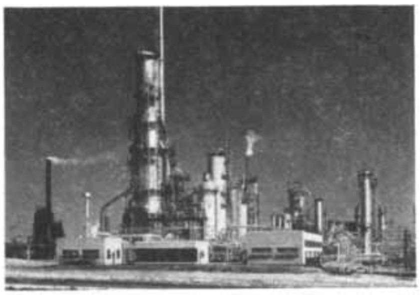


HIGH VOLTAGE IDEA — The Kaiser Aluminum and Chemical Corp. had a problem with high voltage insulators in the switchyard of their Permanente, California, plant. Cement dust would coat the strings of insulators causing current leakage and flashovers during damp weather. Cleaning insulators took eight man hours per string every six months. Of course, the plant had to shut down while power was off.

Then plant maintenance engineers brought silicones into the picture. Insulators were coated with Dow Corning 5 Compound, a greaselike dielectric material. After six months, the silicone-coated insulators came clean with a quick swish of a dry cloth. Results from additional tests were equally favorable. Now Kaiser Aluminum plans to cut cleaning schedules to once a year, do the entire job with fewer people and in less than a shift!

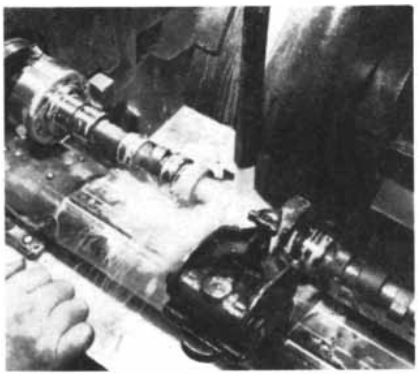
PAINT THAT STAYS NEW — To prevent rust and add attractiveness, Cosden Petroleum Refinery, of Big Spring, Texas, has painted its huge "cat" cracker and all other high-temperature units in a gleaming silver and gold color scheme. How can the paint stay on these hot surfaces?

Cosden's secret is a silicone aluminum paint made by Cactus Paint Company from Dow Corning silicone resins. It withstands temperatures from 300 to 900°F on stacks, furnaces, crackers, and similar equipment. Where several



repaintings a season were formerly needed with conventional paint, the silicone finish resists both heat and weathering . . . is still "like new" after three years. A lot of paint and painting time has been saved, rust has been prevented and the plant "looks good . . . like a refinery should."

BUBBLES BROKEN FOREVER — Foam is one waste you don't have to live with. For example, a metalworking plant had trouble with coolant on a camshaft grinder. The cutting oil foamed so badly it overflowed both the grinding machine tank and the 289-gallon filter tank connected to it. Naturally, this interfered with production. Then the company tried



a ready-to-use Dow Corning silicone defoamer. A single teaspoonful eliminated foam entirely. Now floors stay clean, work is less messy and production runs smoothly . . . due to an occasional spoonful of silicones!

FOR MORE INFORMATION **on any of these silicone products or applications, write Dept. 985**

first in silicones

Dow Corning CORPORATION
MIDLAND, MICHIGAN

ATLANTA BOSTON CHICAGO CLEVELAND DALLAS DETROIT LOS ANGELES NEW YORK WASHINGTON, D. C.
CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST. GOBAIN, PARIS

panded the universities' work in the natural sciences without doing so at the expense of the social sciences and the humanities. It has helped them to devote to teaching money they would have had to use to maintain research.

The committee, headed by Chester I. Barnard and J. W. Buchta, did, however, find a number of points of friction between educational institutions and the granting agencies, and it recommended some reforms. Faculty members working on sponsored projects should be paid through the university at regular university rates. Equipment purchased for a project should be considered the property of the institution rather than of the sponsoring agency, except in special cases. Contracts and grants should cover a longer term, to facilitate planning. The sponsoring agencies should pay the indirect costs of research and should be more liberal in allowing expenses for attendance at scientific meetings and for publication of nonclassified material.

The committee urged that classified research be removed from the campuses as far as possible, and that work in military science and atomic energy be concentrated in government-owned centers such as the Los Alamos Scientific Laboratory.

Kitt Observatory

The site for the new National Astronomical Observatory has been chosen. It will be located on Kitt Peak in the Quinlan Mountains in Arizona, 40 miles southwest of Tucson. The site was selected from some 150 considered in a three-year study by a committee of the Association of Universities for Research in Astronomy, which will build and operate the Observatory under contract with the National Science Foundation. Plans are to build 36-inch and 80-inch reflecting telescopes.

The Kitt Peak site, a flat 70-acre area at an elevation of 6,875 feet, has several virtues which will complement the location of the great telescopes in California. It covers more of the southern sky and has clear skies in the winter and the spring, when California's skies are apt to be cloudy. One complication is that Kitt Peak is sacred to the Papago Indians: a cave in the mountain is said to be the home of a dwarf god. The Indians' councils have agreed to permit the Observatory on their reservation, however, on condition that no caves be molested.

The universities that will operate the Observatory are California, Chicago, Harvard, Indiana, Michigan, Ohio State,

Yale and Wisconsin, with the University of Arizona cooperating.

College Pay

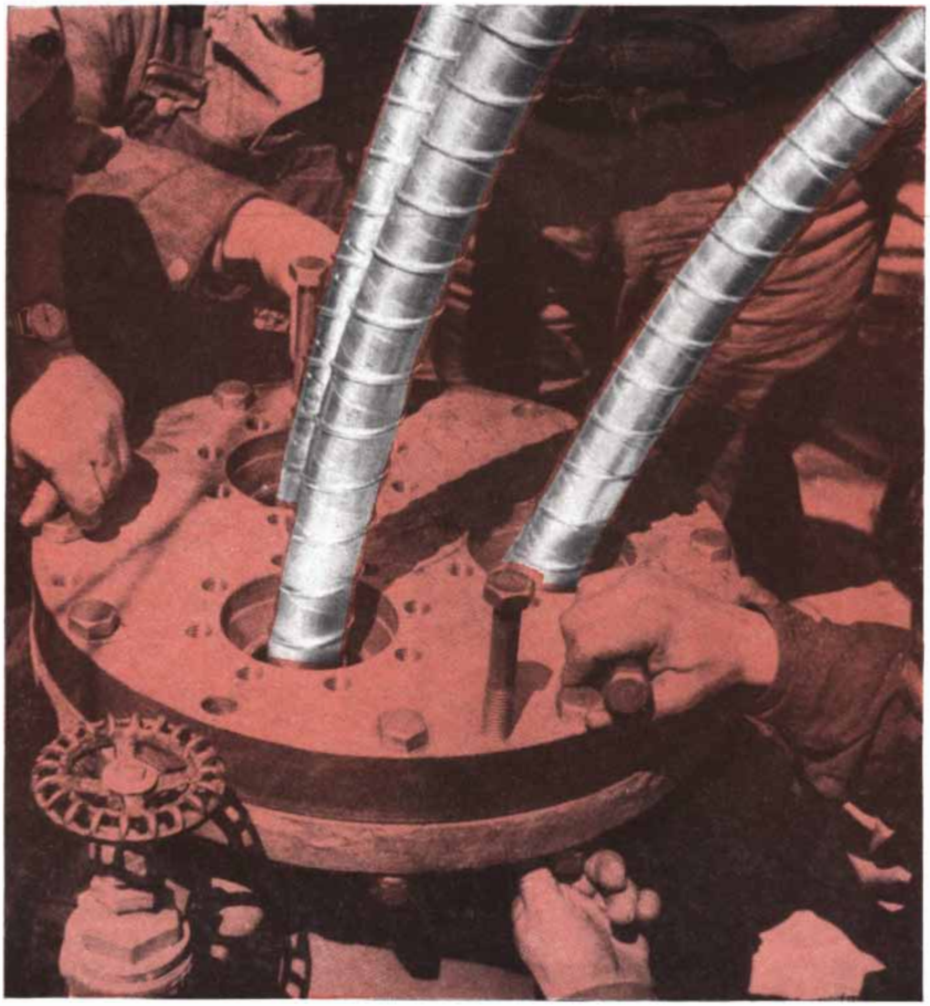
The average salary of college teachers in the U. S. this year is $6,120, according to a study by the U. S. Department of Health, Education and Welfare. In public universities average salaries range from $5,110 for instructors to $8,530 for full professors. The corresponding range in private institutions is $4,230 to $7,360. The highest average salaries reported were $13,800 for full professors in one private university and $12,350 in a public institution. Noting that salaries have risen 20 per cent in the past three years, Lawrence G. Derthick, Commissioner of Education, commented: "This represents little progress in relation to other professions. . . ."

Biophysical Year

In their wide-ranging search for facts about the earth, workers in the International Geophysical Year are willy-nilly undergoing biological experiments themselves. The Antarctic program especially affords a unique opportunity for studying the effects of extreme climatic conditions on man. Such a study has been set up by the U. S. National Committee for the I.G.Y.

One of the chief areas of investigation is Antarctic dentistry. The South Pole brings out the worst in a man's teeth. Small cavities which might go unnoticed in a temperate climate produce rousing toothaches in the cold of Byrd Land. Dead but serviceable teeth hurt so much they must be pulled out. Alloy fillings shrink and fall out of their cavities. Gold inlays allow the cold to penetrate to sensitive nerves. Despite an elaborate dental going-over before leaving the States, many of the Antarctic party have found life there one long toothache. Dentists with the group are experimenting with new materials for fillings and with rubber tooth-guards to keep out the cold. They are measuring mouth temperatures under various conditions and looking into psychosomatic effects.

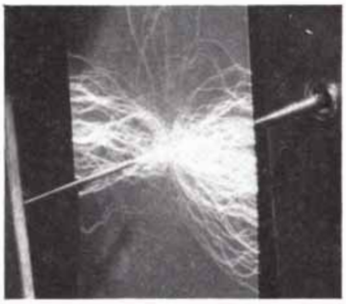
To find out what adjustments, if any, the body makes in adapting to the rigors of polar climate, physiologists are keeping a continual check on the thickness of body fat, the production of body heat, the mobility of joints and the sensitivity of touch. The psychological effects of cold and isolation also are being studied. Members of the various expeditions keep diaries noting their difficulties and an-



PROPERTIES OF "MYLAR"

"Mylar" offers a unique combination of properties that may help you improve performance and lower costs of *your* product. Here are two of the many important properties for evaluation.

REMARKABLE TOUGHNESS. "Mylar," the strongest plastic film ever made, is tough even in extra-thin gauges. It resists aging ... heat, moisture and most chemicals.



HIGH DIELECTRIC STRENGTH. Average of 4,000 volts per mil ... average power factor of 0.003 at 60 cycles ... dielectric constant above 3.0 at 72°F., 1,000 cycles.

General Cable reports ...

New shielding assembly with Du Pont Mylar® limits oil drainage ... restricts moisture pickup

PROBLEM: To provide an outer shielding assembly on General Cable's high-voltage, high-pressure pipe-type cable. The assembly had to resist oil drainage during shipment and storage as well as restrict surface-moisture pickup during installation.

SOLUTION: After extensive tests on various materials, General Cable Corporation adopted two new tapes for the outer shielding assembly ... one tape was "Mylar"* polyester film; and the other, a "Mylar"/foil lamination.

RESULTS: General Cable tests showed that "Mylar" provided a tight, yet flexible, assembly and effectively reduced oil drainage. The high tensile strength and other excellent physical properties of "Mylar" permit its application to the cable under high tension. "Mylar" restricts surface-moisture pickup when the cable is exposed to air during installation. "Mylar" is not affected by the insulating oils ... has no plasticizer ... will not contaminate other materials.

How can "Mylar" help you? Whether you manufacture high-voltage cable or tiny components, it will pay you to evaluate the outstanding combination of properties found only in "Mylar." And when figured on an area basis, this tough, thin polyester film will often *cost less* than materials you are currently using. For more detailed information, send in the coupon below.

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Eight-Mill Atomic Power

The Pacific Gas & Electric Company has laid a large bet that it can make money on nuclear power. It has contracted to install a 60,000-kilowatt boiling-water reactor on Humboldt Bay, a remote area in northern California where the cost of conventional power is high. When the nuclear plant begins operation in 1962, it is expected to produce power at 8.2 to 8.8 mills per kilowatt hour. Three or four years later its first core will be replaced by one of more advanced design and the cost is then expected to drop to 7.6 to 8.2 mills. The present cost of power from oil-fired plants in the area is about eight mills.

The company's optimism stems from its experience with a 5,000-kilowatt boiling-water reactor at Vallecitos, near San Francisco. This experimental unit, which has been running since last October, furnishes twice as much steam as it was designed to produce and has given remarkably little trouble in operation.

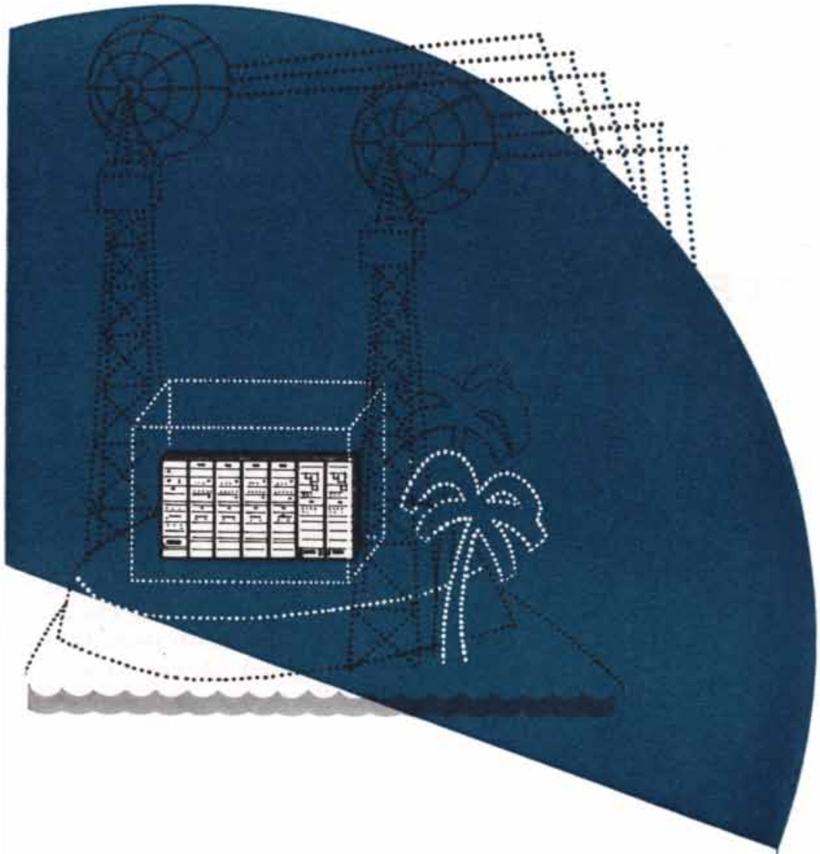
In calculating the nuclear-power costs the engineers have assumed that the plant will run steadily at 90 per cent of capacity and will share service facilities with conventional plants at the same site. No charges for land are included. The plant is to be built by the Bechtel Corporation for a firm price of $20 million. The cores, which will contain enriched uranium oxide, will be fabricated by the General Electric Company. The first one is expected to cost $3 million, the second less than $2 million. At current rates the annual cost of renting uranium fuel from the Atomic Energy Commission will be $200,000.

Formaldehyde Plastics

Formaldehyde, which can be prepared cheaply from natural gas or coal, can now be polymerized into a tough and durable plastic. The new material, called Delrin, was developed by E. I. du Pont de Nemours & Company.

Previous attempts to polymerize formaldehyde produced solids too easily decomposed by heat and poor in mechanical properties. Delrin is unaffected by boiling water and will withstand the heat of an engine. Its toughness compares well with that of nylon, while its resistance to creep and fatigue is greater than that of any other thermoplastic. It resists most common solvents.

The new plastic is expected to find



uses primarily in the mechanical field. It is said to be usable for cams, bearings, gears and pump impellers. The fact that it can be colored easily may lead to its use for household wares such as dishes.

Indulgence v. *Discipline*

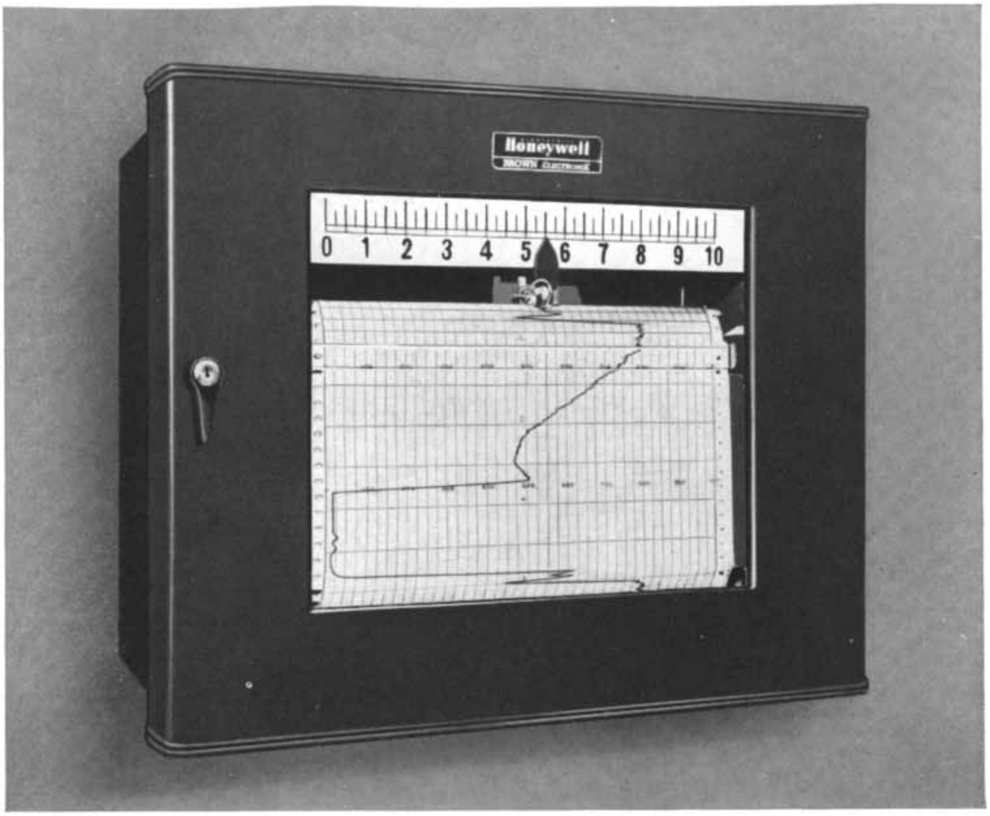
Is it better to bring up children indulgently or strictly? Some new experiments with puppies suggest that indulgence may have its advantages. But, as any parent might suspect, it all depends on the breed of dog.

At the Jackson Memorial Laboratory in Bar Harbor, Me., D. G. Freedman tried the experiments with groups of beagles, wire-haired fox terriers, Shetland sheep dogs and basenjis (small African hounds). Each group was divided in two. Half were brought up "indulgently": that is, the puppies were encouraged to do whatever they wanted and were never punished. The other half were subjected to strict discipline and trained to sit, stay and come on command. At eight weeks of age each pup was tested for obedience. Placed in a room with food, it was punished whenever it touched the food. The experimenter left the room after a few minutes and watched the pup through one-way glass to see what it would do. The experiment was repeated for eight days in succession. Freedman reports the results in *Science*.

Among the fox terriers and the beagles the indulged pups tended to be obedient, staying away from the food as long as 10 minutes, while the strictly reared pups generally began eating soon after the experimenter had left the room. The fox terriers took to sin more quickly than the beagles.

A distinguishing feature of these two breeds of dogs is that they are attracted to and affectionate toward their trainer. The other two breeds—the Shetlands and basenjis—are fearful or indifferent toward an experimenter. And they respond to their upbringing differently from the fox terriers and the beagles. The timid Shetlands, whether indulgently or strictly reared, tended to show obedience in the test. The aloof basenjis tended to be disobedient, whatever their upbringing. The indulged Shetlands and basenjis did, however, show some difference from their strictly raised fellows: they were more active, more vocal and less timid.

Follow-up experiments many weeks later suggested that indulgence is not always an unmixed blessing. Freedman found that the indulged beagles, after exposure to normal experiences, had grown exceedingly shy.



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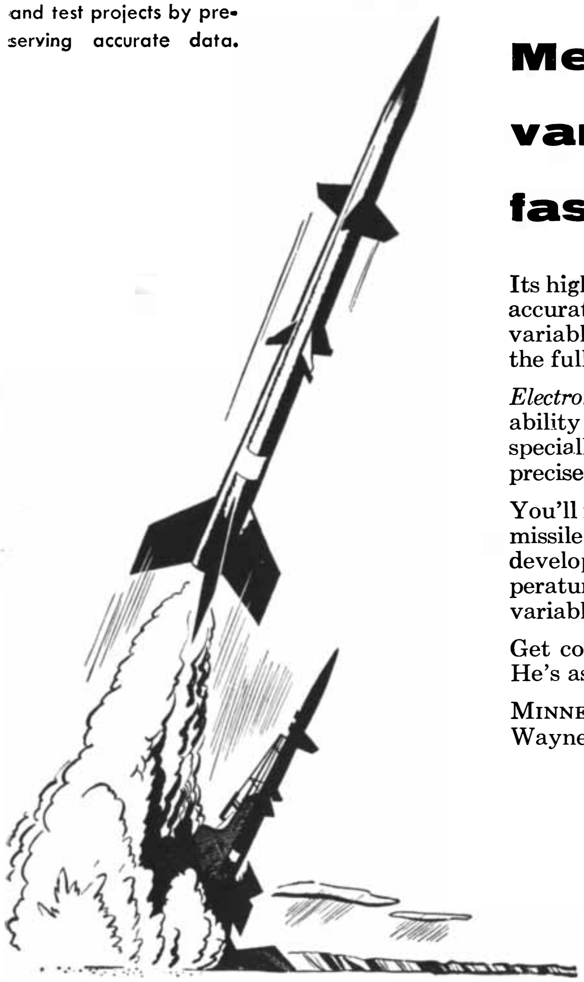

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The Teaching of Elementary Mathematics

Continuing a survey, begun last month, of the current ferment in science education. The outlook in mathematics: The next few years will bring substantial changes in high-school curricula

by E. P. Rosenbaum

If you have a youngster in high school and are occasionally called upon for help on his math, you may not remember the answers but you recognize the problems. It is the same old math that was taught a generation ago and indeed 200 years ago. The methods and the subject matter have not changed. But a revolution is impending. Deeply dissatisfied with the way mathematics has been taught, several influential groups of educators have begun to experiment with radically new methods of presenting the subject. There are high schools where sophomores are now taking home problems such as this: Prove that $[A, B/l/]$ if and only if $(A \not\subset l$ and $B \not\subset l)$ and $\overline{AB} \cap l = \varnothing$. (Translated this reads: "Prove that a point B lies between another point A and a line l if and only if A is not a member of l and B is not a member of l and the segment AB does not intersect l.")

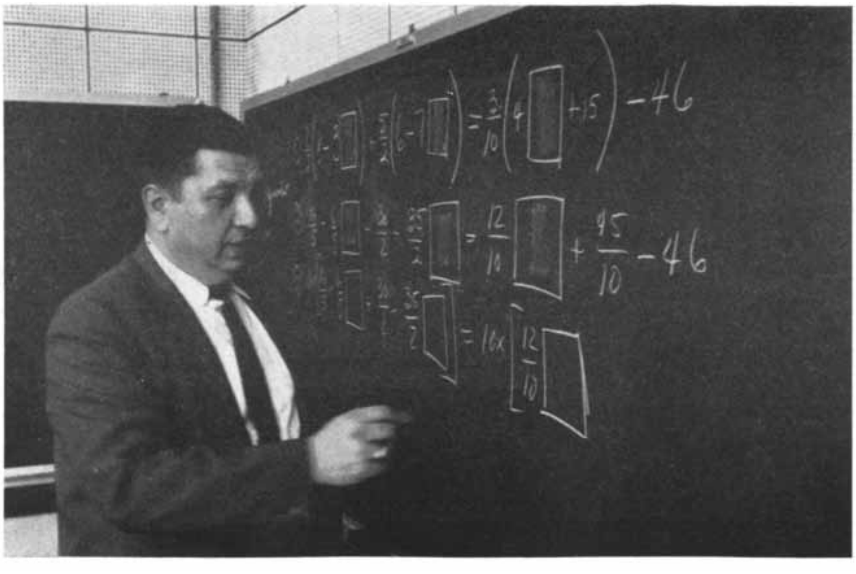
There are sharp differences of opinion about whether this sort of thing is helpful or will get very far. But on one thing almost everyone agrees: The old mathematics course must go. It does not tell the students what mathematics is all about. It does not give them any real understanding of the principles of the subject. It is so far behind the times that it leaves out practically all the new ideas and discoveries of the past 100 years. And above all, it has managed to make mathematics about the most unpopular of all branches of learning. Even cultivated men declare their ignorance of mathematics with a defiance akin to pride.

Something has to be done to make mathematics more meaningful and more exciting. At least three major attempts are under way. I shall try to report briefly the rationale and tactics of their approach.

Their underlying theme is to modernize the subject matter taught—more or less (some want to go modern farther than others). Going modern means mainly two things: pruning out dead wood and introducing some of the new fundamental ideas which within the last century have given more meaning and unity to all the traditional branches of mathematics.

As an example of dead wood one can cite the considerable attention devoted in trigonometry textbooks to solving triangles with logarithms. This was the only method available to surveyors and navigators a century ago; today technicians punch out the answer in calculating machines. Also in the category of dead wood are some of the classic Euclidean "proofs" of geometry; they are not really proofs at all. Today a mathematician attacks these problems with the calculus and the idea of limits, and arrives at truly rigorous proofs.

Mathematics as now taught in the lower schools and even in college seems to be a collection of separate subjects.



MODERN APPROACH to high-school mathematics is being tried by the University of Illinois Committee on School Mathematics. The photographs on these and the two following

Each has its own apparently arbitrary rules, taught by rote. But work on the foundations of mathematics in the last century has shown that all the branches of mathematics can be reduced to purely abstract terms, with common properties. As numbers are the elements of algebra, so points and lines are "primitive" elements of geometry, and we can deal with sets of either in the same way—indeed with the same operations. The rules of mathematical logic are universal. These basic ideas and logical processes can be taught even to school children, the modernists believe. In learning them, students will find mathematics more understandable and more meaningful. They will also get at least some acquaintance with modern thinking in mathematics.

The College Board Program

Foremost among the projects for modernizing the teaching of high-school mathematics is that of the Commission on Mathematics of the College Entrance Examination Board. This group, set up in 1955, is preparing a considerable revision of the high-school courses. Because the Commission represents a wide range of views, and because it hopes to exert an almost immediate influence on every school in the country, its program is comparatively conservative. It proposes to change the approach and spirit of the algebra course without altering the content substantially. It is revising the geometry course considerably. It wants to make certain changes in trigonometry. And it would add some entirely new courses to the high-school curriculum.

Algebra, like geometry, can be regarded as an abstract deductive system. It is built up from a set of undefined primitive notions and a number of assumed axioms. From these all the other rules and facts can be deduced by logical reasoning. The Commission does not propose to make high-school algebra purely an exercise in abstract deduction, but it believes that students should be led to appreciate the deductive nature of algebra, should learn what the axioms are and how they are used to prove some of the principles. The necessary skills in manipulating algebraic expressions will be easier to learn when the reasons behind the manipulations are understood.

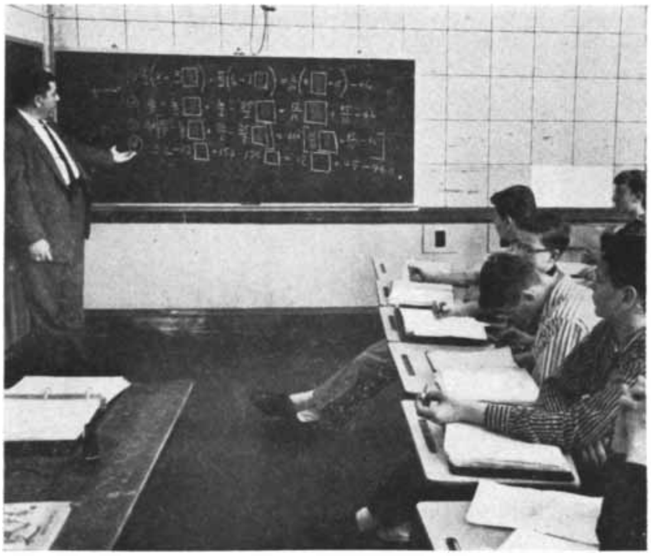
What are the "primitive" notions of algebra? They are the notions of number and of operations such as addition and multiplication. The axioms likewise are simple concepts—so simple that they hardly seem to need stating. If a and b are numbers, then $a + b$ is a number. If $a = b$ and $c = d$, then $a + c = b + d$ (if equals are added to equals, the sums are equal). Then there are the "commutative" laws, $a + b = b + a$, and $a \times b = b \times a$; the "associative" laws, *e.g.*, $(a + b) + c = a + (b + c)$, and the "distributive" law, $a(b + c) = ab + ac$.

Although they may appear mere platitudes, these rules form a mathematical system which underlies all the familiar manipulations of elementary algebra and provides a foundation for deriving further principles. Consider the theorem that the sum of two even numbers is also even. To begin the proof, evenness is defined as follows: A number n is even if and only if there is another number p such that $n = 2p$. The problem is: Given that a and b are even numbers, prove that $a + b$ is even. By the definition of evenness we can say that $a = 2x$ and $b = 2y$. By the axiom about adding equals, $a + b = 2x + 2y$. The distributive axiom says that $2x + 2y = 2(x + y)$. Since x and y are numbers, $x + y$ is a number. Hence $2(x + y)$ is an even number and so $a + b$ is even.

It may strike a layman that high-school freshmen will be neither attracted nor edified by such a laborious proof of a seemingly obvious idea. There are mathematicians who hold the same view. But the proponents argue that in a well-taught course exercises of this kind may become an intriguing journey into the realm of mathematical rigor.

The Theory of Sets

A central feature that distinguishes the "new" algebra is its use of the theory of sets, one of the most powerful tools of modern mathematics. A set is simply a group or collection. The books on a shelf, the people in a room, the letters of the alphabet, the numbers 1, 2, 3, 4 and 5—each of these groups is an example of a set. The set may have only one member or none at all (in which case it is the "empty" set). Or it may be infinite: *e.g.*, all the points inside a circle, or all the positive integers. Mathematicians commonly denote a set by listing its mem-



pages show Max Beberman, director of the project, teaching a first-year class how to solve equations. The squares on the blackboard represent spaces for a numeral. They are used instead of *x* early in the course to make clear the meaning of letters in algebra.

bers within braces, *e.g.*, {1, 2, 3, 4, 5}. There is also a conventional shorthand for statements about sets and their members. For example, the statement that 4 is a member of the set A is written $4 \in A$; that 6 is not a member of the set is written $6 \not\subset A$. To say that A is a subset of B they write $A \subseteq B$. The empty set is "$\varnothing$". The letter U denotes a "universal" set—embracing all the members pertinent to a particular discussion; for example, the universal set for plane geometry consists of all the points in a plane.

This unfamiliar language may seem an undue burden to place on beginning students in mathematics, but actually with a little practice it soon becomes easy to read—considerably easier than mastering stenographer's shorthand.

To illustrate the operations on sets I shall mention only three. The union of two sets A and B (written $A \cup B$) is the set consisting of all the members that are in A, in B, or in both. Thus the union of {1, 2, 3, 4} and {2, 3, 4, 5} is {1, 2, 3, 4, 5}. The intersection of two sets ($A \cap B$) is the set of all the elements that are common to the two sets. Thus the intersection of {1, 2, 3, 4} and {2, 3, 4, 5} is {2, 3, 4}. Finally, the complement of a subset A (written $\bar{A}$) is all the members of the universal set that are not in the subset; *e.g.*, if the universal set is {1, 2, 3, 4, 5} and a subset is {2, 3}, its complement is {1, 4, 5}. These ideas can be presented in a graphic way by simple figures known as Venn diagrams [*see page 69*].

Set theory helps to lay bare the unity of mathematics. Algebra and geometry are both concerned with sets—algebra with sets of numbers, geometry with sets of points. The specific operations in both subjects can be considered examples of the general set operations of union, intersection, and so on.

Let us see how the concept of sets can help to clarify the notions of a variable and of an equation in algebra. The College Board group recommends that students be taught first of all that algebra deals with sets of numbers and relations between them. They would then learn that a variable is simply a general name for members of a set. As such it can be represented by a letter. For example, if the set is the series of all the whole numbers, then x can be any whole number, and $x + 1$ can be $1 + 1$ or $2 + 1$ or $3 + 1$, etc. Further, an equation is a statement about a relationship between members of a set. It may be true or false: $3 + 2 = 5$ is true, $3 + 2 = 6$ is false, but both are statements. If a statement contains letters, it is noncommittal: $x + 2 = 5$ is neither true nor false until the place held by x is filled with some member of the appropriate set. Early in the course the students would also learn to work with inequalities, using the symbols $>$ (greater than) and $<$ (less than).

Now any relation can be regarded as a specification for selecting a certain subset from the universal set of numbers under consideration; in set terminology it can be called a set "builder." Thus if the universal set is all the real numbers, the relation $x + 2 = 5$ selects the set {3}, or $x + 2 > 5$ selects the set of all numbers greater than 3. The set selected by a relation is known as its solution set.

The same concept applies to pairs of numbers and can deal with an equation with two unknowns, conventionally represented by x and y. Such an equation of course has more than one solution. For example, the set selected by the equation $5x + 3y = 15$ includes such pairs as (0, 5), (3, 0), (1, 3⅓). Now anyone familiar with coordinate systems recognizes this at once as the wedding of algebra with geometry: a pair of number variables (x, y) can define either a point or a line [*see diagrams on page 70*]. Thinking in terms of sets, a student can see that the solution of two simultaneous equations of algebra is a matter of finding the intersection of the two solution sets: the solution is the pair of numbers that is common to both sets.

The notion of sets is particularly helpful in dealing with inequalities. The meaning of an expression such as $5x + 3y > 15$ becomes clearer when it is considered as the selector of those pairs of numbers (or points) that lie above the line $5x + 3y = 15$ on a graph. The expression $x^2 + y^2 < 16$ selects the points inside the circle $x^2 + y^2 = 16$. To "solve" this pair of inequalities simultaneously is again a question of finding the intersection of their solution sets [*see the middle diagram in the second column on page 70*].

All these are merely examples to illustrate the College Board group's approach in its proposed revision of the algebra course. Except for the emphasis on inequalities, it does not appreciably

SEQUENCE IS CONTINUED as Beberman discusses the meaning of equations and of the transformations used to solve them. Some excerpts: Teacher: "How can we be *sure* this equation is true?" Pupil: "If we replace the holes by numbers, er, by numerals, the

change the subject matter of the course, but it offers that subject matter in a new context.

The New Geometry

In geometry the group proposes to change the course radically. In the first place, it wants to eliminate most of the propositions and theorems that students are now required to prove, on the grounds that the students will already have had some training in deductive reasoning in the algebra course and that many Euclidean proofs can be demonstrated more easily by other methods.

The College Board Commission would cut down the theorems to be proved to about 12, in place of the 100-odd in today's geometry books. These 12 would provide a sample of how the facts of geometry can be deduced from a set of axioms. From them the students would develop theorems and facts about triangles, parallel lines, similar triangles and finally the Pythagorean theorem (a triangle is a right triangle if and only if the square of the hypotenuse is equal to the sum of the squares of the two sides). The reason for stopping with the Pythagorean theorem is that it makes possible a shift to analytic geometry—that is, algebraic solution of geometric problems with the help of graphs. The analytic methods show the use of solution sets in geometry [*see diagrams on page 71*].

The Commission does not propose to abandon classical Euclidean proofs entirely. Some problems are in fact easier to solve by the Euclidean procedure than by the analytic method. Students would be encouraged to find and use the most effective approach to each problem.

The recommended short cuts would reduce the time needed to cover plane geometry to less than a year, and the Commission proposes to use the time saved to include some solid geometry. Students would be encouraged to think in three dimensions as well as in two, and they would study the important theorems of solid geometry, mostly from an intuitive point of view.

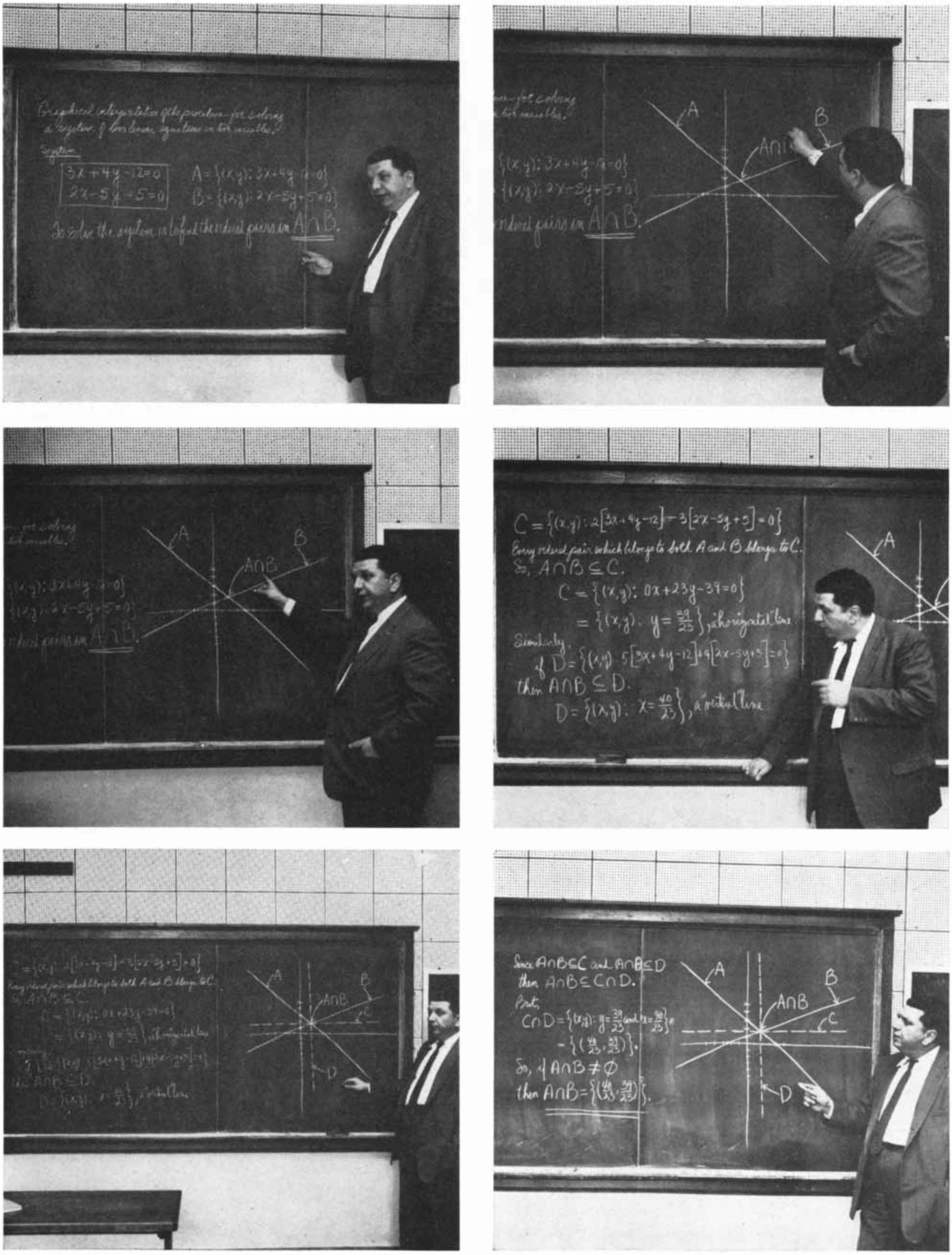
In the third year, after elementary algebra and geometry, the mathematics course would go on to further work in algebra and some trigonometry, with emphasis on the mathematical behavior of the trigonometric functions (sine, cosine, etc.) and their application to such problems as the study of vectors rather than the solution of triangles. For the fourth year the Commission would offer students who continued in mathematics two half-year courses. The first, called elementary analysis, would deal with the idea of relations and functions from a more advanced point of view. It would investigate the properties of polynomials (algebraic expressions containing many terms) and of logarithmic, exponential and trigonometric functions. The idea of limits would be introduced informally, and students would learn a little calculus, *i.e.*, how to differentiate and integrate polynomials. In the second half of the year there would be a course in probability and statistical inference. Here a student would learn to deal with sets of scattered measurements or observations by means of statistics. He would learn how mathematics is applied to processes governed by chance. The course would demonstrate some of the methods of computing the reliability of a sampling program and of measuring the statistical significance of results. The Commission points out that this material is probably more closely related to the daily lives of people than any other part of mathematics. Also, statistics and probability are becoming increasingly important in science and industry.

Because most of the topics in the probability course have never been taught in high school, the Commission has prepared a new textbook for this course; it is already being used in a few schools. The book presents the subject first intuitively and then from a more formal mathematical standpoint. Set theory is used extensively in the course. I found the text readable and interesting and the material no more difficult than many of the traditional topics in advanced high-school mathematics.

The Commission also would like high schools to offer, for students who take part in the College Board's Advanced Placement Program, a course in calculus and analytic geometry—the usual college freshman course.

Such, in brief, is the College Board Commission's program for reforming the teaching of mathematics in the nation's high schools. It is urging schools and teachers to try all or any part of its ideas, in the hope that the ideas can be tested to see which will work and which will not. It is confident that once students

two sides of the equation are both names for the same number." Teacher: "What principles did we use in this operation?" Pupil: "We used the commutative principle and added, and we also used the distributive principle to combine the 12 square and 175 square."



IDEAS OF SET THEORY play a major role in the Illinois course. In this sequence Beberman applies them to the solution of simultaneous equations. In the material on the blackboard *A* and *B* represent the sets of number pairs belonging to the two equations. The solution is their intersection. *C* and *D* (*bottom*) are the sets formed by the elimination of *x* and *y* respectively.

have been introduced to the beauty of modern mathematics, the subject will acquire a new vitality in the schools.

Although the Commission's program is merely a proposal, obviously the College Board is in a position to exercise a powerful effect on the high schools, through its examinations and its close relationship with leading colleges. The Commission has already begun to reach teachers throughout the country by means of pamphlets describing phases of its work, and it will publish its comprehensive report this fall. Very probably its suggestions will generate the writing of radically new textbooks within the next couple of years.

The Illinois Program

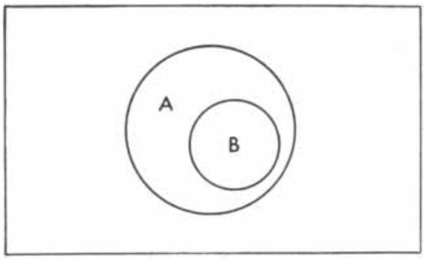
Now let us turn to another approach—the program stemming from the University of Illinois, which has had some public attention in newspapers. The leading spirits of this movement are Max Beberman, a teacher in the University High School at Illinois, and Herbert E. Vaughan, a mathematician on the University faculty. They have worked out a program which goes so far in the direction of modernism that it makes the College Board Commission's program look almost antique.

The Illinois experiment began at the University High School, an adjunct of the University's College of Education, in 1952. It has grown into a four-year program which is being tried this year in a dozen high schools in Illinois, Missouri and Massachusetts, and is also being taught to interested employees of the Polaroid Corporation in Cambridge, Mass. With financing from the Carnegie Corporation, the Illinois group has produced a complete series of textbooks and teaching manuals and brings teachers to the University for up to a year of observation and indoctrination in its courses.

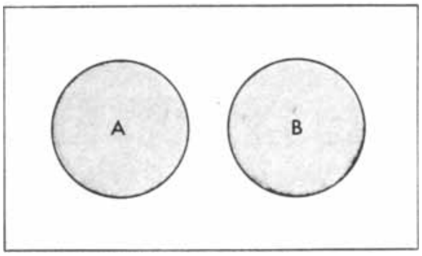
The approach to mathematics via abstract generalizations is the very cornerstone of the Illinois program—not merely an exercise in reasoning or a sampling of some of the foundations of mathematics. Pupils in the ninth grade begin their study of algebra with a set of axioms from which they proceed to prove all the rules they must master. The axioms, called "principles of arithmetic," include such things as the definition of zero (any number times zero equals zero), the definition of the number 1 (any number times 1 equals itself) and of course the commutative, associative and distributive laws. The children are led into their rigorous program by easy stages, sometimes in story form. For example, they learn that a number must be distinguished from the symbol used to represent it by means of a correspondence between Ed Brown, a student at "Zabranchburg High," and Paul Moore, a pen pal in Alaska. The two chums have fallen into the unlikely habit of writing each other about arithmetic. Young Paul advances the reasonable proposition that if you take 2 away from 21, you should be left with 1. Ed is startled: is this a joke, or does Paul have something? The text straightens things out by explaining that "21" is a name for the number, not to be taken too literally. It goes on to show that the number 21 can be described by other names: *e.g.*, "20 + 1" or "7 × 3." The pupils proceed to learn that a letter can stand for a number and that it can be given various meanings (*i.e.*, it is a "variable" or "placeholder" for a number). Indeed, the teacher uses blank boxes for the unknown numbers in equations [*see photographs on pages 64 and 65*]. A substantial portion of the first-year course is devoted to driving this point home. The text observes that a letter plays the same role in a mathematical statement that a pronoun does in ordinary language. The statement "x + 2 = 6" is like the sentence "He was a president of the U. S." Neither is true nor false until a name is put into the proper place. The teacher calls the letters of algebra "pronumerals," and uses this term throughout the course.

A good part of the first year is also given to introducing and exploring the idea of sets. Because of the long pronumeral introduction and the careful development of the set concept, the course covers less ground than the traditional course in elementary algebra.

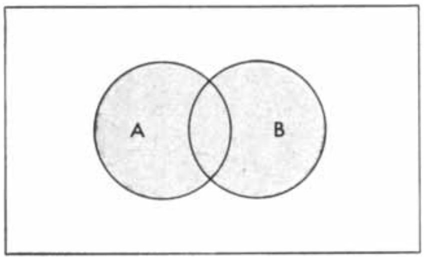
In the second year the program goes modern for fair. This course is nothing less than "a development of Euclidean geometry which is as rigorous as, for example, that due to Hilbert, and yet which is, we believe, accessible to students who have mastered the first course." It attempts to make clear the nature of geometry as a pure deductive theory which, in itself, has only logical structure and is empty of content until specific interpretations are introduced. Consider, for instance, three postulates which are necessary for deducing the rules of Euclidean geometry. These are: (1) every line is a set of points and contains at least two points; (2) there are three points which do not belong to the same line; (3) every two points any-



$B \subseteq A$



$A \cup B$



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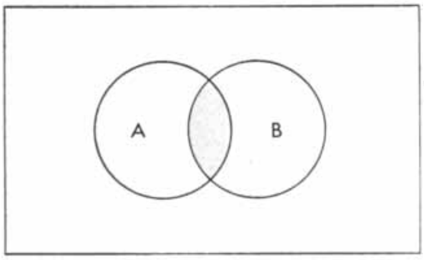
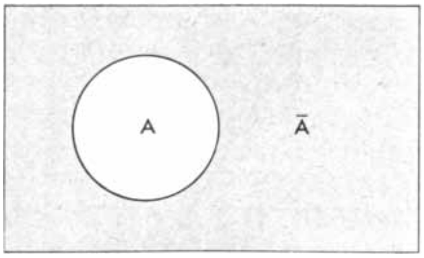


$A \cap B$



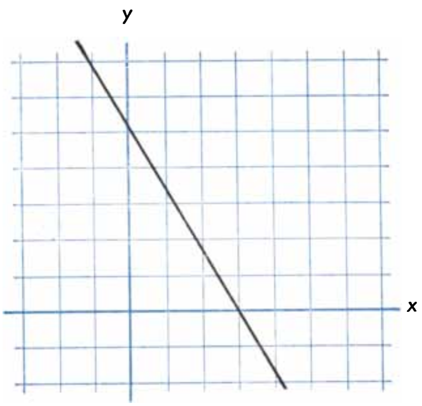
VENN DIAGRAMS are simple pictorial representations of set relations. Top diagram expresses the idea that *B* is a subset of *A*. Shading in second and third diagrams indicates the union of *A* and *B*. In fourth diagram it indicates their intersection. At bottom it represents the complement of *A*.

$$\{x \mid x + 2 = 5\}$$

SETS ARE REPRESENTED geometrically as well as algebraically. Dot represents the set described by equation $x + 2 = 5$.

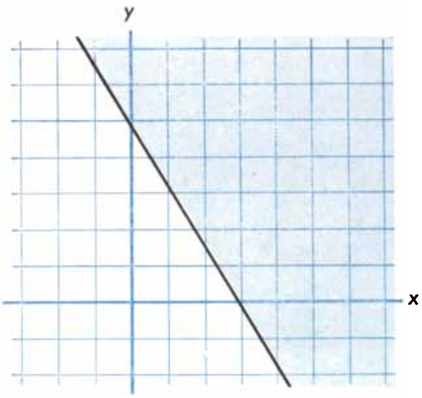
$$\{x \mid x + 2 > 5\}$$

INEQUALITIES also describe sets. The heavy section of the line in this diagram is the infinite set described by $x + 2 > 5$.



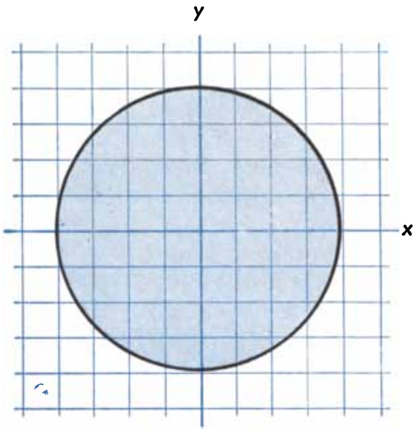
$$\{x, y \mid 5x + 3y = 15\}$$

TWO-VARIABLE expressions describe sets of pairs of numbers. Points on this line represent pairs belonging to $5x + 3y = 15$.



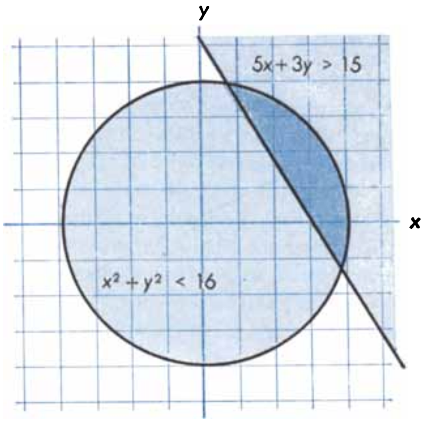
$$\{x, y \mid 5x + 3y > 15\}$$

SET-BUILDER idea helps give meaning to inequalities. Shaded area represents set selected by the inequality in brackets.



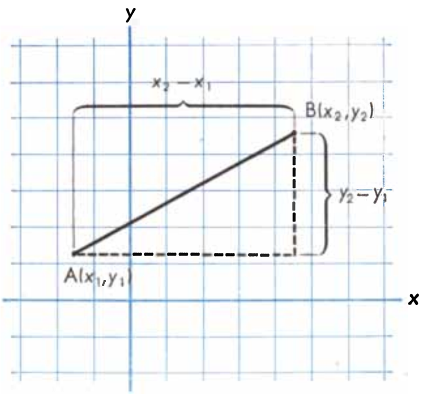
$$\{x, y \mid x^2 + y^2 < 16\}$$

NUMBER PAIRS that belong to the set selected by the inequality appearing above are graphed as the points inside a circle.



$$\{x, y \mid x^2 + y^2 < 16\} \cap \{x, y \mid 5x + 3y > 15\}$$

INTERSECTION of sets described by two inequalities is represented graphically by the heavily shaded area in this diagram.



$$AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

DISTANCE FORMULA in analytic geometry appears under this diagram. Lower-case letters are coordinates of end-points of line.

where are contained in a line. The teacher brings out that the words "point" and "line" can be interpreted in various ways. The main model used in the course is the "number plane," where points and lines are defined in terms of pairs of numbers (x, y); the course develops all the necessary postulates of plane geometry from this model. But to emphasize that the deductive system can have various concrete interpretations, the teacher examines several models, including one in which "point" stands for businessman and "line" for a partnership. The postulates apply here just as they do in geometry. Suppose there are three businessmen, *A*, *B* and *C*, each of whom forms a two-man partnership with each of the others. Each partnership (*AB*, *AC* and *BC*) is a set of businessmen and contains at least two members (postulate 1). None of the partnerships contains all three businessmen (postulate 2). Every two businessmen are contained in a partnership (postulate 3).

I can make a little clearer how the teacher and children deal with these matters by quoting a recording of a review discussion of postulate systems between Beberman and a bright class:

Teacher: "Where do these postulates come from?"

George: "From the number plane."

Teacher: "What do you mean by that?"

George: "They are properties of the number plane."

Teacher: "If we're talking about the number plane when we say, for example, that each line is a set of points and contains at least two points, is that statement true or false?"

George: "True."

Teacher: "But suppose we are *not* talking about the number plane. Then what about these postulates?"

George: "False."

Chorus: "No!!"

Jim: "You have to give a specific meaning to 'line' and 'point' before you can tell whether they are true or false."

Teacher: "What is a 'model' of a postulate system?"

Jane: "Something that has the properties expressed by the postulates or that satisfies the postulates."

Teacher: "Suppose there are several interpretations for the postulates. You can be talking about the number plane, or about businessmen and corporations, or about class presidents and committees. So what?"

George: "Well, when you try to deduce a theorem from the postulates, you can use a model to find out in some cases that you can't deduce it because it's false for that model."

In the hands of a teacher like Beberman the discussion in a better-than-average class is alert and spirited. A leaflet put out by the Illinois group asserts: "High-school students have a profound interest in *ideas.* They enjoy working with abstractions. . . . Despite the current fashion to point out the usefulness of mathematics in various occupations, most high-school students are not genuinely stirred by such a 'sales campaign.' The goal of vocational utility is too remote to make much difference to a ninth grader. He wants to know how mathematics fits into his own world. And, happily, that world is full of fancy and abstractions. Thus students become interested in mathematics because it gives them quick access to a kind of adventure, which is enticing and satisfying."

The course is frankly experimental. Some of the material has proved too time-consuming or too hard to teach. At the moment the Illinois group is considering whether it should postpone some of the rigorous development to the fourth year. But Beberman starts with the attitude that you don't know what you can teach children until you try.

It is too early to tell how much the pupils eventually get from the course; the first group is just completing the four-year program this term. But I have visited the University High School classroom and can testify that the students seem to carry their burden cheerfully and even enthusiastically. The big question is: How would such a course go generally? Some critics concede that it may work well with a gifted teacher and bright students but strongly doubt that the average teacher or the average class could handle it successfully.

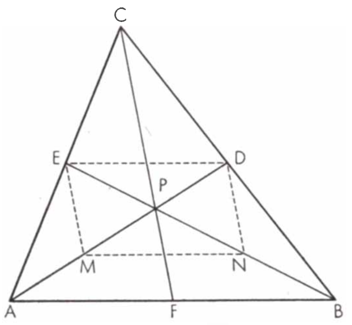
The Critics

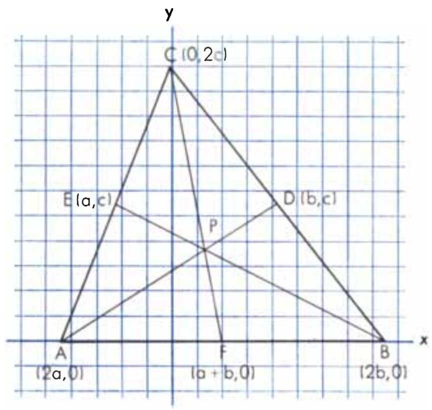
There are those who believe that the whole approach of the modernists is fundamentally wrong. One of the most articulate of these critics is Morris Kline, a professor at New York University's Institute of Mathematical Sciences and a popular writer on modern developments in mathematics. He doubts that the abstract approach will get youngsters interested in mathematics.

Kline argues that you do not abstract until you know what you are abstracting from. Professional mathematicians did not arrive at an understanding of the abstract general features of mathematics until after they had explored many of its specific branches. Why should a schoolboy be expected to? Moreover, Kline believes that set theory has no place in an elementary curriculum: its applications there can only be trivial, and even its importance in advanced mathematics is overemphasized.

Kline and others hold that the way to stimulate more interest in mathematics is to make the teaching more concrete rather than more abstract—to relate it more vividly to problems of the real world. Kline would introduce mathematical ideas by means of simple physical experiments and examples drawn from fields such as music and other arts. An active advocate of this sort of approach is the English mathematician and teacher W. W. Sawyer, now at the University of Illinois. Sawyer has built a number of simple devices which he uses to illustrate mathematical ideas [*see photographs on next page*].

But the anti-modernists seem to be in a losing cause. They are not organized, nor have they formulated a specific program. Meanwhile the modernist movement is spreading rapidly. At the college level, a number of colleges have adopted a new freshman course designed by a committee of the Mathematical Association of America. The course consists of a half year of calculus and a half year on modern topics, collectively called "discrete" mathematics. It deals with noncontinuous sets (*i.e.*, of discrete numbers or objects). This branch of set theory is finding increasing application in science, particularly social





Let AD and BE intersect at P.

Mark M and N, mid-points of AP and BP respectively.

ED is parallel to AB and equal to ½ of it.

MN is parallel to AB and equal to ½ of it.

∴ ED is parallel and equal to MN.

∴ MP = DP and EP = NP.

But AM = MP and BN = NP.

∴ P is ⅔ of the way from A to D and from B to E.

By the same construction, using AD and CF, their intersection can also be shown to be ⅔ of the way from A to D.

∴ the medians intersect in a common point which divides them in the ratio of 2:1.

Q.E.D.

By the rules for writing equations of lines, the equations of AD, BE and CF are respectively

$$cx + (2a - b)y = 2ac$$
$$cx + (2b - a)y = 2bc$$
$$2cx + (a + b)y = 2ac + 2bc$$

These three equations have the common solution

$$x = \tfrac{2}{3}(a + b),\; y = \tfrac{2}{3}c$$

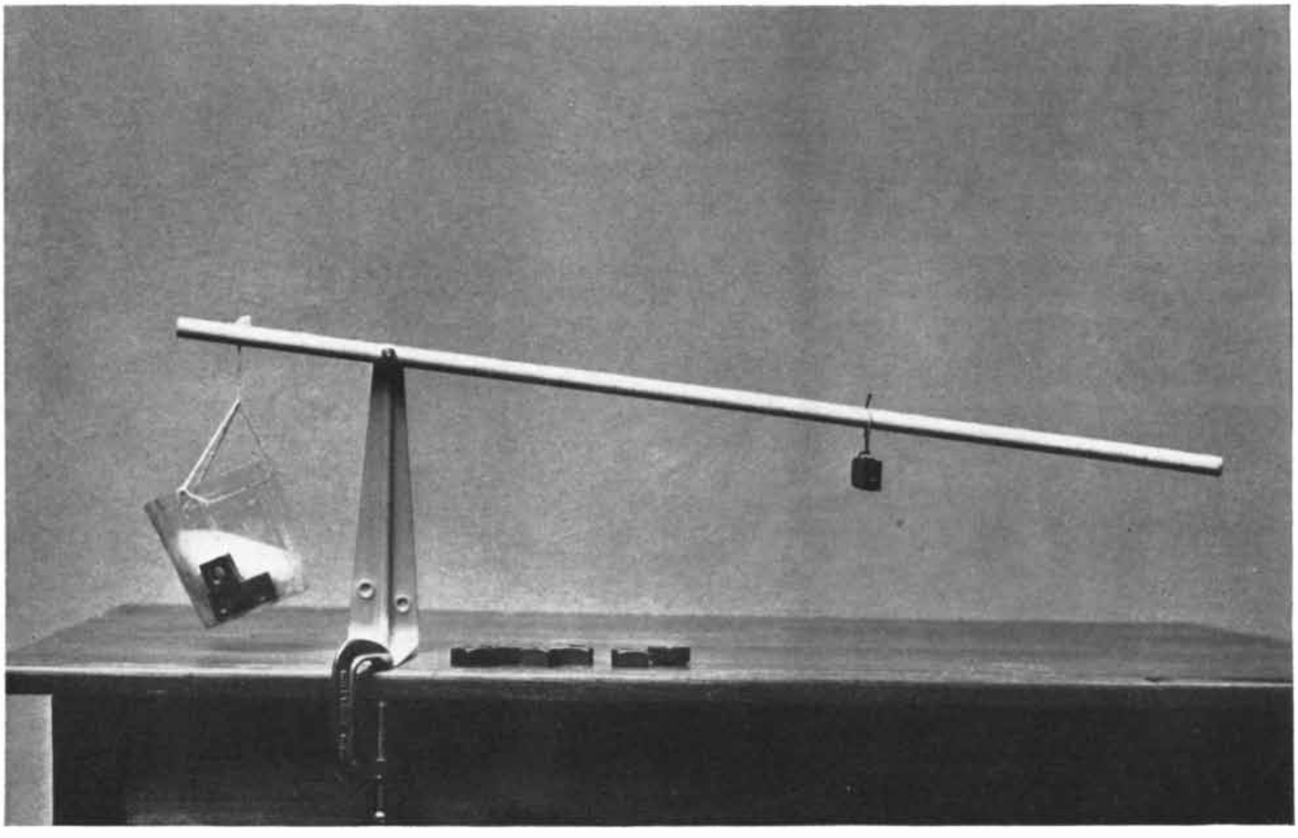
∴ the medians meet in a common point.

Substituting the proper coordinates in the distance formula shows that

AP = 2PD, BP = 2PE and CP = 2PF

Q.E.D.

PROOF OF THEOREM (the medians of a triangle meet in a common point which divides them in the ratio 2:1) is done by Euclidean method (*left*) and analytic geometry (*right*).



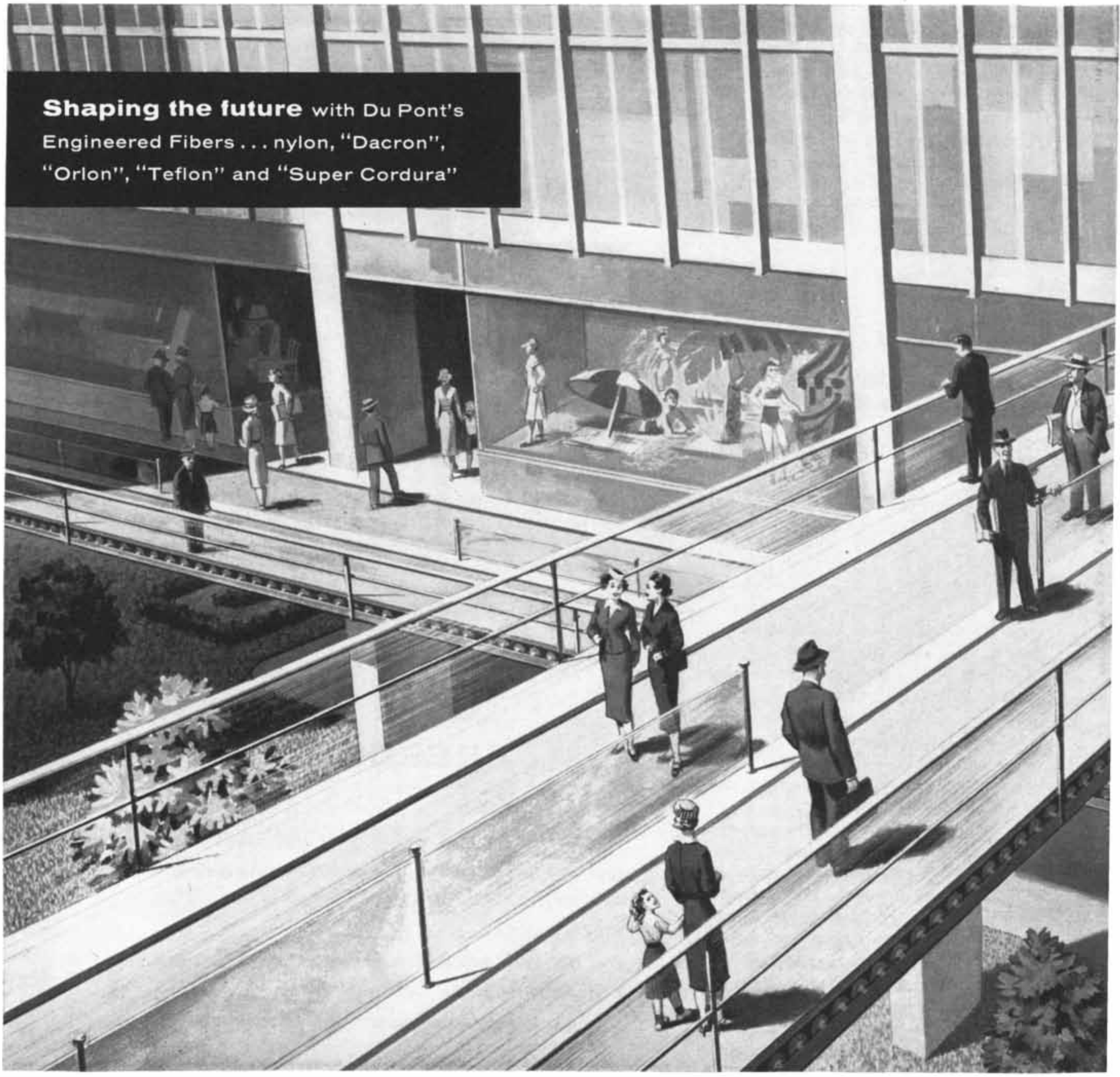
SIMPLE MECHANICAL DEVICES are used by mathematician W. W. Sawyer to illustrate mathematical principles. At top is a water clock whose design involves calculations of the relation between the rate of flow of liquid and its level in the vessel. At bottom is a balance for which students discover a relation between position of the counterweight and number of nuts in weighing pan.

science, which deals typically with groups of persons, units of product, etc. Even physics is discrete at the atomic level, and matrix algebra, one of the topics in discrete mathematics, lies at the foundation of quantum theory. The new college course is intended to give liberal arts students a taste of some modern mathematical ideas and also to acquaint social science majors with mathematical techniques. The text now in most common use includes symbolic logic, probability, the algebra of vectors and matrices, the theory of games and linear programming.

The Teachers

Mathematics teaching in the nation's high schools and elementary schools obviously will not be changed overnight. Most teachers are not prepared to teach either the modern material or any other new scheme. However, the current great expansion of teachers' summer institutes and in-service courses, financed by the National Science Foundation, private corporations and others, is a golden opportunity. This summer there will be 10 university institutes in mathematics, all teaching mainly the modern topics. Some 40 other universities are offering courses in both mathematics and science, and most of them are stressing the modern approach. It appears likely that most U. S. high schools will have shifted more or less toward the modern approach within five years or so.

Finally I must mention a new project which in the long run may have a stronger impact on mathematics teaching in the U. S. than any of the programs discussed in this article. It is the School Mathematics Study Committee, set up by the mathematics department of Yale University and patterned after the Physical Science Study Committee at the Massachusetts Institute of Technology described in this magazine last month [see "The Teaching of Elementary Physics," by Walter C. Michels, April]. The new group will enlist a large number of mathematicians and teachers to consider mathematics teaching in high schools and junior high schools, and very likely it will prepare an elaborate program of textbooks and other teaching aids, as the physical science group is doing. This summer the Committee will hold a conference to review the present experiments and the whole problem. What it will come up with is anyone's guess, but in manpower and financial support it may well carry more weight than any other group seeking to revitalize the teaching of mathematics.



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A Study of Self-Disclosure

How much of what we know about ourselves do we tell others? Plainly it varies with the individuals involved. This variation is examined as an approach to the problem of how we form personal relationships

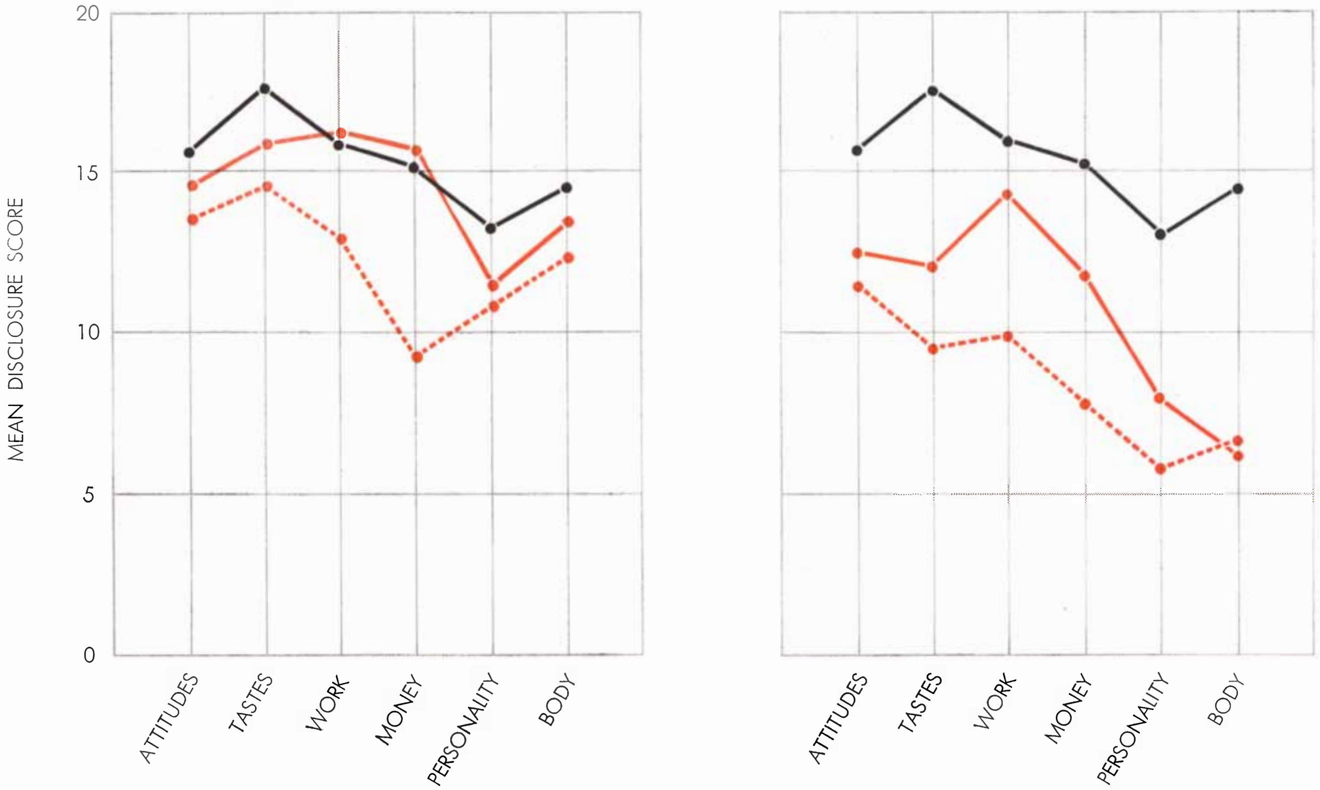
by Sidney M. Jourard

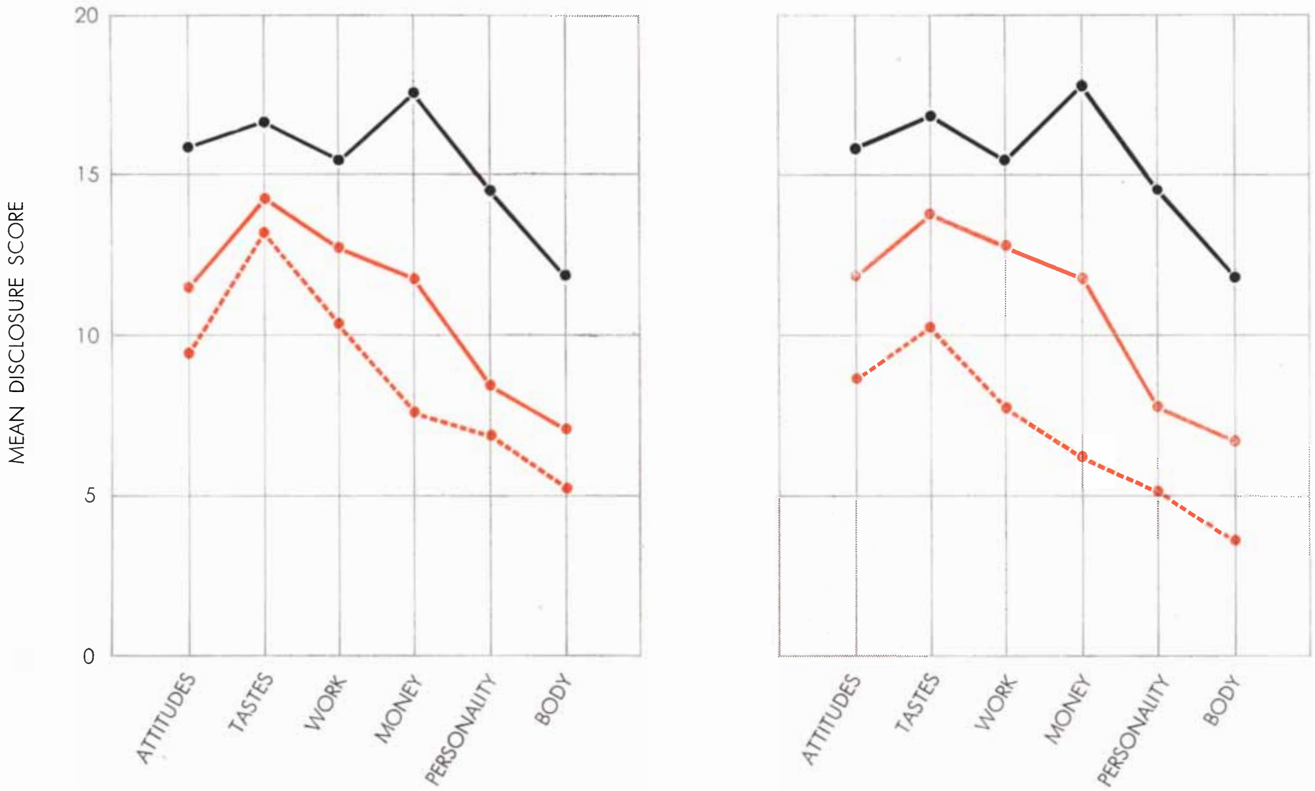
The novelist Thomas Wolfe asked, "Which of us has known his brother?" His question is a sharp social comment which goes to the heart of all human relations. No man fully knows another, for no human being ever fully discloses himself, even to his closest intimates. Most of us live behind a wall or smoke-screen which in some degree hides our true thoughts, feelings, beliefs, desires, likes and dislikes. If no one really understands us, we are ourselves partly to blame. By the same token, if prejudice, fear and conflict between man and man stem largely from misunderstanding, we must lay a major share of the responsibility upon man's all-too-human reticence.

Self-disclosure itself is not a topic people like to talk about. Yet as a basic social and psychological variable it certainly warrants scientific study. People's willingness or reluctance to disclose themselves reflects at once the culture of their society, their individual personality and some fundamental characteristics of human nature in general.

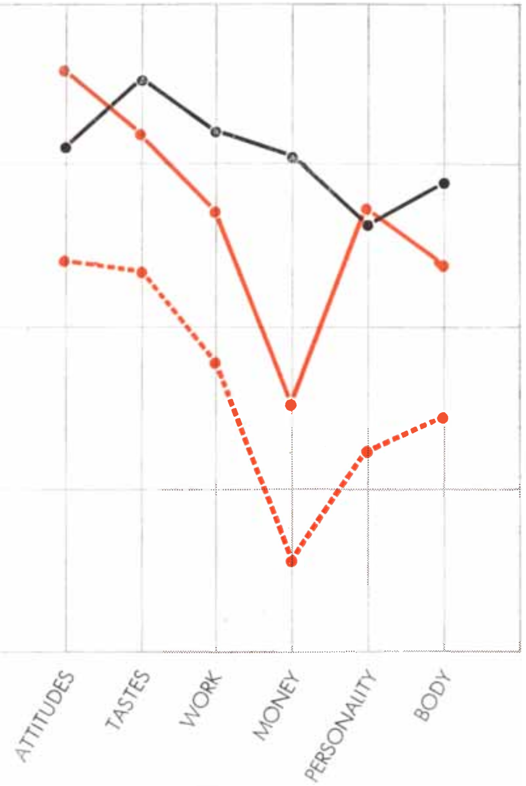
The psychoanalyst Erich Fromm, defining love, has observed that one necessary condition is knowing the loved one. I would add to his definition the proposition that loving also entails wanting to make oneself known to the loved one. But the question of self-disclosure goes deeper than mere willingness. People often cannot disclose themselves, even if they would, because they do not know their real selves—what they really want, feel or believe. Karen Horney has called this phenomenon of being a stranger to oneself "self-alienation," and she finds it characteristic of neurotics. It may be sig-

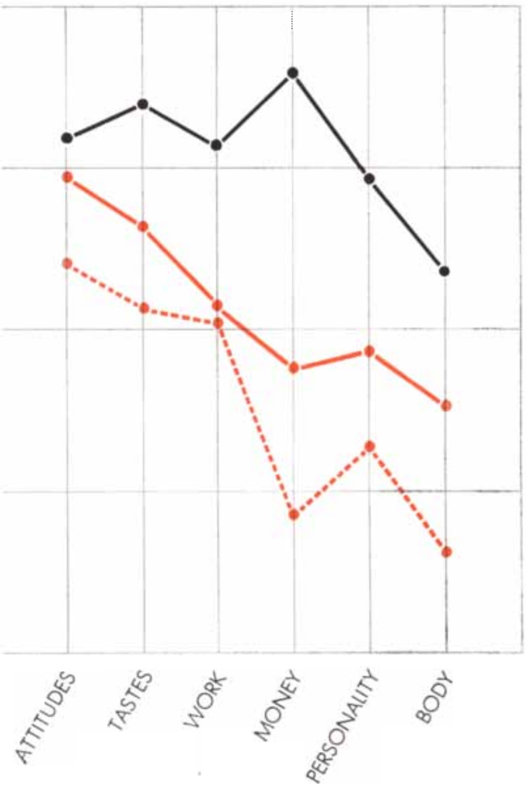
SELF-DISCLOSURE WAS STUDIED by means of a questionnaire which asked subjects to indicate how much they disclosed about themselves to specified individuals such as their parents or their friends. The kinds of disclosure were divided into six categories.





DIFFERENCES IN SELF-DISCLOSURE are plotted. The three charts at top plot six categories of disclosure against the amount of disclosure by unmarried and married white females to mother (*left*), father (*center*) and female friend (*right*). The amount of disclosure is scored on a scale in which 20 is full disclosure. The charts at bottom plot the





categories against the amount of disclosure by unmarried and married white males to mother, father and male friend. The black curve in each chart is disclosure to spouse.

nificant of modern society that so many people have taken to the psychoanalyst's couch to try to know themselves.

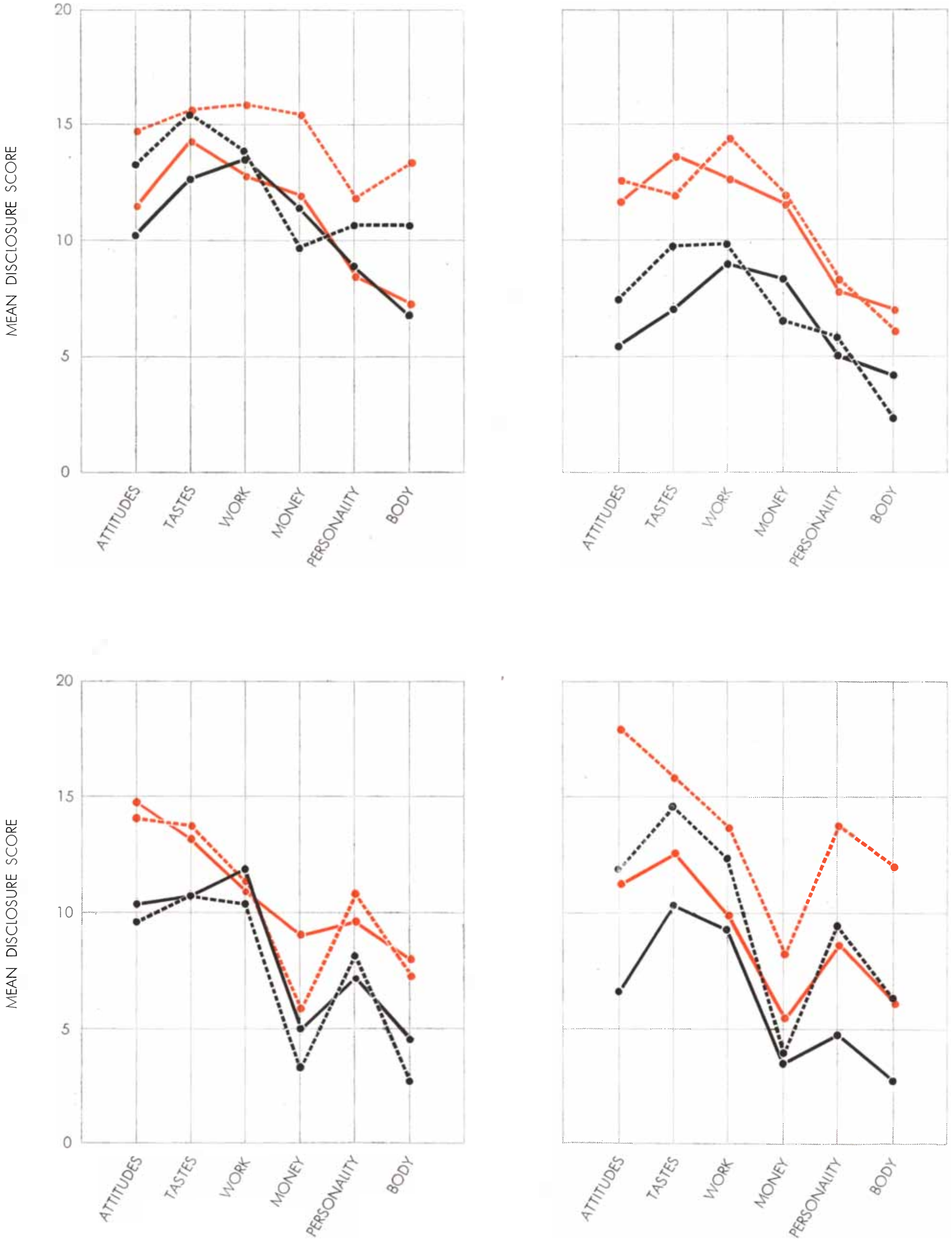
In this article I want to tell about some studies of self-disclosure that we started several months ago. They are a small but encouraging beginning in what promises to be an interesting field of research. Our approach is statistical. We devised a questionnaire asking people how much they disclosed about themselves to specified individuals—their parents, friends and spouses. The questionnaire covered six categories of the subject's personal affairs: his attitudes and beliefs (*e.g.*, on religion), his tastes and interests (*e.g.*, in food), his feelings about his work or studies, his money affairs (*e.g.*, income), his worries about his personality and his concerns with his body or physical appearance. So far we have administered this questionnaire to several hundred subjects, most of them college students, and made some interesting findings.

The first study I shall report was on a sample of college students, all about the same age, all unmarried and all from middle-class homes. They included whites and Negroes, men and women. We asked each subject how much he or she disclosed to mother, father, closest male friend and closest female friend. Our object was to learn how self-disclosure varied with sex, race and the relationship of the target person.

Some very definite patterns emerged [*see table at top of page 82*]. Whites in general took their parents and friends into their confidence more than did Negroes. Women disclosed themselves more than did men; whether or not it is true that women talk more than men, they certainly tell more about themselves, at least to their mothers and female friends.

The questionnaire showed further that mother is generally the closest confidante of an unmarried young person—son or daughter, white or Negro. Women also tend to confide in their girl friends and men in their male friends; women tell the least about themselves to their boy friends, likewise men to their girl friends.

Negroes, both men and women, indicated a striking reticence about themselves toward everyone but their mothers. Particularly noteworthy was the small amount of self-disclosure to their fathers. Our findings bear out the observation of sociologists that the father plays a very small part in the home among Negro families in the South. Our



SIMILAR DIFFERENCES are plotted for self-disclosure of people in various groups to mother (*top left*), father (*top right*), male friend (*bottom left*) and female friend (*bottom right*). The solid colored curve in each chart represents white males; the broken colored curve represents white females; solid black curve represents Negro males; broken black curve represents Negro females.

subjects all came from Southern homes.

We went on to analyze self-disclosure according to topics: which aspects of themselves people discuss most freely, and which they find it hardest to talk about. Here again we found consistent differences. Most people, it appears, are willing to talk to others about their attitudes, tastes and work but are comparatively reticent about their financial affairs and their personality and bodily concerns. The most striking statistical findings here are the reticence about body concerns to father and about money affairs to boy friends and girl friends. The reserve of Negroes on money matters is especially marked [*see charts on opposite page*].

In view of Erich Fromm's definition of love, we were interested to see how love affected self-disclosure. Two separate studies confirmed that love does indeed break down barriers to some extent, but not as much as one might think. In a small sample of unmarried students in a nursing school, it turned out that the subjects who liked their parents most disclosed the most to them. The other study was a comparison of married and unmarried subjects—both young groups of about the same age. We found, as we expected, that the married men and women tended to disclose more about themselves to their spouses than they did to their parents. But this did not mean that the married persons had become more outgiving in sharing confidences. Unmarried people told more to their parents and friends; the married had shifted from confiding in their parents and focused their self-disclosure mainly on their spouses. We might say that libido, turned toward the new love object, acts as a kind of magnet pulling self-disclosure in its wake.

The husbands and wives who responded to our questionnaire varied considerably in the amount of self-disclosure to their spouses. That many married people are almost strangers to each other is of course no new discovery. What our systematic data suggest is that the stability of a marriage may depend in some measure on the amount of mutual self-disclosure between the partners.

We found a marked difference in self-disclosure between two different groups of married men that we questioned. One was a group of policemen, the other a group of married college students. The policemen were far less communicative about themselves to their wives than were the college boys. Very possibly the situations are not comparable because of the differences in length of the marriage,

TARGET PERSON	WHITE MALES	NEGRO MALES	WHITE FEMALES	NEGRO FEMALES
MOTHER	65.80	63.30	86.40	73.70
FATHER	64.60	37.50	64.70	40.00
MALE FRIEND	65.20	49.00	62.40	44.10
FEMALE FRIEND	52.90	36.10	80.10	57.20

ASPECT OF SELF	MOTHER	FATHER	MALE FRIEND	FEMALE FRIEND
ATTITUDES AND OPINIONS	12.40	9.08	12.15	11.73
TASTES AND INTERESTS	14.45	10.48	12.10	13.25
WORK	14.00	11.35	11.08	11.23
MONEY	12.20	9.45	5.63	4.95
PERSONALITY	9.80	6.58	8.78	8.90
BODY	9.45	4.78	5.45	6.53

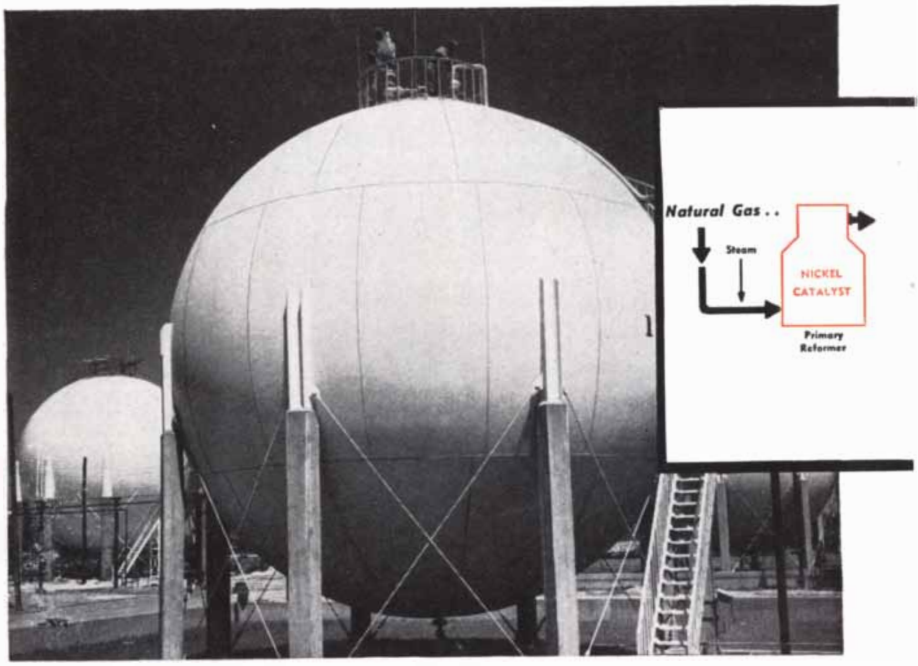
MEAN SELF-DISCLOSURE SCORES are classified by group and target person (*top*) and by target person and aspect of self (*bottom*). In top table the highest possible score, combining scores in six categories, is 120. In bottom table the highest possible score is 20.

age, occupation, social class and so on—all factors which may reduce the exchange of self-disclosure without actually undermining the solidity of the marriage. But the finding suggests some interesting topics for further study.

All the generalizations here reported have stood up in repeated investigations with a number of groups. Some of them indicate that we are dealing with strong cultural patterns which dictate what kinds of self-disclosure are "in good taste" or morally permissible and what kinds are not. Thus systematic analysis of the mores and practices in self-disclosure may be a highly useful tool for investigating some areas of our culture. We can think of many topics that it opens up for studies from a new point of view: personality differences, the roles of family members and friends, marriage and, possibly most important of all, mental illness.

If we live in an age of "self-alienation," it may be well to look into its causes and consequences frankly and directly. Perhaps our culture has made it "bad form" to disclose oneself, and rewards those who present themselves in flattering, though false, colors. But psychologists and doctors know that a person who cannot disclose himself as he is and establish a close relationship with at least one other human being stands in danger of mental breakdown. To paraphrase Paul Tillich, the philosopher and author of *The Courage to Be*, the "courage to be" very likely entails the "courage to be known."

Life on the Chemical Newsfront



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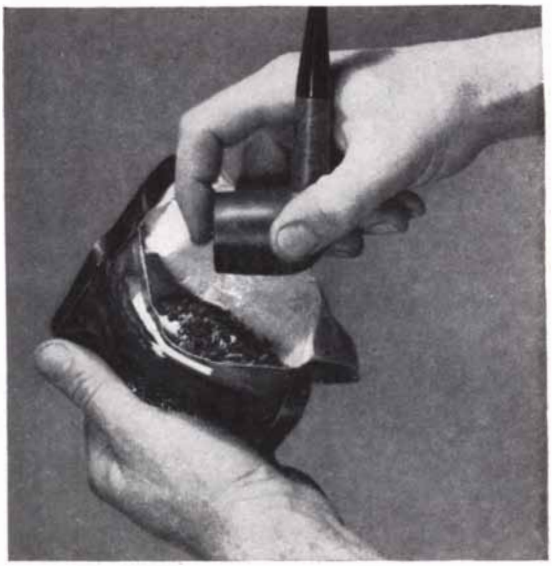

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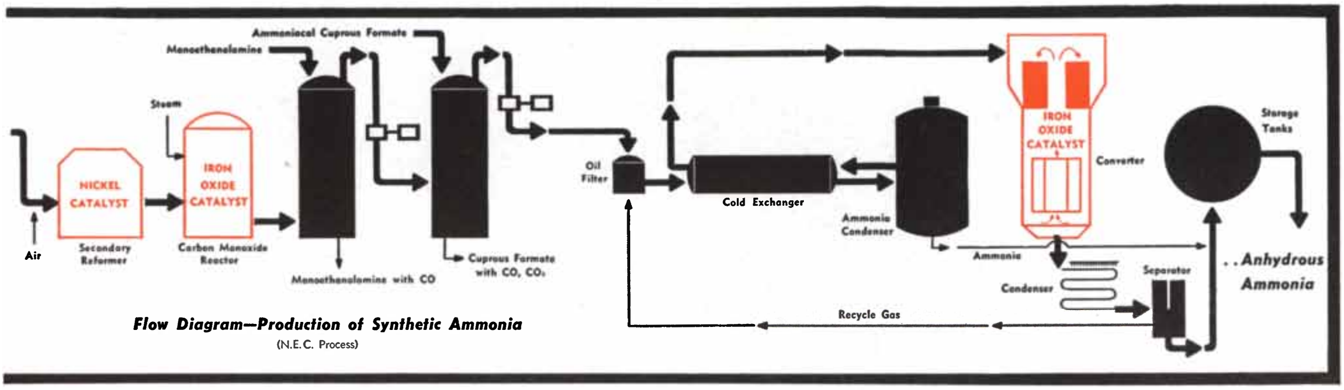
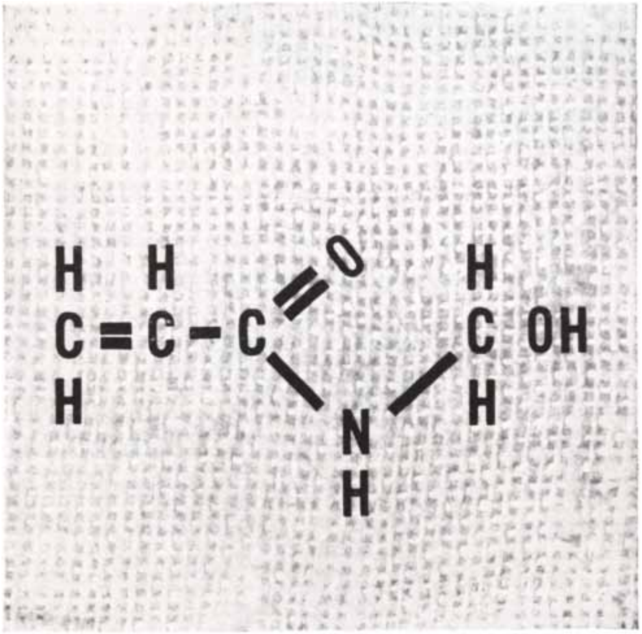


Flow Diagram—Production of Synthetic Ammonia
(N.E.C. Process)



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AN INSECT AND A PLANT

Most plant-eating insects prefer one species of plant. Studies of how the corn borer adapts to its host (the corn plant) have revealed significant facts about insect nutrition and behavior

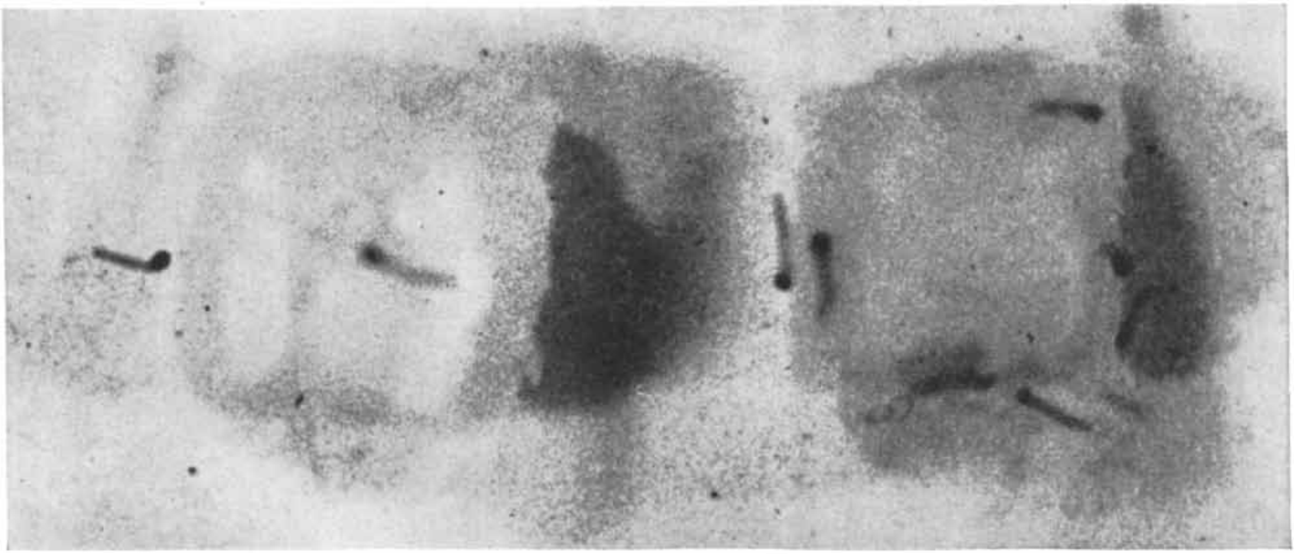
by Stanley D. Beck

A grasshopper will eat almost any green plant. But the tastes of most insects are not so catholic. Many of them have a strong predilection for just one plant species. Why does the apple maggot show partiality to apples, the plum curculio to plums, the spruce budworm to the spruce, the rose chafer to the rose, the Mexican bean beetle to beans and the European corn borer to corn? Here is an interesting question in biological adaptation. The secret of these creatures' nice adjustment to their hosts might throw light on why insects are one of the most successful classes of animals in the whole animal kingdom. And of course the question is very important from a practical point of view. If we can learn precisely what attracts an insect to the plant it ravages, we can take steps to make the plant a less happy or convenient home for the insect.

During the past 10 years some associates and I at the University of Wisconsin have been carrying on a detailed and systematic investigation of the intimate relationship between the corn plant and the European corn borer. The insect is a comparative newcomer to North America. It slipped in from Europe some time between 1912 and 1915. The intruder was first discovered in 1917 near Boston and shortly afterward was detected in the Lake Erie region. By that time the borer had established so solid a foothold that vigorous countermeasures failed to eradicate it. Free from its European parasites and diseases, the insect spread rapidly, and when it reached the corn belt in the Midwest, its population multiplied explosively. Today it is a major pest of U. S. agriculture, costing corn growers more than $100 million a year.

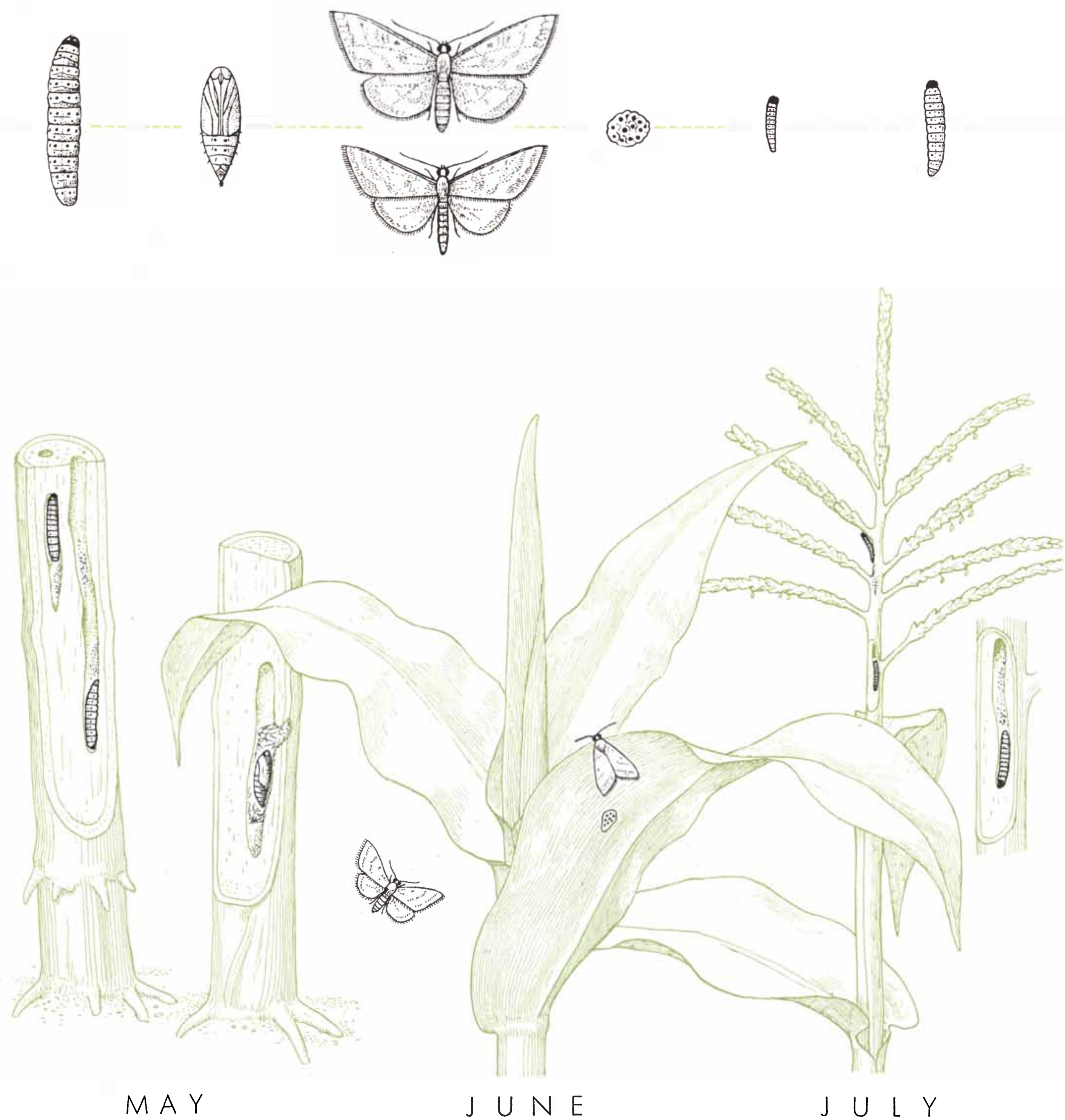
It is ironical that the corn borer should be a native of Europe rather than America, where corn originated. Actually the insect existed in Europe and Asia long before corn was introduced to Europe in the 16th century—probably thousands of years before. It must therefore have lived in other host plants, possibly hops, millet or thick-stemmed weeds. In fact this insect has been found to feed on more than 200 species of plants—potatoes, rhubarb, chrysanthemums, dahlias, green beans, pigweed and many others. But corn is far and away its most favored host. Wherever the insect finds corn it pounces upon that plant, forsaking all others. The vast fields of our corn belt have become its paradise.

The insect apparently is attracted in



SYNTHETIC DIETS were devised to study the corn borer's nutritional needs and preferences. Young borer larvae prefer diet on the right, containing sugar, to that on the left, containing no sugar. At this stage of their growth, however, they do not need sugar.

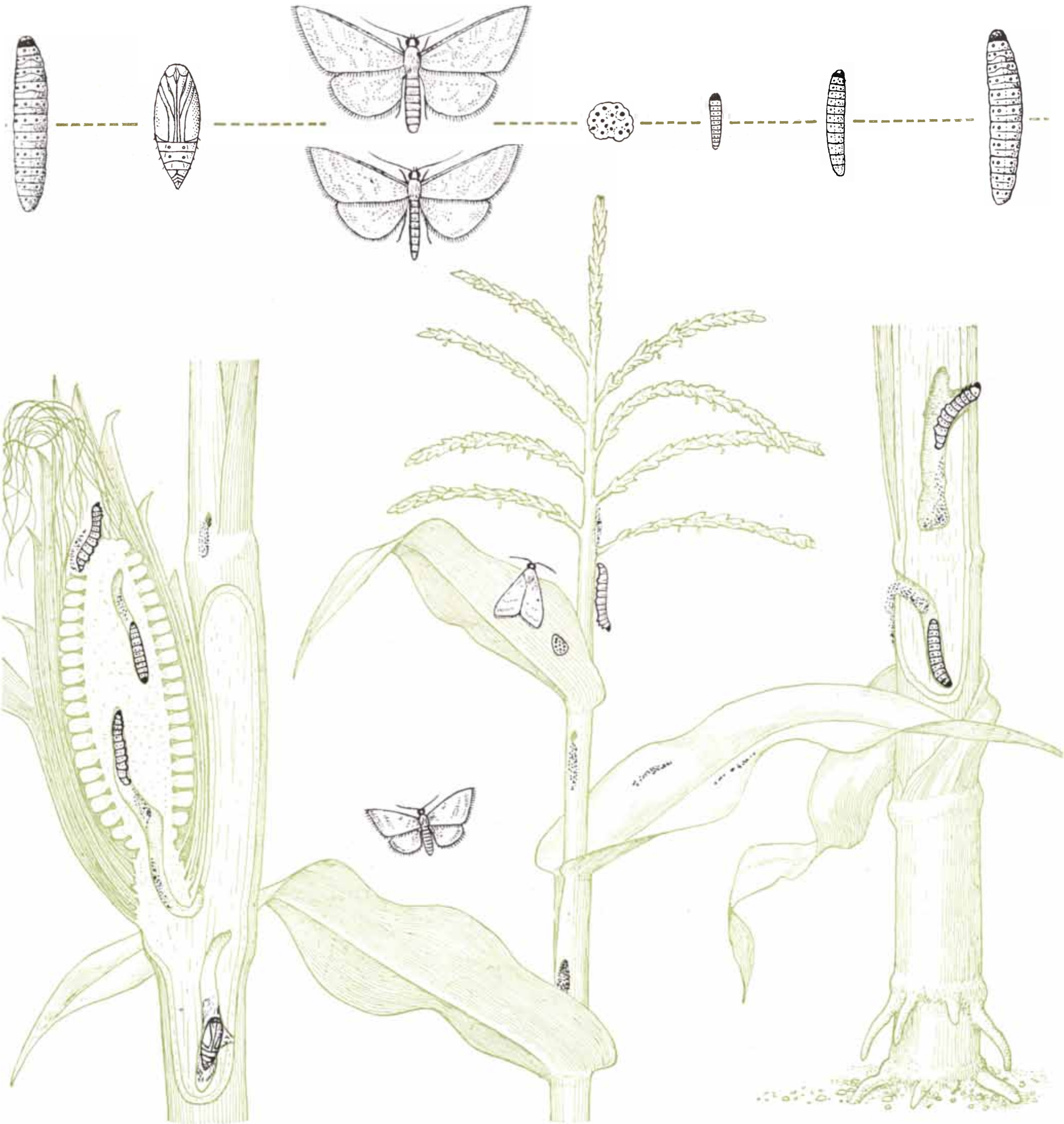
the first instance by the plant's odor. In the adult stage the borer is a small, buff-colored moth (in Europe it is called the "maize moth"). The female lays her eggs in late spring on the underside of the upper leaves of the young corn plant. The developing leaves at that stage of the plant's growth are tightly rolled in a whorl. When the larvae hatch from the eggs, they crawl into the whorl and begin to feed on leaf tissue there. But as the tassel develops and pushes up through the whorl, the borers shift their feeding from the leaves to the young tassel. After the tassel has grown and branched out, the insects tend to move down into the closed spaces—behind leaf sheaths or in the ear husks. They attack the sheaths, the stalk and the ear. Larvae that are hatched in late summer, when the plant is mature, tend to concentrate their attack on the ear, working their way down the silk or between the husks. These late-season young larvae are a sec-



LIFE CYCLE of the corn borer is well-adapted to the growth cycle of its host. Larvae which have hibernated through the winter in corn stubble metamorphose into adults in late spring. Eggs are laid in June, when the plant is in the "whorl" stage of its growth.

ond generation; the insect often produces two in a season.

Now the corn borer's peculiar shifting of its feeding sites as the plant develops has intrigued students of the insect and seemed to us a particularly promising thing to investigate. It might tell us, among other things, why the insect found the corn plant so attractive and so well suited to its requirements. We therefore embarked on a series of controlled experiments to analyze the borer's behavior in a systematic way. In order to do so we had to devise some new experimental techniques for gauging the insect's nutritional requirements and measuring its behavior on a quantitative scale—tasks which took us several years of work. We worked out a synthetic diet which met the borer's food needs so well that it grew faster on this diet than on the corn plant; the mixture consists of sugar, protein, B vitamins,

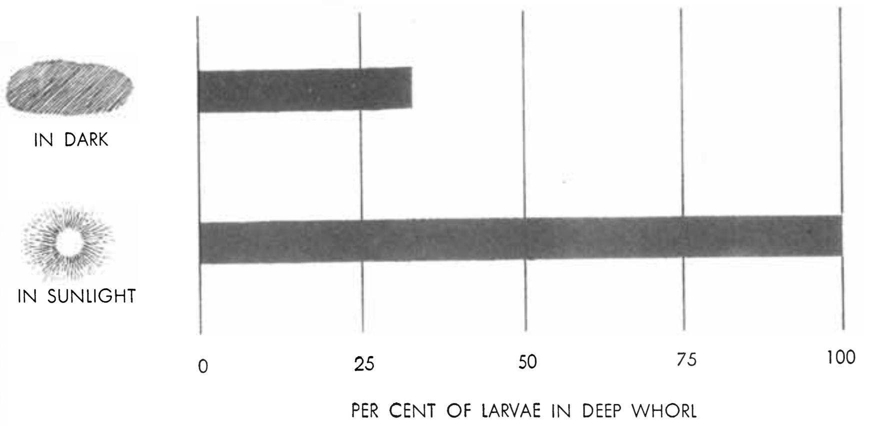


The newly hatched larvae feed on the fast-growing plant during the summer; some may complete their development by August and lay a new batch of eggs. By harvest-time in September all larvae have gone into hibernation until the following spring.

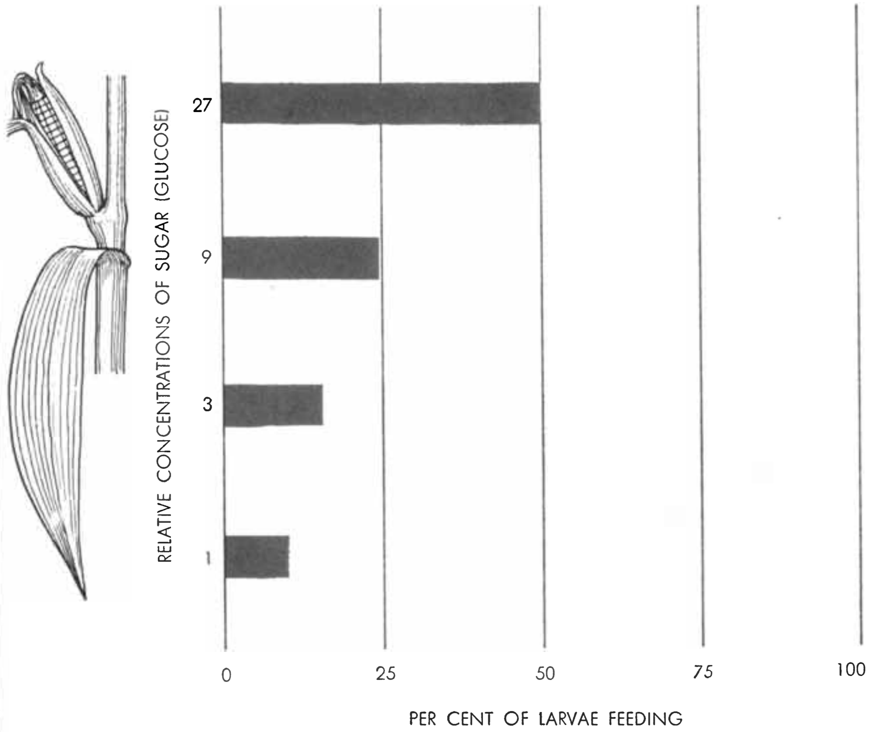
minerals, cholesterol, fat and a concentrate of plant sap. Next we developed a method of measuring the insect's preferences between different diets: 30 or 40 newly hatched larvae were kept for 24 hours in a closed container with different diet offerings; at the end of that time their preferences, if any, were measured by comparing the number found feeding on each diet.

The experiments showed first of all that, given a choice between a completely synthetic food and one which included some ground-up corn-plant tissue, the borers distinctly preferred the one with the plant material. Next we offered them choices between various parts of the plant: the green young tassel, the leaf sheath, the green silk, the ear husks. Surprisingly, they showed no preference whatever among these tissues; in each test about half of the borers would feed on one diet and half on the alternative.

If the borers do not find one part of the plant more appetizing than another, why do they shift locations as the plant grows? It seemed the reasons might be physical rather than nutritional. We knew that corn borers do not like the



BORERS MOVE to protected parts of the corn plant to avoid light. Even in darkness many of them are drawn to these locations by their preference for physical contact (thigmotaxis).



BORERS FEED by preference on diets with a high sugar content. Figures at left show the relative amount of sugar in (*bottom to top*) leaf-tip, leaf-base, husk, and ear or stem.

THIS IS GLASS

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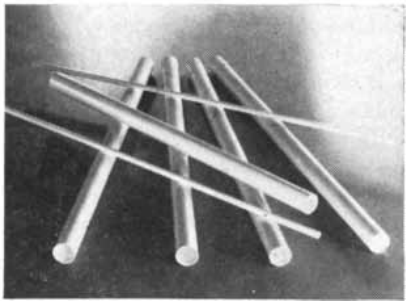

News! PYROCERAM brand Tubing and Rod now available.

We flatter ourselves into thinking that a great many of you are familiar with PYROCERAM Crystalline Materials.

For the sake of review, however, this brief summary: PYROCERAM is the brand name given by Corning to a new group of ceramic crystalline materials made from glass. What with *nucleating* agents and some classified heat processing we end up with a material *unlike* anything you've ever seen. A number of variations, each exhibiting different *combinations* of properties, have been evolved.

On an overall basis, PYROCERAM Materials can be made lighter than aluminum; harder than carbon steel; stronger than tempered glass; immune to the corrosive action of most chemicals; unbothered by heat that warps steel and melts copper; possessed of electrical properties equal to the better ceramics.

And now you can get one variant in the form of PYROCERAM Tubing and Rod. Designated Code 9608, it is a *gastight* white *opaque* material. It has the thermal shock resistance that you'd normally get *only* from fused silica. On the Vickers Diamond Pyramid test it rates 550.

You can use this PYROCERAM Tubing at an operating temperature of 1000°C., *unloaded*—up to 500°C., loaded. (The latter figure is based on preliminary runs with indications that it's *too low*.)

Long-term chemical durability data will be available soon. But we can tell you that linear coefficient of thermal expansion is 9-15 (factor 10^{-7}) between 25° and 300°C. Specific gravity at room temperature is 2.50.

The enthusiasm shown by you when PYROCERAM Materials were first introduced suggests that these *new* forms should prove practical in varied product and process applications. Might just be that the idea you've been noodling around can now become a *reality*.

Inquiries aimed at our Technical Products Division will bring you all the very latest data on PYROCERAM Tubing and Rod.

And for your files, there's Progress Report No. 2. Check the coupon for your copy.

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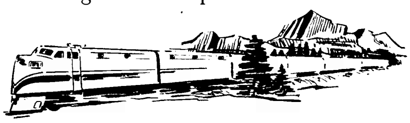

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The approach is simple: Prepare meals in central kitchen; place in PYREX brand dish, insert dish in insulated MEALPACK container. At mealtime waiter serves hot food in the original PYREX dish. No fuss, no muss.

Backing up a bit, a PYREX glass dish was the logical choice, first, because dishes are *heat-charged* to a skin temperature of 250° F. to act as a heat-battery for each meal.

Then, *piping* hot food is placed in the dishes by workers wearing gloves. But even with all this heat there's *no* worry about a PYREX brand glass—it won't crack, craze, or change shape.

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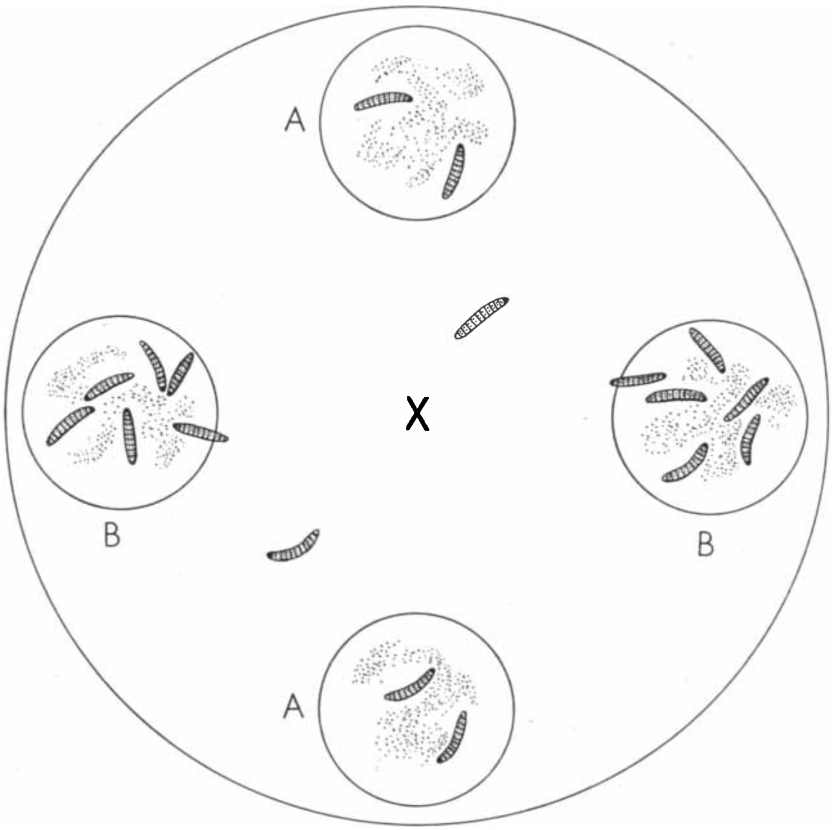
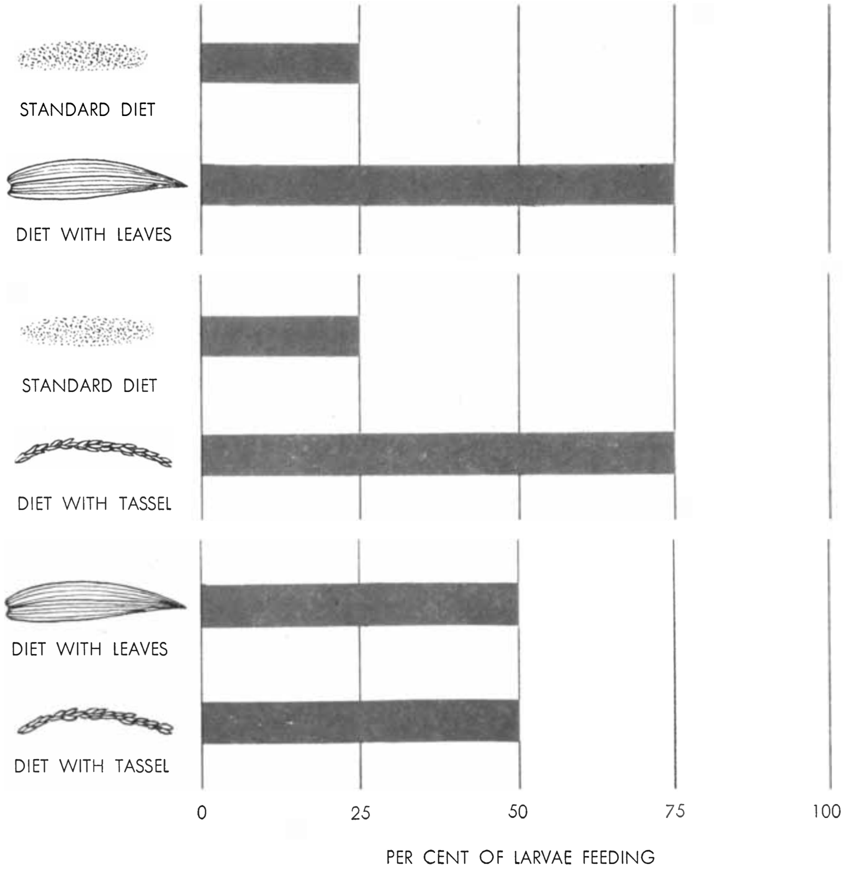


FEEDING PREFERENCES of borer larvae are measured as shown above by placing them in a dish containing different diets (A *and* B). After 24 hours the number of larvae feeding on each diet is counted. As shown in graphs below, borers prefer diets containing corn tissue to synthetic "standard diet." They show no preference between corn leaves and tassel.



light: exposed to sunlight, they will retreat to a dark place as fast as their short legs can carry them. It was also suspected that the larvae are partial to narrow places where their body surfaces are in contact with the walls (a tendency called "thigmotaxis").

To test these reactions we made some dummy corn plants with stems of rolled cotton and leaves of wax paper. We then deposited corn-borer eggs on the underside of the "leaves" and followed developments. The larvae, after hatching, went to precisely the place they would in a real corn plant—namely, deep in the "whorl." Even when the artificial "plant" was kept in complete darkness, about one third of the larvae sought out this location, showing that thigmotaxis, as well as avoidance of light, plays a part in drawing borers there.

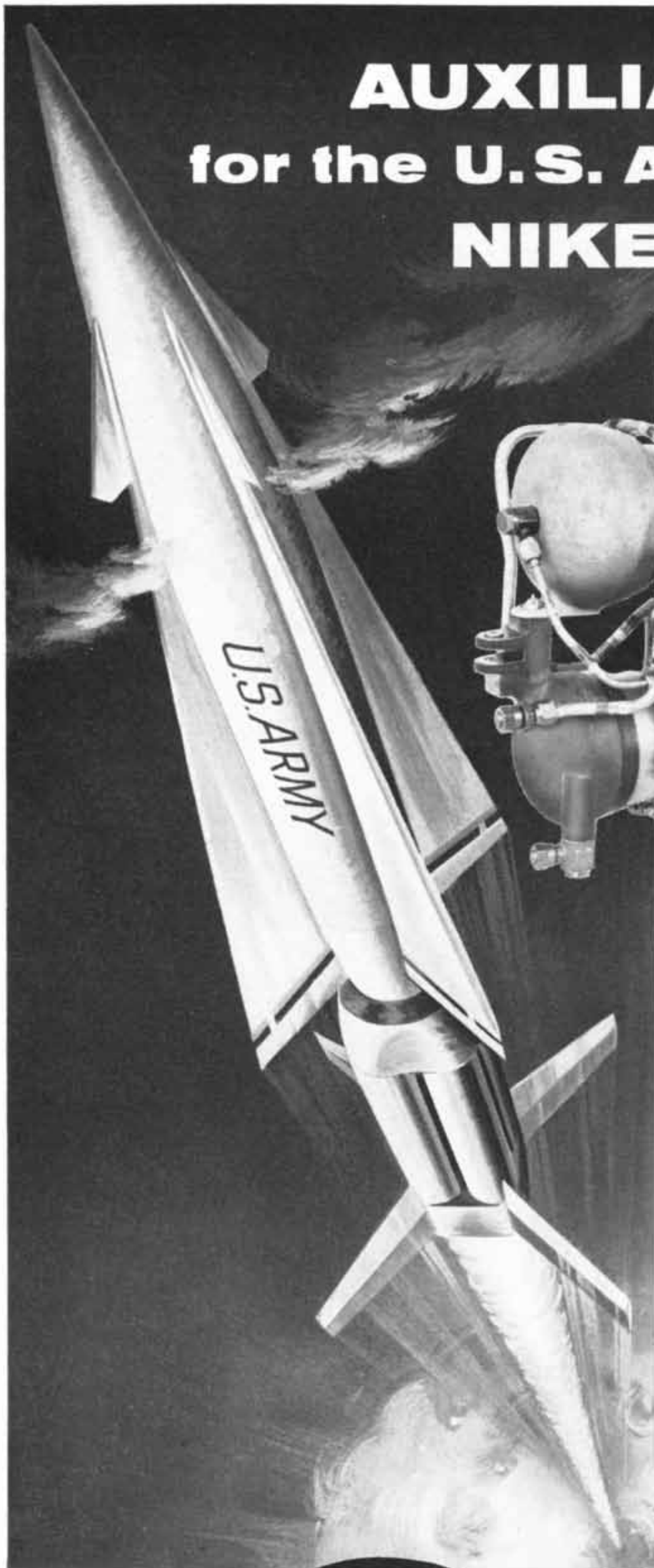
So we can take it as proved that the migrations of the borer in the developing corn plant are prompted by nothing more than the plant's changing physical form. As long as the whorl is tight, the insects take shelter there and feed on the leaves and the young growing tassel. When the tassel grows out and leaves them exposed, they crawl down under the leaf sheaths and into the husks of the developing ears.

This is not, however, the whole story. Within the place that a borer inhabits at any particular time, it does show a preference of taste. Under a leaf sheath it tends to feed on the stalk in preference to the sheath; in the whorl it prefers the young tassel, if present, to the leaves; in the ear it likes the inner husks better than the outer husks, and silks better than either.

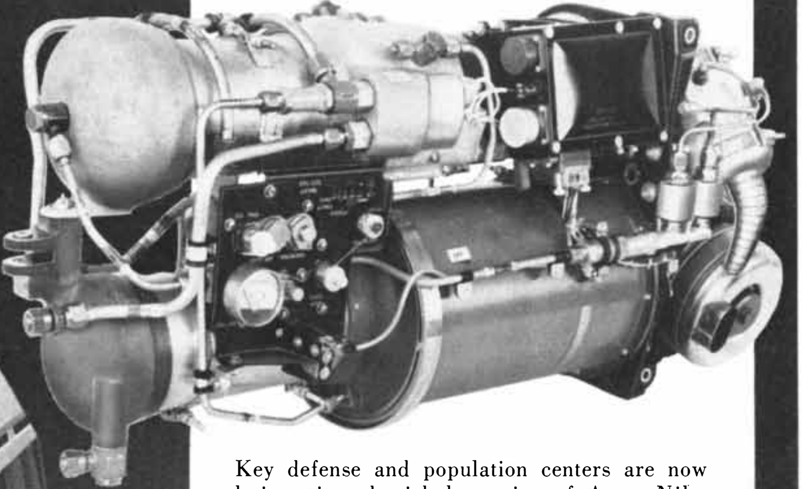
We returned to feeding experiments to see what food substance might be responsible for the preference. In successive tests we found that protein, cholesterol, fats, minerals and B vitamins had little or no special attraction for the borers: they would feed readily on a diet devoid of any one of these substances even though it was grossly inadequate nutritionally. But sugar was another matter. The insects were very sensitive indeed to the presence of this food. In every test the borers tended to concentrate their feeding on the diet containing the most sugar. The sugar had no power to attract the insects to the food (*e.g.*, by odor), but once they had tasted it, they stayed longest with the food that had the highest sugar concentration.

Chemical analyses of the various tissues of corn plants now confirmed the findings in the simplified dietary tests. Young tassel was found to contain a

AUXILIARY POWER for the U.S. Army's deadly NIKE HERCULES



AiResearch units power the controls of America's most potent defense weapons



Key defense and population centers are now being ringed with batteries of Army Nike Hercules missiles to deter or destroy aggressors. *Supplying power for flight controls* is the AiResearch auxiliary power unit pictured above, now in production.

As a member of the Army-industry team producing the Nike Hercules (Army Ordnance, Western Electric-Bell Telephone Laboratories and Douglas Aircraft), AiResearch was chosen to design, develop and manufacture this vital accessory power source for the missile because of nearly two decades of experience in lightweight turbomachinery.

This experience includes applications utilizing solid propellants, liquid mono-propellants, bi-propellants, atomic power, cryogenic gases as well as gasoline and air. AiResearch's ability for high capacity production as well as in research and development, made it the logical choice.

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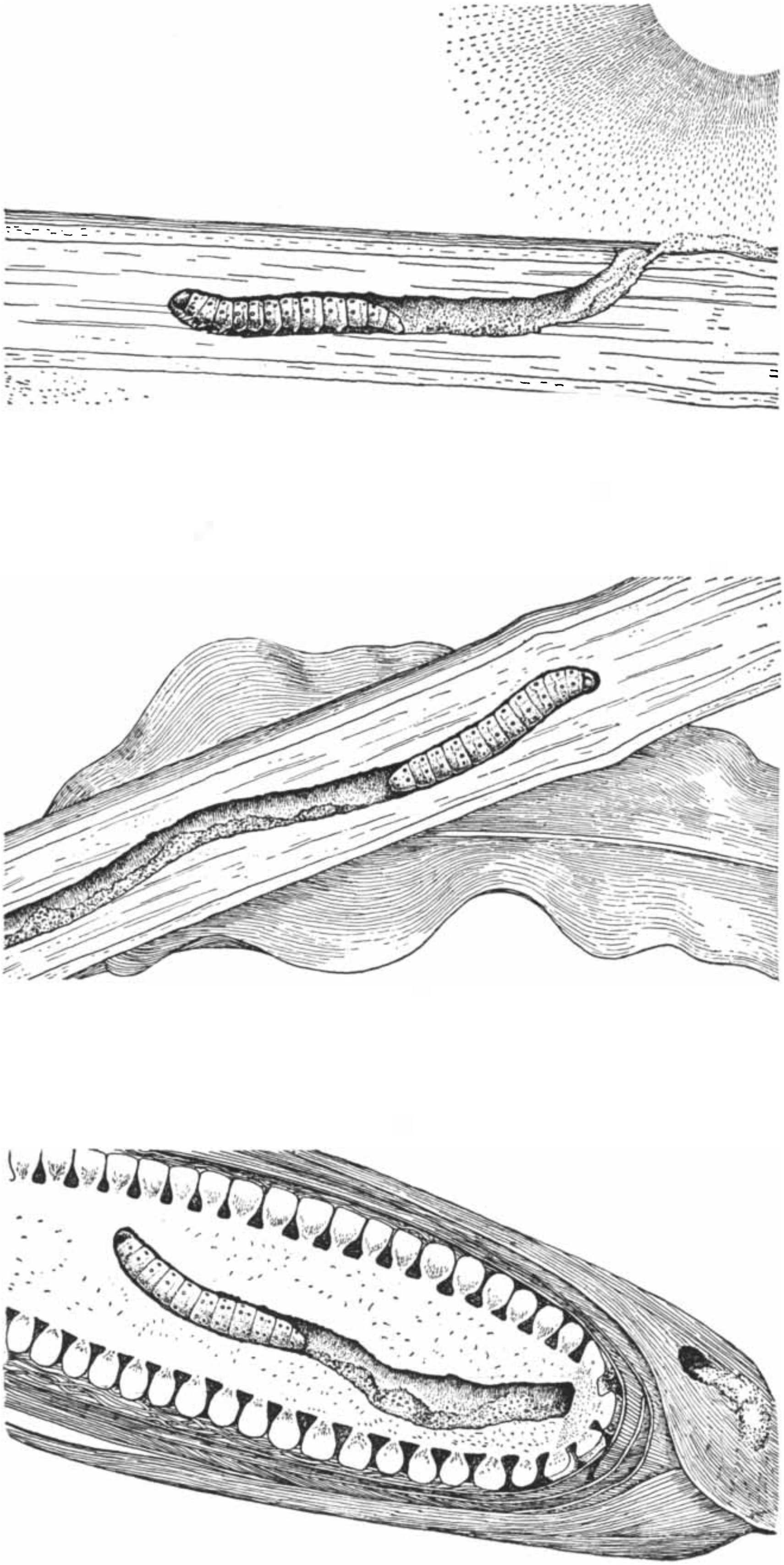
Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS higher concentration of sugar than the surrounding leaves, the stalk more than the leaf sheath, the green silk of the ear more than the husks. In every case the tissue that the corn borer attacks most enthusiastically is the one with the most sugar.

The feeding behavior of the corn borer, then, is governed by an aversion to light, a predilection for tight spaces and a liking for sugar. All three of these seemingly irrelevant traits actually serve to help the insect to survive. The avoidance of light and thigmotaxis drive it into the deep parts of the corn plant, where it is protected from adverse weather and its natural enemies and is also held in contact with its food supply. The value of its liking for sugar is less obvious. The larva does not actually need sugar in its diet until the last stages of its growth. But we found that for young larvae sugar performs a very important service other than nutrition. It fortifies them against a toxic chemical (6-methoxybenzoxazolinone) in young corn plants; that is, it acts as an antidote against this poison which the borers inevitably take up in feeding on the plant tissues. Many young borers are killed by the poison; the more sugar they eat, the more immune they are.

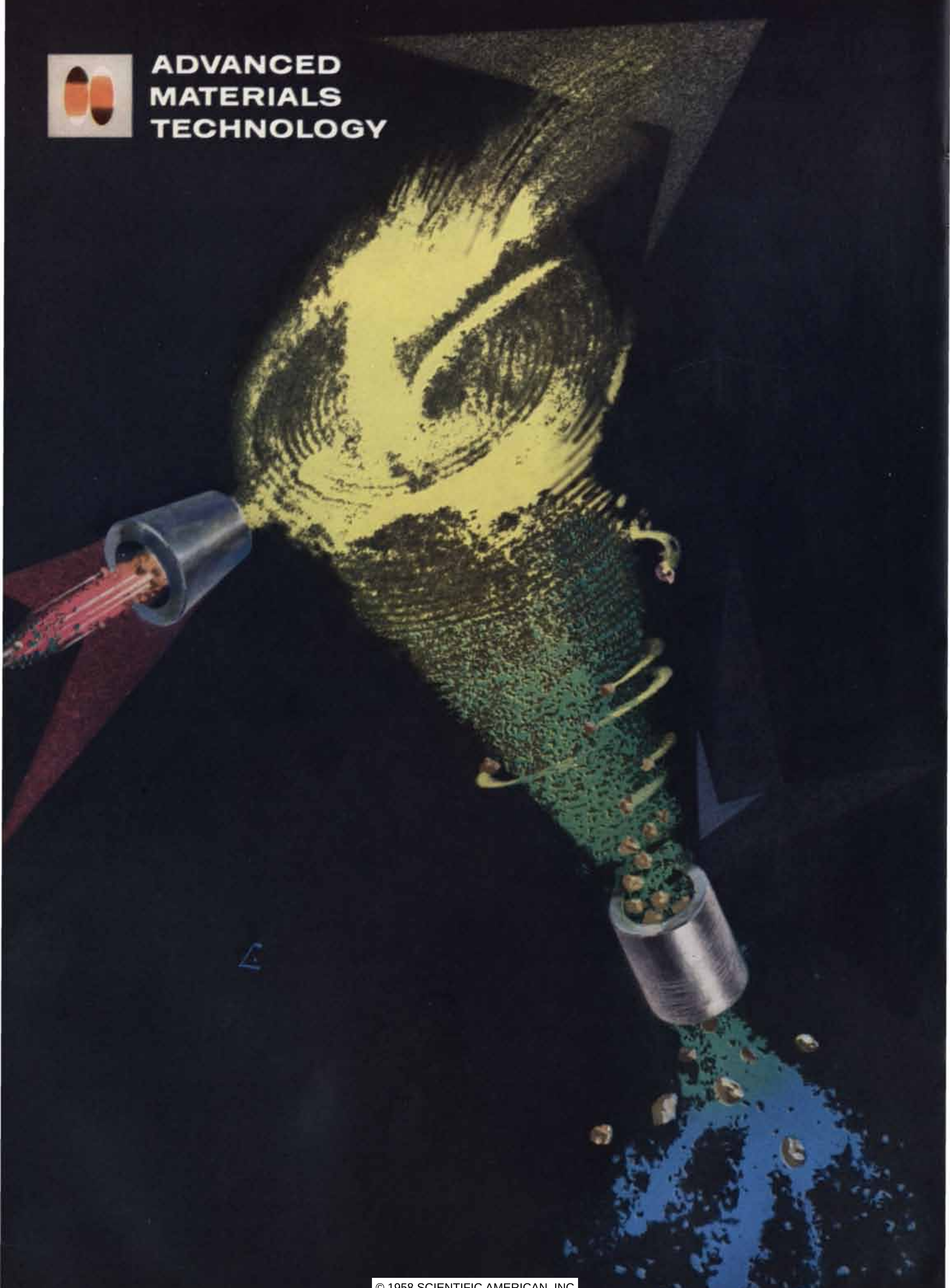
It would be hard to find anywhere in nature a neater adaptation than the corn borer's to the cultivated corn plant. Corn is planted fairly early in the spring, and its growth is nicely timed to the season when the borer moth lays her eggs. The plant affords rich nutrition for the larvae; it grows fast; it is on hand for a long season; even in death it provides hollow stalks where the larvae can hibernate over the winter. The borer, for its part, possesses just the traits needed to make full use of the plant's advantages and to counteract its minor disadvantages.

Ten years of persevering research have given us a better knowledge of the relations between the corn borer and its host than we have of any other insect-plant combination. This article has covered only one aspect of the study. What we have learned suggests various ways of fighting the insect: qualities of resistance that can be bred into the plant, planting times that will put the plant out of phase with the insect's breeding cycle, measures for destroying the hibernating larvae, and so on.

It would be well worthwhile to go on to study other insects in the same way. Our findings and the techniques we have used should be applicable to many other plant-feeding insects.



BORER'S BEHAVIOR on the corn plant is explained by its dislike of light (*top*), and its preference for physical contact (*center*) and for tissues with high sugar content (*bottom*).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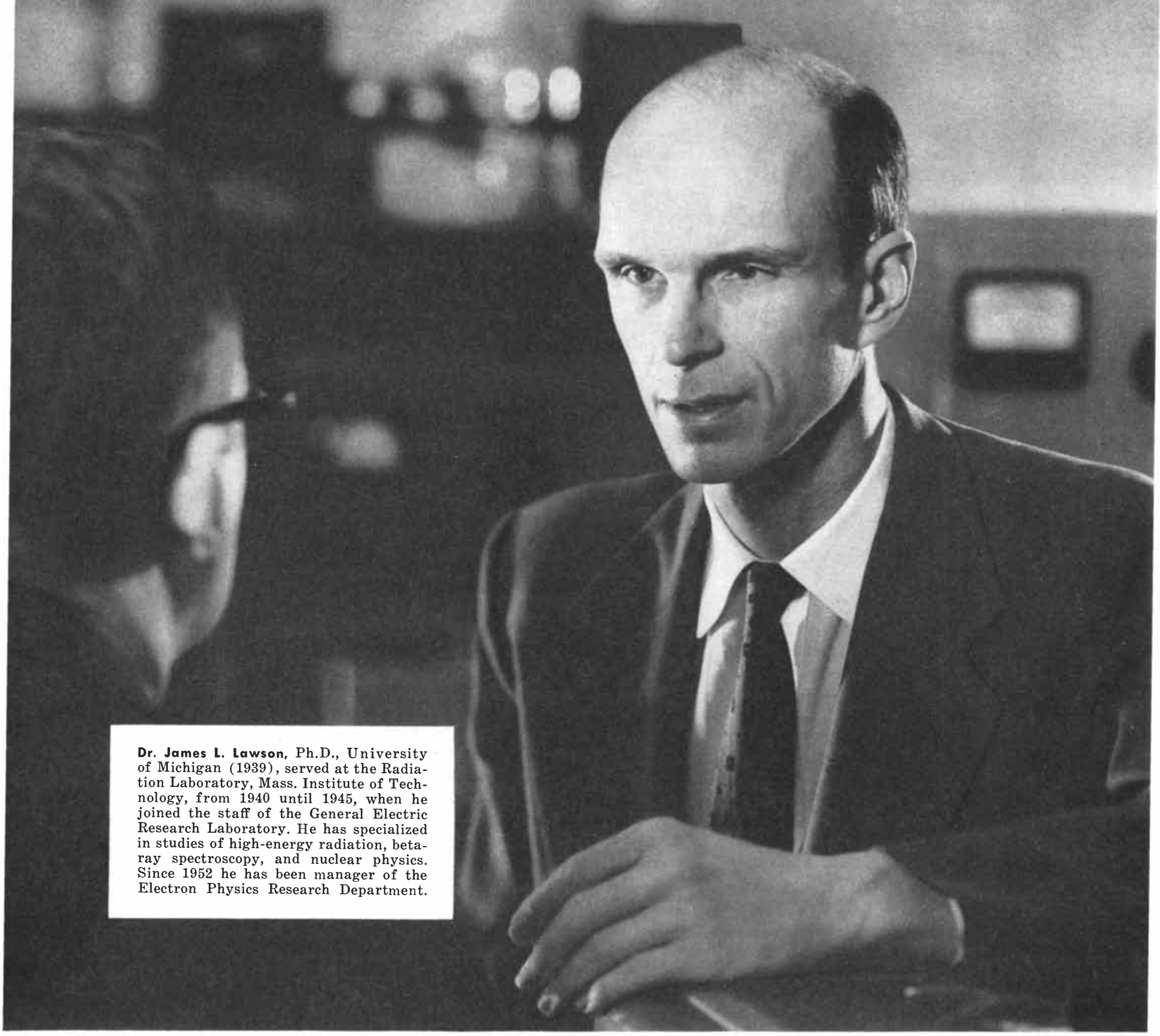

Dr. James L. Lawson, Ph.D., University of Michigan (1939), served at the Radiation Laboratory, Mass. Institute of Technology, from 1940 until 1945, when he joined the staff of the General Electric Research Laboratory. He has specialized in studies of high-energy radiation, betaray spectroscopy, and nuclear physics. Since 1952 he has been manager of the Electron Physics Research Department.

Uniting scientific skills

Dr. James L. Lawson of General Electric leads research studies in nuclear and electron physics

As manager of *electron physics research* at the General Electric Research Laboratory, Dr. James L. Lawson is responsible for programs ranging from nuclear physics to high-temperature electronics and the study of information theory.

Dr. Lawson's group, which includes scientists of many and varied skills, is uniquely able to undertake research projects requiring versatility, as well as cooperative effort. An example is the work now being directed toward the peaceful use of fusion power. In programs of such broad scope, success depends particularly on those leaders of research who — as scientists themselves — can understand, encourage, and integrate the work of other scientists.

While making contributions to his chosen profession, nuclear physics, Dr. Lawson is at the same time contributing as a *research leader* to an atmosphere in which scientists have the incentives, the tools, and the freedom to seek out new knowledge.

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THE ACTION OF INSULIN

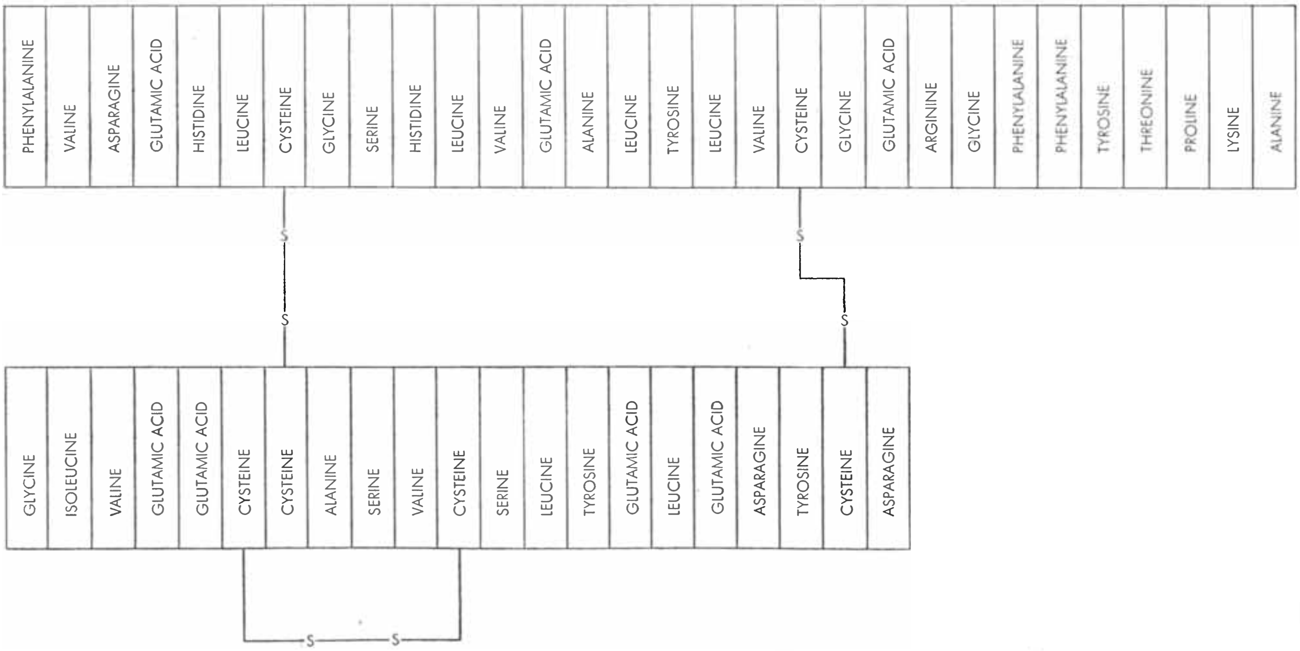
It is well known that this hormone is involved in the metabolism of sugar. But how? Recent experiments indicate that it presides at the passage of sugar through the outer wall of certain cells

by Rachmiel Levine and M. S. Goldstein

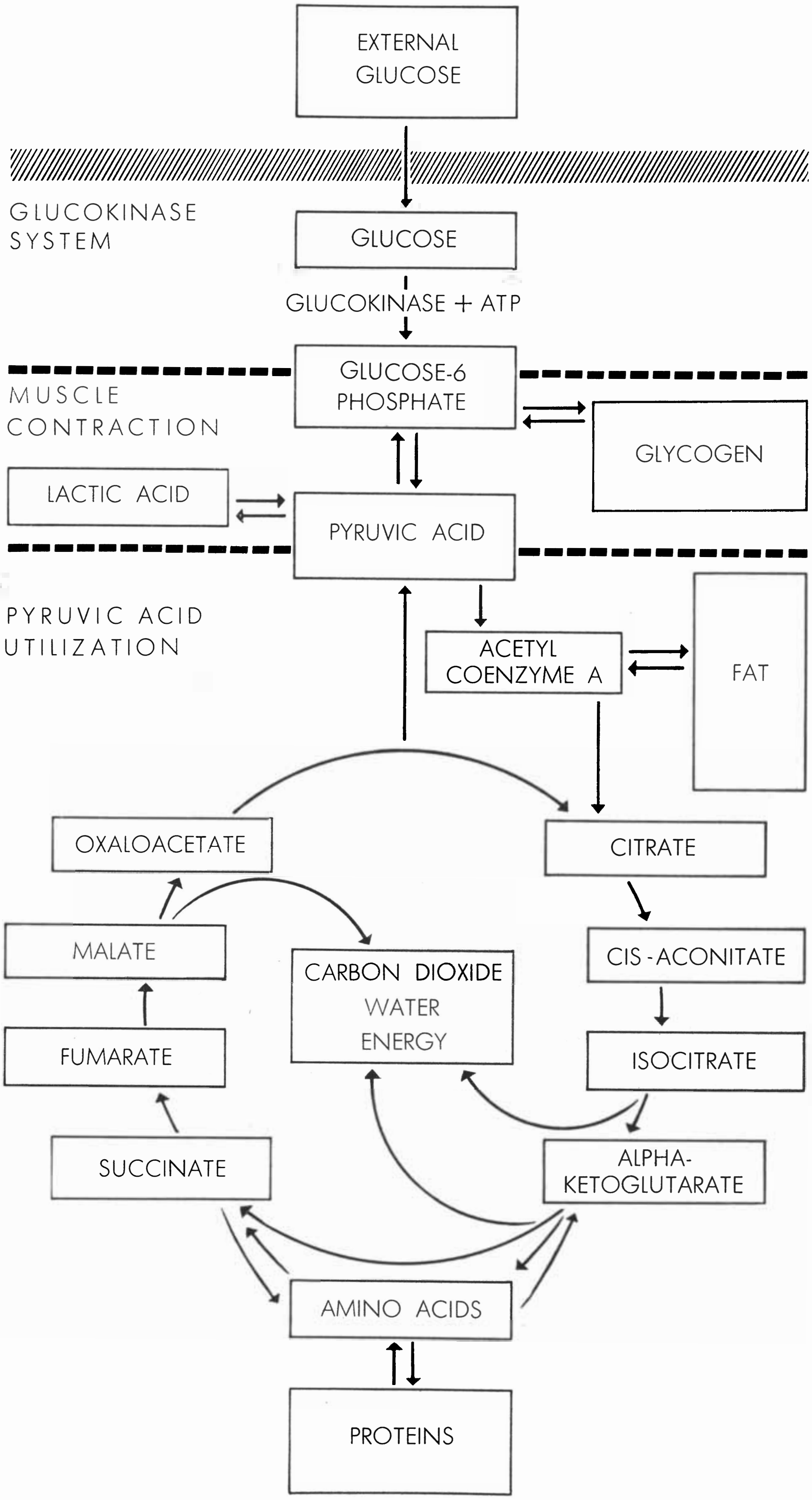
For more than a third of a century insulin has been one of the great puzzles of biology. It has been celebrated and used throughout the world as a life-saving treatment for diabetes mellitus ever since it was first discovered by Frederick G. Banting, Charles H. Best and John J. R. Macleod at the University of Toronto in 1922. But after a generation of the most intense research biologists are still not sure exactly what chemical function insulin performs in the body. We know that the hormone helps the body to use sugar. But how? If we had a complete answer to that question, it would not only give us a better understanding of the "sugar disease" but might also clarify how other hormones regulate the metabolic processes of the body.

In the department of metabolic and endocrine research of the Michael Reese Hospital in Chicago we have been exploring a new theory about insulin's action. The experiments are quite encouraging. The site of the hormone's action has at last been located, and it may now be possible to proceed to work out the chemical mechanism itself, although that promises to be very difficult.

The metabolism of sugar is one of the most thoroughly investigated subjects in all biochemistry. Oddly enough, it was the brewing industry that first gave impetus to this study. Seeking to improve the quality and uniformity of beer, the brewers pushed research into the vagaries of the fermentation of sugar by yeast. These investigations showed that yeast cells, aided by various enzymes, transform sugar into a whole galaxy of different compounds. Experimenters soon found that sugar goes through an analogous series of transformations in the chemical machinery of animal cells. Glucose, for instance, first combines with adenosine triphosphate (ATP) to form a glucose-phosphate compound;



INSULIN MOLECULE is composed of amino acids (*labeled rectangles in this schematic diagram*) in two chains joined by disulfide bonds (S-S). This structure was determined by the studies of Frederick Sanger and his colleagues at the University of Cambridge.



METABOLISM OF SUGAR in a typical cell is outlined to show its principal products and the interrelationship of carbohydrate, fat and protein metabolism. Glucose, a sugar in the blood, enters the cell through the cell membrane (*hatching*). Heavy broken lines separate the reactions into those of the glucokinase enzyme system (*top*), those occurring in muscle contraction (*middle*), and those involved in the utilization of pyruvic acid (*bottom*).

this breaks down to pyruvic and acetic acids; they in turn furnish energy and raw material for a thousand uses and products, including fats and proteins [*see chart at the left*].

Contemplating this scheme, medical scientists could understand why diabetes was so serious a disease. Obviously any important disturbance of the metabolism of sugar was bound to have far-reaching repercussions, for it disrupted the whole chemical machinery of the body, interfering with production of all its major substances. No wonder diabetics grew weak and wasted away.

Clues to what was happening could be seen in the patients' blood and urine. Because diabetics cannot convert sugar to other substances efficiently, much of it passes through the body unused. The blood shows a sugar level of 200 milligrams or more per 100 cubic centimeters, instead of the normal 80 to 100 milligrams. Eventually the sugar is excreted in the urine. The body, for want of sufficient nourishment, breaks down its proteins and fats for energy to survive, and it steadily becomes emaciated. Moreover, some of the acid products of the rapid breakdown of fats have a poisoning effect on the body (acidosis), which may produce abrupt coma and death. All this from just one defect: failure to metabolize sugar fast enough!

Research eventually showed that a commanding role in the control of sugar metabolism was played by insulin, a hormone manufactured by special cells in the pancreas. The power of this hormone proved to be remarkable. As little as one or two milligrams of insulin a day, given to a patient who could not manufacture his own, was enough to clear the glucose pile-up and restore the patient's entire metabolism to normal. The tissues regained their ability to use sugar at a normal rate and to synthesize fats and proteins; the liver recovered its function of storing sugar (as glycogen) and doling it out in nice proportion to the body's needs.

How did insulin perform this service? Biochemists began a systematic examination of the chemical machinery of the cell, part by part. It was natural to suppose that insulin acted on some key enzyme system, of which there are a great many in the cell. The first metabolic system to be tested was the breakdown of glycogen to lactic acid, which provides the energy for contraction of muscles. If this process required insulin, presumably a diabetic animal would not be able to

New shaker top of TENITE POLYETHYLENE sells more salt for Morton

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The desired blue color is achieved by using a Tenite Polyethylene color concentrate, added in fixed proportion during the molding process. By this means, Morton secures uniform color results while employing several different molders.

In Tenite Polyethylene, the Morton Salt Company also found the more general characteristics needed to make the idea practical. First of these were low material cost and ease of fabrication. Important, too, were resistance to corrosion by salt or water; moldability that would permit one-piece design; and resilience that would make possible a tight friction-fit between cover and sprinkler.

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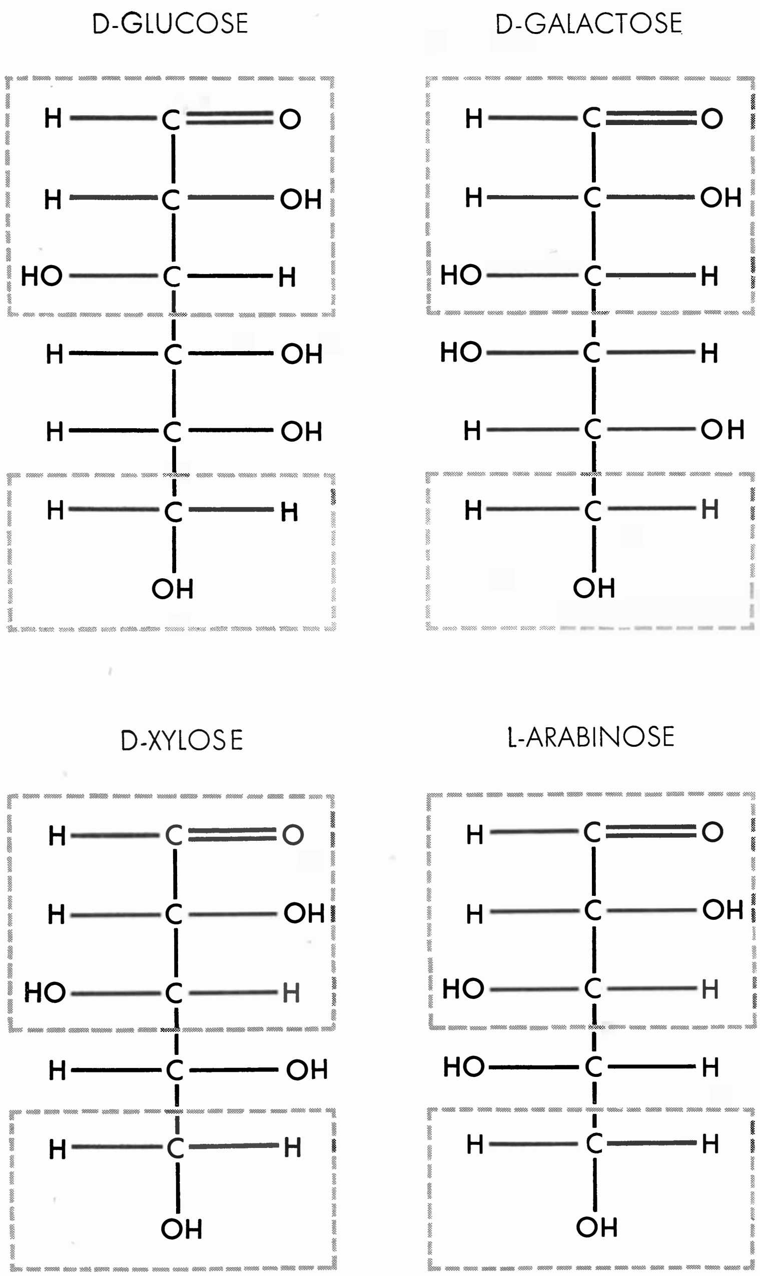
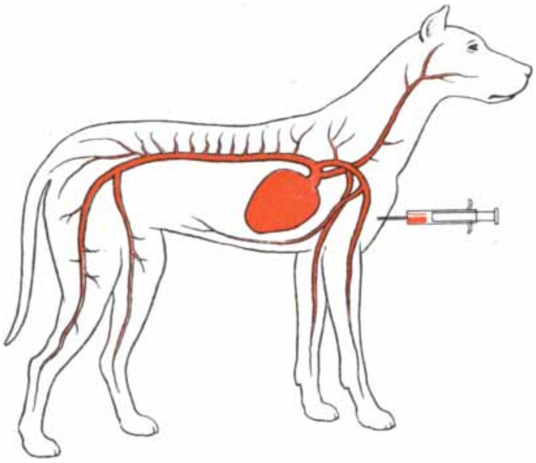
convert glycogen to lactic acid. But the experiments on animals showed that even without insulin the muscles of an animal during exercise did produce lactic acid in normal amounts. So all of the enzyme systems involved in conversion of sugar to lactic acid were ruled out as targets of insulin's action. Next it was found that insulin was not necessary for the metabolism of pyruvic acid; a dog deprived of insulin could still metabolize pyruvic acid in normal fashion. Finally it turned out that the third major phase of sugar metabolism—conversion of glucose to glucose-phosphate—also could proceed without insulin.

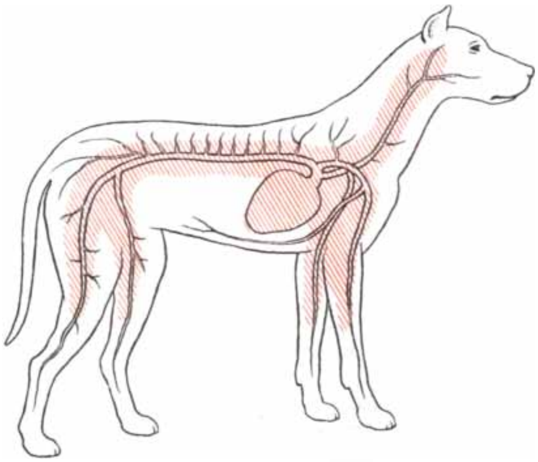
In short, the process of elimination had only succeeded in showing that every known component of the cell's machinery for using sugar could function perfectly well without insulin! This was indeed an embarrassing impasse. There



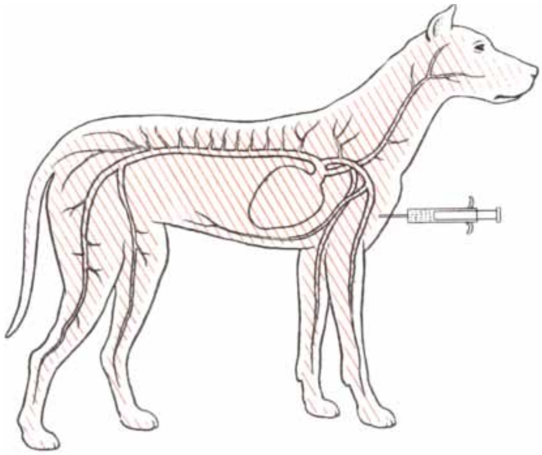
FOUR SUGARS which in the presence of insulin will enter cells in the dog have similar structural formulas. At the ends (*broken gray rectangles*) the four molecules are identical.



D-GALACTOSE (*colored*) is injected into the vein of a dog from which the kidneys, pancreas and other abdominal organs have been removed. Within five to 10 minutes the sugar spreads throughout the blood, occupying the space in 8 per cent of the body by weight.



SPREADING of the sugar continues for 45 to 60 minutes until the galactose has penetrated all the extracellular fluid and tissues which readily accept it. It then occupies 45 per cent of the body by weight. Galactose is used for this experiment because it is not metabolized.



INSULIN injected into a vein can open up the remaining tissues of the dog to the sugar, enabling it to enter into all the body fluid, both inside and outside of cells. The sugar finally occupies a space which is equivalent to about 65 to 70 per cent of the body by weight.

was no doubt whatever that insulin played a leading role in the body's use of sugar, and yet biochemists could find no place for it to act.

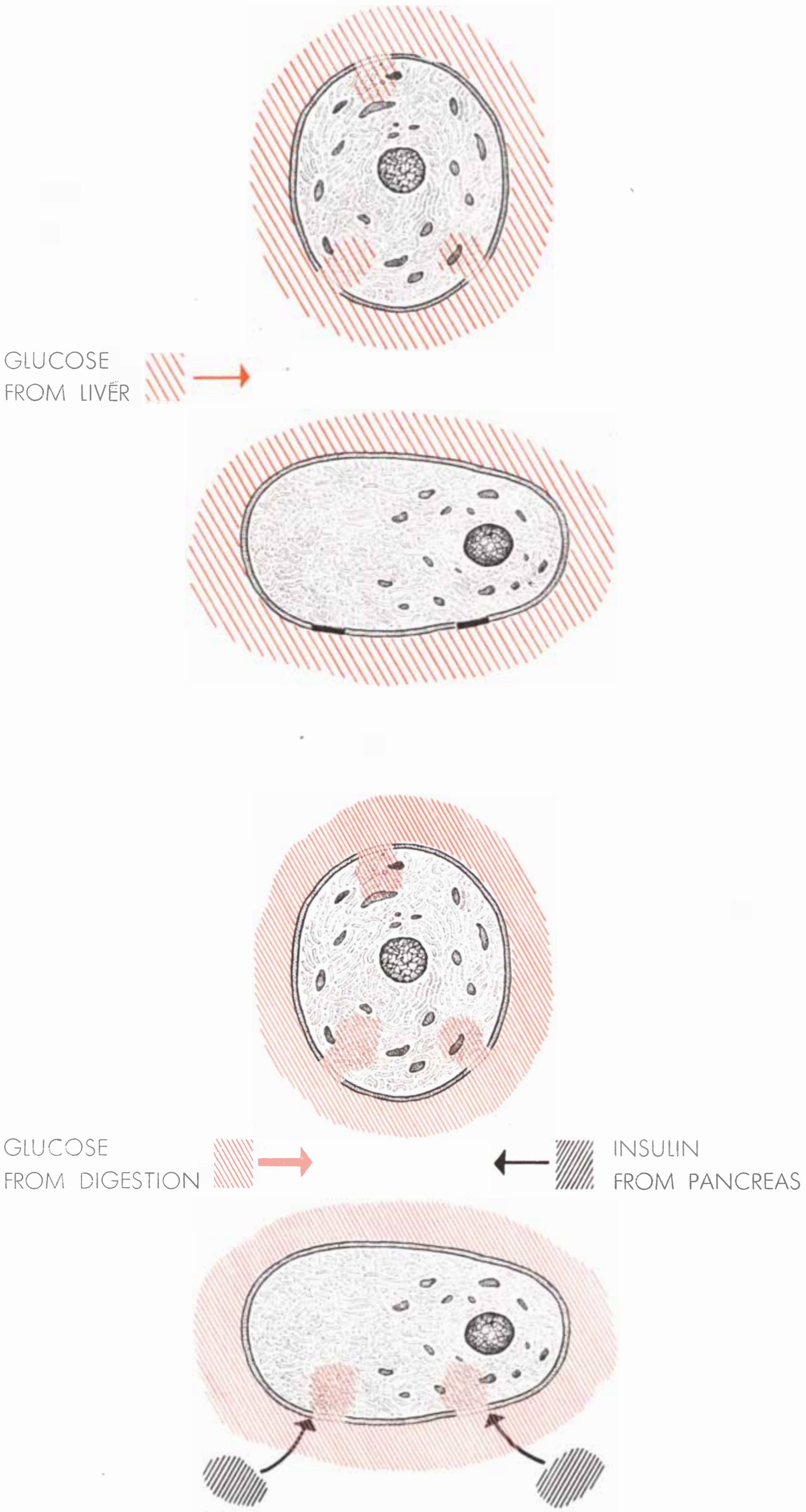
If insulin had nothing to do with the internal chemical machinery of the cell, where else might it operate? Our laboratory went back to an old idea suggested many years ago. Perhaps insulin had something to do with sugar getting into the cell. In order to be metabolized, sugar must reach the machinery inside the cell where metabolism takes place. Suppose we assume that the reason a diabetic cannot use sugar is that the sugar fails to enter his tissue cells. It would follow that the function of insulin is to help sugar get through the cell membrane into the cell—to open the door, so to speak.

This offered a new lead for experiments. We injected sugar into the bloodstream of animals and then examined them to see to what extent their cells took up the sugar. We could not use glucose itself, for this would promptly be transformed to other substances once it entered the cell. But we found other sugars (galactose, xylose and others) which under certain conditions are not metabolized and serve as satisfactory tracer substitutes for glucose. The results of the experiments upheld our working hypothesis. Analysis showed that a large proportion of the cells in the animal did not take up sugar unless insulin was injected at the same time.

That many cells did absorb sugar without such an addition of insulin was not surprising. It was known that the cells of some organs of the body, including the brain, the kidney and the intestinal tract, are able to metabolize sugar even in the absence of insulin. The principal tissues where sugar metabolism fails in diabetes are the muscles and the connective tissues, especially the cells that synthesize fat.

Other laboratories have confirmed our finding that insulin controls the admittance of sugar into such cells, and C. R. Park of Vanderbilt University and E. J. Ross of London have recently verified that what applies to the special sugars we used as tracers also applies to glucose itself.

We can now picture the following general scheme of insulin's action. When an animal eats carbohydrate, sugar goes into the bloodstream and raises its sugar level. This is a signal for the pancreas to secrete more insulin. The



NORMAL TRANSPORT OF SUGAR to two kinds of cells is represented in these two pairs of diagrams. Under fasting conditions glucose (*colored hatching*) in the blood can penetrate the membranes of some cells (*top diagram*), but is kept out of other cells (*second diagram*). If the glucose level in the blood rises, as it does after a meal, insulin (*black hatching*) is released from the pancreas and is carried to the cells by the blood. The insulin acts at points on the "covered" cell to open its transport system so that glucose can enter.

hormone travels via the bloodstream to the muscle and fat cells, attaches itself to some specific point on the surface of the cell, and thus opens the gate for sugar. The pancreas's insulin secretions nicely regulate the cells' uptake and the level of the sugar in the blood so that none is wasted. Some sugar is taken up by the liver and stored as glycogen; between meals the liver keeps rationing out just about enough glucose to fuel the brain, the kidney and the beating heart.

This is a highly satisfying picture which clears up many puzzles; one of its beauties is that it also leads us into interesting new fields.

To begin with, we want to know more about the sugar-transfer system in the membrane of the cell. Apparently insulin is not the only gateman that works at this door. Experiments have shown that muscles, during strenuous exercise, also release a substance, not yet identified, which can open the door. This has been demonstrated by connecting the blood vessels of two animals—one resting, the other exercising. Although both animals lack insulin, because of removal of their pancreas, the working animal supplies its resting partner via the bloodstream, with an agent which allows entry of sugar into its cells. That muscular work promotes the uptake of sugar by the tissues has been known for a long time, and exercise has been prescribed for diabetics.

It will not be easy to investigate the chemistry of the sugar-entry system itself. As in all living systems that work only so long as they are intact, we are faced with the problem of how to analyze the system chemically without taking it apart. To study the chemical activities of the cell membrane in its intact condition we shall need radically new methods of analysis.

Meanwhile the membrane of the cell takes on fresh interest. We see once again that it is a very important little organ—fully as important as the nucleus, the mitochondria and the other tiny "organelles" within the cell. The cell membrane contains vital transport systems not only for the passage of sugar but also for the traffic of sodium and potassium ions, amino acids and a host of other foodstuffs and breakdown products in and out of the cell. Now that insulin has been identified as a gatekeeper, we may well look for other hormones that act as engineers controlling the flow of materials in and out of the chemical factory of the cell.

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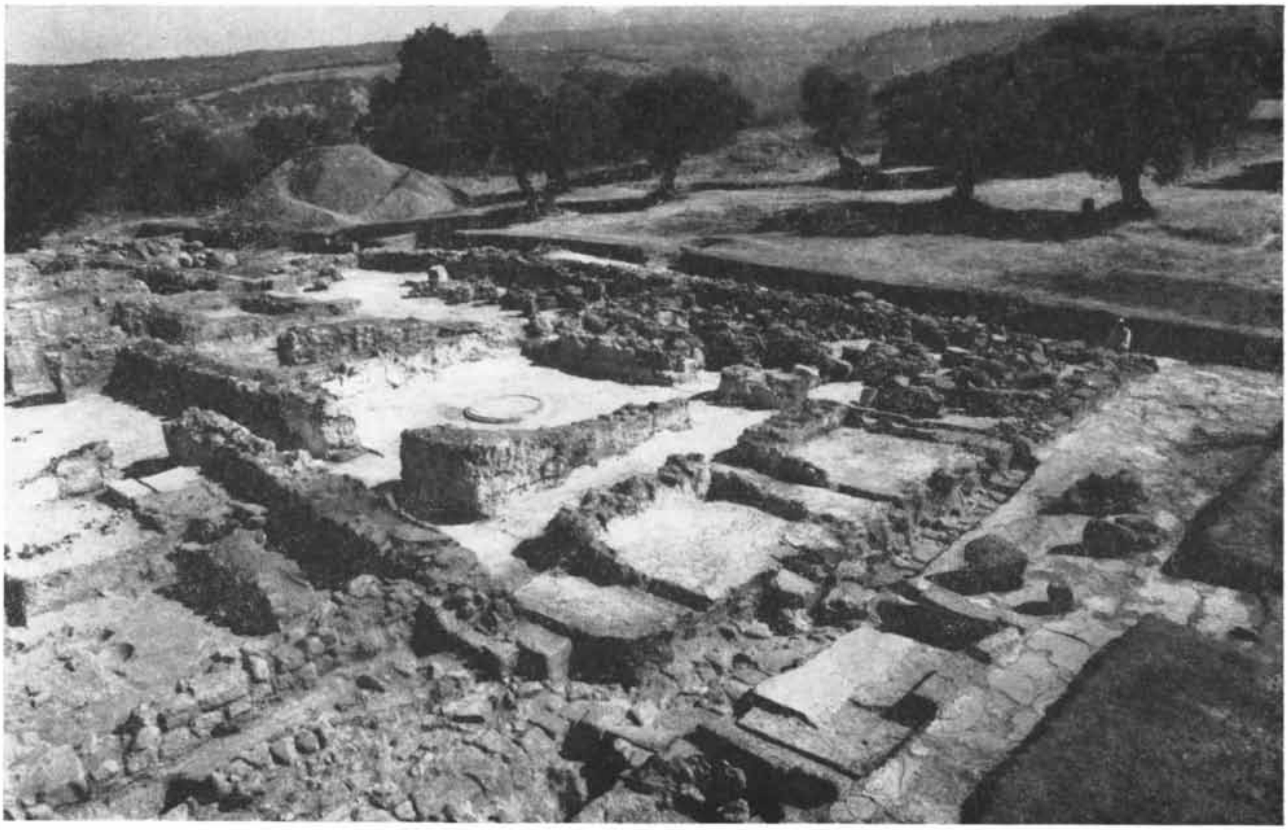
KING'S PALACE at Pylos is shown after its excavation. The throne room, with its round hearth, is in the center. To the left of this room is the entrance of the palace; to the right are magazines for oil and wine jars. In distance is the island of Sphacteria.



QUEEN'S APARTMENTS in the palace are seen from near the propylon or palace gate (*see floor plan on page 112*). In the center is the queen's reception room. Like the throne room, it has a central hearth. At right are the queen's boudoir and "powder room."

King Nestor's Palace

Archaeologists have excavated a large structure in southwestern Greece which was probably the home of the man who, the Odyssey relates, received Telemachus as he began his search for Odysseus

by Carl W. Blegen

One of the most charming stories in the *Odyssey* tells of the visit of Telemachus, the son of Odysseus, to the palace of King Nestor of Pylos, his father's old friend. Setting forth from Ithaca to search for Odysseus, who had not been heard from for nearly 10 years since the end of his successful siege of Troy, Telemachus went first to Nestor to ask whether the king had any information that might help him find his father. Nestor, delighted to see the son of his old comrade, warmly invited Telemachus to spend the night at the palace, and Homer's story gives a detailed account of how Telemachus was wined and dined in the palace, how he was given a bath by Polycasta, Nestor's youngest daughter, and how he was sent on his way in the morning in a chariot with the king's blessing and such little information about Odysseus as Nestor could provide.

If there ever was a King Nestor—and archaeology has of late found much evidence that the Homeric sagas were based on historical facts—we can confidently say we have now discovered his palace: the very place where Telemachus was so royally entertained. The remains have been found where Greek tradition placed the palace—in the territory of Pylos in western Messenia at the southwestern tip of Greece. On a flat hilltop covered with a wheat field and olive trees, the extensive ruins of the ancient building and its contents have been brought to light by excavations within the past six years.

Archaeologists have been combing over Greece from end to end for some 80 years, and they have uncovered one after another of its ancient cities and towns. One might think that after this thorough going-over there would not be much of any consequence left to find. But the soil of Greece covers seemingly inexhaustible deposits of antiquities, and occasionally archaeologists favored by the goddess of luck still manage to hit a "jackpot."

Twenty years ago my friend Constantine Kourouniotis, director of the Greek Archaeological Service, invited me to join him in an archaeological investigation of the southwestern Peloponnesus, where some ancient vaulted tombs of the Mycenaean period had been accidentally discovered. We formed a joint Helleno-American expedition to explore the area, Kourouniotis representing the Greek Archaeological Service and I the University of Cincinnati. Judging that the large newly discovered tombs belonged to kings and members of ruling families, we decided to search for the palace where these royal personages must have lived. After two seasons of systematic exploration of the whole district on foot, we settled on what looked like by far the most promising site: a flat-topped hill, now called Epáno Englianós, four miles from the Ionian Sea coast. Commanding a wide view in all directions, and dominating the surrounding district, the hilltop was obviously an ideal place for a royal stronghold—near enough to the coast to maintain a seaport yet far enough inland to be safe from surprise attack via the sea.

Our first inspection of the hilltop disclosed two small projections of fused mudbrick and limestone resembling concrete. Local people assured us that they must be part of the ruins of a Roman building. We had a different view. To us the concretions looked like the calcined debris of the famous ancient palace already uncovered at the Peloponnesian city of Mycenae, which had been burned by a great fire. We also found fragments of pottery lying about in the field which clearly were of the Mycenaean period. Consequently we began to dig into the site with some confidence.

The very first day's digging demonstrated that we had really found what we were seeking (and nothing is sweeter to an archaeologist than to have his deductions substantiated!). We unearthed some thick stone walls badly damaged by fire, fallen plaster with traces of frescoed decorations, stuccoed floors, many pieces of broken Mycenaean pottery, and, most exciting of all, several clay tablets in the ancient Linear B script, previously found only on the island of Crete [see "The Language of Homer's Heroes," by Jotham Johnson; SCIENTIFIC AMERICAN, May, 1954]. Within a few days we found hundreds of tablets, nearly all coming from a small room evidently used for the storage of archives. By the end of the season we had established the existence of the palace and worked out plans for its complete excavation. It was with rosy dreams that I went home to Cincinnati at the season's end in the summer of 1939.

But the war intervened, and many years passed before we were able to return to Greece to carry out the project. At last in 1952 we were able to go back to the excavation. Dr. Kourouniotis had died in 1945, and the Cincinnati wing of the expedition took over responsibility for completing the clearing of the palace. With financing provided by Professor and Mrs. W. T. Semple of Cincinnati we have devoted six seasons to the excavation and have uncovered most of the building.

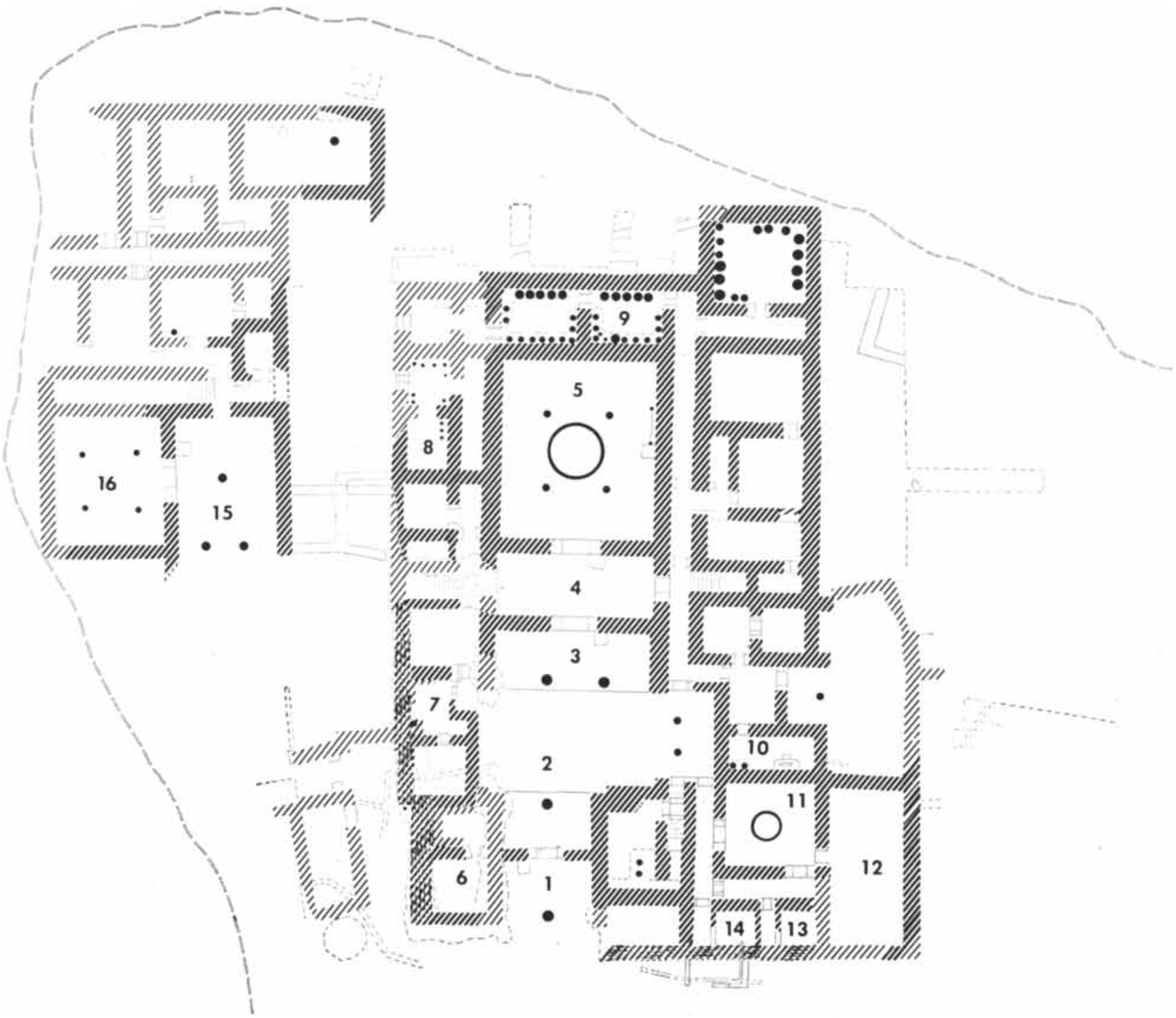
The palace seems to have been destroyed by fire around 1200 B.C. The upper story collapsed into the lower, and some of the walls apparently were blown out in huge chunks. The site was never occupied again: in time it came to be covered by three or four feet of earth and eventually became an olive orchard. In the Classical period of Greece, when Thucydides wrote his history, no one knew the exact spot where Nestor's palace had stood. It had been lost to sight for 2,500 or 3,000 years when it was rediscovered in 1939.

This building at Pylos is the third palace of the Mycenaean period found on the mainland of Greece: the other two are at Mycenae and at Tiryns. The ground plan of Nestor's palace is completely preserved, and so its architecture in the original state is much easier to understand and to visualize than are the other Mycenaean palaces, which were damaged by later constructions or have been in large part destroyed.

Nestor's palace was a royal residence of respectable dimensions. On its ground floor it had more than 60 rooms or units of one kind or another—courts, porches, corridors, halls, stairways, chambers and storerooms—and there were nearly as many more in a second story. The establishment evidently consisted of three distinct parts—a central structure and two wings. The palace as a whole spread over an area about 120 yards long and 65 yards wide.

The central unit, containing the apartments of state, was laid out in a formal five-part pattern leading to the throne room as its climax (the same basic plan as in the palaces at Mycenae and Tiryns). The main gateway, or propylon, was a covered, H-shaped passage with the doorway in the center of the crossbar [*see plan below*]. Next to the doorway is a slightly raised stand—probably for a sentry or gatekeeper. The roof of this entrance portico was supported by two wooden columns—one centered in front and one in back. The wooden shafts themselves were of course consumed in the fire, but well-preserved impressions in a decorative stucco ring around the surviving base show that the columns were fluted with 60 delicately carved grooves.

On passing through the gateway, you emerged into an open courtyard some



FLOOR PLAN of the palace shows its location on a hilltop (*indicated by broken line*). The numbers indicate the propylon or gate (1), courtyard (2), portico (3), vestibule (4), throne room (5), archives (6), waiting room (7), pantries containing pottery (8), storerooms for wine and olive oil (9), bathroom (10), the queen's reception hall, courtyard, boudoir and "powder room" (11, 12, 13, 14), entrance hall of old wing (15) and old throne room (16). Another wing, housing administrative offices, is not shown.

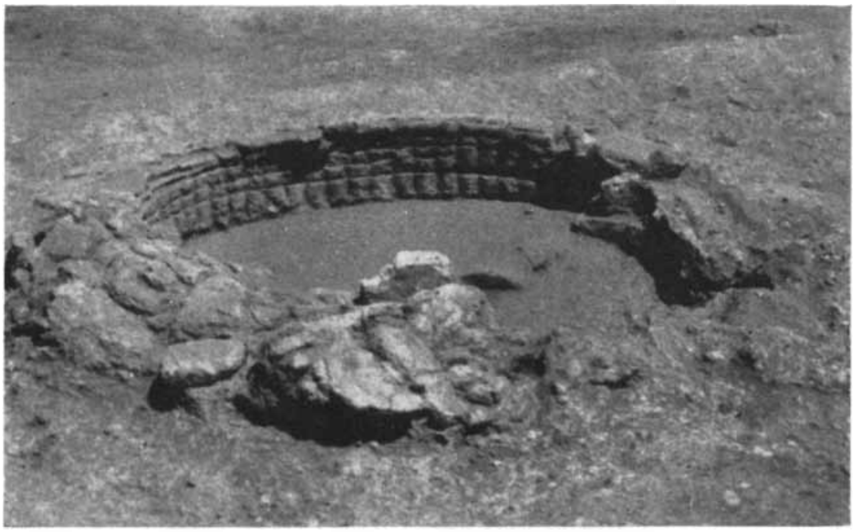
40 feet wide, flanked by a porch and balcony from which the ladies of the palace may have looked on at arrivals or events in the court. You crossed the court to the main portico of the palace, fronted by two large wooden columns, and went through a broad doorway into the vestibule or antechamber of the throne room. Decorated with wall paintings on all four sides, the large anteroom was an impressive preparation for the great hall of ceremonies beyond. The doorway to the throne room was broad and no doubt lofty; there is no evidence of settings for doors, so it was probably covered only by heavy drapes. Beside the doorway again there was a stand for a guard.

The throne room was a nearly square hall about 37 feet wide by 43 feet long. Four fluted wooden columns, each standing on a stone base, supported the roof and a balcony which probably ran around the four sides of the room. In the center of the hall was a big circular hearth, 13 feet in diameter: it had a terra-cotta chimney above to carry the smoke through the roof. The king's throne itself stood against the wall on the right of the hall. The throne is gone, but a slot in the floor marks its position. No doubt it was much like the Mycenaean throne found in the palace of Minos at Knossos in Crete.

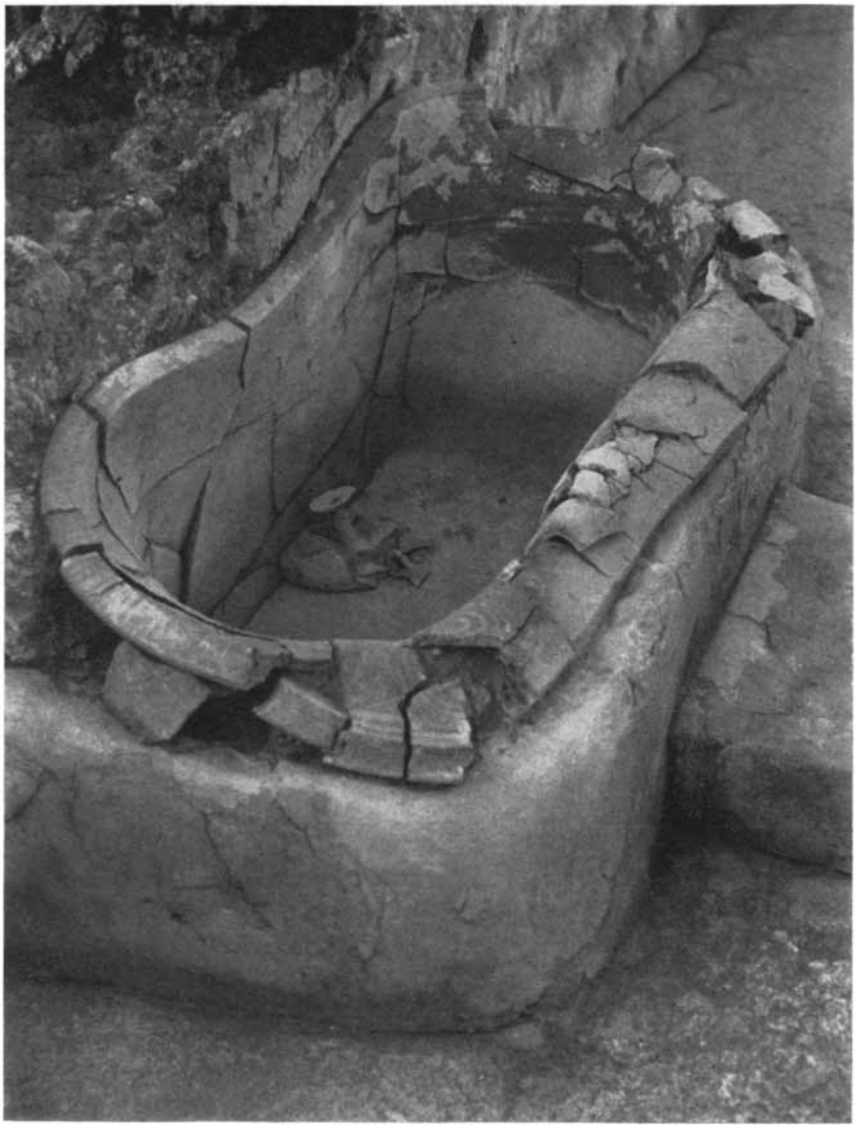
The throne room was brightly decorated with gay designs painted in lively colors on all available surfaces. Its stucco floor was a mosaic of checkerboard squares with various abstract linear patterns, usually in two or more colors. One square in front of the throne pictured a semirealistic octopus. We have reason to believe that the octopus held a high place in the esteem of the royal family, for it plays an important role in the decoration of the building and also appears on royal seals.

The raised hearth, too, carried painted designs, and probably also the woodwork and the room's four supporting columns. Frescoes embellished the four walls. Behind the throne were huge winged griffins in a heraldic arrangement, apparently reinforced by a lion on each side. On the same wall was a fresco of a human figure playing a lyre and apparently taming a strange flying creature—perhaps a representation of Apollo or Orpheus.

The throne room, with its wall paintings, vivid floor designs and richly ornamented woodwork gleaming in the mellow glow of the fire on the hearth, must often have been the scene of gay assemblies and receptions. One can pic-



MOLDING of stucco surrounded the base of a wooden column which supported the roof of the propylon. On the inside of the molding is an impression of the column's carved fluting.



BATHTUB bears a striking resemblance to modern designs. It is made of terra cotta and has a clay base. At bottom of tub is a wine cup which has been left where it was found.

POTTERY from the palace includes many Mycenaean types. Among the samples shown in these photographs are one- and two-handled cups, dippers, vases and cooking vessels.

ture the king seated on his throne, pouring a libation to the gods in the presence of a large company of brightly costumed guests and subjects, while attendants bustled about to see that wine was duly served to all. One can also imagine the women and children of the household eagerly looking down on the festivities from the surrounding balcony—if they were not indeed permitted to take part in the gathering below.

Along the sides of the central building, flanking the halls of state, was a series of utilitarian rooms: offices, a waiting room, pantries, storerooms, stairways, a bathroom, and in one corner an elegant suite which may have been the queen's formal apartment. It was in two small rooms next to the front gateway that we found the clay tablets, more than 1,000 in all, inscribed in the famous Linear B, a pre-Homeric form of Greek which the late Michael Ventris deciphered in 1952. Our tablets seem to be economic records—lists of persons, agricultural accounts, notes or contracts relating to land, tithes and offerings, inventories and the like. Nestor and his successors clearly conducted a well-organized administration. It may be that the collector of internal revenue had his headquarters in these archives rooms and there received taxes in kind: in one of the rooms stood a huge earthenware jar which was apparently full of olive oil the day the palace caught fire.

Next to these rooms was what appears to have been a waiting room. In one corner we found a long, right-angled bench; there was also a stand for one or two large wine jars and an adjoining pantry with hundreds of drinking cups. Very likely visitors waiting on the bench for an audience in the throne room were offered refreshment while they waited.

On the same side of the building were five pantries containing a vast stock of household pottery—more than 6,500 vessels of many shapes had been arranged in neat and orderly array on wooden shelves. One of these pantries was devoted exclusively to high-stemmed drinking cups, shaped somewhat like a champagne glass. We counted 2,853 stems. Nestor's palace has yielded by far the largest collection of crockery and china yet found in any Mycenaean residence.

Other storerooms in the palace were crowded with jars, large and small, for wine and olive oil: the latter commodity obviously was a measure of wealth as well as a part of the daily diet.

Although the upper story of the palace collapsed in the fire, we have evidence of its contents in some burned rubbish found where it had fallen in the lower rooms. There are innumerable small fragments of ivory, many bearing traces of beautifully carved decoration: these evidently are the remains of combs, mirror cases, toilet boxes and the like from the quarters of the ladies of the palace.

On the ground floor we found a bathroom complete with its simple fittings: a decorated terra-cotta tub set on a clay base, with a step to facilitate getting into the bath; a high stuccoed stand of clay with two large earthenware jars, probably for holding water; and a hole for draining the floor. The tub itself had no outlet: apparently it had to be emptied with a bailing vessel and a swab. Lying on the floor of the tub was a wine cup, and we found other goblets of the same kind in the big jars. Possibly bathers were in the habit of sipping wine with their bath, but more likely these cups were used for olive oil or water.

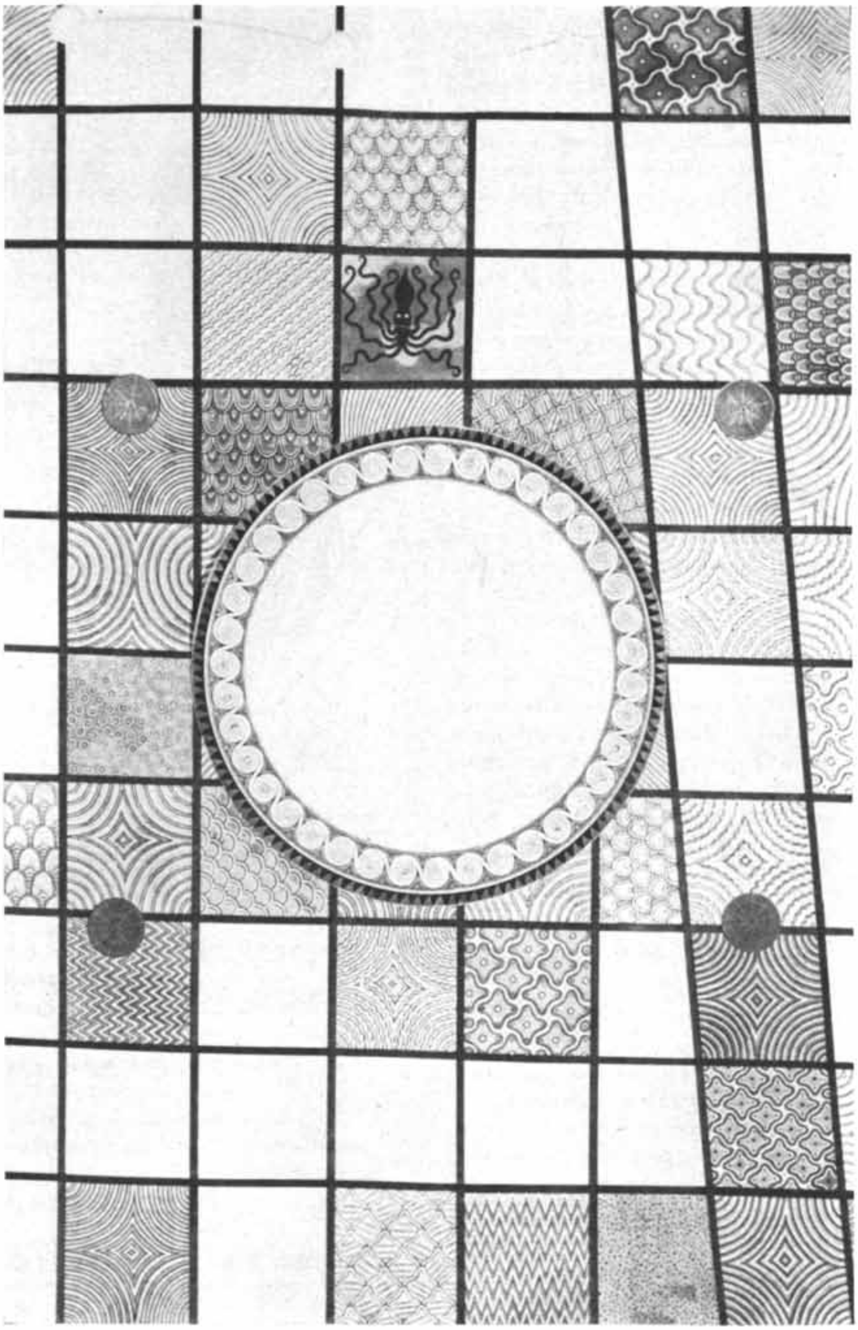
It is tempting to imagine that this may have been the very room in which Telemachus was given his bath by Polycasta—a ceremony from which, when he had been washed, rubbed down, anointed with oil and clothed in a fine tunic and cloak, Telemachus emerged, as Homer phrased it, looking like one of the immortal gods.

The queen's state apartments, as I have mentioned, seem to have occupied a corner of the palace's main building. Here is a large reception hall, about 20 by 23 feet, with a raised hearth in the center, decorated in painted patterns. The floor was no doubt adorned with checkerboard paintings as in the throne room, but all details were burned out by the fire. There are, however, remains of the wall frescoes, representing zoological scenes which include griffins, lions, panthers or possibly savage hounds.

From her reception hall the queen could step out into a private walled court. A corridor also led to an elegant little room, perhaps a boudoir, with a stucco floor delicately painted in abstract or realistic representations of octopuses, dolphins and other fishes. Another small room in her suite, also gaily decorated, looks like a "powder room." On the floor stood at least a dozen narrow-necked jars, probably for washing hands, and there seems to have been a primitive water-closet—a stone slab pierced by a round aperture to a stone-lined underground drain.

We need not linger long over the two wings off the central structure of the palace. The wing on the southwestern side is older than the main building and seems to have been the original palace. A spacious forehall in this wing gave onto another hall through a doorway in its left-hand wall—very different from the straight-line approach through a series of chambers to the throne room that appears in the later Mycenaean plan. Here there were but two chambers: the large entrance hall, with three wooden columns, a stucco floor and frescoed walls, and the throne room itself, which seems to have had four columns and a central hearth but is too poorly preserved to give us much basis for reconstruction.

Behind the two halls of this wing were many smaller rooms, approached by corridors and passages. One diminutive chamber contained several hundred coarse cooking pots; other rooms evidently were storerooms, and one may have been a bath. There was at least one stairway, showing the existence of an upper story, no doubt given over to domestic and sleeping quarters. We can



PAINTED STUCCO FLOOR of the throne room is partly reconstructed. Above the central hearth is an octopus, a motif which figures prominently in the decoration of the palace.

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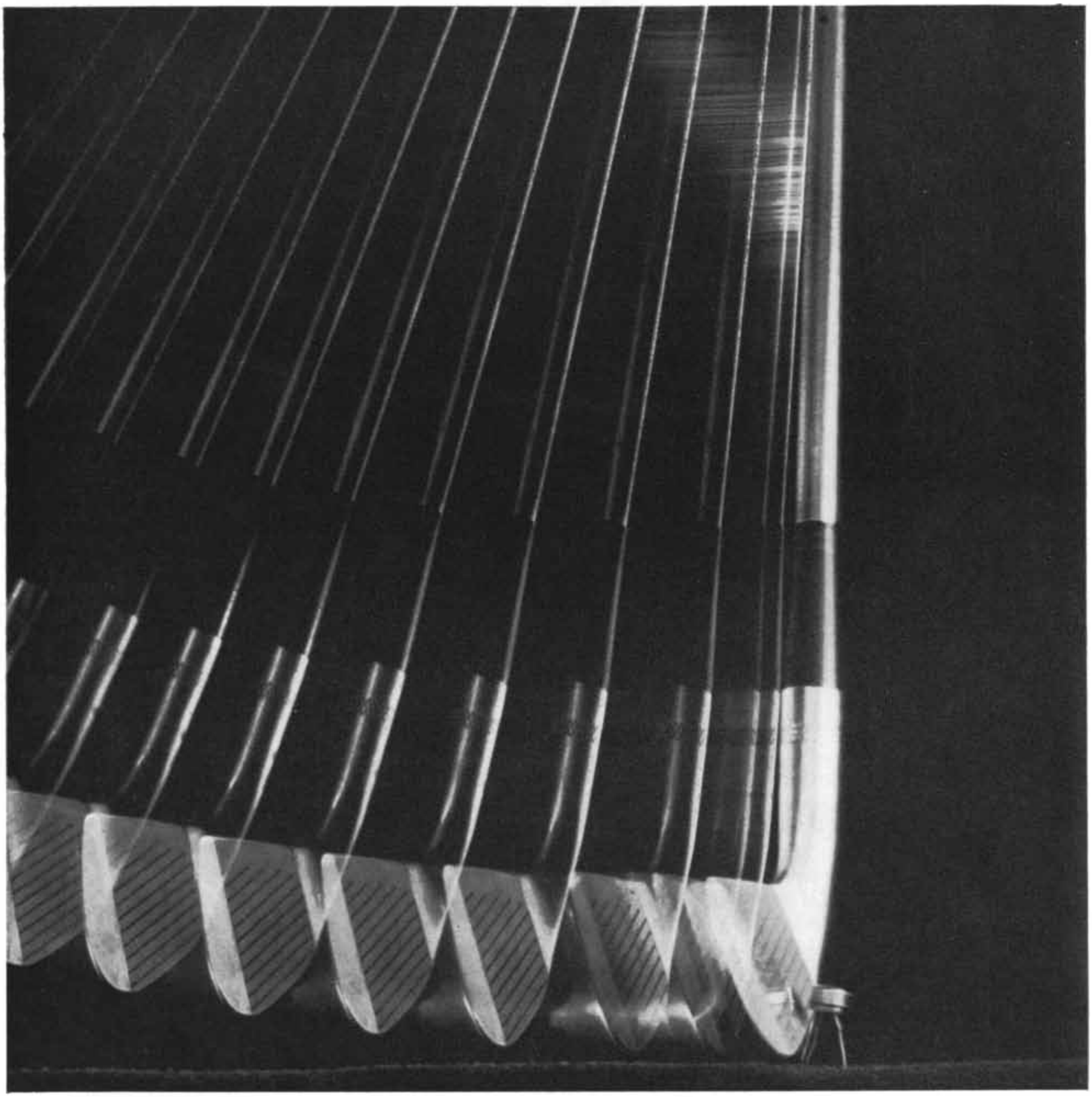

Tee off on a General Electric transistor and it continues to work perfectly!

General Electric transistors have been hit by golf clubs and fired from shotguns. They worked afterwards.

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GENERAL ELECTRIC

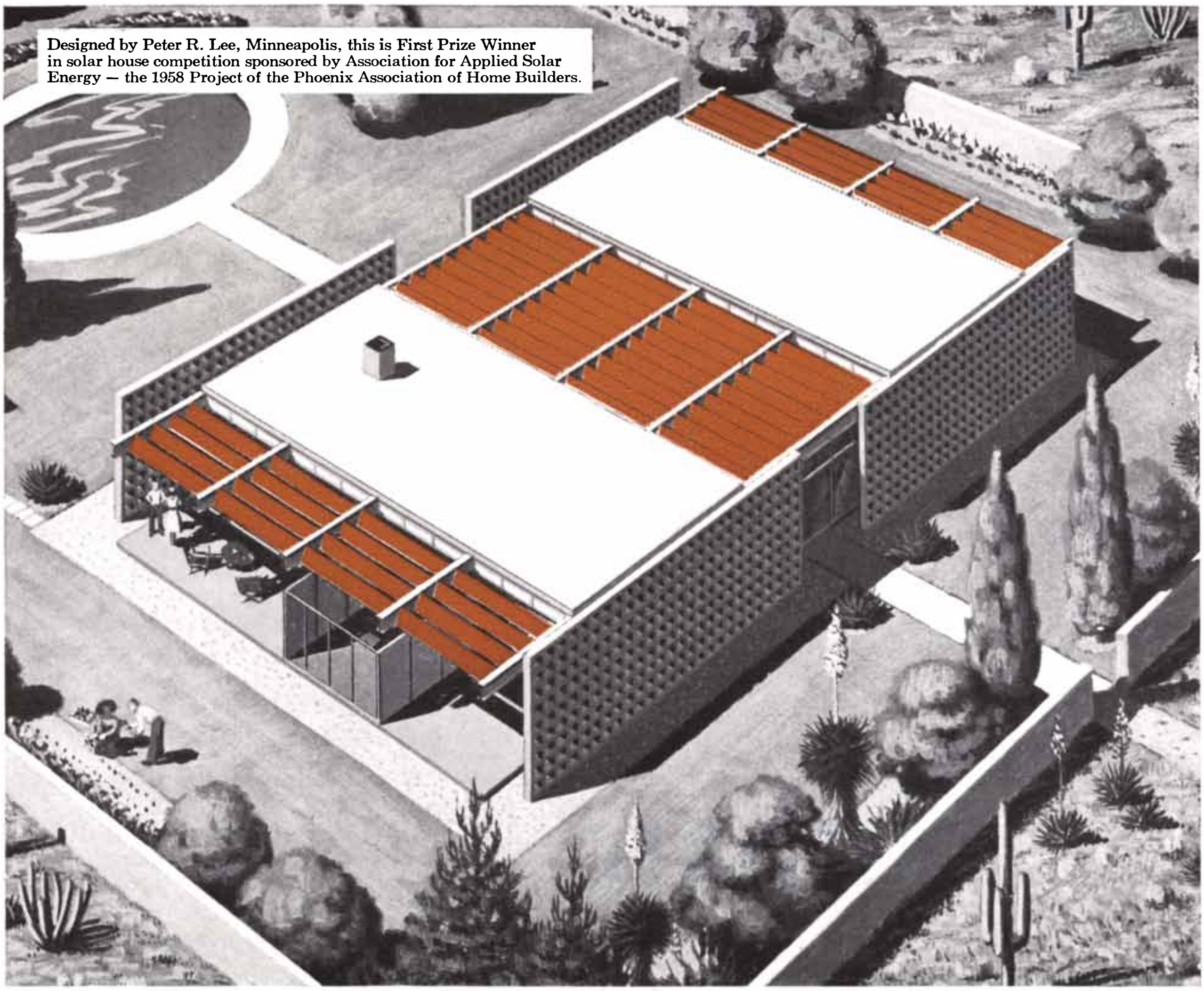
"LINEAR B" TABLET found in a pantry enumerates bathtubs and other vessels. In the Pylos archives are the first examples of Linear B writing found on the mainland of Greece.

plausibly conjecture that after the later central structure was built this older wing may have served as the residence either of a dowager queen or of the crown prince and his family.

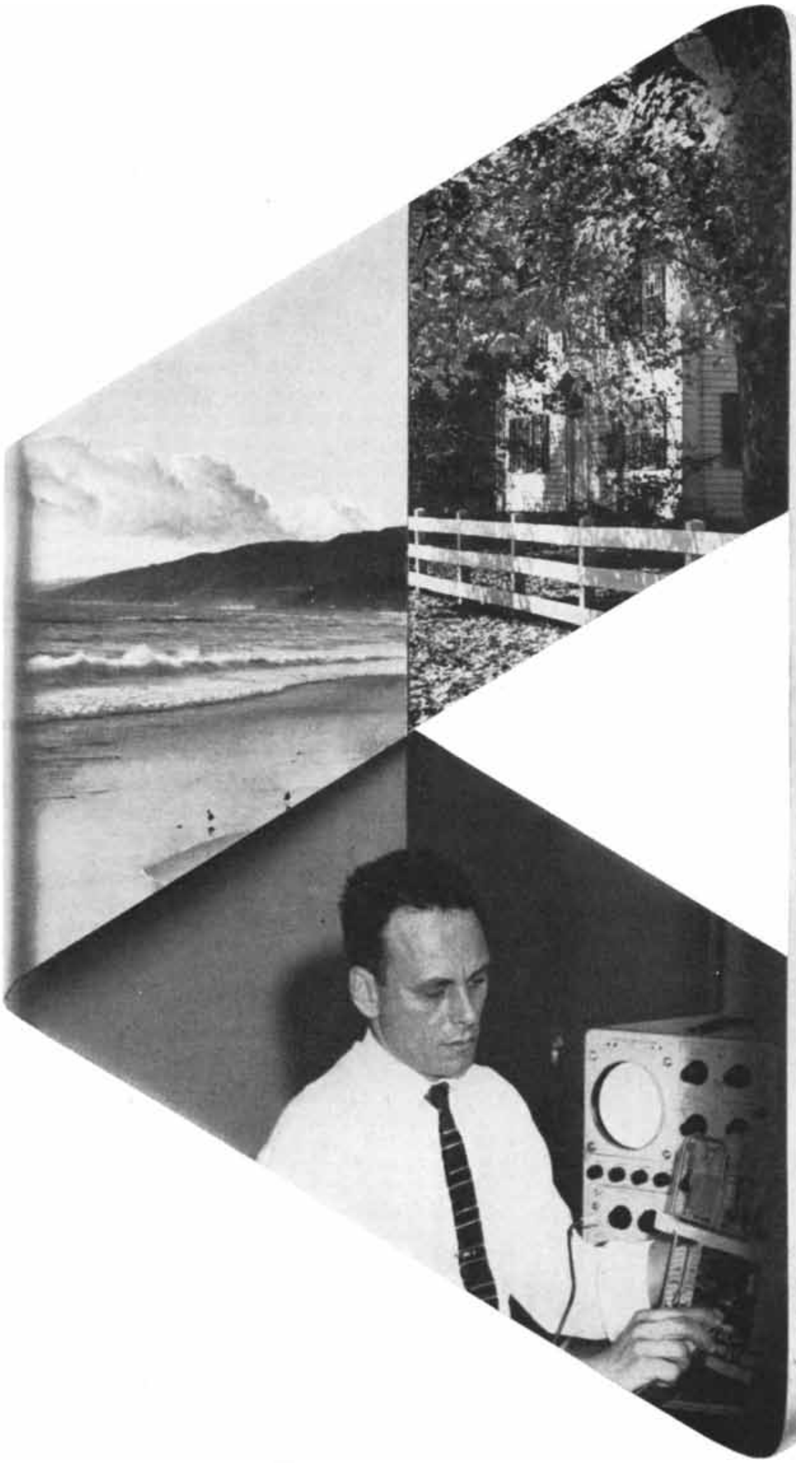
The other wing, off the northeast side of the main building, was quite different. It seems to have been the administrative department of the palace, perhaps also the headquarters of the palace guard and its armory. The building was about 106 feet long, 52 feet wide and contained about seven rooms. It had a small open court with a stone altar and what may have been a small stepped shrine facing the altar. A broad corridor led from this court to the several rooms. Their floors were merely trodden earth; the walls, crude brick. The building probably had no upper story. We found its rooms strewn with crushed pots and many arrowheads, of flint and of thin bronze. More exciting were some 56 inscribed clay tablets and a large number of lumps of clay bearing impressions of official seals, which the fire had fortunately preserved for us by baking the clay hard.

No inscriptions specifically identifying the palace as King Nestor's were found anywhere in the buildings. But there can be no serious doubt that this was actually the home of the Homeric king who, along with Agamemnon, largely outfitted the Greek expedition against Troy. In size, splendor, sophistication of design and evidence of wealth and political power this palace is equal to those at Mycenae and Tiryns. Its date—the 13th century B.C.—also places it at the time of the celebrated Trojan expedition, conducted by a coalition of kings and princes of this region in Greece. The ancient Greek stories mention only one royal family in southwestern Peloponnesus that was rich enough and had the military force to maintain a capital on the scale of our palace. That was the family whose greatest scion was Nestor, "ruler over nine cities." Nestor, according to the *Iliad*, fitted out 90 ships with crew and equipment for the Trojan enterprise. He ruled over Pylos for three generations. Greek tradition says that he was followed on the throne in turn by a son and a grandson, and that the palace was finally sacked and burned by Dorian invaders. We are convinced that the palace we have now dug out can be none other than the residence of old King Nestor.

MAN'S HEAD, made of gold and niello (a black alloy) once decorated the side of a silver cup found in the palace gateway.



Designed by Peter R. Lee, Minneapolis, this is First Prize Winner in solar house competition sponsored by Association for Applied Solar Energy — the 1958 Project of the Phoenix Association of Home Builders.



MATHEMATICAL GAMES

About tetraflexagons and tetraflexigation

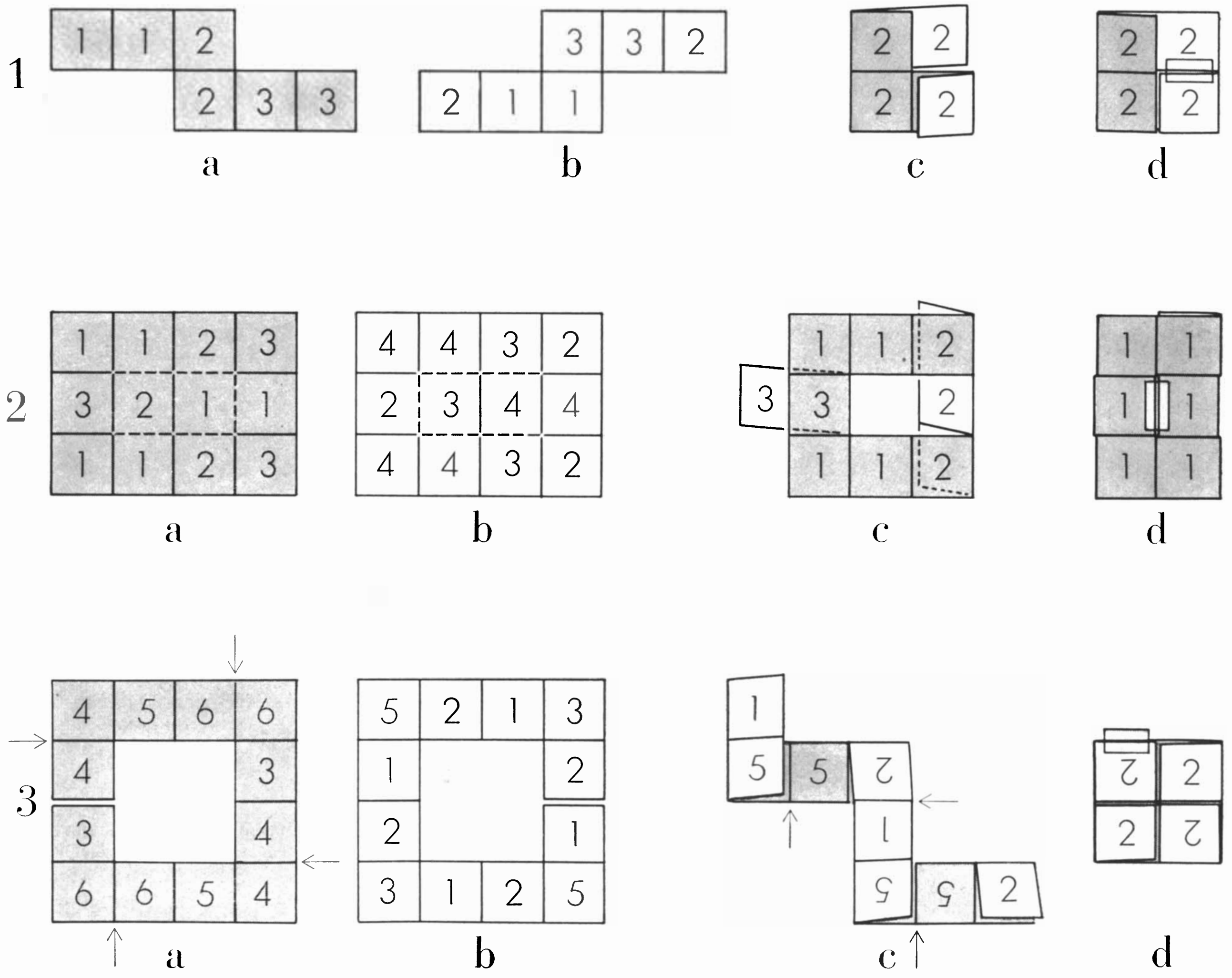
by Martin Gardner

Hexaflexagons are diverting six-sided paper structures that can be "flexed" to bring different surfaces into view. They are constructed by folding a strip of paper as explained in this department for December, 1956. Close cousins to the hexaflexagons are a wide variety of four-sided structures which may be grouped loosely under the term tetraflexagon.

Hexaflexagons were invented in 1939 by Arthur H. Stone, then a graduate student at Princeton University and now a lecturer in mathematics at the University of Manchester in England. Their properties have been thoroughly investigated; indeed, a complete mathematical theory of hexaflexigation has been developed. Much less is known about tetraflexagons. Stone and his friends (notably John W. Tukey, now a well-known topologist) spent considerable time folding and analyzing these four-sided forms, but did not succeed in developing a comprehensive theory that would cover their discordant variations. Several species of tetraflexagon are nonetheless intensely interesting from the recreational standpoint.

Consider first the simplest tetraflexagon, a three-faced structure which can be called the tri-tetraflexagon. It is easily folded from the strip of paper shown below (1a is the front of the strip; 1b, the back). Number the small squares on each side of the strip as indicated, fold both ends inward (1c) and join two edges with a piece of transparent tape (1d). Face 2 is now in front; face 1 is in back. To flex the structure, fold it back along the vertical center-line of face 2. Face 1 will fold into the flexagon's interior as face 3 flexes into view.

Stone and his friends were not the first to discover this interesting structure;



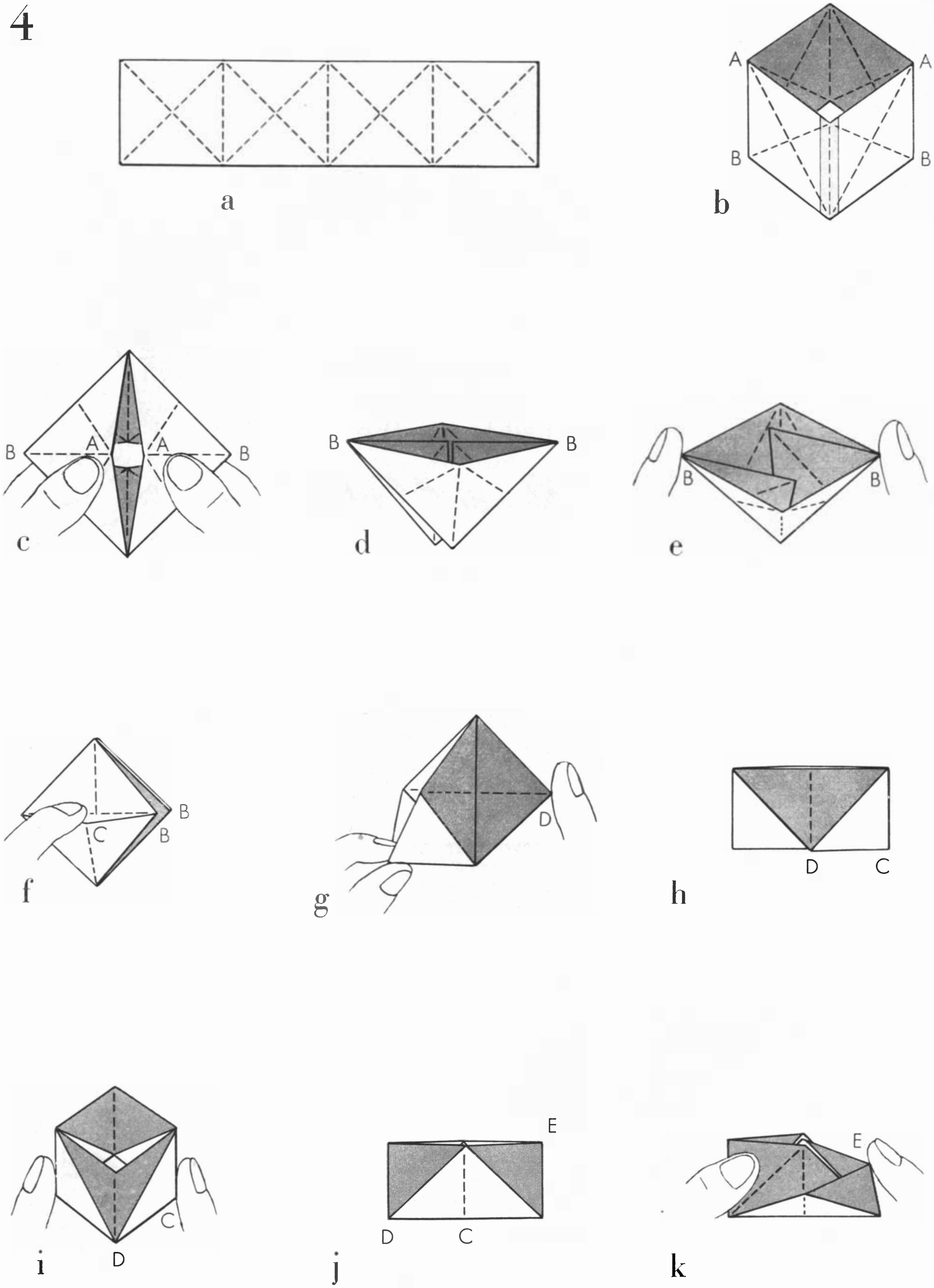
How to make a tri-tetraflexagon (1), *a tetra-tetraflexagon* (2) *and a hexa-tetraflexagon* (3) it has been used for centuries as a double-action hinge. I have on my desk, for instance, two small picture-frames containing photographs. The frames are joined by two tri-tetraflexagon hinges which permit the frames to flex forward or backward with equal ease.

The same structure is involved in several children's toys, the most familiar of which is a chain of flat wooden or plastic blocks hinged together with crossed tapes. If the toy is manipulated properly, one block seems to tumble down the chain from top to bottom. Actually this is an optical illusion created by the flexing of the tri-tetraflexagon hinges in serial order. The toy was popular in the U. S. during the 1890s, when it was called Jacob's Ladder. Two current models sell under the trade names of Klik-Klak Blox and Flip Flop Blocks.

There are at least six types of four-faced tetraflexagons, known as tetra-tetraflexagons. One of them has often been used as an advertising novelty because the difficulty of finding the fourth face makes it a pleasant puzzle. A good way to make a tetra-tetraflexagon is to start with a rectangular piece of thin cardboard ruled into 12 squares. Number the squares on both sides as depicted on the opposite page (2a and 2b). Cut the rectangle along the broken lines. Start as shown in 2a, then fold the two center squares back and to the left. Fold back the column on the extreme right. The cardboard should now appear as shown in 2c. Again fold back the column on the right. The single square projecting on the left is now folded forward and to the right. This brings all six of the "1" squares to the front. Fasten together the edges of the two middle squares with a piece of transparent tape as shown in 2d.

You will find it a simple matter to flex faces 1, 2 and 3 into view, but finding face 4 may take a bit more doing. Naturally you must not tear the cardboard. Higher-order tetra-tetraflexagons with an even number of faces can be constructed from similar rectangular starting patterns; tetra-tetraflexagons with an odd number of faces call for patterns analogous to the one used for the tri-tetraflexagon. Actually two rows of small squares are sufficient to make a tetra-tetraflexagon, but adding one or more additional rows (which does not change the essential structure) makes the model easier to manipulate.

Another variety of tetraflexagon, and one which has the unusual property of flexing along either of two axes at right angles to each other, can also be made with four or more faces. The construc-



How to make and flex the tetraflexatube tion of a hexa-tetraflexagon of this type is depicted on page 122. Begin with the square-shaped strip shown in 3a (front) and 3b (back). Its small squares should be numbered as indicated. Crease along each internal line in 3a so that each line is the trough of a valley, flatten the strip again, then fold on the four lines marked with arrows. All folds are made to conform with the way the lines were originally creased. The strip now looks like 3c. Fold on the three lines marked with arrows to form a square flexagon. Overlap the ends so that all the "2" squares are uppermost (3d). Attach a piece of transparent tape to the edge of the square at upper left, then bend it back to overlap the edge of a "1" square on the opposite side.

The hexa-tetraflexagon can now be flexed along both vertical and horizontal axes to expose all six of its faces. Larger square strips will yield flexagons whose number of faces increases by fours: 10, 14, 18, 22 and so on. For tetraflexagons of different orders, strips of other shapes must be used.

It was while Stone was working on right-triangle forms of flexagons ("for which, perhaps mercifully," he writes in a letter, "we invented no name") that he hit upon a most remarkable puzzle—the tetraflexatube. He had constructed a flat, square-shaped flexagon, which to his surprise opened into a tube. Further experimentation revealed that the tube could be turned completely inside out by a complicated series of flexes along the boundaries of the right triangles.

The flexatube is made from a strip of four squares [*see drawings on opposite page*], each of which is ruled into four right triangles. Crease back and forth along all the lines, then tape the ends together to form the cubical tube. The puzzle is to turn the tube inside out by folding only on the creased lines. A more durable version can be made by gluing 16 triangles of thin metal or cardboard onto cloth tape, allowing space between the triangles for flexing. It is useful to color only one side of the triangles, so that you can see at all times just what sort of progress you are making toward reversing the tube.

One method of solving this fascinating puzzle is illustrated in drawings 4b through 4k. Push the two A corners together, flattening the cube to the square flexagon of drawing 4c. Fold this forward along the axis BB to form the triangle of drawing 4d. The two B corners are now pushed together to make a flat square, but make sure that the two inside flaps go in opposite directions (4e). Open the square as in drawing 4f; then pull corner C down and to the left to make the flat structure shown in drawing 4g. Corner D is now pushed to the left, behind the structure, creating the flat rectangle of drawing 4h. This rectangle opens to form a cubical tube (4i) that is half the height of the original one.

You are now at the mid-point of your operations; exactly half the tube has been reversed. Flatten the tube to make a rectangle again (4j), but flatten it in the opposite way from the way shown in drawing 4h. Starting as shown in drawing 4k, the previous operations are now "undone," so to speak, by making them in reverse. Result: a reversed flexatube. At least two other completely different methods of turning the flexatube inside out are known, and both are as devious and difficult to discover as this one.

Recently Stone has been able to prove that a cylindrical band of *any* width can be turned inside out by a finite number of folds along straight lines, but the general method is much too involved to describe here. The question arises: Can a paper bag (that is, a rectangular tube closed on the bottom) be turned inside out by a finite number of folds? This is an unsolved problem. Apparently the answer is no, regardless of the bag's proportions, though it would probably be extremely difficult to find a satisfactory proof.

The answer to Ben Ames Williams's coconut problem posed here last month is 3,121. On the first five divisions into fifths there is an extra coconut for the monkey. Following the reasoning given last month, the smallest number of coconuts that will permit these five steps is 5^5-4, or 3,121. After the last operation there will be 255 coconuts left. Because this is evenly divisible by five, with no coconut for the monkey, 3,121 is the answer.

The general solution of the problem requires two Diophantine equations. If the number of sailors is odd, the original number of coconuts equals $(1+nc)n^n-(n-1)$, where n is the number of men and c is any integer including zero. If the number of sailors is even, the formula is $(n-1+nc)n^n-(n-1)$.

The answer to the simpler problem of three sailors, at the close of last month's department, is 15 coconuts.

The two Tac Tix problems, also presented last month, are solved as follows. In the first problem the only winning play is to remove counters 9, 10, 11, 12. The second problem has two winning moves: counters 9 or 10.

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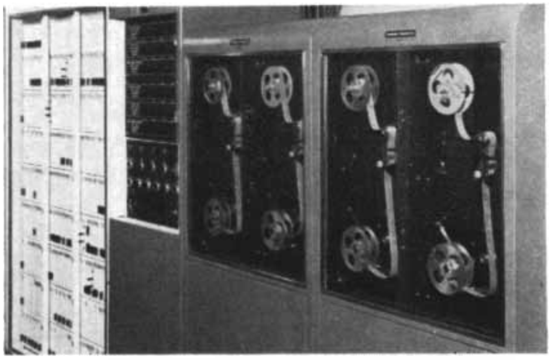
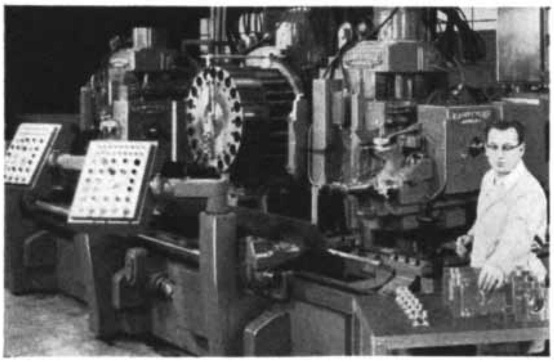


The punched tape is then inserted in electronic "readers" that feed the information into control cabinets, automatically converting it into instructions for the machines.



Shown here is a line of milling, drilling and boring machines (Kearney & Trecker) automated by HUGHES controls. Several different parts can be handled by a line at the same time.

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THE AMATEUR SCIENTIST

A refracting telescope in which the main lens consists of only one piece of glass

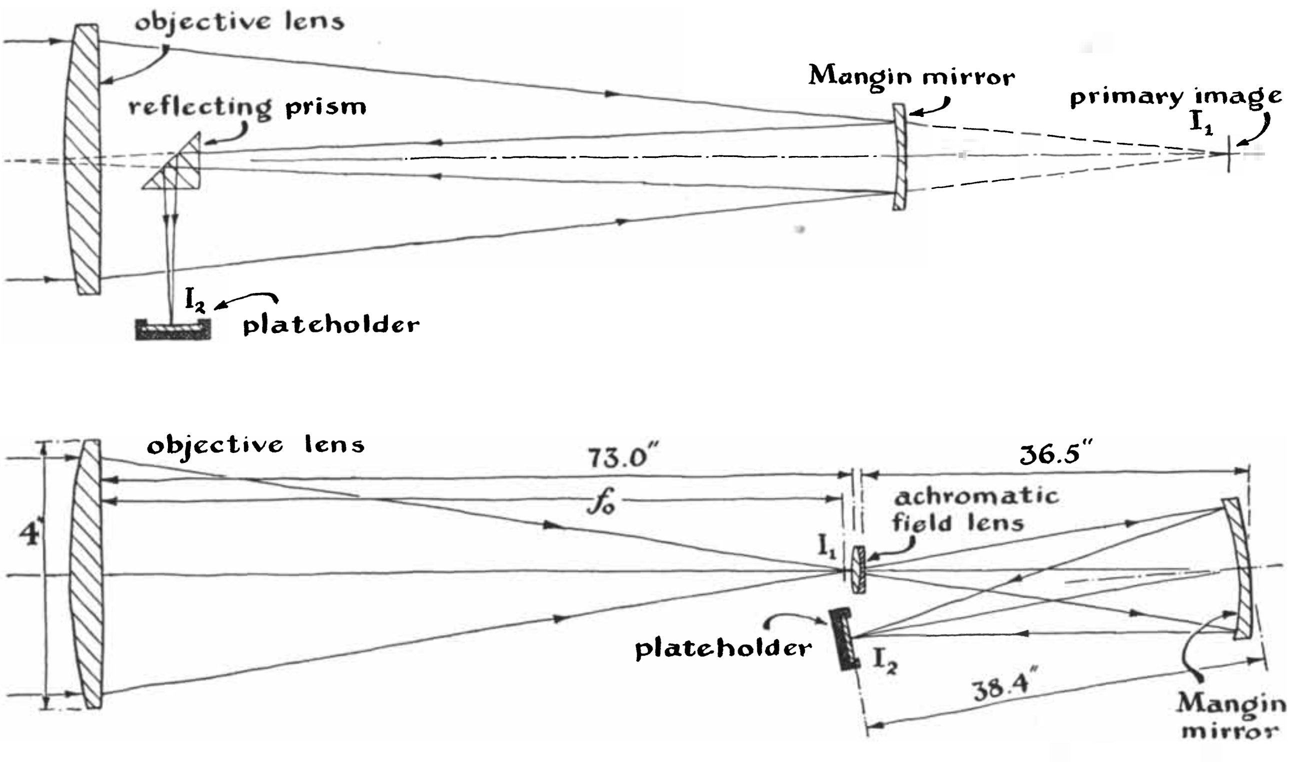
Conducted by C. L. Stong

Familiar optical devices such as eyeglasses and binoculars form an image by refracting light with glass lenses. Yet when an amateur makes a telescope its main optical element is almost always a mirror. Why? Primarily because in making the mirror of a reflecting telescope the amateur need grind and polish only one optical surface. If a refracting telescope is to bring images in various colors to even roughly the same focus, its objective lens must ordinarily consist of two pieces of glass. Thus the maker of a refractor objective must grind and polish four surfaces. To make matters worse, the edges of both lens elements must be ground and fitted to a precisely machined cell so that their curves are centered on the optical axis of the telescope.

J. H. Rush of Boulder, Col., suggests an easier way to make a refractor: a remarkable design which, although it is completely corrected for color, has an objective lens consisting of only one piece of glass!

Rush writes: "Chromatic aberration has plagued the designers of refracting telescopes from the time of Galileo down to the present. This defect causes images to be blurred by overlapping colors and to be surrounded by colored halos. Yet a truly achromatic (color-free) refractor design has been available since 1899. In that year a German optical worker named L. Schupmann published a small book on what he called 'medial' telescopes. His work was curiously neglected. Lately it has been rediscovered and adapted to modern telescope designs by James G. Baker of the Harvard College Observatory, to whom I am indebted for much of my information on the Schupmann system.

"A brief review of the evolution of refractors may focus some light on the advantages and disadvantages of the Schupmann telescope. Isaac Newton decided (on the basis of inadequate experiments) that 'all refracting substances diverge the prismatic colors in a constant proportion to their mean refraction'; that is, the focal lengths of a lens for two particular wavelengths of light must always be in the same ratio, regardless of what kind of glass the lens is made of. This conclusion was in error, but it led Newton to decide that a color-compensating lens was impossible because any two pieces of glass that could cancel the dispersion of colors would also can-

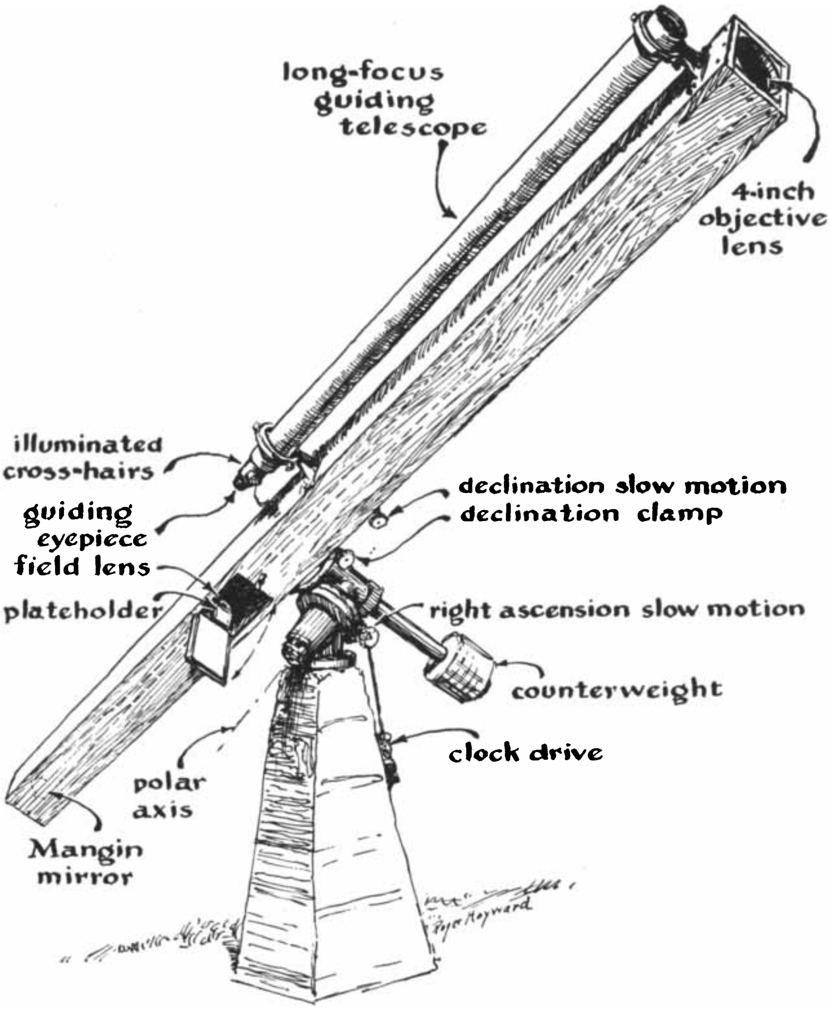


The optical path in the two kinds of Schupmann telescope: the brachyt (top) *and the medial* (bottom) cel the desired refracting power. He turned his attention to reflectors, and his great reputation discouraged others from challenging his conclusions.

"About 1730 Chester M. Hall of England disputed Newton's authority and produced the first achromatic lenses. It is interesting to note that Hall was encouraged in this undertaking by his observation that the various 'humours' in the eye produce an achromatic image. He concluded that a combination of different glasses should also do so. His observation was just as erroneous as Newton's (the eye is not achromatic), but Hall's error was optimistic and led to a notable advance in optics.

"Hall did not do much with his invention, but a few years later John Dollond independently invented the achromat and promoted it so energetically that it revolutionized telescope design. Achromatic lenses take advantage of the differing optical properties of various kinds of glass. A converging (positive) lens, usually of crown glass, is combined with a diverging (negative) lens, usually of flint glass. Because the dispersion of the flint glass (its power to bend light of one color more than another) is greater than that of the crown glass, the flint element can be designed to reverse and cancel the color dispersion of the crown element without entirely canceling its mean refractive power [*see drawing at top of next page*]. The resulting 'achromatic doublet' is commonly used as a telescope objective, and the same principle is of course applied in more complex lens systems.

"Unfortunately the doublet does not give perfect color correction. Color dispersion by glass or other substances is irrational. That is, the refraction for different colors is not proportional to their wavelength. Hence when refraction is plotted against wavelength, the resulting curves for different glasses do not have the same shape. A doublet can be designed to bring two chosen wavelengths to a focus at exactly the same distance from the lens; intermediate wavelengths fall a bit short, and those beyond the corrected region deviate seriously from the common focus. This 'secondary spectrum' is quite troublesome in a large instrument. The 40-inch achromat at the Yerkes Observatory, for example, focuses the yellow-green about a centimeter nearer the lens than the red and blue for which it is corrected. If three different kinds of glass are combined, three wavelengths can be brought to a common focus. Such a lens is called an apochromat. It gives a much better color correction than does the achromat, but is costly and suffers from other disadvantages.



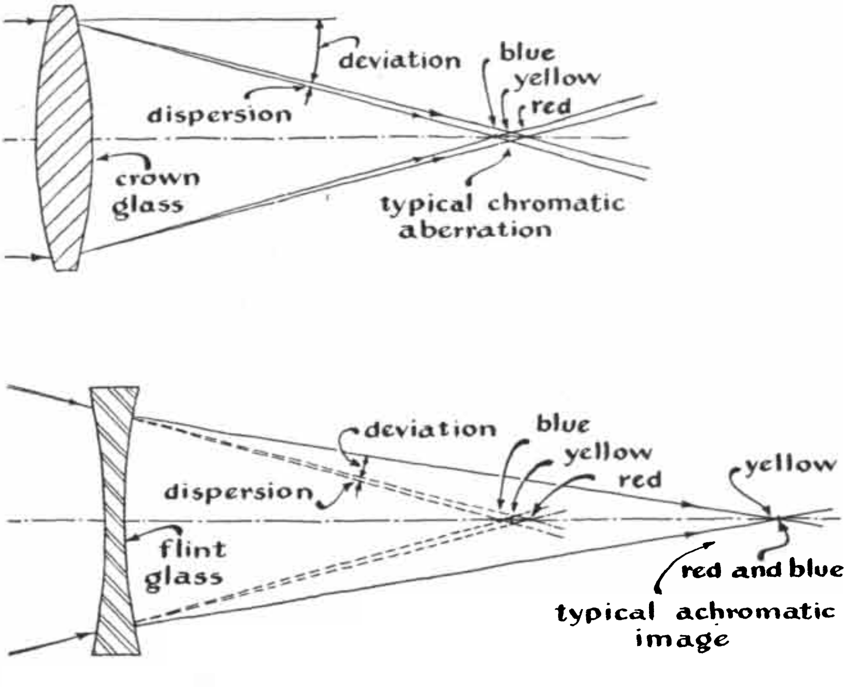
Suggested mounting for a Schupmann refracting telescope

"In complex lens systems an additional defect called lateral color usually appears. Such a system may focus all wavelengths of interest at practically the same distance from the last lens element. Yet the images in different colors may be of different sizes, so that they do not coincide except on the optical axis of the telescope. The result is an overlapping color effect similar to that produced by the more familiar longitudinal color just discussed.

"At this point one may ask: Why bother with refractors at all? Mirrors are entirely free of chromatic aberration, since the simple law of reflection holds for all wavelengths. The answer is mainly that a mirror system usually wastes more light than a good achromatic objective (a minor objection), and that, usually having only one figured surface, the mirror does not permit adequate control of other aberrations.

"The ideal mirror shape for focusing parallel rays, with which we are concerned in an astronomical objective, is the paraboloid. Its spherical aberration is zero. All light coming into such a mirror parallel to its axis is reflected (within the limitations due to the wave properties of light) to a single focal point on the axis. So far, so good. But parallel rays coming in at an angle to the axis, such as the light from a star that is not centered in the field, do *not* converge to a common focus—as any telescope-making enthusiast is painfully aware. The image is distorted by two types of aberration: astigmatism and coma. In the case of astigmatism, an object point off the optical axis is imaged as two lines at different focal distances and perpendicular to each other. The effects of coma, on the other hand, resemble those of spherical aberration. But instead of a point-source coming to focus as a circular patch of light in the plane of the image, as in spherical aberration, coma results in a comet-shaped patch. Moreover, the image field is a curved surface.

"There is nothing you can do about these defects. You have already deter-



The positive and negative elements of an achromat produce opposite color dispersion

mined the shape of the mirror, making it a paraboloid to eliminate spherical aberration; and you have determined its scale, to obtain the desired focal length. You can do nothing more with a single surface. Of course, in the case of compound reflecting telescopes, the experts do some tricks with secondary mirror surfaces and sometimes with special correcting lenses, but most amateurs leave these strictly alone.

"In a simple lens the index of refraction of the glass and the *difference* in the curvature of the two surfaces determine the focal length. By 'bending' the lens—keeping this difference constant while changing both radii of curvature—the designer can eliminate all coma and nearly all spherical aberration. Of course the designer still has to live with astigmatism, chromatic aberration and curvature of the field. In designing a doublet, he computes powers for the two elements that will give the desired focal length and color correction. Then, by suitably bending both elements independently, he eliminates both coma and spherical aberration. The perfection of these corrections depends very much on some subtle wisdom in the choice of glasses, which the designer usually attains by surviving his previous efforts.

"Here, then, is the principal advantage of the refractor. A doublet or triplet lens affords the designer degrees of freedom enough to correct the most troublesome aberrations independently. However, astigmatism remains a problem. It is an obstacle to good definition over wide fields, and usually limits an astronomical refractor to a very small area of the sky. But a reflector is even more sharply limited by astigmatism and coma.

"About 1930 Bernhard Schmidt of Germany came up with an excellent solution to these limitations with his now-famous lens-and-mirror combination. His instrument is especially advantageous for fast photography of wide angular fields at low magnification. Its peculiarly curved lens, or 'correcting plate,' is an obstacle to any but the most skilled opticians, but modified designs using spherical lens-surfaces have eliminated even that difficulty for some purposes. Yet the Schmidt is not a substitute for the long-focus refractor, so useful for astronomical observations that require a relatively large image. A Schmidt telescope is twice as long as a simple reflector or refractor of the same focal length.

"Schupmann described two types of unconventional telescopes: the brachymedial (or brachyt) and the medial. The brachyt is not capable of correcting chromatic aberration completely. For that reason I have not investigated its possibilities in detail. It has the great advantage of compactness and might be capable of acceptable performance over a limited field and spectral range, if carefully designed. The optical path of the brachyt is depicted in the accompanying drawing [*page 130*].

"Schupmann's other design, the medial, is something else again. It is capa-

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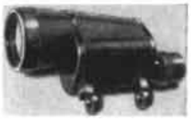

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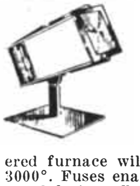

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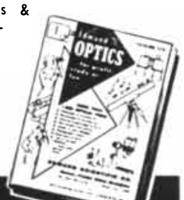

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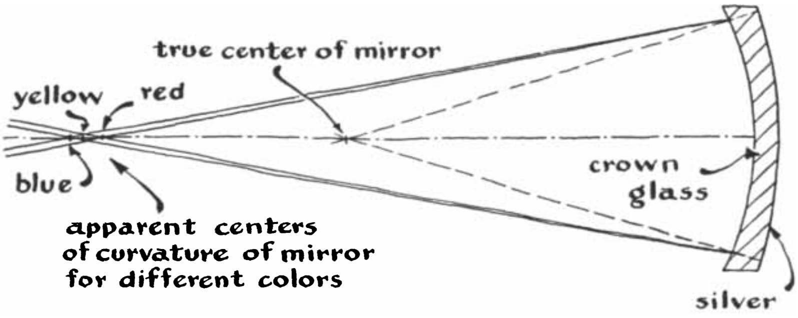

A Mangin mirror of crown glass performs like a negative lens of flint glass

ble of practically perfect correction of chromatic aberration over the full photographic spectral range. The medial, like the Schmidt system, uses both lenses and a mirror, but it is mainly a lens instrument and even in its simplest form it need not be much longer than the equivalent simple refractor. The objective is a simple lens of a good telescopic-quality crown glass, such as borosilicate crown No. 2 (BSC-2) or Schott boronkron No. 7 (BK-7). It is designed to have the desired focal length for some intermediate wavelength and is bent for zero coma.

"The mirror of the Schupmann telescope is called a Mangin mirror. It is simply a negative lens whose convex back surface is aluminized [*see drawing on this page*]. It is made of the same glass—preferably the same melt—as the objective.

"The secret of the medial's performance is found in the field lens. Its function is to image the objective onto the Mangin mirror. Optically the effect is to superimpose the objective and the Mangin so that their combined dispersive power is that of a flat plate. The Mangin is bent so that its surface contributes enough positive power to form the final image.

"You can easily see how the medial tends to correct chromatic aberration. Since the lens power of the Mangin is negative, the focal length of the Mangin is greater for blue than for red light. But the primary image formed by the objective in blue light is nearer the objective and thus farther from the Mangin than the red image. Consequently the final image in both wavelengths will tend to fall at or near the same distance from the Mangin, because the difference in object distance is offset by the difference in focal lengths of the Mangin for blue and for red light. Detailed calculation shows, however, that this correction cannot be exact for more than two wavelengths unless a field lens is used to image the objective onto the Mangin.

"If the field lens were perfectly achromatic, the Mangin could be designed to form final images of the same size and at the same distance from the Mangin in all wavelengths. Practically, the field lens cannot be perfectly achromatic, and its secondary spectrum produces a slight amount of lateral color in the final image. Even a simple, single-element field lens will reduce the secondary spectrum in the final image to a small fraction of that produced by an achromatic doublet objective of equivalent power. A good crown-flint field lens, designed for the image and object distances at which it is to be used, contributes an entirely negligible residue of chromatic aberration over the spectral range and image fields ordinarily used.

"To sum up: The medial telescope uses a negative lens to cancel the dispersion of a positive objective of the same glass, and then interposes a concave mirror to intercept the light that has been so treated and focus it as the final image. Why bother? Why not forget the lenses and just use a mirror in the first place? The complication is justified by the superior optical corrections that can be made in the medial telescope. The medial telescope has several advantages, in addition to freedom from color, over the ordinary refractor. Its spectral range is not limited by the absorption in flint glass because other materials can be substituted—even in the field lens. The surfaces of the objective are less sharply curved than those of the equivalent achromat, so that residual aberrations are reduced and the mechanical strength of the lens is improved. The positive and negative powers of the objective and Mangin result in a nearly flat image-field.

"A unique advantage of the Schupmann medial is its adaptability to the Lyot solar coronagraph. The essential features of this instrument are: a simple objective to minimize scattering of white light into the system, a metal disk to eclipse the bright solar disk at the pri-

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For centuries men have tried to develop new and more powerful weapons to achieve victory in war.

Lately these have been weapons of unprecedented power.

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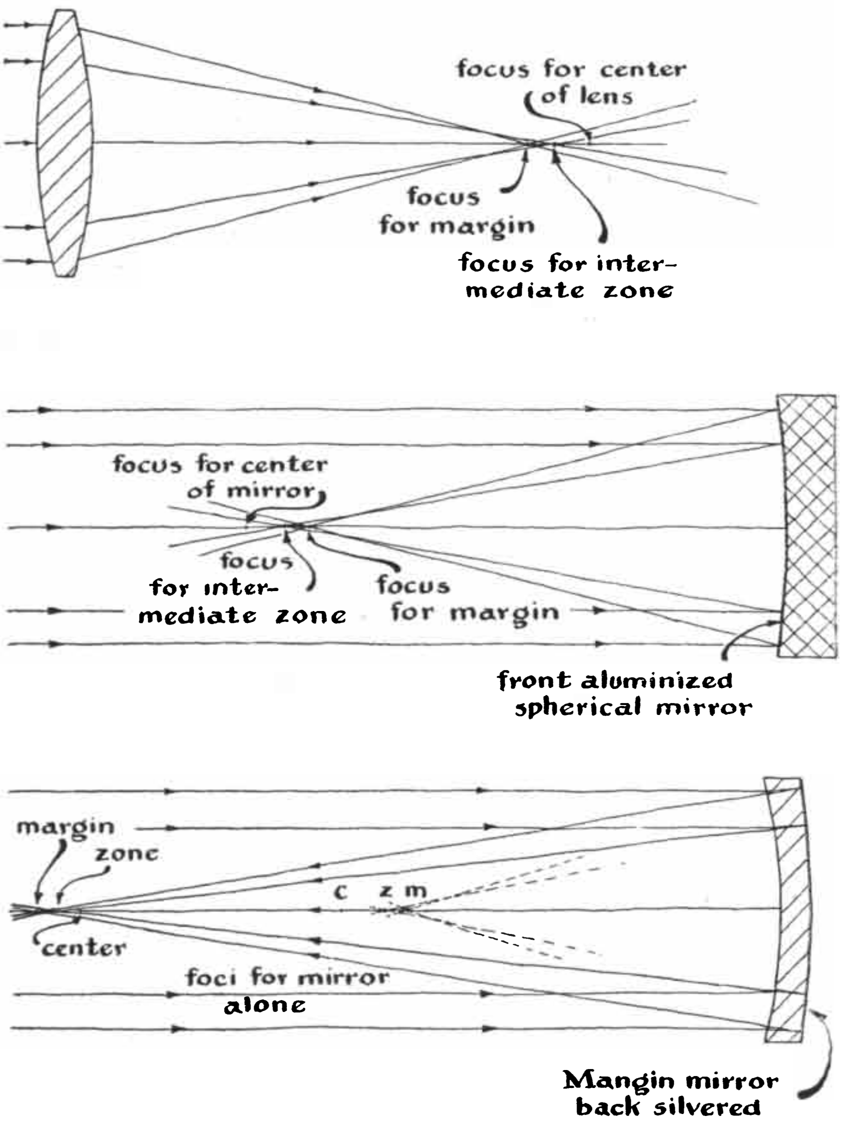
mary image, and a field lens and diaphragms to eliminate white light introduced by diffraction and reflection at the objective. To meet these conditions most coronagraphs have suffered the disadvantages of chromatic images; the medial offers an ideal way to get a color-free image without interfering with the essential optics of the coronagraph.

"Coma causes no trouble, because it is eliminated in the objective by a suitable choice of radii, and in the Mangin by making the image and object distances equal for a mean wavelength. Two difficulties arise, however. Since the shape of the Mangin is totally determined by the twin requirements of color correction and mirror power, it is not possible with spherical surfaces to meet these conditions and at the same time shape the Mangin to cancel the spherical aberration of the objective. Probably the best way out of this difficulty is to figure an aspheric surface on the front of the Mangin, departing just enough from a sphere to bring the spherical aberration of the entire system to zero as determined by knife-edge or other test at the final image. This chore is comparable to parabolizing a mirror objective, but is tricky because of the relatively small size of the Mangin. It is possible, of course, to make the corrections on the primary, which is somewhat easier to work because of its size. Or, if you insist on spherical surfaces, you might make the Mangin lens and mirror elements separately, and bend the lens to cancel the spherical aberration (though I have not checked this possibility in detail).

"The Mangin must be tilted so that the reflected beam will clear the field lens and give access to the final image. This tilt introduces additional astigma-



Spherical aberration of a Mangin mirror (bottom) *is the opposite of a simple lens and mirror*

STRAIGHT TALK TO ENGINEERS

from Donald W. Douglas, Jr.

President, Douglas Aircraft Co., Inc.

Here at Douglas we're involved in a greatly accelerated missile and space program. This requires one of the most intensive engineering and research efforts in our history.

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If you're interested in tackling these problems with us... in giving your best in an all-out drive to solve them... we're interested in you!

Please write to Mr. C. C. La Vene
Douglas Aircraft Company, Box 620-N
Santa Monica, California

	OBJECTIVE	MANGIN
MATERIAL	BSC-2	BSC-2
RADIUS (FRONT SURFACE)	40.44 INCHES	–9.2 INCHES
RADIUS (BACK SURFACE)	–440.8 INCHES	18.635 INCHES
THICKNESS (CENTER)	.5 INCHES	.25 INCHES
CLEAR APERTURE	4.0 INCHES	2.0 INCHES

Data for the objective lens and Mangin mirror of a Schupmann telescope

tism into the image. Hence the tilt angle should be held to the absolute minimum. In a large instrument, astigmatism introduced by the tilt is eliminated by figuring a toroidal surface on the back of the Mangin, but it is more practical in a small telescope to cancel the astigmatism by the stratagem of tilting the objective on an axis perpendicular to the tilt axis of the Mangin.

"Two medial systems have been built on modernized plans developed by Dr. Baker at the Harvard College Observatory. Chester Cook of the Boston Amateur Telescope Makers has built an eight-inch; and Richard Dunn and James Gagan have developed a 16-inch. Both of these instruments have given fine results and have confirmed the theory of the color-free medial.

"To indicate what can be done, I have computed the objective and Mangin for a system of aperture $f/18$ at the wavelength of the hydrogen alpha line of the spectrum (6,563 angstrom units). This system is suitable for amateur use. The plans are based on an objective aperture of four inches. They can, of course, be scaled to a larger size, if the proportions among all dimensions are maintained. Data for the objective and the Mangin are given in the accompanying table [*above*].

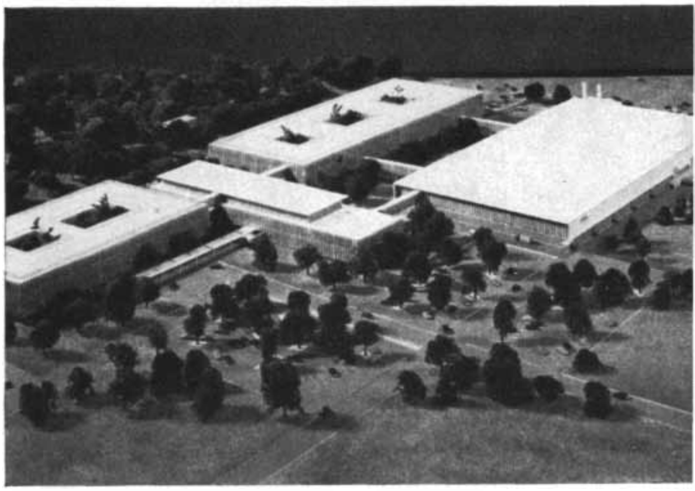
"I have not specified the elements of the field lens because the procedure for designing a doublet is simple. A recommended procedure is given in the paper 'Computation of Achromatic Objectives,' by Robert E. Stephens. This paper is National Bureau of Standards Circular 549 (1954), and may be obtained for 10 cents from the Superintendent of Documents, Washington 25, D. C.

"In the design presented here the final image will be about 38.4 inches from the back of the Mangin. A diagonal eyepiece will be necessary to keep the observer's head out of the optical path. The system will be about 9.5 feet long—awkward, but not impractical, since the elements are light and little more than self-support is required of the tube. The telescope can of course be shortened by folding the optical path with a double mirror or reflecting prism behind the field lens. In addition to compactness, this arrangement has the advantage of locating the eyepiece in the usual position at the rear of the telescope.

"The Schupmann medial principle offers an opportunity to make a telescope of exceptionally fine definition, and making the telescope is not particularly difficult for the advanced amateur. Only one unconventional element is used, and it requires only one aspheric surface—a job no worse than parabolizing an ordinary mirror. I shall be interested in hearing from anyone who decides to try a medial."

Nelson M. Griggs of R. D. No. 2, Old Baltimore Road, Boyds, Md., has announced the formation of a global network of amateur radio stations to provide fast communication without cost between scientific groups both in the U. S. and abroad. Although the network began operating only a month ago, participating stations already span the U. S. Some 30 astronomical groups are now using the facilities. More amateur stations are needed, particularly in Europe, Asia, Latin America and the South Pacific. The network clears routine traffic Monday through Friday on 7,125 kilocycles at 9 p.m. Eastern standard time, and on 14,085 kilocycles at 9:30 p.m. E.S.T. Scientific groups may arrange to use the new facility by communicating directly with Griggs, whose amateur call is W3UCT.

Robert D. Grange

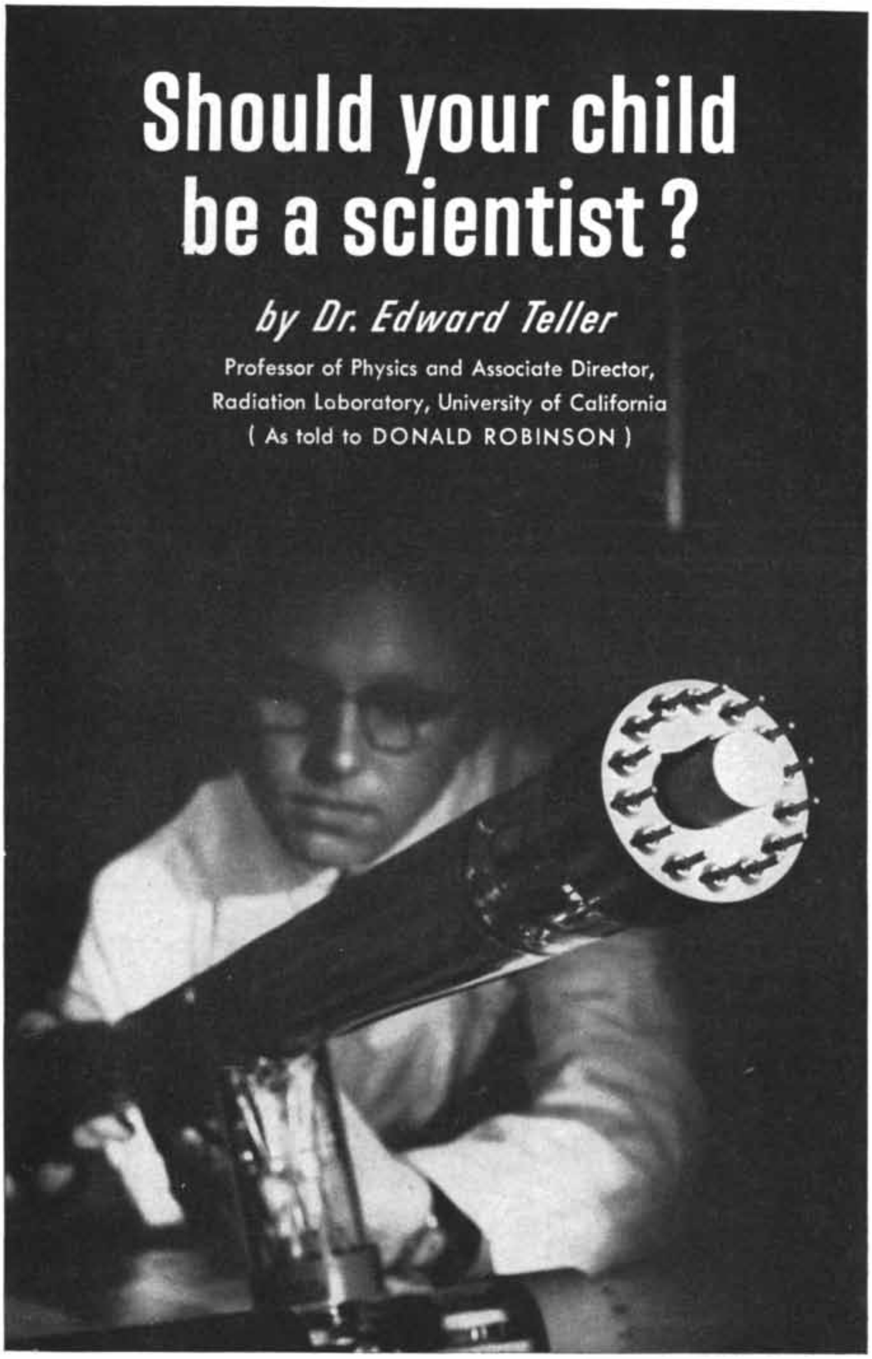


The 31st in a Series of Advertisements Presented by New York Life to Help Guide America's Children to a Better Future

Should your child be a scientist?

by Dr. Edward Teller

Professor of Physics and Associate Director, Radiation Laboratory, University of California
(As told to DONALD ROBINSON)



Laboratory research often occupies a considerable amount of the scientist's time. Here a scientist examines an experimental tube for testing photosensitive devices.

NEVER HAS MAN learned so much, and so fast, about the universe he lives in as he has during this century.

We have learned things that are more surprising than any story in science fiction, more beautiful than anything in music.

Just think of the way we have expanded the boundaries of the universe. On New Year's Day, 1900, our main attention was still focused on stars a few thousand light years away. Today, we are studying galaxies a billion light years away.

At the turn of the century, even a simple item like the size of the atom was unknown to us.

The chemists had used atoms as a kind of symbol, but in the year 1900 we didn't even have proof that atoms really existed.

Today, the atom is a demonstrated reality. Both its structure and the laws which underlie this structure are completely understood. We know, for instance, that each atom has a nucleus, loaded with very much more energy than the atom itself. We know, too, that individual atoms are as unpredictable as people are supposed to be, but that we can calculate their behavior *en masse* through the laws of averages.

These are just some of the epochal advances pure science has made. There are more. Many more.

We have gotten an entirely new conception of time in this century. The mathematicians have given us new forms of logic. The geneticists have discovered the laws of inheritance. The chemists have come to understand the structure of crystals, and the complex molecules upon which life depends.

Is it any wonder that historians are calling this "the golden age of pure research"?

In the applied sciences, progress has been as spectacular. It has literally transformed our world within the past few decades.

In this short span the applied scientists have given us automobiles and supersonic airplanes. They have developed rockets that can attain speeds of 18,000 miles-per-hour and lift satellites up into outer space.

They have given us instant, world-wide communication. They have electrified our homes and made our lives far easier. They have evolved electronic equipment that promises us real automation.

And that's not all, by any means.

Years back, tuberculosis and pneumonia took an appalling toll. No longer. The problem of infectious disease has been largely solved in our time.

Years back, we had to rely on particular places for their particular riches. Such as rubber. No longer. Chemistry has provided us with synthetics.

No more do we have to worry because our coal and oil stocks are petering out. We have nuclear power at our disposal now. It should generate all the energy we require for at least 200 years, and it will enable us to supply electricity to the most remote corners of the globe.

Much as science has accomplished in this century, there is still more to be done.

Science will do it. Of that I'm confident.

Before the century is over, we will have explored our entire planetary system reasonably well. We will have found out how to influence the weather. We will have learned how to make proper use of the ocean. Today, our methods of fishing are as crude as they were in the Stone Age, but in the not distant future we will be seeding fish and plants in the sea as effectively as we cultivate cattle and crops on land.

Come the year 2000 and we will have achieved a cure for cancer and heart disease. We will know how to make materials to order, synthetically.

On the broad front of pure science we will have explored the basic structure of the atomic nucleus. We will have peered into the history of the universe down into the distant past, six or seven billion years ago.

Can you think of any other profession that affords its followers the chance to find such towering, demonstrable truths, and to do so much good?

Yet, let me say this as strongly as I can.

I do not want any young person to choose science as his lifework simply because he hopes to be the one to solve these big, exciting problems.

In my opinion, one should never enter science with a view to the end results. The thought of achievement, fame, position or monetary reward should have no bearing on the decision.

There is but one good reason for going into science. It is that a person enjoys the day-to-day details of scientific research for the sake of those day-to-day details.

Only this kind of a boy or girl will find contentment and success in science. The others are foredoomed to failure and frustration.

I have seen youngsters embark on a scientific career with the fervent expectation that they were going to make world-shattering discoveries. Instead of relishing their everyday activities, they kept fretting about the "big break-through" they dreamed of.

Naturally, it didn't come. Knowledge cannot be wooed so brusquely.

If your child is interested in science, for science's sake and for no other reason, he will find all doors opened to him.

We have a desperate need for new scientists today in America. The fact is that we must have them if we are to survive as a free, democratic nation. The President of the United States himself has termed this "the most critical problem" confronting the American people.

Year by year, the Soviet Union has been overtaking us in the scientific arena. Back in the '30's, the Russians had to bring in American engineers and machinery to help them with comparatively easy jobs like constructing dams. Today, Russia has more scientists, engineers and technicians than the United States, and is graduating more than twice as many as we are each year.

Not long ago, the National Science Foundation made a check on the status of higher scientific education in the United States. The findings for one sample year were shocking.

In all America, only 986 persons got their Ph.D.'s in chemistry, that year, only 470 in physics, only 230 in mathematics.

Just twenty-three persons got their Ph.D.'s in astronomy. A mere ten got them in meteorology.

Figures like that explain why the U.S.S.R. now has 15,000 more people at the doctorate level in the various sciences than we have in the United States.

If Russia continues to outpace us in this fashion, the results will be catastrophic for us. The Russians will be the ones to land on the moon first. They will be the ones to control weather first. They will be the ones to perfect weapons so overwhelming that no one will be able to resist them. They will lead the world in everything, including science and its peaceful applications.

Then freedom will be lost here and everywhere.

A scientific career is more than a duty, though. It is an opportunity.

Science is fun. It offers people the supreme pleasure of clear, complete understanding, of creating order where there was confusion.

You have the fun of being thoroughly absorbed in what you're doing. And you have the fun of working for a clear-cut decision. It's like chess. Ordinarily, in that wonderful game, there is no question of who wins or loses. Similarly, in science, there is no doubt as to whether you have solved or failed to solve a problem. The proofs are definite.

In many fields, another person's success can be a disadvantage to you. Not in science. Here anybody's success is your success. For one thing, you gain personally from the new knowledge that has been reached. For a second, progress of any sort points out the path for you to further progress.

Best of all, science has objective criteria and a language that are the same in every country. With them, scientific people can, and do, cooperate with each other no matter what their nationalities are.

Let me put it this way. A person who becomes a good scientist joins an international community of people who practice the brotherhood of men.

Sometimes, parents say to me,

"Don't you have to be a genius to make a career for yourself in science?"

My answer to them is "No."

To my mind, talent is nothing but an unusual amount of concentrated interest. If you have this intense interest in a subject—and the capacity to work hard—you will do well at it.

In most sciences, this interest is manifested young. When Karl Friedrich Gauss, the greatest mathematician of all, was a little boy of nine, for example, his teacher in a Brunswick, Germany, school asked the class to add up a long series of progressive numbers.

The other children worked an hour, laboriously adding the lengthy columns of figures. Little Karl spent scarcely a minute on it. He looked up, looked down, and jotted the correct answer on his slate. At his tender age, he'd already figured out how to work arithmetic progression.

I know that in my case I was fascinated by numbers in earliest childhood. My mother used to put me to bed before I wanted to go. So, I'd lie there in the dark and compute the number of seconds in an hour, a day, a month, and a year. I did not always get the right answers, but it was fun.

It is up to parents to recognize such interest in science if their children have it and to encourage its growth.

How do you know if your child's interest in science is a genuine one?

By his curiosity about scientific subjects.

By the fact that he asks intelligent questions about science and profits from your answers, so that each successive question shows a higher level of understanding.

By the fact that he loves to work scientific problems—mathematical puzzles, perhaps—and by the fact that he insists on solving each problem completely.

By a bull-dog quality which won't let him drop a subject until he understands it inside out.

A child does not need a lightning-fast mind to be a scientist. Nor does he need a miraculous memory. Nor is it necessary that he get very high grades in school.

The only point that counts is that the child have a high degree of interest in science.

What should parents do to encourage this interest?

Since a child's attitudes are usually set by the time he is twelve, parents should start early to expose him to science and to create the kind of an environment which will stimulate him in that direction.

I was lucky along those lines. When I was ten, my father saw that I had a scientific urge and took me to visit an old mathematics professor of his.

The professor was not very impressive in appearance or anything else. But I learned something priceless from him. He started speaking to me about his specialty, projective geometry, and I discovered that mathematics was fun for him. That he had more fun than any grown-up I'd known.

Then and there, I resolved to have fun like that, too.

If you ask me, the wise parent should talk about science to his children, give them books to read, and arrange for them to meet scientists. He should see to it that they take all the science courses their school offers.

A good teacher can do wonders in this regard. Let me say here that the essential characteristic of a good teacher is not that he knows his subject well or can teach it efficiently. It is that he loves his subject and makes that love evident to his pupils.

In the event that your child does settle upon science for a profession, I would recommend that he get as thorough an education as possible. I do not say that a Ph.D. is a prerequisite to advancement, but it does have great value. If your child does not choose science for his profession, I would urge that he at least take science appreciation courses at school. In this scientific age, all of us should have some grasp of the developments that are shaping our lives.

Much as I respect science, I don't want to leave you with the impression that a career in it is all milk and honey.

It isn't. Unfortunately, scientists are a group apart in America. People often think of them as "high-brows" and "squares."

As a result, the scientists have tended to withdraw into themselves. Many have lost contact with the common man.

This is bad.

However, I feel that the public attitude toward science is gradually beginning to change. Eventually, I believe, scientists will come into their own and be recognized for what they are —one of the most important, small components of our big society. The time may even come when teen-agers will look up to their school's science stars as admiringly as they do to their school's football heroes.

A healthy sign in this connection is that salaries for scientists are now edging upward. Throughout the country, universities, private research laboratories, industrial concerns and the government are bringing scientists' pay up to a level which will assure them a comfortable, secure life.

Not that money should be a factor in deciding on a scientific career.

I well remember the day I told my father that I planned to be a scientist. He was vehemently opposed.

"You'll never make a decent living as a scientist," he warned.

"I don't care," I replied. "If I do anything else, I may make more money but I'll only have fun after hours. If I work at science, I'll have fun all the time."

I do.

Nylic

HOW TO HELP YOUR CHILD HAVE THE CAREER HE WANTS

Many factors will enter into your child's choice of a career: his interests, his ambitions, his abilities, the counsel he receives from teachers, friends and family. But, most of all, it will depend on his opportunities *to get the training he needs to enter the field of his choice.*

Even though his college days are still years away, it's never too soon to start making sure that your child will have the opportunity to continue his education when the time comes.

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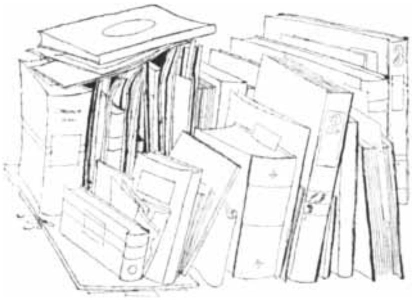

BOOKS

A biologist decries some scientific applications of statistical theory

by Morris Kline

Statistical Theory, by Lancelot Hogben. W. W. Norton & Co. ($9).

During the 18th century economists and political theorists turned an envious eye on the physical scientists who were revealing the perfection of the Newtonian system of celestial mechanics. The order and harmony of the physical world made a striking contrast with the disorder and misery in the world of human affairs. The students of society conceived a plan. It was clear that the physical sciences had achieved their successes by finding fundamental principles such as the Newtonian laws of motion and gravitation, by expressing these laws in mathematical terms and by applying mathematical procedures. The would-be social scientists decided that they too must find fundamental principles and apply mathematics to them. Though this introduction of reason into the affairs of man must still be welcomed as a positive contribution, the efforts of the social theorists led only to absurdities such as Malthus's law of population and Ricardo's law of wages.

During the 17th century Blaise Pascal and Pierre de Fermat created another kind of mathematics—the theory of probability—to assist the nobility at the gaming table. Then Edmund Halley, Daniel Bernoulli and Abraham de Moivre showed how this same theory could earn profits for life insurance companies and enable governments to substitute pleasant lotteries for painful taxation. A little later Pierre Simon de Laplace extended the theory of probability to show that the solar system was indeed designed and not a rare accident, and Karl Friedrich Gauss applied the theory to measurement and showed how the true value of a physical constant could be determined with a high probability of correctness. The appetites of the social theorists were again whetted: they turned to statistics and the theory of probability for the resolution of their problems. It was L. A. J. Quételet, the Belgian astronomer and geodesist, who decided that the social world could be subjected to these mathematical disciplines. Quételet's idea was that the Gaussian theory of errors of measurement must also be applicable to the distribution of the mental and physical qualities of men. The variations were obviously due to the fact that nature in creating man aimed at an ideal but made errors. The application of statistics and the theory of probability would determine the ideal, and once this average or mean man (*l'homme moyen*) was determined it would be possible to devise social institutions to fit his needs and desires. The aspiring social scientists pounced on the vision of Quételet and proceeded to apply it to the reconstruction of their disordered domains.

Additional stimulus was provided by another successful application of the theory of probability to the physical sciences. Rudolf Clausius, James Clerk Maxwell and Ludwig Boltzmann showed how to derive the laws of gases from probabilistic assumptions about the behavior of individual molecules; they erected new branches of physics, notably statistical mechanics and thermodynamics. Not only social theorists but also biologists took up the program of Quételet and expanded the applications of the theory of probability. It was not long before statistical theory became the arbiter of social and biological controversies and a household word.

But Lancelot Hogben, who is a biologist and might be expected to rejoice in this powerful tool, has come to bury and not to praise it. He wants to halt the mushrooming of the theory and its applications, and to have us re-examine their value. He is not only critical of what statistics and probability are purportedly accomplishing; he is also convinced that the current generation of research workers has relinquished the obligation to examine the mathematical credentials of the principles it uses. In their frantic haste to get on with research they take on trust the procedures recommended by a few leaders and perform meaningless calculations. More and more they rely upon methods which they understand less and less. Though Hogben would not drive social scientists out of the paradise they have discovered, he would have them make themselves worthy of it.

The central theme in Hogben's attack is that statisticians have become so attracted by tidy mathematics that they have overlooked the major reason for the existence of their subject, namely, its value in deriving knowledge of real phenomena and in giving power to biological, social and psychological investigations. Hogben does not decry the intellectual activity of mathematicians seeking to perfect abstract systems of thought. But he is not concerned with it. His book examines the value of statistical theory in enlarging our understanding of living organisms and social systems. His harsh conclusion is that the theory is not successful in the solution of practical problems.

In view of the widespread use of statistics, and the weight given to the results of statistical investigations, one must pay attention to Hogben's criticisms. He believes that he can make these criticisms clearer, and show how the weaknesses in the current theories arose, by dividing the applications of statistics into four domains. These divisions are not concerned with statistics in its original meaning, in which simple arithmetic yields helpful summaries of unemployment, birth rate, death rate and so on. Rather he devotes his attention to statistical theory which invokes the theory of probability.

The first domain is the calculus of errors. This calculus assumes that measurements of a physical quantity such as length or angle are random samples of a fixed "universe" or "population" of all possible measurements. It seeks to determine the true value of the quantity by the application of the theory of probability.

The second class of applications Hogben calls the calculus of aggregates. This too has its origins in physical science. There it makes probabilistic assumptions about subsensory particles of matter; for example, the probable distribution of the velocities of molecules in a gas. From such assumptions it deduces general laws about the behavior of gross matter. The assumptions stand or fall on the success with which the derived laws work, that is, on how they fit our observations of the behavior of gross matter.

The third domain of statistical applications Hogben calls the calculus of explorations. This calculus is concerned with statistical procedures such as regression and factor analysis; its underlying concept is covariance. Though these procedures may invoke tests of significance and therefore intrude on the next division, Hogben prefers to consider them separately.

The fourth major division is the calculus of judgments, or statistical inference. It is mainly concerned with testing the reliability of hypotheses. It includes the theory of significance, decision tests and interval estimation in terms of the limits of confidence. The calculus of judgments, unlike the calculus of aggregates, does not deduce from definite assertions involving the concept of probability; it rather prescribes probabilistic rules for deciding on the merits of hypotheses. It does this by working backward, so to speak, from the information provided by a sample.

To analyze the strengths and weaknesses of these four calculi Hogben deems it desirable to show how the classical theory of probability created by Fermat and Pascal for games of chance was gradually extended to cover the newer applications. This historical approach does prove to be enlightening; it also shows how older ideas persist and exert their influence.

Pascal and Fermat used pure reasoning, or what is often called *a priori* probability, to decide that the probability of a "two" turning up on a single throw of a die is one sixth. Thus they implied that in practice the "two" will appear about one sixth of the time in a long series of throws. In other words, they assumed as self-evident that what should occur will occur. They also assumed that the throws are random, so that in a long series all possible ways in which a die can turn up will have their rightful proportion. The die must not be loaded nor the deck of cards stacked. Stated otherwise, the possible events must be lawless for the laws of *a priori* probability to apply.

The theory of probability was then applied, as I have already noted, to insurance and lotteries, wherein the frequency of actual occurrences was used to estimate probabilities. More important, however, is the fact that Laplace, in applying himself to problems of mortality, assumed that the people one actually wishes to study are part of a hypothetically infinite population. Laplace assumed further that the sample one actually uses to calculate a mortality rate is a random sample from this hypothetical population. While these assumptions may have provided a more systematic and mathematically more convenient method of treating a large but finite number of cases, they immediately provoke objections. Not only is the infinite population purely fictitious, but why should the actual sample be a random sample of this population? Fortunately, in the field of insurance, assumptions are tested by practice. Hogben points out, in fact, that the full theory of probability is really not needed for insurance.

Nevertheless two procedures had crept into the domain of probability: the use of a static, infinite population, and the treatment of actual samples as random. These procedures gained wider acceptance when Laplace and Gauss applied them to the theory of errors of measurement, for in this domain it does prove to be reasonable to assume that there are an infinity of possible measurements and that the measured values are indeed a random selection from the infinite universe. The calculus of errors also established the "normal curve" as the distribution of the frequencies of possible measurements of a single quantity, and the mean of these measurements as the true value of the quantity. Hogben has no criticism of this calculus as applied to physical measurements.

Then Quételet, with his resolve to apply the calculus of errors to social problems, entered the picture. Having observed that the distribution of the heights of people in a group seemed to follow a normal curve, he concluded that there must be a law of nature to account for the fit. It was only a step to the next conclusion, also suggested by the sound calculus of physical errors: that there were true norms of height, weight, birth rate, death rate and crime rate. Here Hogben enters his first class of serious objections. The word population, which Laplace had introduced for the entire infinite set of errors, was now applied to population literally: the urn of nature was now supposed to contain an infinite number of balls. Moreover, the human population and social conditions were assumed to be static. Students of society should know that society constantly changes, in fact changes in response to measures often introduced as a consequence of statistical investigations. The social world is not passive like the physical world. "The subject matter of the social sciences consists of unique historical associations which are unrepeatable." One cannot assume that two samples are really drawn from the same universe. Further, the norms or means which Quételet took as the true values of nature's ideal man are pure suppositions. Quételet's mean man, possessing the mean height, mean weight and so forth, might be a monstrosity of nature. The norms which Quételet and his followers imposed on reality can refer only to people in some "felicitous heaven of Platonic universals but are devoid of conceivable content in the dismal terrain of the efforts of living men to come to grips with inexorable nature."

The major fallacy in Quételet's work was to confuse errors of measurement, which merely signify man's fallibility in apprehending natural law, with natural variations. The deviations in height from a norm are the law itself in the biological domain. One cannot identify the variation in height which can be observed among 10,000 people with the errors which an experimenter might make in 10,000 measurements of the height of one person. Almost as weighty is the criticism that blindfold selection does not necessarily imply random selection. Just because we do not know the make-up of the individual choices, we cannot argue that they must be random.

Hogben is inclined to excuse Quételet, who lived in an age which worshiped laws wherever man investigated. Moreover, Quételet was an astronomer, and could not help being impressed by the value of the calculus of errors. Hogben holds Francis Galton and Karl Pearson much more to blame. These men not only swallowed Quételet's ideas but extended them to the concept of a mean natural environment, and went so far as to argue that a population could not be improved except by selective inbreeding. Through the work of Quételet, Galton and Pearson, the normal law came to occupy an honored position in social and biological research.

The extension of the calculus of errors to more advanced applications in the social and biological sciences leads to techniques such as regression and factor analysis. These two concepts fall within

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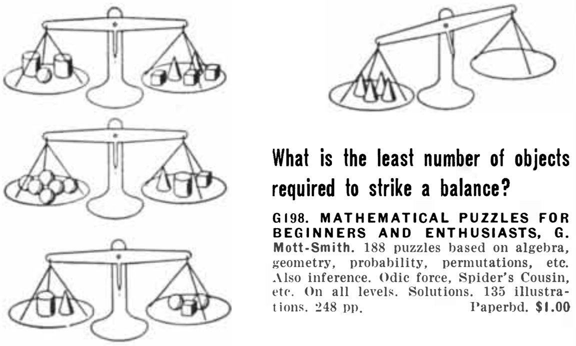

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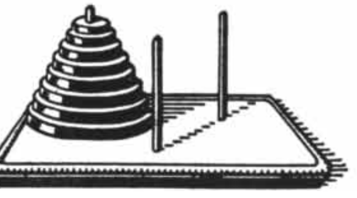

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Hogben's calculus of explorations. But these extensions, since they depend upon the calculus of errors, or are best derived from it, are subject to the same criticisms leveled at Quételet's original work. Hogben censures sharply these widely applied techniques.

We may pass quickly over his treatment of the calculus of aggregates. There the uses of probability in formulating hypotheses are perfectly acceptable because their consequences can be tested.

Hogben contrasts the calculus of aggregates with the calculus of judgments, another method of testing hypotheses. In this branch of statistical theory one observes a sample of some population and uses knowledge obtained from the sample (for example, its mean) to decide on the reliability of a hypothesis about the entire population. More precisely, the theory of probability tells us, on the basis of the hypothesis, the frequency with which samples of various means can be expected. We can then judge such matters as whether the sample in hand is sufficiently improbable to discredit the hypothesis.

In the domain of the calculus of judgments one can use knowledge of the sample as a check, as in the control of quality in manufacturing. Hogben calls such applications statistical prudence. But the major applications of the calculus of judgments are those wherein one tries to decide whether, for example, a certain medical procedure is advisable by noting its effects on a sample of people or animals. But when one tries to establish judgments about entire populations by arguing from the evidence presented by the sample, the entire burden of the argument falls on the statistical theory.

With these latter applications Hogben finds many reasons to be dissatisfied. In the first place the Gaussian theory of errors is involved; hence all of the objections Hogben raises to Quételet, Galton and Pearson apply at once. The concept of a supposed static infinite population which has no real counterpart is especially inappropriate here. The effect of a medical procedure depends upon age, medical history, nutrition and innumerable other changing circumstances.

Hogben has other objections, too detailed to be presented here, to the techniques of the calculus of judgments. It may suffice to point out that his indictment of the present state of the entire body of statistical theory is almost wholesale; his remarks are biting and even sarcastic. He would send to the nether regions, doubtless to join Malthus and Ricardo, such misconceptions as the normal man and the normal environment. He suggests that it may be necessary to destroy the entire facade of irrelevant computation and let laboratory experiments stand on their own feet.

All of Hogben's criticisms apply to the applications of statistics in the social and biological sciences; the physical sciences not only escape scot-free but also receive some praise. Hogben would even use the experience of the physical sciences to argue that statistical theory may not be needed in the design of experiments. He points out that the great historic experiments in physics were performed without resort to statistical theory. But many proponents of current statistical theory have used the example of the physical sciences to defend their position. Their argument is that even the mathematical theory which is used in physics states an ideal case which does not occur in practice. The analogy is a questionable one. A real circle may not be the mathematicians' ideal circle, but the error in calculating the area of a real circle cannot be terribly important. On the other hand, the assertion that something may happen in less than 1 per cent of the cases, which are therefore negligible, may cause real trouble if it is applied to deciding whether a medical procedure will cure or kill.

Are Hogben's criticisms correct? In some cases, it seems to me, he is beating a dead horse. Some of his criticisms are valid only if one ignores advances in statistical theory during the past 30 years. However, not all of Hogben's criticisms have been met. At the very least the value of statistical theory in reaching decisions is more limited than is often claimed by its authors.

Hogben's criticisms of the practitioners, as opposed to the theorists, may be on safer ground. If the consumers of statistical theory in social and biological laboratories are still blindly following the older rules and procedures, and confidently drawing the unwarranted conclusions that he rails against, then his attacks are justified. It is likely that he is right; many potential users of statistics in economics, psychology and education seem to want to learn statistics without mathematics. The chief value of Hogben's book is to point out that statistical practice is behind theory.

Short Reviews

A History of Technology, Vol. III, edited by Charles Singer, E. J. Holmyard, A. R. Hall and Trevor I. Williams. Oxford University Press ($26.90). This pioneering history does not falter. The first two volumes, which carried the story from stone implements to the end of medieval times, drew their information from archaeological evidence and contemporary documents. The account in the third volume is itself the beneficiary of a major technological advance, namely printing; for during the period covered a large and rapidly expanding literature describing the arts and crafts made its appearance. The same period of course witnessed the emergence of modern science, but this movement as such falls outside the compass of the book. Nevertheless, the effects on the rise of theoretical science begin to be reflected in the present volume, and much more marked repercussions will undoubtedly make themselves felt in the two installments still to come. Technology branched out so profusely in the 200 years from 1500 to 1700 that it is quite impossible, as the preface points out, even in 750 pages to summarize adequately the techniques of manufacture and production. The editors have therefore "necessarily been highly selective in their choice of topics for discussion" and have imposed rather stringent restrictions of space on the contributors. There are five main parts which treat in turn primary production, manufacture, material civilization, communications, approach to science. R. J. Forbes, writing on food and drink, describes the new food crops adopted by the European farmer in the 16th and 17th centuries, the introduction of tea, coffee and cocoa, the rise of the potato (which came not from Virginia, as was long thought, but from South America) and the only new contribution to the European table from the animal world, the turkey, which made the transatlantic voyage from Mexico in 1520 and "became common Christmas fare a century later." A masterly survey of metallurgy and assaying by Cyril S. Smith and Forbes is included in the first part, along with an interesting paper on coal mining and coal utilization by J. U. Nef. This points out that by 1660 coal was so extensively burned in London that the dark pall of filthy smoke from tens of thousands of domestic fires and hundreds of breweries, soap- and starch-houses, sugar refineries, brick kilns, earthenware works and glass furnaces led foreigners first visiting the city to pronounce it unfit for human habitation. The second part of the volume contains R. A. Salaman's fascinating essay on tradesmen's tools—which have changed remarkably little from classical Mediterranean times to the present—papers on

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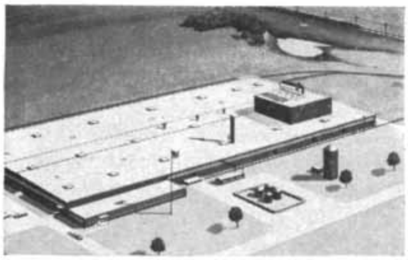

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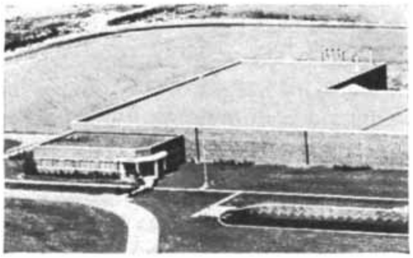

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☐ Payment enclosed – send postpaid. Same refund privilege SA-3 farm tools, vehicles and harnesses, on spinning and weaving, on figured fabrics and on glassmaking. In the third part are articles on building construction, town planning, land drainage, machines and mechanisms (gear-operated chain-and-bucket pumps, water-driven ore-crushers, water mills, suction pumps, screw-cutting lathes, screw presses, power-driven rollers), and military technology. An account of the origins of printing by Michael Clapham, which concludes this part, presents vivid reconstructions of the methods of working of a mid-15th-century printing office, as well as others of later date. (The Mainz printing office of Fust and Schoeffler, where the great 42-line Bible—commonly attributed, for no clear reason, to Gutenberg—was printed, had in the 1450s a staff of at least 25 men: two type-founders and six compositors, a reader, 12 pressmen and assistants, and a few others.) Articles on bridges, canals and river navigation, ships and shipbuilding, cartography, survey and navigation comprise the fourth part; in the last part are papers on the calendar, precision and scientific instruments, mechanical timekeepers, and invention in the chemical industries. An epilogue discusses the rise of the West to dominance in technology. The stage was set for theoretical science to come to the aid of practice in the 18th century, but during the two centuries embraced in these pages the methods of modern science "were being begotten from the conjunction of [experimental] philosophy with the practical observation and intuitive knowledge of those who actually handled the materials" and conducted the processes. The illustrations in this volume are many and admirable (though a few are too much reduced); dress, typography, design are distinguished.

THE SHAKESPEARIAN CIPHERS EXAMINED, by William F. and Elizabeth S. Friedman. Cambridge University Press ($5). In 1728 a certain "Captain" Goulding wrote a little book questioning Shakespeare's sole authorship of the plays. Shakespeare, he said, was no scholar, no grammarian, no historian and "in all probability cou'd not write English." This marked the birth of an anti-Stratfordian movement which, while never very strong, never lacked supporters, survives to this day and deserves a footnote in any work on fads and delusions. A branch of the movement bases its claims on cryptographic proofs, that is, on evidence derived from ciphers or other cryptographic systems allegedly incorporated in the plays themselves. The prophet or leading nut in this endeavor was one Ignatius Donnelly of Minnesota, a 19th-century lawyer, pioneer, entrepreneur and politician. Donnelly said Francis Bacon wrote the plays, and he (Donnelly, not Bacon) purported to find embedded in the texts a cipher system which he traced to the Lord Chancellor. The present book, by two leading cryptanalysts (Colonel Friedman is credited with the chief role in breaking the Japanese diplomatic cipher in 1941 by reconstructing their "purple" cipher machine, and his wife is "cryptologic expert" for the U. S. Secret Service) disposes of Donnelly's claims and those of dozens of successor zanies. One may, if one is so inclined, continue to doubt that Shakespeare wrote Shakespeare, and put forward in his place a favorite son such as Bacon, or Thomas Dekker, or Walter Raleigh, or Christopher Marlowe, or the 17th Earl of Oxford (it has even been suggested, and this long before the present vogue of togetherness, that the plays were written by a "team" of which the aforementioned were members); one may even argue that the plays were composed not by Shakespeare but by another man of the same name; but thanks to this book one may no longer rationally claim that there is a cipher in Hamlet or Othello or Macbeth or any other of the plays. The cipher theory is permanently dead. The Friedmans having quieted the tempest and exposed the comedy of errors, love's labour has not been lost.

NATURAL MAGICK, by John Baptista Porta. Basic Books, Inc. ($7.50). An attractive facsimile reprint of the 1658 English translation of an enormously popular Italian scientific book. The author of *Magia Naturalis* was a 16th century Neapolitan gentleman who overcame the handicap of being a child prodigy and devoted his long life (he died in 1615, aged 80) to study and writing and to the organization of the first scientific society of modern times: the *Otiosi* (Men of Leisure). Porta wrote works on distillation, meteorology, ciphers and secret writing; on pneumatics, astronomy and the refraction of light; on architecture, physiognomy and astrology. He also composed 14 prose comedies, two tragedies and one tragicomedy, which provided an "unacknowledged source of material for 17th-century English playwrights." But it is for his *Natural Magick*, which went through several Latin editions and was translated into half a dozen languages, including Arabic, that he is best remembered. It is a delightful hodgepodge, filled with nonsense as well as nuggets of natural science. The optical sections, for example, describe the camera obscura, with and without a lens (Porta, however, was not the inventor of this device), and explain the use of a combination of convex and concave lenses for viewing objects far off or near at hand. Another section deals in some detail with magnetism and contains a hint of a "sympathetic magnetic telegraph": "And to a friend that is at a far distance from me, and fast shut up in prison, we may relate our minds, which I doubt not may be done by two Mariners' Compasses, having the Alphabet writ about them." There are chapters on perfumes and cosmetics, on cookery and tempering steel, on how to take off pimples or put them on the face for disguise, on dentifrices and counterfeiting, on correcting "the ill sent of the Arm-pits," on making a virgin of a "deflow'red woman," making spectacles, separating water from wine, catching partridges by getting them drunk, writing in an egg, or causing women "to cast off their clothes and go naked" ("jugglers and impostors" do this by burning hare's fat in a lamp).

VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA. D. Van Nostrand Company, Inc. ($30). The third edition of this work has been enlarged and revised. Its 1,839 pages (the second edition had 1,600 pages) bear two million words, 14,000 articles and 1,400 illustrations (of which 12 are in color); its entries cover some 30 subjects from aeronautics to zoology. The editors state that the encyclopedia will serve the "inquiring lay reader" and the student as well as the "professional" and the "trained technician." If this were so, the new Van Nostrand would be a valuable and welcome book; in truth it is in many respects below standard and does not adequately meet the needs of either expert or nonexpert. According to the preface there is a "progressive development of the discussion of each topic, beginning with a simple definition expressed in the plainest of terms and progressing to a final reflection of the more detailed aspects of the topic treated." This promise is often broken, especially in the entries for the physical sciences and mathematics. A polite nod to the nonexpert, consisting of a brisk dictionary definition, is usually followed by a densely technical summary which will convey little to anyone except the reader who does not need it. Leafing through the pages, one is astonished at the omissions. A few at random: Pythagorean theorem, theory of games, cybernetics, operations research, *pi*, infinity, quality control, natural selection. The editors have included no biographical articles. This policy can be defended, but not the frequent practice of presenting entries about laws, theories and formulas without mentioning their discoverer (*e.g.*, the articles on the Planck law, the Schottky effect, the Schrödinger equation do not mention Planck, Schottky or Schrödinger). The disproportionate emphasis on various topics is incomprehensible except on the assumption that this is an engineering manual. *Stochastic process* receives five lines; *stoker*, two and a half pages; *potential*, half a column; *perfumes*, almost four columns; *general theory of relativity*, half a column; *photomechanical reproduction processes*, three columns. One of the annoying and occasionally comic features of the encyclopedia is its built-in treasure-hunts and wild-goose chases. Examples: There is no entry for *infinity;* but if one looks up transfinite number, the concept is mentioned. One notes, however, that the reference is in bold-face type, which means, according to the preface, that the term itself is "explained and described in its alphabetical position." Hastily one turns back to recheck; there is no such entry. Under *heredity* there is a cross reference to *selection;* no such entry. *Cosmology* is not mentioned, but in its place is an entry for *cosmological models* which invites the reader to consult *Einstein law of gravitation, Einstein universe, de Sitter universe, expanding universe.* The first three items are not found in this book; the last is cross-referenced to *spirals*. The publishers, contributors and editors pray the readers' "indulgence" in case of "any significant omissions and in the case of errors"; anyone who has paid $30 for this book will have to be more than indulgent.

THE DEVELOPMENT AND MEANING OF EDDINGTON'S FUNDAMENTAL THEORY, by Noel B. Slater. Cambridge University Press ($7.50). When Sir Arthur Eddington died in November, 1944, there was found among his papers the nearly completed manuscript of a book in which he synthesized the "diverse accepted principles of physics" and derived by purely theoretical means certain fundamental ratios of physical constants in agreement with observation. This book, published in 1946 under the title *Fundamental Theory*, is profound, at times obscure, and often very difficult to follow. Eddington himself found it difficult to write; most of it took five or six drafts. A substantial part of the earlier versions, in beautifully neat manuscripts, was preserved. Slater has undertaken a painstaking examination of these manuscripts, collating them with each other and with the final version, and the results of his analysis, presented in detail, should be of considerable value to physicists in clarifying Eddington's conceptions, and in making more accessible the main ideas of what the late E. A. Milne described as a "notable work of art."

THE WARBLERS OF AMERICA, edited by Ludlow Griscom and Alexander Sprunt, Jr.; illustrations by John Henry Dick. The Devin-Adair Company ($15). A number of leading ornithologists have collaborated to produce this natural history of one of the most beautiful North American birds. Brief essays describe 99 species from the prothonotary to the painted redstart, ranging from the Arctic tree-line to the Panama Canal, as well as to South America and the West Indies. Appearance, habits, habitat are given, and agreeably discursive details. In addition to maps and black-and-white drawings, the book presents 35 color plates, which are useful and pretty but undistinguished.

JANE'S FIGHTING SHIPS, 1957-1958, compiled and edited by Raymond V. B. Blackman. The McGraw-Hill Book Company, Inc. ($30). In one of the major revolutions of the naval world, *Jane's* has taken a 90-degree turn. This famous annual, founded in 1897, celebrates its diamond jubilee by changing from horizontal to a vertical format; thus keeping pace, one supposes, with the changing philosophy of navies, which have adapted themselves to the new conditions of war by converting increasingly to craft that move up or down (*e.g.,* airplanes and submarines) rather than merely chug along on the surface. In addition to this daring innovation in design, which will further unsettle those who already regard the new look in navies as a catastrophe, *Jane's* has a large amount of fresh material, extensive revisions and more than 800 new illustrations. Cambodia, Liberia and Vietnam, let it be known, each now has a navy.

THE STRUCTURE OF A MORAL CODE, by John Ladd. Harvard University Press ($8). Ladd, a philosopher turned anthropologist, describes his approach to the scientific study of ethical systems. It consists principally of an analysis of ethical discourse, that is, of what people say about moral issues. This volume contains a rigorous statement of the author's views as well as a report of their application to the ethics of the Navaho Indians. It is aimed at the expert.

Notes

THE SEMINOLES, by Edwin C. McReynolds. University of Oklahoma Press ($5.75). This 47th volume in the Civilization of the American Indian Series is an extensive history of a small but valiant and formidable tribe which, though tricked, robbed, defrauded and abused, refused to give up, and is the only Indian nation that never officially made peace with the U. S.

ANCIENT MAN IN NORTH AMERICA, by Hannah Marie Wormington. Denver Museum of Natural History ($5.20). The fourth edition, fully revised, of a nontechnical survey of knowledge about the earliest inhabitants of North America. Extensive bibliography; many illustrations; an excellent book.

THE FASCINATION OF NUMBERS, by W. J. Reichmann. Essential Books, Inc. ($4). An agreeable diversion about numbers: series, digital roots, primes, divisibility, ratios, recurring decimals, congruences, irrationals, continued fractions, magic squares, number oddities, tricks and fallacies.

THE MACMILLAN WORLD GAZETTEER AND GEOGRAPHICAL DICTIONARY, edited by T. C. Collocott and J. O. Thorne. The Macmillan Company ($6.95). Revised edition of a convenient and inexpensive gazetteer.

LES MÉTHODES NOUVELLES DE LA MÉCANIQUE CÉLESTE, by H. Poincaré. Dover Publications, Inc. ($7.35). An unabridged and unaltered re-publication of Poincaré's great treatise on mathematical astronomy. The publisher earns a cheer for making this expensive work available in a three-volume set of clearly printed paperbacks which is considerate of the student's wallet.

DE MOTU CORDIS, by William Harvey, translated from the Latin by Kenneth J. Franklin. Charles C. Thomas ($3.50). This immortal work, first published in 1628, appears now in a fresh translation by a noted British physiologist and scholar. The translation, occasioned by the tercentenary of Harvey's death, has been widely praised as a contribution to historical and experimental research upon the circulation of the blood.

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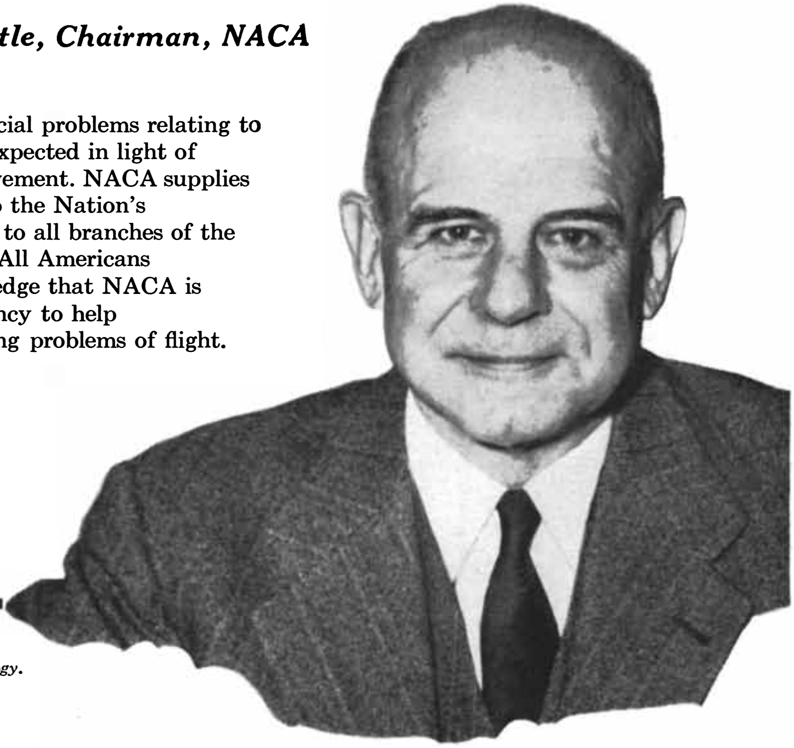

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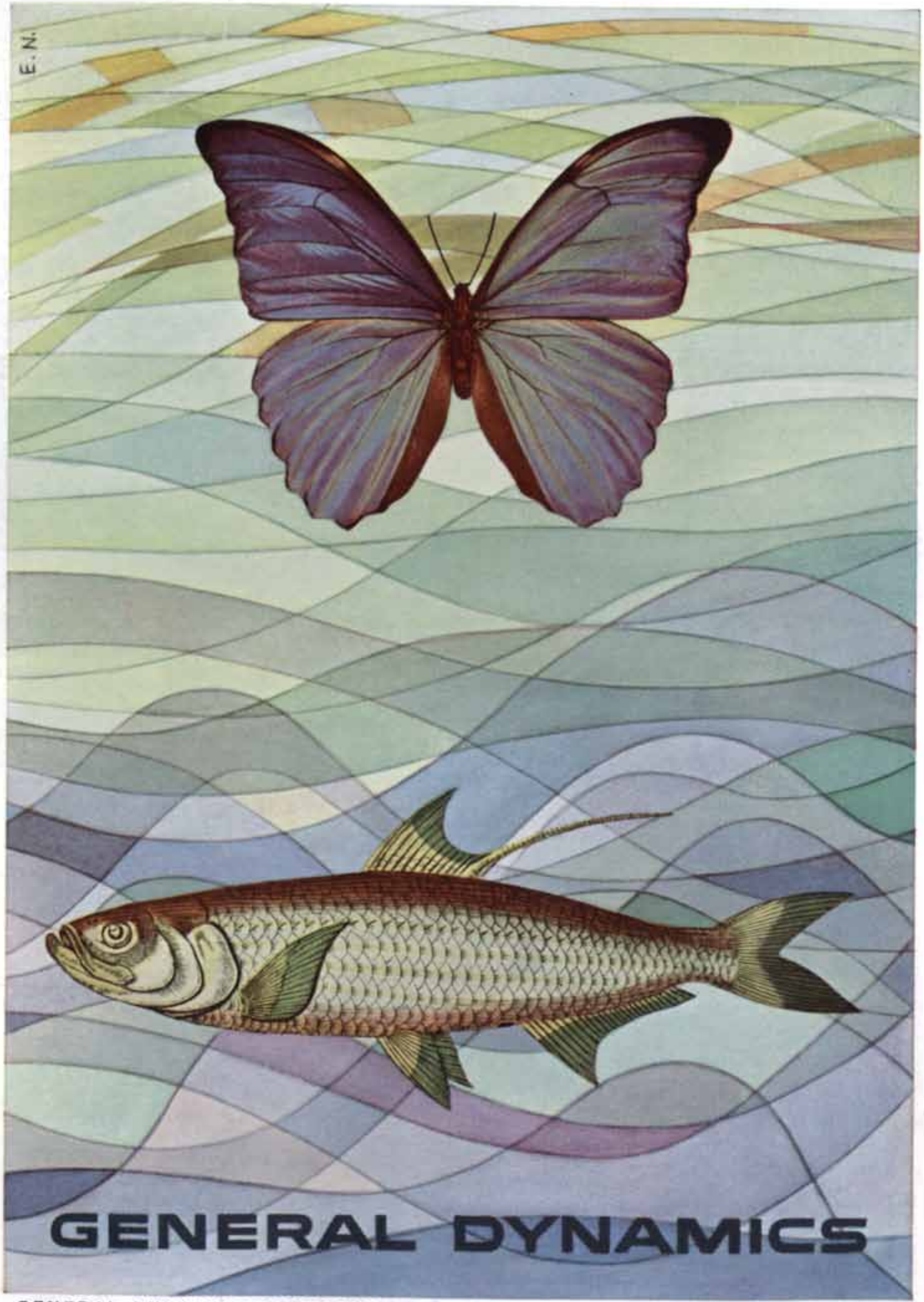
Let the earth bring forth the living creature after his kind . . . .
Let us make man in our image, after our likeness: and let them have *dominion*
over the fish of the sea, and over the fowl of the air . . .
and over all the earth . . . . Be fruitful, and multiply, and replenish the earth,
and subdue it: and have *dominion* over the fish of the sea,
and over the fowl of the air, and over every living thing
that moveth upon the earth." (Genesis 1.20, 24, 26, 28)



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