SCIENTIFIC AMERICAN

MOUSE IN METABOLISM CAGE

FIFTY CENTS

November 1956

Niagara Falls in Kansas?

A 6,000-DEGREE flame, slicing through hard steel to repair a harvester in a Kansas wheat field, echoes the roar of its faraway birthplace—the tumbling waters of mighty Niagara Falls.

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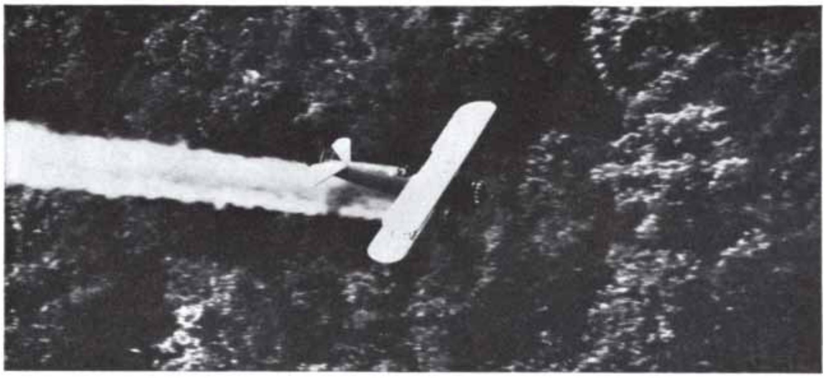
- *farming forests*
- *chromyl chloride*
- *aluminum chloride*



Farming Forests

As Joyce Kilmer put it, "Only God can make a tree," but we are not immodest in saying that now science can make it grow better and faster.

This is the revolutionary concept of silviculture: treating a tree as a crop—for its cellulose content. Its purpose is to make available more and cheaper pulp and paper products.

Forestry has long been held back by the concept that a tree will grow, if it just has enough water. For years we have practiced extractive forestry by cutting down our natural, virgin forests for wood products. When this area is restocked, or when it is farmed and then returned to the growing of trees, the growth is inferior, because plant foods—nitrogen, phosphorous, potassium—have been lost from the soil.

The solution to this problem is simply putting food back into the soil, but most foresters have felt that giving trees nutrients is generally impractical.

To determine exactly how practical it is to fertilize trees, Allied Chemical's Nitrogen Division sponsored a five-year study at North Carolina State College. This pioneering work, just being completed, indicates beneficial effects of plant food on Loblolly pine.

Other recent studies have revealed that fertilization produces a 40 to 65% increase in tree growth, cutting years off the growing cycle of pulp wood. By speeding a tree's growing time, the forester gets a faster turnover of capital and shortens the time the tree is exposed to danger from fires or pests.

Growth is the most dramatic indicator of forest fertilization. But there are many more advantages: an increase in sap and nut production, and in the quality and quantity of seeds; a healthier tree, better able to stave off fungus and pest attacks; a better root system and thicker foliage, making the tree more efficient.

Aerial fertilization is an important economy, for dusting planes can "feed" hundreds of trees in a day.

What is believed to be the first aerial application of a complete fertilizer to a forest recently took place at Rutgers University Dairy Research Farm at Beemerville, N. J. The test, on an 11-acre stand of red pine, was by Rutgers' Forestry Department and Allied's Nitrogen Division.

Fertilizers currently being used in forest studies are ARCADIAN 12-12-12—a balanced, granular (nitrogen-phosphorous-potash) combination, ARCADIAN UREA 45—a high analysis, pelleted, 45% nitrogen fertilizer, and ARCADIAN nitrogen solutions.

In conjunction with its field studies, Nitrogen Division is also sponsoring the first world-wide bibliography of forest fertilization with a grant at the College of Forestry of New York University at Syracuse.

This definitive work contains over 600 references, and the important point is that most of them relate studies which show a favorable response to forest fertilization. The Allied Chemical-New York University bibliography demonstrates that it is technically feasible to fertilize our forests. The Allied Chemical-North Carolina test demonstrates that it is economically feasible.

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A new chromium chemical—with many unique properties—has been developed in a high-grade of purity by Allied's Mutual Chemical Division.

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In suitable solvents, many controllable and selective reactions may be carried out between organic materials and chromyl chloride. It is a starting material for making chromium organic compounds, some of which have unique and useful properties as surface coatings and bonding materials.

Until recently, the researcher needing chromyl chloride was required to prepare it himself. Mutual Chemical has since put this interesting chemical in pilot plant production.

Aluminum Chloride

We can only suggest the variety of uses to which aluminum chloride ($AlCl_3$) can be put. It is, for example, a catalyst in chemical synthesis; it promotes reactions in the production of dyestuffs and intermediates, insecticides and pharmaceuticals; most recently, it is finding use for the first time in aluminum plating.

The older and perhaps more often thought of application is in the Friedel-Crafts reaction. SOLVAY anhydrous aluminum chloride is produced as a high quality crystalline solid and is shipped in a variety of granulations.

Information Service
ALLIED CHEMICAL
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Please send me the following material:

- ☐ Information on tree fertilization
- ☐ Technical data on chromyl chloride
- ☐ Technical data on aluminum chloride

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Established 1845 **SCIENTIFIC AMERICAN** November, 1956 Volume 195 Number 5

ARTICLES

DEPARTMENTS

THE COVER

The apparatus on the cover is used at the University of Chicago to study the metabolism of tuberculosis drugs by experimental animals (*see page 135*). The operation of the apparatus is described in detail by the diagram shown at the bottom of page 142. The apparatus was made by Arno P. Roensch of the Southwestern Scientific Glass Co. in Santa Fe, N.M.

THE ILLUSTRATIONS

Cover painting by Rudolf Freund

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74	Standard Oil Co. (N. J.)
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112-114	Paul Weller
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121-132	Lord Rothschild, University of Cambridge
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136	Robert Ebert, University of Chicago
138	Amy Kasai
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144	Lloyd J. Roth, University of Chicago, and Roland W. Manthei, Jefferson Medical College
161-168	Roger Hayward

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

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

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

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

NON-METALS

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

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

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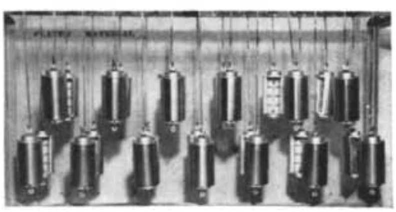
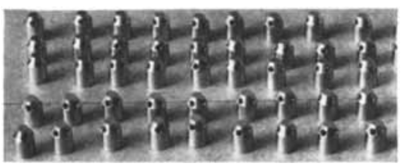


Kanigen-coated cast-iron rolls



Kanigen-coated aluminum parts

Kanigen-coated brass fitting

Kanigen-coated stainless steel cylinder

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

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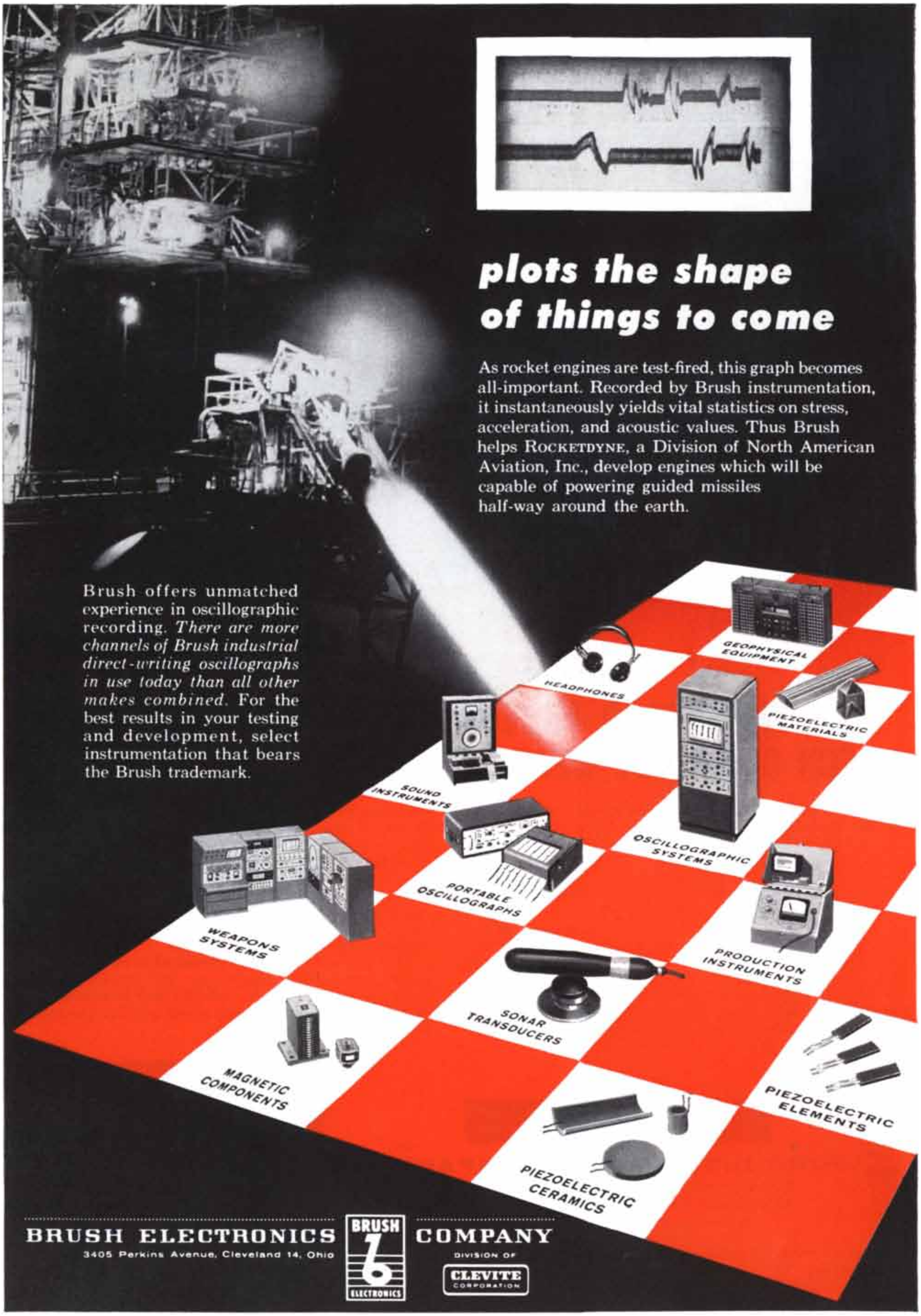
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BUSINESS IN MOTION

To our Colleagues in American Business . . .

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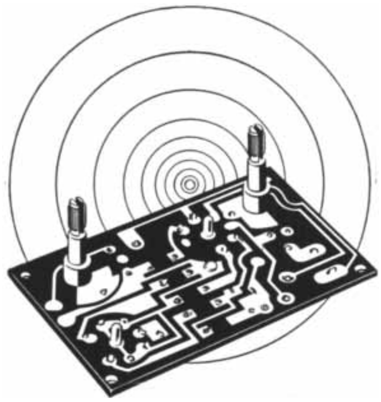
Revere, naturally, has been interested in printed circuits from their very inception. So Revere Research Engineers immediately went to work to perfect a copper that would meet all of the rigid requirements encountered in manufacturing printed circuits as well as those necessary to their efficient operation. Accordingly, they set up these rigid specification standards: there can be no peaks or valleys. Surface must be hard and of uniform density through and through and side to side to maintain positive conductivity throughout the circuit. Also, a hard surface permits resist to clean off easily as there are no pores to hold resist and cause trouble later when soldering. Even the most closely spaced and finest lines encountered in a printed circuit must have a sharp definition of the edges and be freer from pits, pinholes and imperfections.



Also, the copper must be free from oxidation as it comes from the mill and without lead inclusions, present a sufficiently clean surface so that fluxes will wet readily and when automatically soldered the solder coat will be uniform every time . . . free of skips or bald spots. Copper-to-laminate bond strength must be uniform and adequate. Revere Rolled Copper also shall exceed standard specifications as well as meet ASTM B5 specification for purity with a 99.9% minimum rating.

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LETTERS

Sirs:

Upon reading your special issue entitled "The Universe," I recalled the following poetical comment which appeared a while back in the British magazine *The Listener:*

The ears of a Hoyle may tingle,
The blood of a Dingle may boil,
When Hoyle pours hot oil upon Dingle
And Dingle cold water on Hoyle.

But the last of the wrangle will settle.
Old stars will look down on new soil.
The pot will lie down with the kettle
And Dingle will mingle with Hoyle.

JOHN E. PFEIFFER

New Hope, Pa.

Sirs:

Your September issue on the universe . . . makes an impact which might be misleading. Its power stems, not from the data nor from their actual interpretation by the scientific community, but from an editorially determined unanimity which does not correspond to the realities of modern cosmology. Grant me, therefore, space for this brief and belated presentation of the contrary minority opinion.

It is not the case, as Allan Sandage affirms (page 171), that "there is one solid meeting ground between the theories and the observations, and that is the apparent expansion of the universe." On the contrary, Finlay-Freundlich and Born reported in February, 1954 (*Proceedings of the Physical Society*, London), that the red-shift results from photon-photon collisions. This finding is in accord with all the other data; specifically with the fact that the red-shift increases as the distance of the light source except at the outer limits, where photon-photon collisions are relatively few. Thus at one stroke they throw in serious doubt the exclusiveness (the "solid" meeting ground) of the expanding-universe interpretation. . . .

EDWARD F. HASKELL

New York, N. Y.

Sirs:

It is entirely proper that Mr. Haskell point to other possible interpretations of the red-shift data. The very nature of science requires that scientists approach their problems with unpledged and unprejudiced minds. To do otherwise is to court disaster. We must be ready at all times to discard accepted theories and interpretations if they prove to be either inadequate to explain additional data or inferior to some new theoretical structure. But there are well recognized rules by which a new idea must be tested. It stands or falls on its ability to explain and predict.

The September issue outlines a theory of the expanding universe based primarily upon Einstein's theory of gravity. These concepts have, up to now, withstood the tests of inquiry. In 1954 Finlay-Freundlich put forth a new hypothesis which suggests that interactions of photons with a radiation field might cause an effect similar to the Compton red-shift for photon-electron scattering. Finlay-Freundlich argued that such an effect could explain certain small but anomalous red-shifts observed in particular stars in our own galaxy. His equation seemed to also provide an alternate explanation for the observed red-shift of the external galaxies. How does Finlay-Freundlich's hypothesis fare when tested by its ability to explain and predict?

First it must be clearly understood that Finlay-Freundlich's suggestion is a hypothesis and not a theory. It is a first postulate instead of a necessary consequence deduced from a set of more basic postulates. The fundamental equation is put down *ad hoc*. If the equation works, this of course is no objection *per se*, since presumably a formulation could

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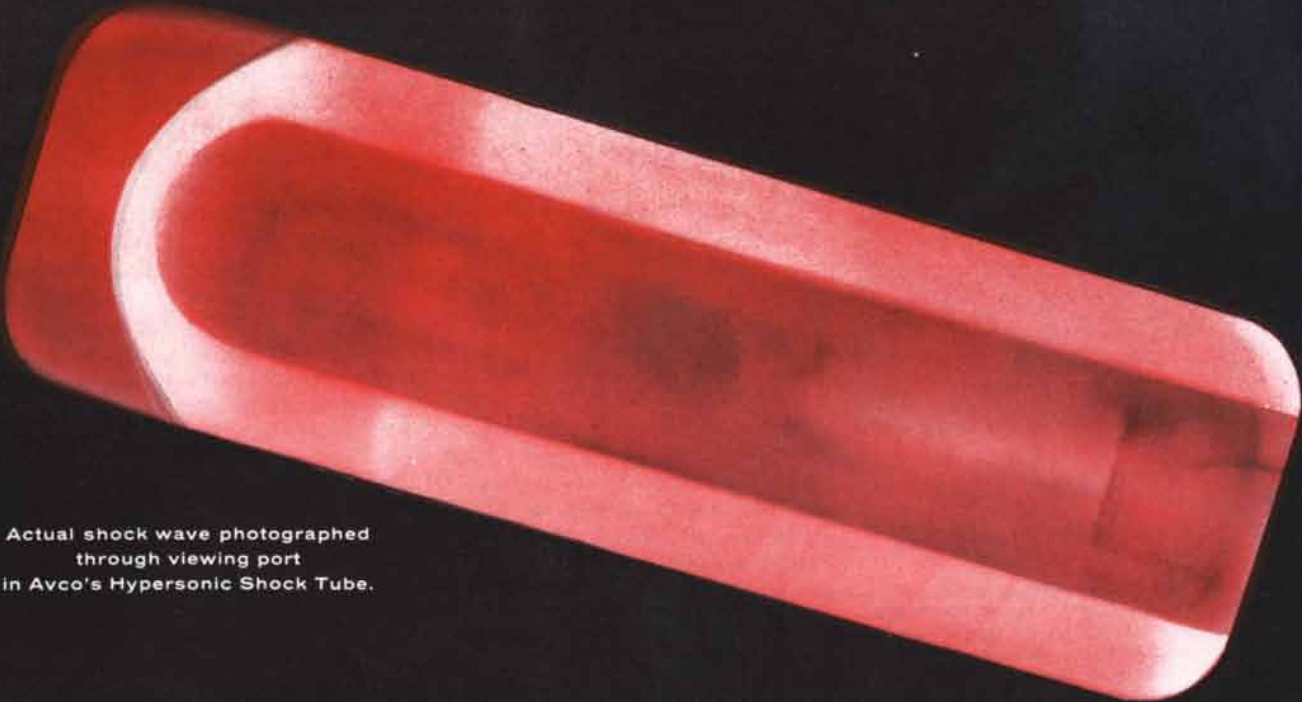

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then be found which would explain *how* photons interact to produce the desired effect. However, the unfortunate fact of the matter is that the equation does not appear to work. Predictions of observable effects can be made on the basis of Finlay-Freundlich's ideas. These predictions do not correspond with reality.

The most striking contradiction (first considered by H. L. Helfer and independently by W. H. McCrea) comes from the consideration of a double star whose orbital plane is nearly in the line of sight. In such a system, light from one star must travel through the radiation field of the other and in so doing will exhibit a red-shift according to Finlay-Freundlich's hypothesis. Because the stars move around each other, the path length of photons from one star through the radiation field of the other is changing and this will appear as a change in the red-shift. For the eclipsing star system Gamma Cygni, Finlay-Freundlich's original equation predicts that this change amounts to 200,000 kilometers per second. The observed change, due to the orbital motion, is only 245 kilometers per second, which is in violent contradiction with the theory. There are other equally serious objections to Finlay-Freundlich's ideas and these have recently been discussed by M. A. Melvin, G. R. and E. Margaret Burbidge, O. Struve and D. Popper. Because of this, cosmologists are not yet ready to accept Finlay-Freundlich's hypothesis as a substitute for the general theory of relativity.

It is very likely that our present ideas of cosmology do not represent ultimate truth just as those of Aristotle, or of Kepler, or even of Newton do not. Certainly changes in the philosophy and in the detail of our present system will occur in the future. It may even be that the entire system itself will eventually be shown to be untenable and must be discarded. Consequently, it is quite essential to guard against complacency by continually testing and questioning. But it is necessary to test all new ideas against the real world. Finlay-Freundlich's hypothesis appears to have withered under this comparison.

ALLAN R. SANDAGE

Mount Wilson and Palomar Observatories
Pasadena, Calif.

Sirs:

I should like to mention a small point in connection with Herbert Dingle's article in the September issue of *Scientific American*. The details of this are, of course, far more familiar to the expert knowledge of Professor Dingle than to that of a casual reader like myself, but as the matter seems to me of some interest I welcome the opportunity to bring it up.

On reading Professor Dingle's article, and as a matter of fact the entire September issue, one might get the idea that the first man to propose that the solar system (for want of a better term) was heliocentric was Copernicus. This is not correct, and Copernicus knew he had a predecessor.

Up to the time of Plato, astronomy was not studied openly in Athens. Anaxagoras, an Ionian resident in Athens from 480 to 450 B.C., was jailed and later expelled for his refusal to leave astronomy to the theologians. Observational astronomy was a subversive activity. The heavens and their populations were presumed to be divine, and an important characteristic of this divinity was their ordered motion in regular and perfect circles, proving that they were under the control of divine intelligence. Since the apparent motion of the sun, moon and planets was irregular, the secular attitude of the Ionian natural philosophers might receive encouragement, or the religious attitude of those with keen eyes but little piety might suffer.

Since Plato was convinced that the true motions of the planets were in perfect circles at uniform speeds, he asked his disciples just what uniform and circular motions could account for the apparent motions. In what may amount to the first Fourier analysis of periodic functions, the apparent paths of the planets were analyzed by Eudoxos and Callippus into the resultants of over 30 uniform circular motions.

It was impossible to force all the observed data into so strait a jacket. Eudoxos assumed that the annual motion of the sun was perfectly uniform. In order to do this, he must have of necessity ignored the discovery of Meton and Euctemon some 100 years before (430 or so B.C.) that the sun does not take the same time to describe the four quadrants of its orbit between the equinoctial and solstitial points.

Attempted simplification of a system for which each new discovery was an embarrassment was perhaps not inevitable if one considers the prevailing religious temper, but something of the Ionian influence still remained. Heraclides of Pontus, who lived from 388 to 310 B.C., proposed that since Venus and Mercury are never observed at any great

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angular distance from the sun, they rotate about it. He proposed further that the apparent diurnal rotation of the heavens might be explained as a diurnal rotation of the earth about an axis.

It would seem a short step from the position of Heraclides to a totally heliocentric hypothesis. Aristarchus of Samos, who was born the year that Heraclides died, was the first man to propose that the earth revolves about the sun.

Heliocentricity got no farther than this during antiquity. Seleucus, a Babylonian, was the last man before Copernicus to support such a hypothesis. The religious principles that placed earth at the center of all things finally suppressed attention to experimental fact. The Ptolemaic system was established at Alexandria before 125 B.C. (Ptolemy died after 161 A.D.). Only the Epicureans (as typified by Lucretius) thought of the sky, sea, stars and moon that they "are so far from divinity, so unworthy of a place among the gods, that they may rather serve to impress upon us the type of the lifeless and the insensible."

KERAN O'BRIEN

Jamaica, N. Y.

Sirs:

Mr. O'Brien is quite correct in stating that some among the early Greeks had conceived a heliocentric universe: Copernicus himself seems to have taken this as a license permitting him also to suggest something contrary to the orthodox view. But these ideas were no longer alive in his day, and would not have affected the course of astronomy without the detailed discussion of the movements of the spheres, based on many centuries of observations, which Copernicus was able to provide. The convincing element in Copernicus' work was not possible to Aristarchus. Even Nicholas of Cusa, who taught the same doctrine in the 15th century but without applying it in detail, made no impression.

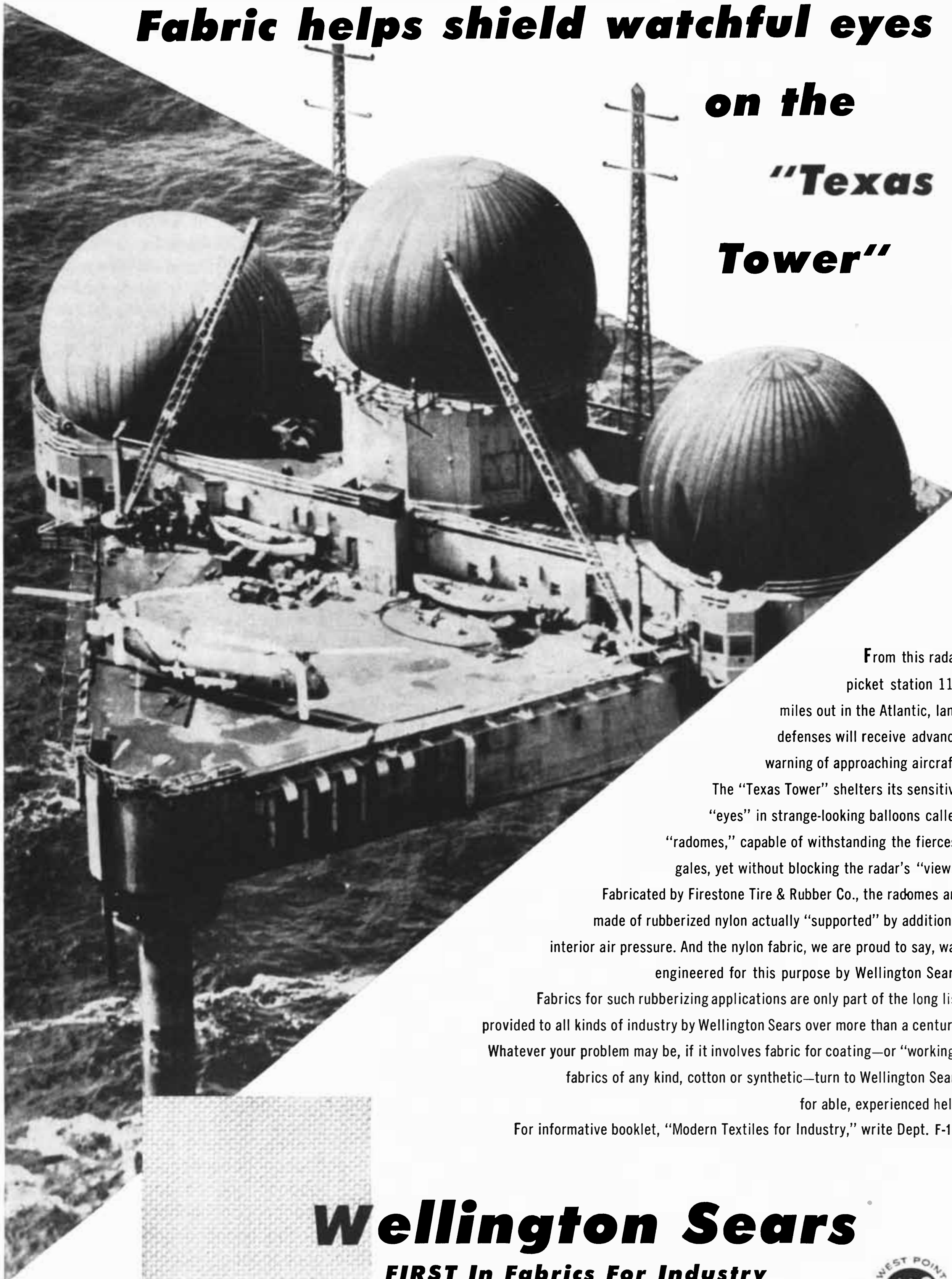
HERBERT DINGLE

Purley
Surrey, England

Sirs:

In the August issue of *Scientific American* the section "Science and the Citizen" carried a story on the "ultraviolet sky." Robert J. Davis of the Harvard College Observatory had computed the brightness of stellar objects in the far

Fabric helps shield watchful eyes on the "Texas Tower"



From this radar picket station 110 miles out in the Atlantic, land defenses will receive advance warning of approaching aircraft. The "Texas Tower" shelters its sensitive "eyes" in strange-looking balloons called "radomes," capable of withstanding the fiercest gales, yet without blocking the radar's "view." Fabricated by Firestone Tire & Rubber Co., the radomes are made of rubberized nylon actually "supported" by additional interior air pressure. And the nylon fabric, we are proud to say, was engineered for this purpose by Wellington Sears.

Fabrics for such rubberizing applications are only part of the long list provided to all kinds of industry by Wellington Sears over more than a century. Whatever your problem may be, if it involves fabric for coating—or "working" fabrics of any kind, cotton or synthetic—turn to Wellington Sears for able, experienced help.

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ultraviolet and found that, apart from the sun, the brightest objects would be the southern Wolf-Rayet stars, Zeta Puppis and Gamma Velorum. Also no fewer than 23 stars will have ultraviolet magnitudes brighter than minus 1.

Scientific American introduced its review of Davis' work with the prediction that "as rockets and earth-circling satellites rise above the atmosphere, astronomers will be able for the first time to capture the ultraviolet light emitted by the stars." Ultraviolet astronomy has in fact already begun with the use of high-altitude rockets. At 2 a.m. on November 17, 1955, the first measurements of far-ultraviolet emissions of the celestial sky were made by E. T. Byram, T. A. Chubb, H. Friedman and J. E. Kupperian, Jr., of the Naval Research Laboratory with an Aerobee rocket flown from the White Sands Proving Ground in New Mexico. The results of this experiment were reported late in August by Dr. Kupperian at the American Astronomical Society meeting in Berkeley, Calif.

The rocket reached an altitude of 104 kilometers. It was equipped with several photosensitive detectors of the photon-counter variety which were designed to respond uniquely to narrow bands of far ultraviolet radiation between 1,100 and 1,350 Angstroms. Stars with temperatures 10 times as great as that of the sun would radiate with maximum intensity at these short wavelengths rather than in the visible region.

The photon counters were collimated to view a small portion of the sky at any instant. As the rocket spun and yawed through its flight, the collimators swept out a large field of the night sky, and the instantaneous ultraviolet signals were telemetered to radio receivers on the ground. The strongest signals were received from the galactic plane and particularly bright emission could be identified with Zeta Puppis and Gamma Velorum.

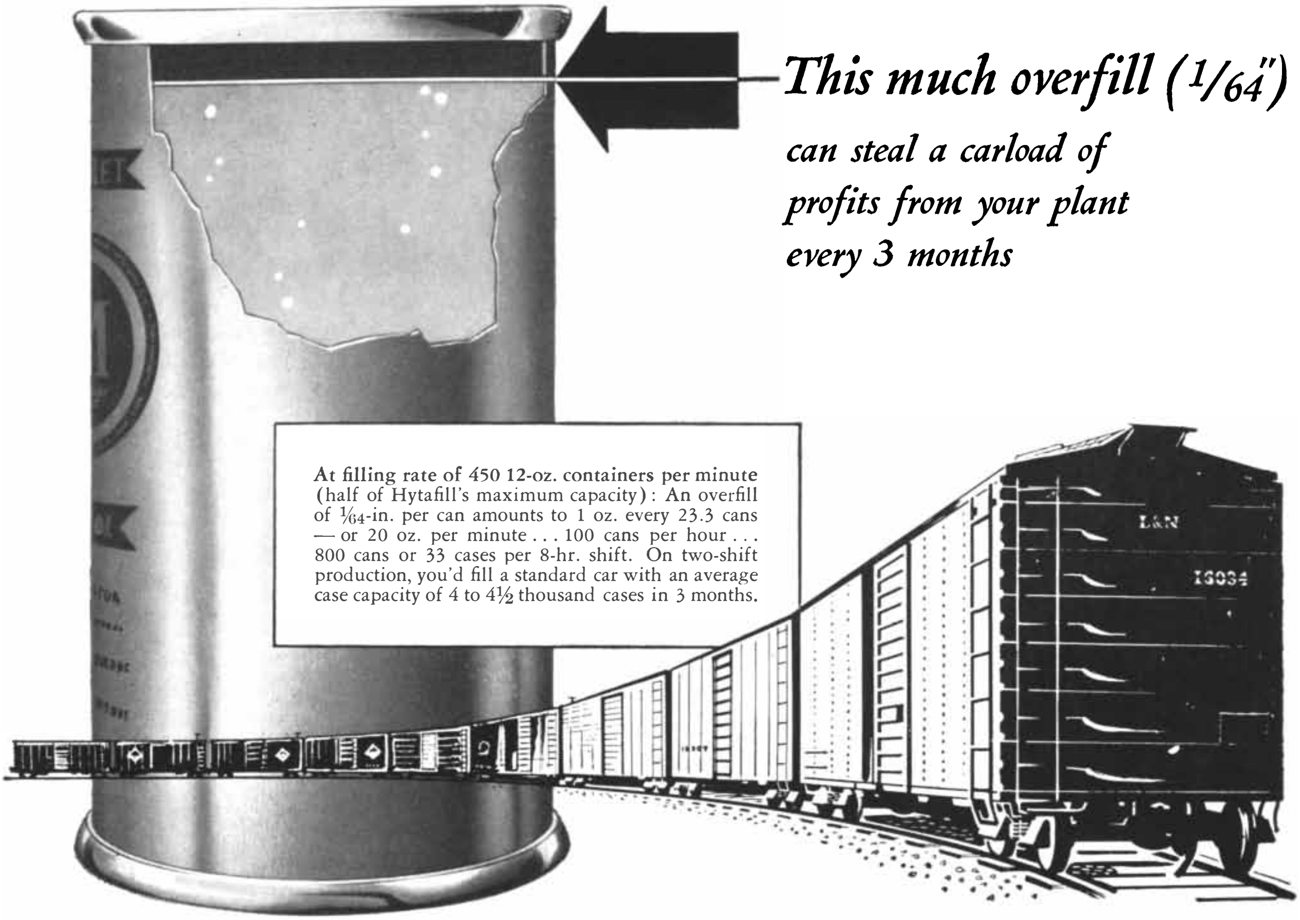
It was also possible to isolate the discrete line of emission of atomic hydrogen at 1,216 Angstroms known as the Lyman alpha line. It appeared as a diffuse radiation over the entire night sky. Future studies of this particular radiation may provide a clue to the distribution of hydrogen between earth and sun. More refined experiments are already being designed, and rocket astronomy will certainly develop rapidly during the next few years.

HERBERT FRIEDMAN

Naval Research Laboratory
Washington, D. C.

This much overfill (1/64")

can steal a carload of profits from your plant every 3 months



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Fast installation — adapts to existing conveyor lines. Hytafill consists essentially of a tube head and detector with remote control. Requires very little space. Tube head and detector are sealed against moisture . . . may be washed with steam and hot water. For full details on Hytafill, call your nearest General Electric x-ray representative. Or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, for Pub. **TT-114.**

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TO HELP YOU COMPARE a U. S. PowerGrip XX Heavy Duty "Timing" Belt drive with the four other common forms of power transmission of equal capacity, a power transmission engineer offers his recommendations based on published application and load ratings, for the following:

A 300-HP drive (at 1160 rpm.) including application factors. 3.00: 1 speed reduction. Approximately 50" center distance.

Here, complying with minimum pulley sizes and other practices commonly observed, are his recommendations (with approximate comparative cross sections of space occupied by each drive):

"TIMING" BELT DRIVE

Belt: XXH "Timing" Belt 10" wide by 160" P. L.

Motor Pulley: 9.549" P. D. (24-groove) 1¼"-pitch

Driven pulley: 28.648" P. D. (72-groove) 1¼"-pitch

Belt speed: 2900 feet per minute

V-BELT DRIVE

Belts: 10 Super Service "D"-Section V-Belts (DP-225)

Motor pulley: 18.0" P. D. x 10 D-groove, 14¾" wide

Driven pulley: 54.0" P. D. x 10-groove, 14¾" wide

Belt speed: 5380 feet per minute

GEAR DRIVE

Herringbone gear speed reducer with 3:1 ratio. (A typical reducer of required capacity weighs 1440 lb., measures 33" long, 26⅝" high and 19" wide.)

ROLLER CHAIN DRIVE

Chain: #80-8 (8 strands) 1"-pitch x 152 pitches

Motor sprocket: 7.979" P. D. (25 teeth)

Driven sprocket: 23.880" P. D. (75 teeth)

Chain speed: 2380 feet per minute

(Requires Type #3 lubrication with oil-tight case for sump pump)

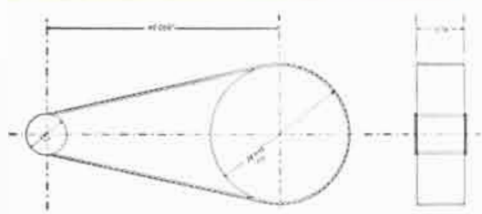
FLAT BELT DRIVE

Belt: 21" wide x 8-ply x 18' 4" long

Motor pulley: 18" O. D. x 23" wide

Driven pulley: 54" O. D. x 23" wide

Belt speed: 5380 feet per minute



Schematic of "Timing" Belt drive used for comparison above

Rubber cut away to show steel cables


POWERGRIP "1000"
THE "TIMING"® BELT DRIVE FOR HEAVY-DUTY MACHINERY
THIS LIFE-SIZE illustration only begins to suggest the brute strength built into this double extra-heavy-duty tooth-grip belt with steel-cable tension member *designed for drives up to 1000 hp.* Appearance doesn't tell the whole story, because, rating for rating, U. S. PowerGrip "Timing" Belt drives are lighter in weight and occupy less space* than any other form of mechanical power transmission.
Approximately 2½ times larger—and 2½ times stronger—than the standard "Heavy Duty" series, the new XX Heavy Duty drives bring to high-torque power transmission a never-before-obtainable combination of features:
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• Complete elimination of drive lubrication (including the problems and accessories involved).
• Precise angular synchronization ("Timing") between two or more shafts.
• Quiet operation.
• Practical elimination of power loss due to slippage, friction and high initial tension.
• Compactness and high strength-to-weight ratio.
• Belt speeds as high as 7500 fpm.
• Low initial cost; no maintenance; long life.
A complete line of U. S. PowerGrip "Timing" Belts—plus expert engineering assistance—is available at any of the 28 "U.S." District Sales Offices, at selected "U.S." power transmission distributors, or by writing U. S. Rubber, Mechanical Goods Div., Rockefeller Center, New York 20, N. Y. In Canada, Dominion Rubber Co., Ltd.
*Including accessories required by some other drives.
US RUBBER
Mechanical Goods Division
United States Rubber

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

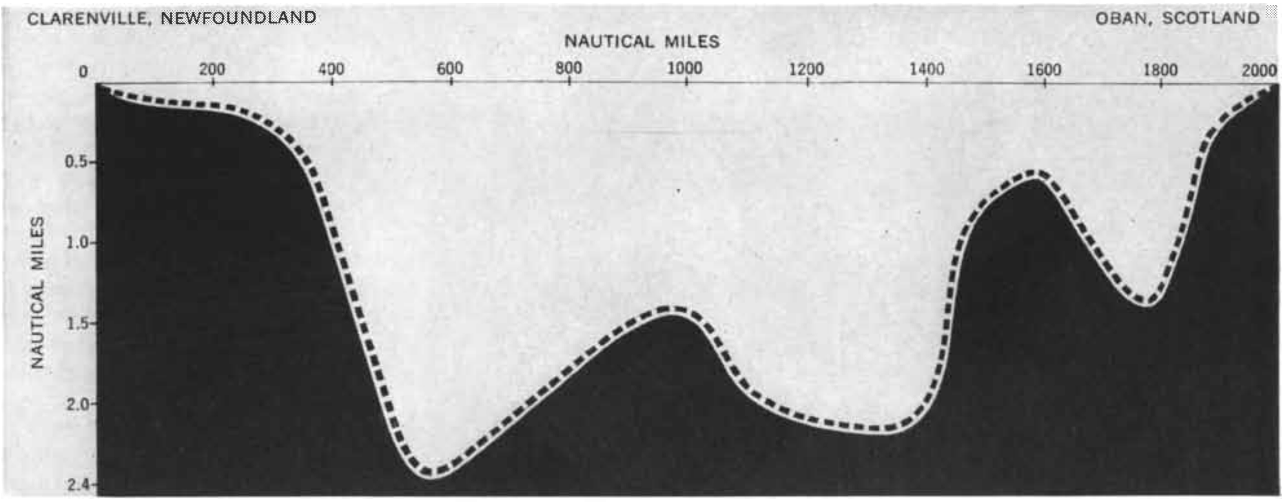
NOVEMBER, 1906: "Present roads are quite unable to stand up under the severe usage imposed by automobiles. The most serious difficulty is the abominable dust from which there seems at present to be absolutely no escape. As matters now stand, the only way to avoid dust-raising is to reduce speed considerably below the present speed limit; and this is out of the question. The automobile has come to stay. It is an industry too vast, a sport too noble to be subjected to any restrictions which would ultimately kill its popularity. Therefore if the automobile may not be brought down to the road, the road must be brought up to the automobile, and some way found by which the dust horror may be mitigated. None of the various dust-preventers has proved to be a success, although a mixture of blast furnace slag and tar is spoken of hopefully."

"A cable dispatch from Paris announces that Santos-Dumont, at 4 o'clock on Monday afternoon, Nov. 12, made a new record with his aeroplane, '14-bis.' He flew against a slight breeze for a distance of 210 meters (689 feet), or a trifle over one eighth of a mile. The machine was in the air for 21 seconds, which corresponds to a speed of 22.36 miles per hour. Santos is so elated by his success that he prophesies that aeroplanes for private transportation will soon be in use in large numbers."

"Commander Robert E. Peary has sent a message stating that he succeeded in reaching latitude 87 degrees 6 minutes. This is higher than the point reached by the Duke of the Abruzzi, who held the record. Peary wintered on the north coast of Grant Land and then traveled by sledge northward. Gales broke up the ice, destroyed his caches, and cut off communication with his supporting bodies. On the return his party had to eat eight dogs."

"Some little discussion has taken place recently regarding the possibilities of 'seeing electrically.' Selenium when

A TRIUMPH OF TELEPHONE TECHNOLOGY



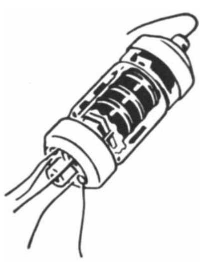
Contour of ocean bed where cable swiftly and clearly carries 36 conversations simultaneously. This is deep-sea part of system — a joint enterprise of the American Telephone and Telegraph Company, British Post Office and Canadian Overseas Telecommunications Corporation.

A great new telephone cable now links North America and Europe—the first transoceanic cable to carry voices.

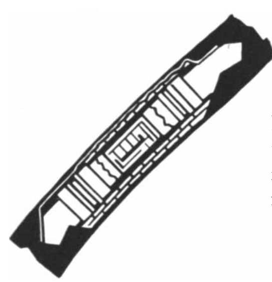
To make possible this historic forward step in world communications, Bell Laboratories scientists and engineers had to solve formidable new problems never encountered with previous cables, which carry only telegraph signals.

To transmit voices clearly demanded a much wider frequency band and efficient ways of overcoming huge attenuation losses over its more than 2000-mile span. The complex electronic apparatus must withstand the tremendous pressures and stresses encountered on the ocean floor, far beyond adjustment or servicing for years to come.

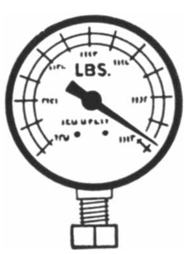
Here are a few of the key developments that made this unique achievement possible:



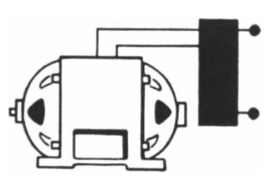
More than 300 electron tubes of unrivaled endurance operate continuously, energized by current sent from land.



Precisely designed equalizing networks and amplifiers compensate for the loss in the cable every 40 miles and produce a communication highway 144 kc. wide.



A unique triple watertight seal protects the amplifiers from pressures as high as 6500 pounds per square inch.



Power supplies of exceptional reliability send precisely regulated current along the same coaxial that carries your voice to energize the amplifying units.

BELL TELEPHONE LABORATORIES

World center of communications research and development carefully prepared becomes an electrical conductor whose resistance is affected by incident light. If a selenium surface were divided into a large number of small squares each of these would represent the small squares of a half-tone. If, from each square, a wire be led out and an equal source of electromotive force be introduced into it, the current flowing will correspond to the intensity of light on the corresponding square and determine the amount of illumination which should fall upon the corresponding square of the receiving surface. The final picture would be built up of a large number of small squares and would resemble a half-tone reproduction. It is, of course, out of the question to carry a considerable distance any such numbers of wires as this arrangement would require. However, the impressions might be produced successively with sufficient speed requiring that two different mechanisms, one at the transmitting station and one at the receiving station, run in absolute synchronism. At the present time, we seem to be a long way from accomplishing this result."

SCIENTIFIC AMERICAN

NOVEMBER, 1856: "Modern ethnology is something like spiritualism; neither is a new subject, but as treated by their students they develop many new absurdities. At present the German believes the Teutonic to be the model race; the Englishman and American believe the Anglo-Saxon to be the model type; while the French and Irish boast of the Celt. The truth is that virtue, bravery and industry are the qualities that make a model man and a model race. If such qualities were race peculiarities, then the nation first dominant would always be dominant, the Egyptian would still be the Prince of Men."

"In Gregory's *Inorganic Chemistry*—the most recent work on the subject published in our country—we find that there are now 61 simple substances (elements) known to chemists, and of these 14 constitute the great mass of the earth and the atmosphere; the remainder occur only in small quantities, and some are very rare."

"Collisions between vessels have become frequent, and, next to fires at sea, they are the most appalling and heart rending. The new French steamer *Lyon-*

New trends and developments in designing electrical products . . .

General Electric thermistors and Thyrite* varistors have unique properties that apparently contradict normal electrical laws. Here's how they can be harnessed to improve your product.

General Electric thermistors and Thyrite varistors are ceramic-like semiconductor resistance materials. Each has unique properties – apparently disobedient to normal physical laws – that enable it to perform tasks in electrical and electronic circuits which otherwise would require costly, complex components.

The distinguishing feature of thermistors is their *thermal* sensitivity. Thermistors have large *negative* temperature coefficients of resistance (i.e., their resistance decreases tremendously when heated, instead of increasing slightly like other materials).

Thyrite varistors, on the other hand, are *voltage*-sensitive. Contrary to Ohm's law, a current through a Thyrite varistor varies as a *power* of the applied voltage (i.e., doubling the voltage through a Thyrite varistor can increase the current from 15 to 25 times, instead of the normal 2 times).

The applications based on the unique properties of these materials are almost limitless. In general terms, thermistors are used in the detection, measurement, and control of minute energy changes; Thyrite varistors are used to protect, stabilize, and control circuits.

To give a clearer understanding of the ways thermistors and Thyrite varistors can be applied, here's how they have solved two of the electrical engineer's most vexing problems – temperature compensation and surge suppression.

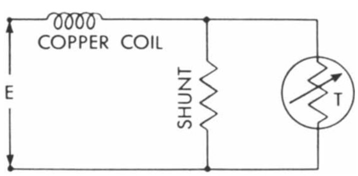


FIGURE 1 — Typical thermistor temperature-compensation circuit

The resistance of a conventional conductor is so affected by ambient temperatures that steady current flow cannot be maintained. For example, as the temperature of copper swings from –60° C to +80° C, the resistance increases 53%.

However, when the copper is compensated with a properly selected thermistor, the maximum deviation from the total average resistance at 25° C is only 3½% – despite the 140° swing in temperature.

In the circuit in Fig. 1, the thermistor's negative temperature coefficient of resistance offsets the positive temperature coefficient of the copper to stabilize current flow. In other circuits, thermistors can be utilized for signal and warning devices, sequence switching, and other time delay applications, because of the inherent thermal inertia involved.

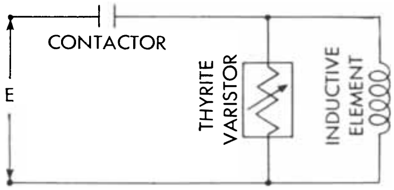


FIGURE 2 — Thyrite varistor surge voltage suppression circuit

Sudden interruptions of inductive circuits cause surge over-voltage, arcing, and high-frequency oscillations – all of which can cause trouble. The circuit in Figure 2 shows how a Thyrite varistor can be connected to hold these effects within safe limits.

With the Thyrite varistor out of the circuit, the surge voltage caused by interruptions of the current may rise to 9 times applied peak voltage (Oscillogram, Figure 3).

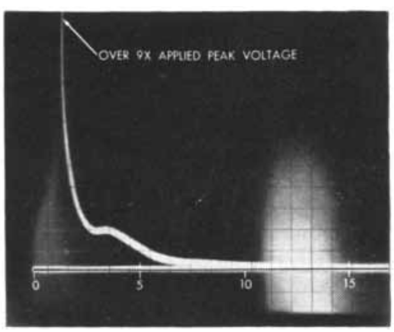


FIGURE 3

But with the Thyrite varistor in the circuit, (Figure 4), the surge voltage is limited to less than 3 times the normal applied peak voltage.

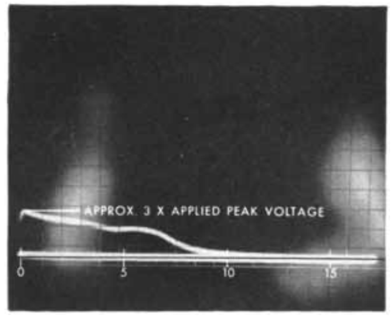


FIGURE 4

The Thyrite varistor draws negligible current at rated voltage, yet offers sufficiently low resistance at the peak current to limit the surge voltage to a safe value and to reduce arcing. Also, the Thyrite varistor quickly discharges circuit energy by providing increasingly higher resistance as the inductive current decays.

If a linear resistor were used to provide the same voltage suppression level, it would have to draw a current equal to more than 30% of the inductive element current.

In addition to surge suppression, a Thyrite varistor can be used as a nonlinear resistance parameter, a potentiometer, and a frequency multiplier. It can also be used as a bypass resistor to protect personnel and equipment from circuit faults.

Technical literature giving complete data on properties, applications, sizes, and shapes of G-E thermistors and Thyrite varistors is available. And, for the experimenter, there are two engineering test kits on each.

To obtain kits, literature, or the assistance of a General Electric Engineer on your problem, write: *Metallurgical Products Department of General Electric Company, 11199 E. 8 Mile Road, Detroit 32, Michigan.*

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*Registered trademark of General Electric Company *nais* was run into on the night she left this port by the bark *Adriatic*, which cut her through the middle. It is believed that all on board—150 persons—with the exception of 16 who escaped in a boat, have perished. The captain of the *Adriatic* reports that he saw the steamer 20 minutes before his vessel struck her and that the collision was caused by the steamer *suddenly* altering her course. He also states that there was a slight haze but that it was not foggy. From all the evidence gathered, each of the vessels was driving on its course with inexcusable speed."

"The U. S. steamer *Arctic*, which was sent by the Secretary of the Navy to survey the intended route across the Atlantic Ocean between Newfoundland and Ireland for the ocean telegraph cable, has arrived at this port, having sounded all the way across the bed of the ocean. The section traversed by the *Arctic* is a plateau. The bottom, in the deepest part, is a very fine mud. Toward the shores on each side, this mud changes into a fine green ooze. No substances were met with that might prove fatal to a telegraph wire. The distance across was 1,640 sea miles, and the greatest depth, 2 miles 186 feet."

"Chemists have been very successful in analytic chemistry, that is, in resolving substances into their elementary parts, but not quite so successful in synthetic chemistry, that is, in manufacturing substances found in a state of nature, by endeavoring to combine their known elements. There have been some splendid achievements in synthetic chemistry, but not one tithe of what must and shall be obtained. Why cannot many articles, now very dear, be manufactured by synthetic chemistry from cheap materials? We have directed attention to a cheap substitute for leather, but there are hundreds of other articles of importance to mankind to which similar attention might be given."

"Henry Bessemer has now obtained an American patent for his improvement in the manufacture of iron; namely, producing combustion without fuel by forcing air, steam or other gases through molten iron in a vessel to supply oxygen to the carbon in the molten crude metal and thus produce combustion to burn out the excess of carbon. The claim is based upon this idea, not that he was the first that used air or steam in this manner, but that he discovered the effect of driving oxygenated gases through molten iron."

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Solve the big problems of small assemblies by letting Elgin produce them for you at lower cost. Elgin puts the highly trained people and specialized facilities needed to handle miniaturized components at your service. After all, miniaturization has been our business for years.

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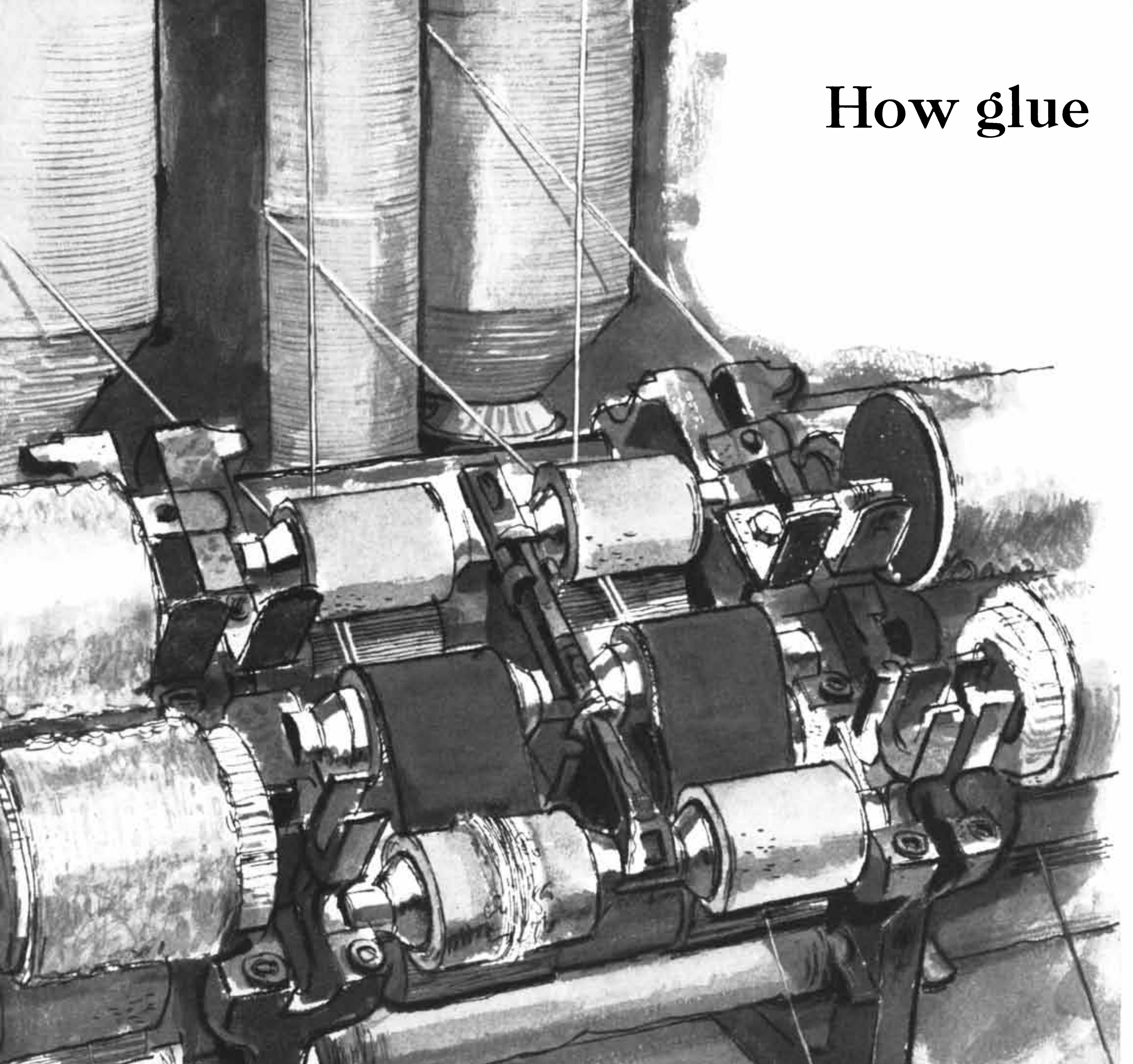
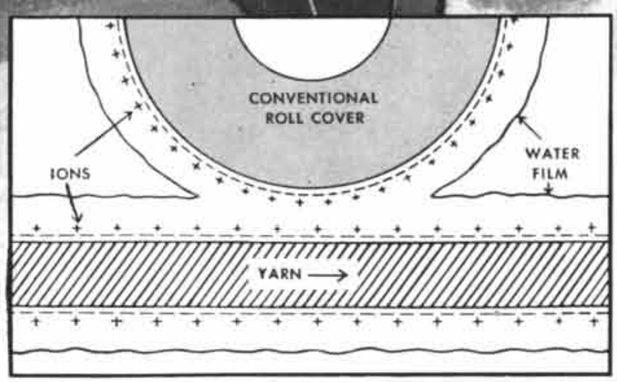
ELGIN NATIONAL WATCH COMPANY

MICRONICS DIVISION • ELGIN, ILLINOIS

How glue



In spinning, a soft, rope-like ribbon of fibers called "roving" is drawn out and twisted to make yarn. If yarn breaks, adhesive force of invisible water films on both yarn and front spinning roll may cause yarn end to "lap up" or wrap around the roll, as shown in center above. Lapped yarn must then be cut away. If adhesive force is destroyed, however, broken yarn will fall away from roll, making it easier to "piece up" the end.



Two layers of ions (electrically charged particles) form in the microscopic films of water on both yarn and spinning roll cover. (Moisture film and yarn greatly enlarged in drawing.) This ion arrangement creates an adhesive force (electro-kinetic potential) that bonds water films tightly to surfaces of roll cover and yarn.

keeps water from becoming "sticky"

Unique electrolyte gets rid of surface attraction on yarn spinning rolls; may lead to improved drive and feed rolls for other industries

You can't see it, you can't feel it; but covering practically everything exposed to humid air is a microscopic film of water. Sometimes this film becomes "sticky" like an adhesive and bonds things together.

This stickiness, known technically as a form of surface attraction, has been the cause of serious problems in industry, particularly in spinning textile yarns. A few years ago, however, Armstrong textile research men found a way to prevent this water film from becoming sticky. Strangely enough, they did it with glue!

Armstrong chemists reasoned that a water film on a surface acts like an adhesive because it contains layers of electrically charged particles called ions. One layer of ions is positive, the other negative. This layer arrangement of ions creates an electrical potential that acts like an adhesive force. It actually bonds the moisture film tightly to the surface of the material it covers.

In the manufacture of yarn, the film of moisture on both spinning rolls and yarn frequently causes a phenomenon known as "lapping up." When the yarn breaks during spinning, the loose end sticks to the spinning roll and wraps tightly around it. Production is stopped until the lapped yarn can be removed from the roll.

Armstrong scientists prevent this "lapping up" by adding an electrolyte to the synthetic rubber used in making spinning roll covers. According to theory, this new roll covering material releases into the water film additional ions which cancel out, or neutralize, the bonding force created by the double-layer arrangement. The water film no longer holds the yarn to the roll.

Of all the electrolytes tested, one of the best at preventing water from becoming sticky is animal glue. (The details of this development are covered in Patents No. 2,450,409-410). Special studies are now going on at the Armstrong Research and Development Center to see if such electrolytic materials used in roll coverings can help solve surface attraction problems in other industries.

If you manufacture equipment using resilient rolls for handling web or film material, you may be troubled by a similar form of surface attraction. Specialists at the Armstrong Research and Development Center will be glad to determine whether or not an electrolytic rubber roll covering would improve the operation of your equipment. For details, call the nearest Armstrong Industrial Division Office or write on your letterhead to Armstrong Cork Company, Industrial Division, 8211 Inland Road, Lancaster, Pennsylvania.

Armstrong Industrial Products

... USED WHEREVER PERFORMANCE COUNTS

ADHESIVES
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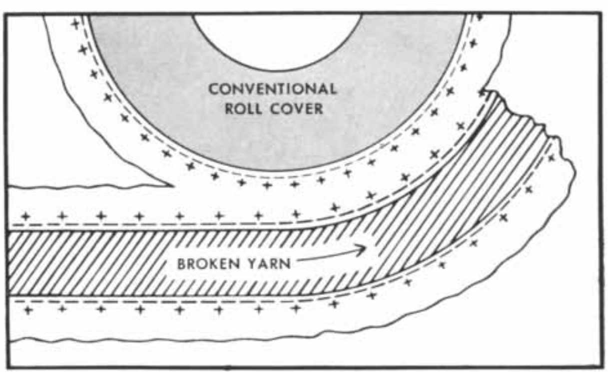
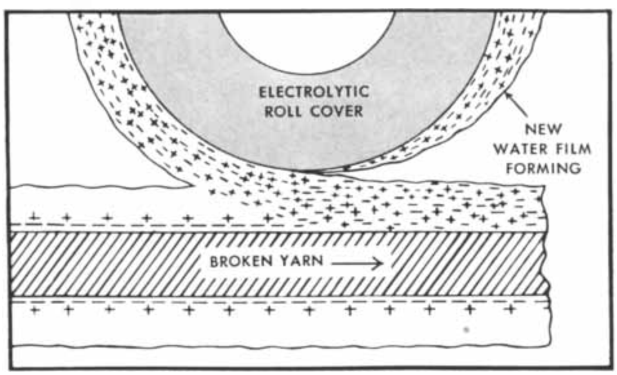


If yarn breaks after being drawn under roll, water films hold broken end to roll cover causing a "lap up." This is a result of two water films meeting under pressure of roll and merging into one. Internal forces in single film make it resist splitting . . . and ion arrangements bond it to surfaces of both yarn and roll.



Such "lap ups" are stopped by roll cover containing electrolyte which puts additional ions into water film. These break up ion arrangement, destroying adhesive force or electro-kinetic potential. Water film loses its stickiness . . . weight of yarn pulls it away from roll cover . . . and broken yarn end cannot "lap up."

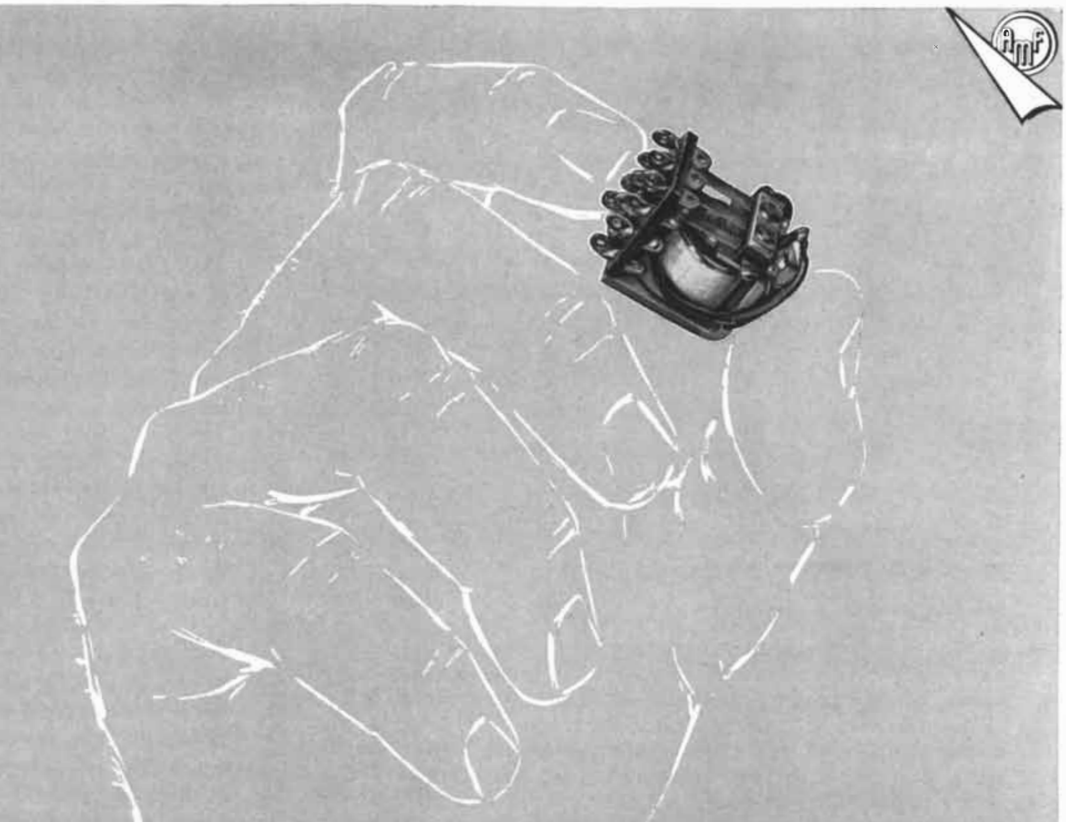
THE AUTHORS

JAMES A. VAN ALLEN ("The Artificial Satellite as a Research Instrument") is a professor of physics and head of the physics department at the State University of Iowa, where he received his doctoral degree in 1939. He is a native Iowan. During World War II he served as an ordnance and gunnery officer in the U. S. Navy and had a hand in developing the radio proximity fuze for the Office of Scientific Research and Development. Since the war he has pioneered in the application of rocketry to upper-atmosphere research. For his role in supervising the development of the Aerobee rocket he was awarded the C. N. Hickman Medal of the American Rocket Society in 1949. Later he organized and commanded rocket-firing expeditions to the central Pacific, Greenland and the Gulf of Alaska for research on cosmic rays. Van Allen has been chairman of the Upper Atmosphere Rocket Research Panel since 1947. He is a member of the U. S. Technical Panels for the International Geophysical Year in Cosmic Rays, Rocketry and the Earth Satellite Program. In the latter committee he is chairman of the working group on internal instrumentation.

ROLLIN D. HOTCHKISS AND ESTHER WEISS ("Transformed Bacteria") together performed the first transformations producing drug-resistant bacteria at the Rockefeller Institute for Medical Research in New York, of which Hotchkiss is an associate member. Hotchkiss graduated from Yale University's Sheffield Scientific School and received a Ph.D. from Yale in organic chemistry. After a year as an instructor at Yale he went to the Rockefeller Institute in 1935. He has worked there since, except for a year of study in Copenhagen and a wartime tour of scientific duty with the Navy. At the Institute he was associated with René J. Dubos in determining the composition of the antibiotics tyrocidine and gramicidin. This led him to study the metabolism of bacteria as the object of attack in chemotherapy, which in turn led to his work in genetic transformation. In his spare time Hotchkiss is an ardent do-it-yourself carpenter, photographer and mineralogist. Miss Weiss holds a B.A. in biology from Smith College. She worked with Hotchkiss at the Institute from 1950 to 1952, and later was with the Olin Mathieson laboratories in New Haven and Children's Hospital in Boston. She is a science editor and writer as well as a biologist, and by avocation a pianist and composer.

MUZAFER SHERIF ("Experiments in Group Conflict") is professor of psychology and director of the Institute of Group Relations at the University of Oklahoma. As a student at Istanbul University he was greatly impressed by the writings of William James. He came to the U. S. to study psychology at Harvard University, where he took an M.A. in 1932, and at Columbia University, where he earned his Ph.D. under the direction of Gardner Murphy in 1935 with a thesis entitled "A Study of Some Social Factors in Perception." If Sherif's interest in perception owes something to the inspiration of James, his concern with group conflict derives in part from his eyewitness experience of war and revolution in his native Turkey, of mass hysteria in Germany in 1932 and of social decay in prewar France. These occurrences made a considerable impression on him, he says, leading him to form the idea of a social psychology "which would embody the main features of actual life events, pointing if possible to realistic solutions of such problems." From Columbia Sherif returned to Turkey and taught psychology at Ankara University. A State Department fellowship brought him to Princeton University in 1945; in 1947 he went to Yale as a Rockefeller fellow and began the experiments which he describes in his article.

HARRY L. FISHER ("Rubber") is professor of chemical engineering and rubber technology at the University of Southern California. He is a graduate of Williams College (class of 1909) and received his Ph.D. in organic chemistry from Columbia University in 1912. A synthetic rubber tire was demonstrated at a chemical conference at Columbia in the same year that he received his doctoral degree. Fisher was attracted to the new field and became an outstanding pioneer in it. He joined the B. F. Goodrich Company in 1919 as a research chemist, moved on to the U. S. Rubber Company and was director of organic research in two other concerns before returning to the academic life in 1953. He holds about 50 patents, dealing chiefly with adhesives and thermoplastic resins, including substitutes for shellac, balata and gutta-percha. He has been active in the American Chemical Society since 1910, has organized two international conferences and has been national president of the American Institute of



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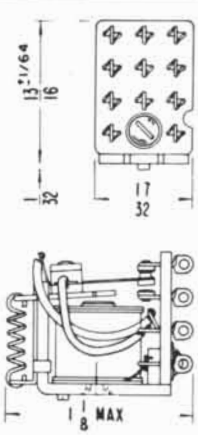

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Chemistry and Phi Lambda Upsilon. Fisher is fond of color photography, hiking and mountain climbing.

E. N. da C. ANDRADE ("The Birth of the Nuclear Atom"), a physicist and writer who has previously contributed to Scientific American, was an associate of Lord Rutherford in 1913 and a participant in some of the events he describes in his article. Andrade is a man of many parts—the discoverer of Andrade's law for the creep of metals, a historian of science, for 21 years a Fellow of the Royal Society, a Chevalier of the Legion of Honor, a corresponding member of the Académie des Sciences and of the Institut de France, a skilled linguist, a poet, bibliophile and gourmet. His career was recapitulated in this department in connection with his biographical sketch of Robert Hooke in the issue of December, 1954.

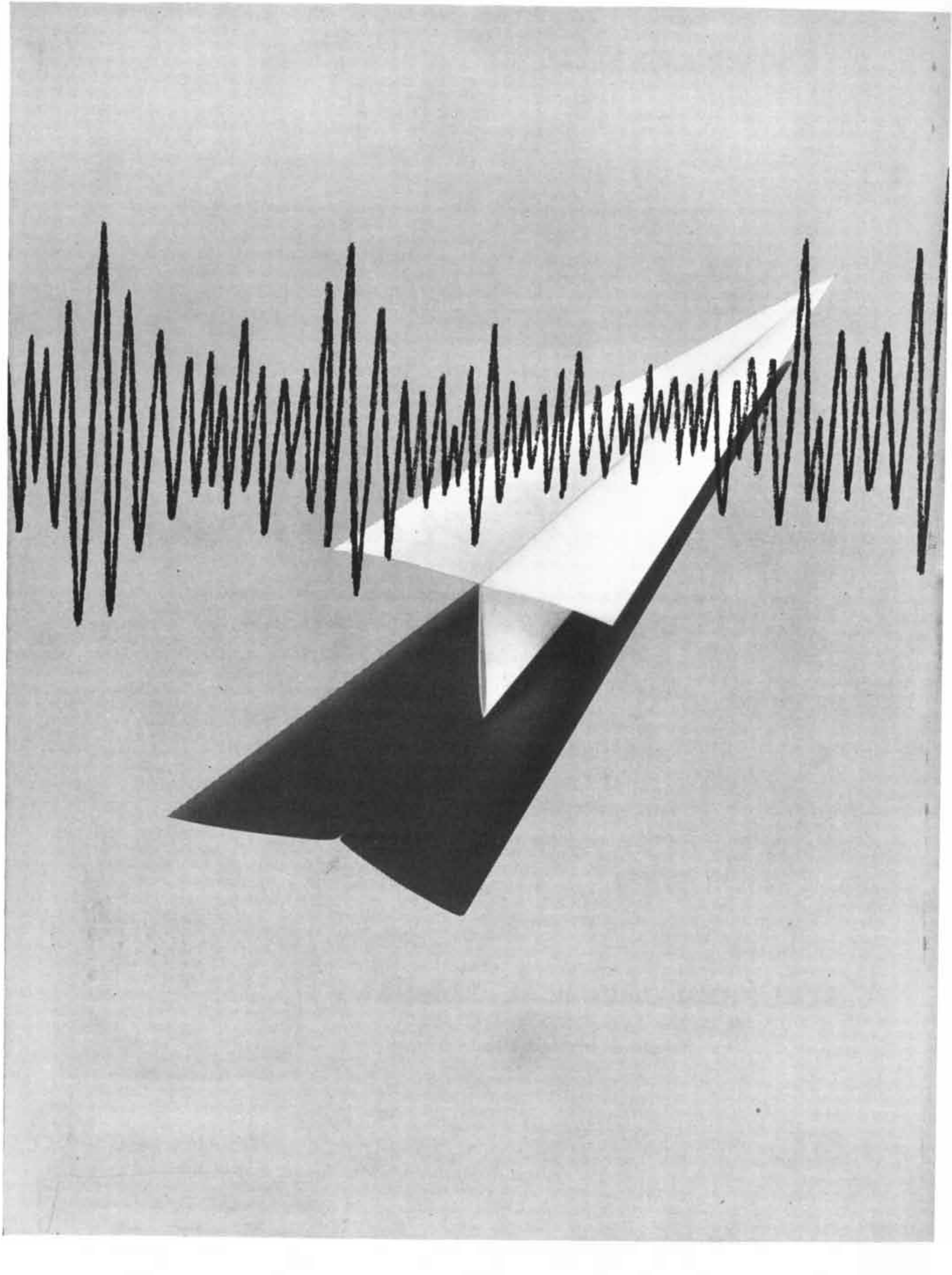
JEAN MAYER ("Appetite and Obesity") is associate professor of nutrition in the Harvard University School of Public Health. The son of André Mayer, a well-known physiologist, he was trained at the University of Paris and became a Fellow of the Ecole Normale Supérieure in 1939. When war broke out he joined the French Army as an officer of artillery and campaigned with the Free French for five years; his services in Africa, Italy and the landing in France won him the Resistance medal and several Croix de Guerre. In 1945 he went to Yale University as a Rockefeller Foundation fellow, receiving his Ph.D. in physiological chemistry in 1948. The following year he was nutrition officer with the Food and Agricultural Organization of the United Nations. He joined the Harvard faculty in 1950, after taking a Doctor of Science degree at the Sorbonne. He is the author of some 150 scientific papers dealing with such subjects as vitamins and the regulation of body temperature, as well as with his specialty, obesity.

LORD ROTHSCHILD ("Unorthodox Methods of Sperm Transfer") is assistant director of research in the department of zoology of the University of Cambridge, and a Fellow of the Royal Society. He follows in the footsteps of his uncle, the second Baron Rothschild, who was also a zoologist trained at Cambridge. Lord Rothschild holds the degrees of Ph.D. and Sc.D., was a research fellow at Trinity College and is the author of many studies on fertilization. This, however, is only one of his occupations. He is chairman of the British Agricultural Research Council and a

member of the British Broadcasting Corporation General Advisory Council. He spent three months at the age of 21 in the famous family institution, Rothschild's Bank, but left it because he found scientific work more interesting. During the war Lord and Lady Rothschild were both engaged in antisabotage bomb disposal for the British Intelligence Service, and both were decorated "for dangerous work in hazardous circumstances." Lord Rothschild was attached to the U. S. Army for a short time as a Lieutenant Colonel, and was awarded the U. S. Bronze Star and the Legion of Merit. His avocations are golf (with a handicap of five) and farming. Lady Rothschild is a justice of the peace in Cambridge. They have six children, ranging from one and a half to 22 years.

LLOYD J. ROTH and ROLAND W. MANTHEI ("Radioactive Tuberculosis Drugs") worked together at the University of Chicago, where Roth is associate professor of pharmacology. Roth is an M.D. and a Ph.D. He received his Ph.D. in chemistry at Columbia University in 1942, worked on incendiary bombs and jellied gasoline and was later assigned to the Los Alamos Scientific Laboratory, where he was a research chemist until 1948. In his last year at Los Alamos his interests shifted from chemistry to biology, and he went to Chicago for his M.D. Manthei worked with Roth as a graduate student and received a Ph.D. from Chicago in 1953. He is now assistant professor of pharmacology at Jefferson Medical College in Philadelphia.

MAX BLACK, who reviews James R. Newman's *The World of Mathematics* in this issue, is Susan Linn Sage Professor of philosophy at Cornell University. He was born at Baku in Russia, moved to England and graduated in 1930 from Queens College of the University of Cambridge. He began as a mathematician, but the influence of Bertrand Russell and Ludwig Wittgenstein diverted him into logic and the philosophy of science and language. During the 1930s he was a lecturer for the Workers' Educational Association and the University of London Institute of Education. Shortly before World War II he received his Ph.D. from the University of London and came to the U. S., where he has been a naturalized citizen since 1948. Black is the author of many books, including *Critical Thinking* and *Science and Civilization*. He reviewed Pierre Duhem's *The Aim and Structure of Physical Theory* in SCIENTIFIC AMERICAN for August, 1954.



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The Artificial Satellite as a Research Instrument

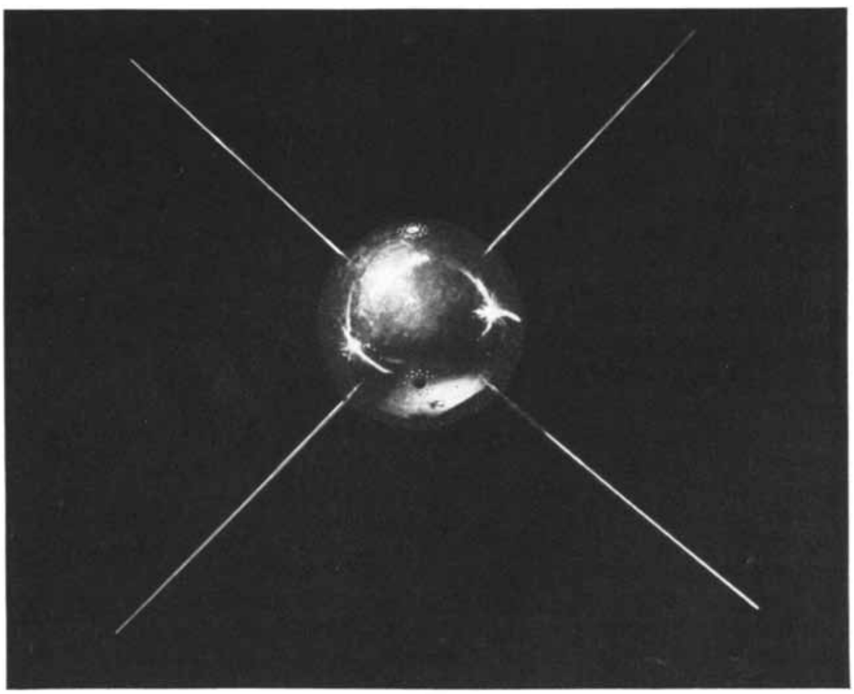
Its payload of 10 pounds will telemeter information about conditions at the edge of space. When its batteries have run down, we can still learn much by observing its flight

by James A. Van Allen

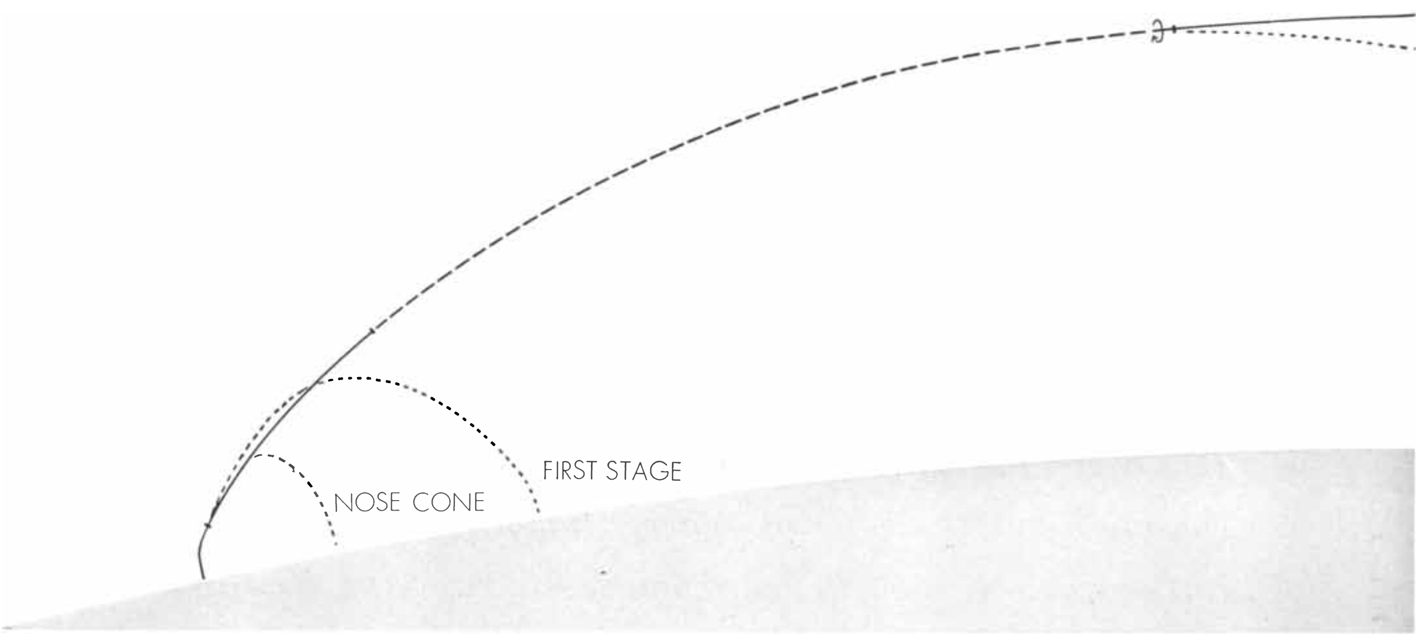
Most persons interested in space travel will be willing to wait until the second or third spaceship has made it to the moon and back before booking their reservations. The artificial earth satellites are another story. If all goes well, the first of them will be on orbit by early 1958, during the International Geophysical Year. Already there is a long waiting list of research projects for these first satellites. Unhappily they will have little space for research apparatus. Only about half of their 20-pound weight can be devoted to instruments for recording and reporting physical conditions at the edge of outer space.

The National Academy of Sciences and the Defense Department have announced that they plan to make enough launching attempts to establish at least one satellite in a durable orbit: there may be 12 such attempts during the I.G.Y.

Each successful flight should vastly enrich our knowledge of the earth and its environment in space. Much has been learned during the past 10 years by means of high-altitude research rockets, and some 200 such rockets will be fired during the I.G.Y. But a rocket flight lasts only a few short minutes. By comparison, a satellite traveling around the earth for days or months will be a semipermanent observatory. From it we can undertake direct and more or less continuous monitoring of the intensities of arriving radiations which are absorbed and obscured by the protecting blanket of the atmosphere. We can get a count and a spectrum of the sizes of the micrometeorites that the earth sweeps up on its orbit. The round-the-world travels of the satellite will make possible surveys of the outer reaches of the geomagnetic field and the cloud cover over vast areas of the earth below. These and other satellite observations can be correlated with observations



SPHERICAL SATELLITE, as represented by this Naval Research Laboratory model, would be 20 inches in diameter. The antennas are for the tracking and telemetering transmitters.



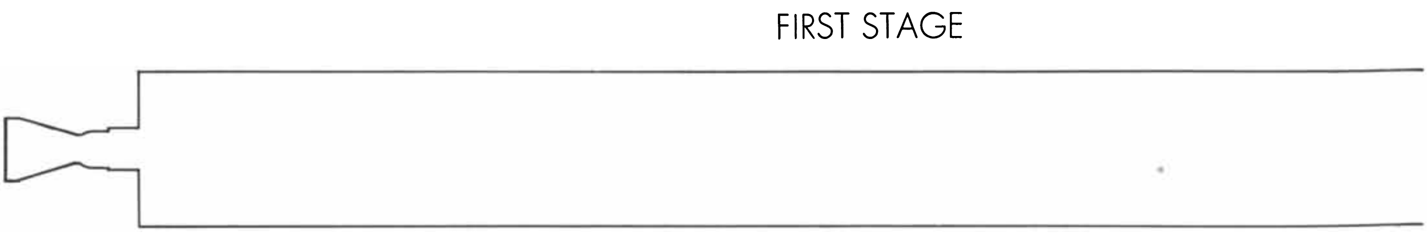
LAUNCHING FLIGHT PLAN calls for unprecedented feats of rocketry and control engineering. The three-stage rocket (*see diagram at bottom of these two pages*) will take off vertically (*left*) and tilt gradually to a 45-degree angle. At the burnout and separation of the first stage, the vehicle has attained an altitude of 36 miles and a velocity of 3,600 miles per hour. The second stage accelerates to 11,000 miles per hour at burnout, reaching an altitude of 140 miles. The vehicle then coasts upward (*broken line*) to an altitude

from the ground to establish more clearly the connection between events inside and outside our atmosphere.

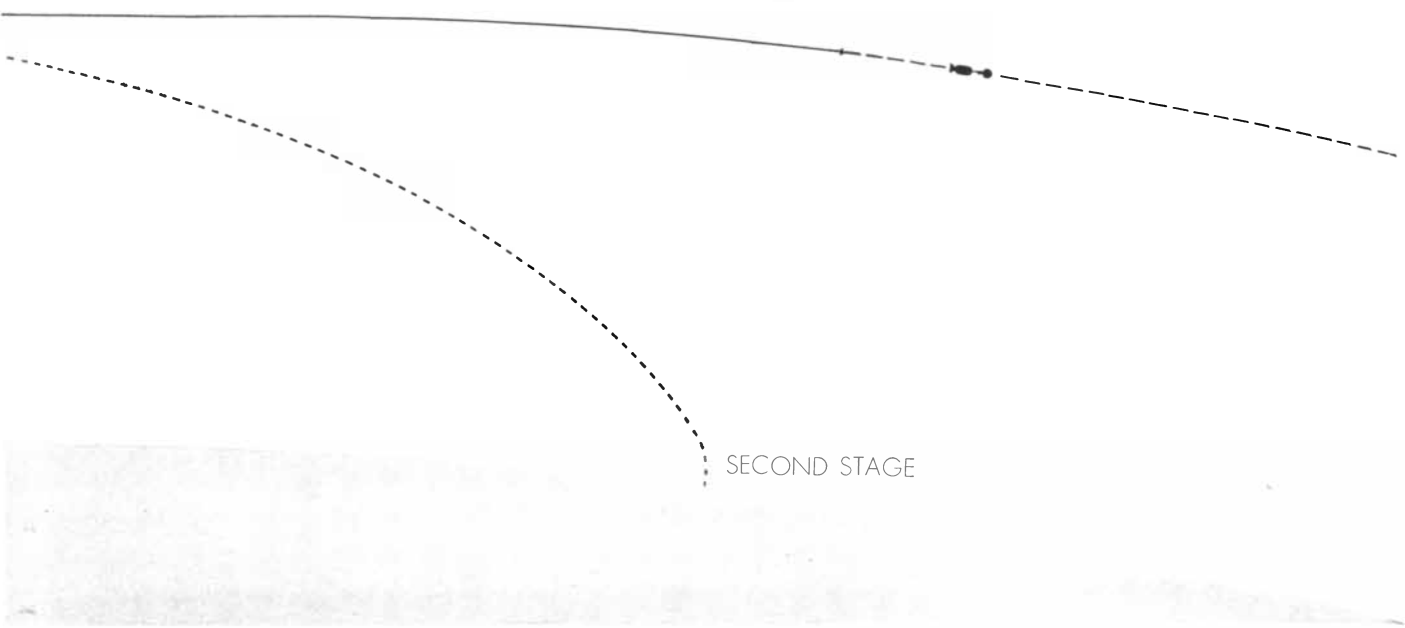
Even without instruments a satellite can be a useful research tool. When conditions are right, against a twilight sky, it will be visible to the naked eye as a very faint and fast-moving "star"—about as dim as the faintest star an acute human eye can see. The direction and speed of its flight can be plotted by sky cameras and by observers equipped with low-power telescopes and binoculars. The variation of its velocity and the perturbations of its orbit will yield precise information about the density of the upper reaches of atmosphere and about the true shape of the earth and the distribution of its mass within. Fixes taken on its position from observatories around the globe will locate reference points on different continents with great precision and reduce present errors in the world map.

The laws of physics set certain inexorable limits on the design and behavior of a satellite. In the first place, to hold an orbit around the earth the satellite will have to have a velocity of at least five miles per second. Man has not yet succeeded in hurling any sizeable object at this velocity. At the present stage in the art of rocketry, the velocity requirement sharply restricts the mass of the satellite. To get a 20-pound object up to orbital velocity at sufficient altitude above the earth to free it from the drag of the atmosphere will require a launching rocket weighing 22,000 pounds. It might seem that with a propulsion system of this size a few extra tens of pounds of payload would make little difference. But to deliver a 40-pound satellite on the same orbit would require a propulsion system weighing 44,000 pounds.

The choice of orbit is likewise restricted. It is not possible, for example, to have a satellite describe a halo over the globe around, say, the Arctic Circle.



LAUNCHING VEHICLE is to be a finless three-stage rocket, 72 feet long and 45 inches in diameter at its thickest point, with a total weight of 11 tons. The first stage, an improved version of the Viking rocket, burns liquid oxygen and a mixture of alcohol and gasoline to deliver a thrust of 27,000 pounds for 140 seconds. The motor is mounted in gimbals, permitting its jet to be turned for steering. The second-stage rocket, an improved version of the Aerobee, contains the control system for all three stages and carries in

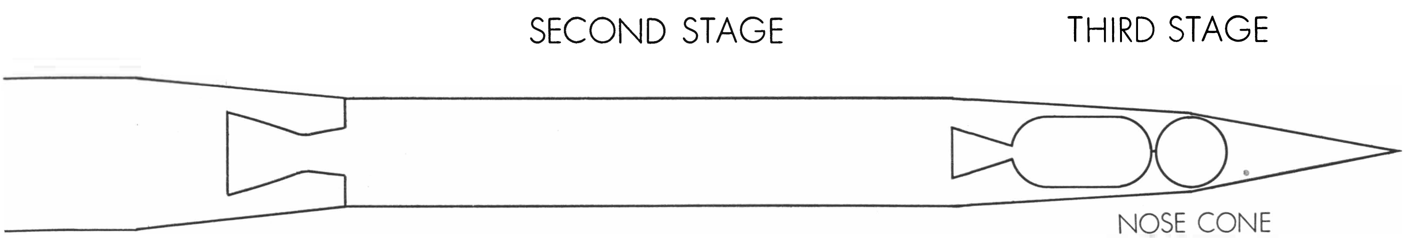


of 300 miles and a distance of 700 miles from the launching point, decelerating to 9,000 miles per hour. The nose cone is jettisoned early in the second-stage powered flight. Just before the second stage separates (*center*), an array of pinwheel jets spins the vehicle on its long axis. The third-stage rocket then accelerates (*solid line*) to 18,000 miles per hour at burnout, 10 minutes and 1,500 miles away from the launching point. Finally the satellite separates from the third-stage shell (*right*) and the two continue together on orbit.

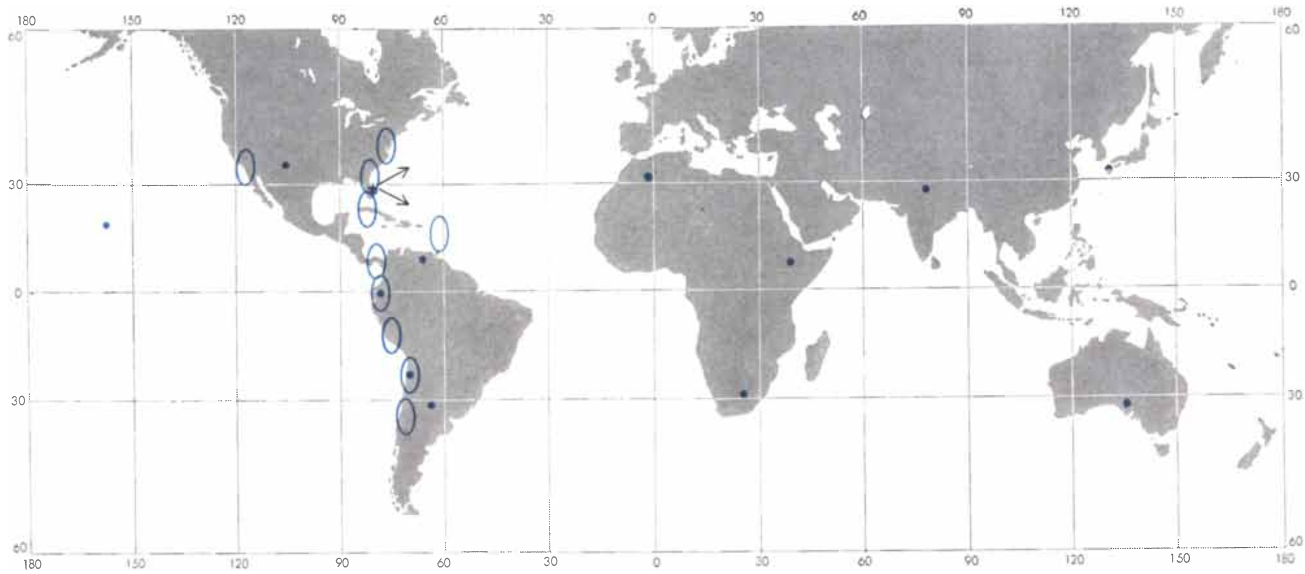
The orbit must lie in a plane through the center of the earth. For some purposes a perfectly circular orbit would be ideal, but since perfect directional control of the satellite is impossible, the actual orbits will be mildly elliptical in shape, with the center of the earth at one of the two mathematical foci. Here the question of altitude becomes important. The lifetime of a satellite is determined by the atmospheric resistance it encounters. At 300 miles, the projected launching altitude, it will find the atmosphere about as thin as that in a laboratory vacuum. On an elliptical orbit, however, it will travel through lower altitudes during part of its flight. Air resistance there will slow the satellite so that it will spiral inward to the denser regions where friction will finally burn it up. Because knowledge of atmospheric density at high altitudes is so uncertain, we cannot make firm predictions about the life expectancy of satellites. The objective for the first satellite is an orbit which will take it no closer than 200 miles from the earth's surface at perigee and no farther than 1,500 miles at apogee. Estimates of its lifetime in such an orbit range from a few weeks to a year.

For convenience of observation, among other reasons, the first satellites will be set on orbit at a 40-degree angle to the Equator. This orbit will keep them circulating overhead in a zone between the 40th latitudes north and south. At the orbital velocity of 18,000 miles per hour, a satellite will circle the earth in about 100 minutes, or 14 to 16 times per day. The eastward rotation of the earth will cause its path to describe a sinusoidal curve around the Equator. The equatorial bulge of the earth, and detailed mass irregularities such as mountain ranges, will produce perturbations of the satellite's orbit [*see diagram at bottom of page 45*].

Over a sufficiently long time the satellite will come at least once within sighting distance of everyone within the orbital zone, covering some 125 million



its nose the third stage and the satellite. It is powered by nitric acid and hydrazine. The second-stage motor is also mounted in gimbals for steering. Supplementary control is provided by auxiliary jets which stabilize the vehicle during coasting flight (*see diagram at top of pages*) and spin it on its long axis just before the ignition of the third stage. The third stage is a solid-propellant rocket. It is unguided, but its spin averages out the variations in the thrust of its motor so that it stays on a smooth course.



TRACKING STATIONS will form a "picket fence" roughly along the 75th meridian from Washington, D.C., south to Santiago, Chile, and will be located at strategic points elsewhere. Ellipses indicate range of the radio tracking stations; dots locate optical stations.

square miles of the earth's surface. It will be sighted most frequently near northern and southern boundaries of the zone. To a casual observer the arrivals of the satellite overhead may appear quite capricious. It will cross the sky at different speeds, at different altitudes and in different directions.

One of the reasons for choosing a lateral orbit around the earth is to take advantage of the earth's rotation to help launch the satellite. The plan is to launch the objects from Cape Canaveral, Fla., toward the east over the Atlantic Ocean. The earth's eastward rotation will add, by a kind of slingshot effect, to the velocity given the satellite by the rockets. Every bit of velocity is precious. A velocity of 18,000 miles per hour and an altitude of 300 miles represent an enormous advance over the present record of 6,000 miles per hour and 250 miles established in 1949 by a two-stage rocket. The vehicle that is to accomplish this is a three-stage 72-foot finless rocket [*see lower diagram on the preceding two pages*].

No less remarkable than this achievement in rocketry will be the feat of control engineering that will carry out the flight plan. The vehicle will be self-guided by an intricate control system housed in the second stage. This system will take command on the launching platform. It will time the ignition and the separation of the spent rockets, and it will direct the jets of the gimbal-mounted motors of the first- and second-stage rockets to swing the vehicle smoothly from its initial vertical trajectory onto a course parallel with the earth's surface [*see upper diagram on preceding pages*]. Just before it ignites the third stage, it will fire a pinwheel array of jets which will set the vehicle rotating on its long axis. The third stage, spinning at several revolutions per second, will then streak away in stable flight on the orbit. The shell of this rocket might itself serve as a satellite, without instruments. If it carries an instrument-loaded "bird," the final propulsion shell and the bird will separate at a pretimed moment. In that case we shall have two companion satellites, for the third-stage shell as well as the bird will continue on orbit. The instrument-carrying satellite may be a sphere, a cylinder or some other shape; there is even a possibility that it may be made inflatable, to improve its visibility.

The launching, if all goes well, will set the stage for the nerve-wracking task of the first sighting of the satellite. Down-range observation of the departing rocket will predict the arrival of the satellite over a given observation point with an error of no less than six minutes and several hundred miles. There may well be doubt that the object is actually in a durable orbit. The number of fully equipped optical observatories will be limited. Their coverage will have to be extended by mobilizing amateur observers all over the world and assigning them systematically plotted areas of sky. If the satellite is not sighted on its first time around, the game of sighting it will assume constantly greater uncertainty. It is needless to enlarge on the haunting fear that a satellite might be on orbit and yet escape detection.

Such a possibility dictates that the first satellites be equipped with a low-power radio transmitter even if they carry no other instruments. A radio beacon and storage batteries to give it several weeks of life can be installed at a cost of about one pound in weight. Its signal can be used to report observations as well as for location. To pick up the signals, an array of tracking stations will be located along the 75th meridian from Washington, D.C., to Santiago, Chile. The satellite will have to pass through this picket fence every time around. Additional stations will be located elsewhere around the globe. Some of them may be in the U.S.S.R., which recently agreed to tune its satellites to the same radio frequencies as ours, and in China. Coverage of the sky by these stations will be extended by enlisting radio hams to monitor the satellites' frequency, especially during the critical first trip around the earth and during the dying phase.

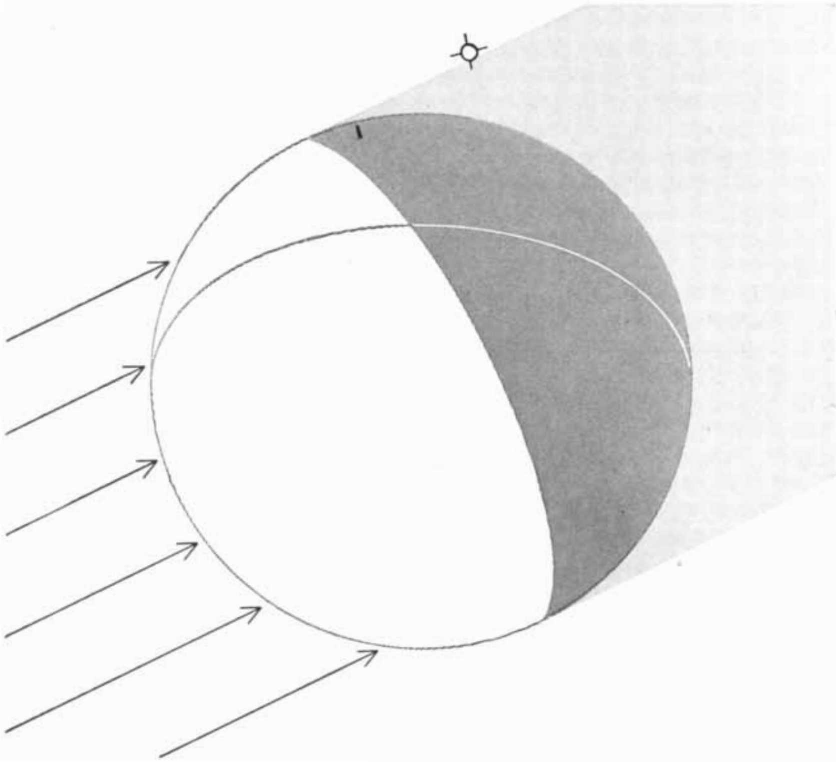
Once the satellite has been sighted and its first few orbits plotted, prediction of its future orbits can be made with increasing precision. The National Academy of Sciences is establishing special computation laboratories in Cambridge, Mass., and Washington. Their bulletins will alert the observers and the public at large to the satellite's appearances in the sky at ideal seeing times over observatories and centers of population.

The primary optical observations will be conducted from 12 specially equipped stations. Each will have a 20-inch Schmidt sky camera, capable of registering the image of a 15-inch sphere at 1,000 miles or a three-foot sphere at the distance of the moon. They will take a series of exposures of each passage on strip film. On these pictures the satellite can be located within a minute or two of arc in the sky and within milliseconds in time. Such precision will make it possible to locate observing stations relative to one another and to the center of the earth to an accuracy of 30 or 50 feet. A dozen such fixes will allow geographers to connect the maps of the continents with new accuracy and will help to establish the shape of the earth. The perturbations of the orbit, observed with the same precision, will give important information about the shape and structure of the earth. The rate of spiraling caused by atmospheric drag will provide an extremely sensitive measurement of atmospheric density as a function both of latitude and altitude.

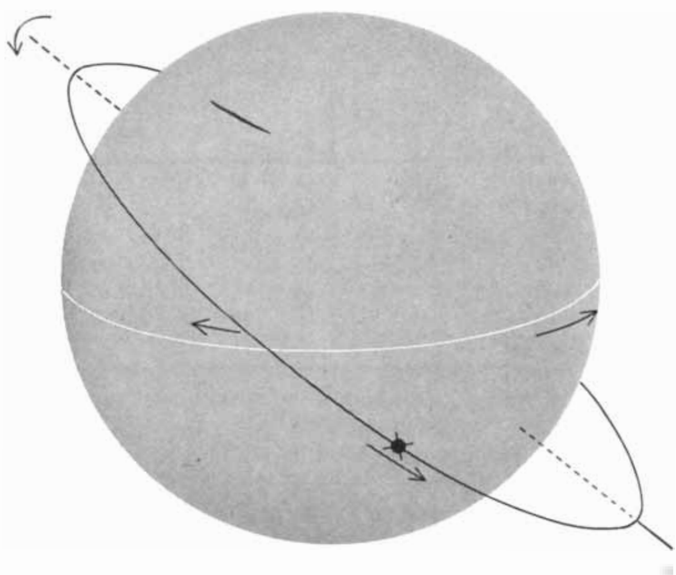
In the last few revolutions before the satellite disintegrates, orbital changes are likely to be so rapid as to evade prediction and hence observation by the widely scattered "official" stations. The picture of what happens then will have to come from the stop watches, radio receivers and binoculars of amateurs.

All the information recorded by on-board instruments of the early satellites will have to be transmitted by radio, for we cannot expect to recover the instruments after the flight. As a practical matter, to avoid the need for a vast number of receiving stations around the globe, messages will be taken from the low-power satellite transmitters as they pass over a picket fence of receivers after circling the earth. This will require storage of the instrumental observations by some memory device in the satellite. A simple type of memory would be a circuit storing the minimum and maximum readings of a given instrument during a trip. Readings from a number of instruments can be stored in detail with a more elaborate device, such as magnetic tape, but at greater cost in weight. The read-out will be triggered by radio command. The command frequency will be kept secret in order to protect the readings and the power supply from dissipation by kibitzers.

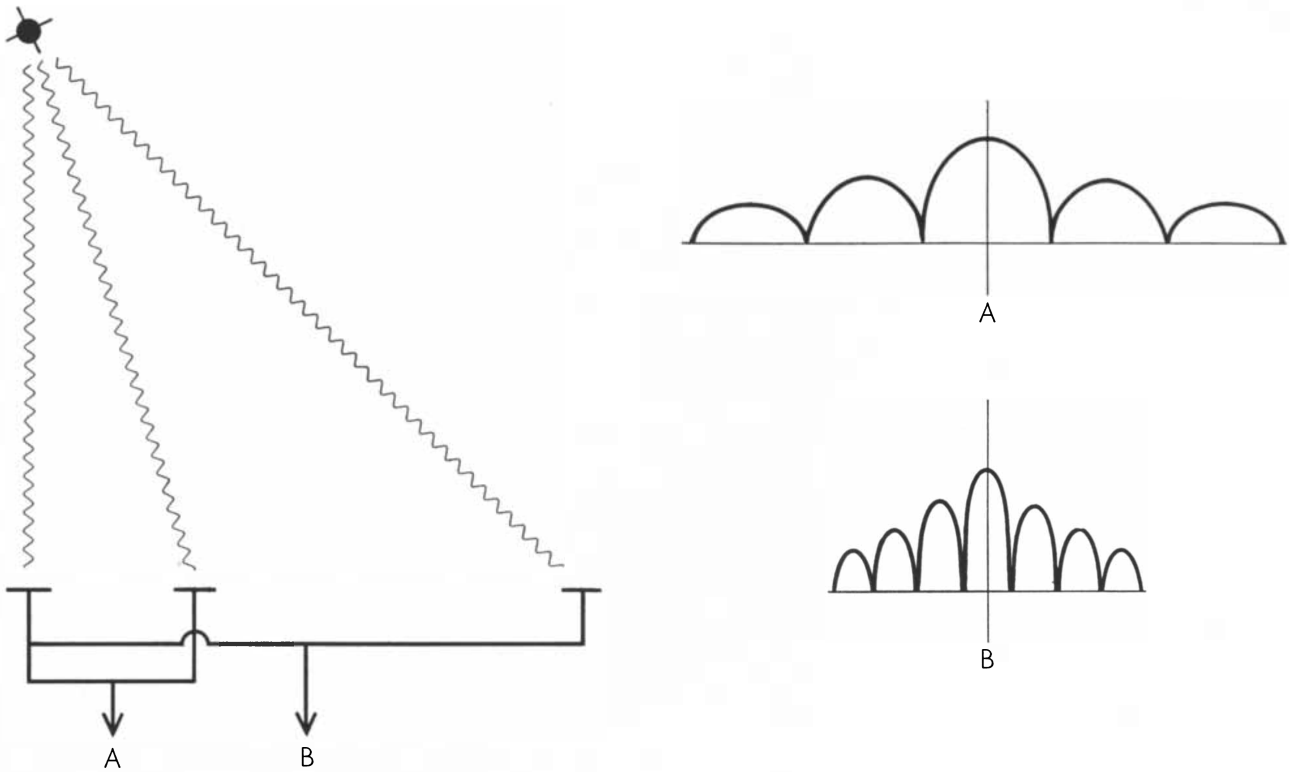
Power supply is a knotty problem. Chemical storage batteries appear to be the simplest and most reliable solution for short-life satellites. The best commer-



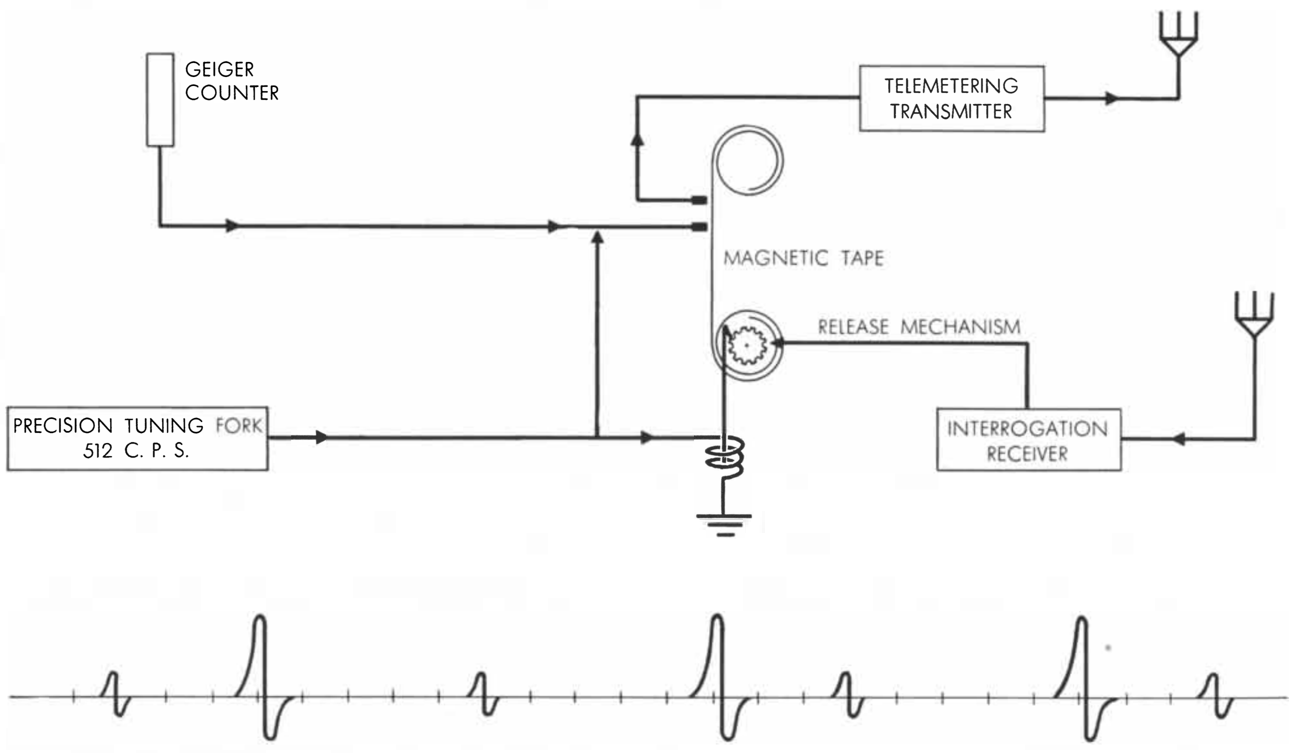
VISUAL OBSERVATION will be possible with binoculars when the conditions are right. Satellite will be seen and photographed against a twilight sky by sunlight reflected from it.



PERTURBATIONS caused by the equatorial bulge of the earth will shift the point of intersection of the orbit and the Equator westward and will shift the long axis of the elliptical orbit eastward. The plane of the orbit will thus make a complete revolution in about 60 days.



GROUND STATION ANTENNAS will be set up to measure angular direction to the satellite. Phase difference between signals reaching each antenna of pair A indicates the angle between their base line and the satellite transmitter. But this information is ambiguous; a given phase difference could mean any of a set of angles. The second pair (B) eliminates the ambiguity. Only the correct angle is common to the receiving sets of both pairs. The curves at the right show the reception pattern for each of the antenna pairs.



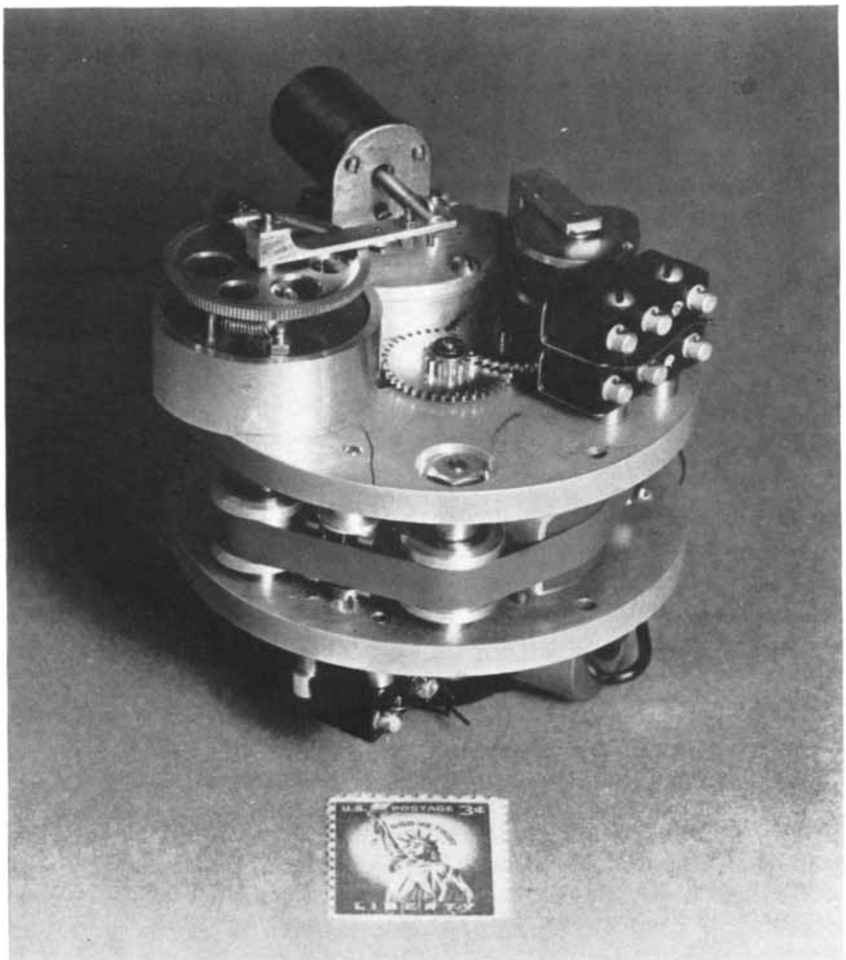
COSMIC RAY INSTRUMENTATION for satellite is diagrammed here. Tuning fork causes magnetic tape to advance stepwise .006 inch each second and registers a pulse each eight seconds (*small peaks on line at bottom*). The Geiger counter registers a pulse on the tape each 2,048 counts (*large peaks*). Upon command from the ground the tape reads record over the telemetering transmitter.

cial batteries yield about 45 watt-hours per pound. For operation over periods longer than a few weeks we shall have to look to new devices such as solar batteries or radioactive cells. A system which uses several solar batteries to trickle-charge a small storage battery is now being developed by the U. S. Army Signal Corps. This system will provide indefinitely about one fourth of a watt per pound of total weight; during its exposure to the sun it will store a small surplus of energy to supply power for the half-hour or so on each trip when the satellite is on the dark side of the earth.

In the successive passages from the sunlit to the shady side of the earth the outer skin of the satellite will go through marked variations in temperature—from about 100 degrees Fahrenheit to about 70 degrees below zero. It will be necessary to protect the instruments inside from these extremes. By sagacious insulation it should be possible to hold the cycle within the reasonable limits of 40 and 70 degrees.

What instruments shall we put in the satellite observatory? There are a number of good possibilities for the few flights we shall have available. With a simple photocell installed in the satellite we could, for example, make a detailed survey of the cloud cover over large areas of the earth. As the spinning satellite circled the globe, the photocell would alternately look out into space and down at the earth, making a detailed survey of reflected light from points below it. The reflected radiation would be a reliable index of the cloud cover. A small microphone could record the number and momentum of the micrometeorites that beat on the metal skin of the satellite. To measure the density in space of microscopic dust particles, we might paint on the surface a simple stripe of radioactive material, whose erosion would record the rain of particles. Among the interesting questions these observations might settle would be whether micrometeorites play any part in generating the airglow in our upper atmosphere and in creating the noctilucent clouds.

High on the list of things to be done is a survey of the outer reaches of the ionosphere, the electrified region which is so important to all long-range radio communication on the earth. A satellite should also give us information about the density of electrons in space in the near vicinity of our planet. Another important topic for investigation is the earth's magnetic field. This might be surveyed with a sensitive, miniaturized magnetometer especially designed for installation in a satellite.



TAPE RECORDER, miniaturized for installation in a satellite, was developed by the author and his associate George Ludwig. The tape will store data for 120 minutes and will read them out, upon command, during a few seconds while the satellite is in range of a station.

But at the very top of the list of subjects that scientists want to study are the sun's short-wave radiations and cosmic rays. During 1957-58 there will be a sunspot maximum bringing heavy fluctuations in both types of radiation. This will provide ideal opportunities for observation of their interactions with the earth's upper atmosphere. Measurement of ultraviolet radiation and soft X-rays from the sun would illuminate their role in the formation and behavior of the electrically charged layers of the ionosphere. An ionization chamber and photon counters in a satellite could record the varying intensity of this radiation and help determine its relation to flares on the sun. A Geiger counter hooked up to a magnetic tape memory could make corresponding measurements for cosmic rays. During quiet periods the same instrumentation could survey the rays' geographical distribution above our atmosphere. Such a survey would test the traditional theory that the earth's magnetic field controls the arrival of cosmic rays against the new notion that their trajectories are shaped by magnetic fields elsewhere in the interplanetary region. An apparatus for cosmic-ray observations in satellites is being developed by George Ludwig and the writer at the University of Iowa [*see lower diagram on the opposite page*].

It is clear that there is more work to be done than the first satellites can handle. It is equally clear that the Geophysical Year will be only the beginning of this adventure. After the first satellites have proved their usefulness, we can confidently predict that others will be abundantly available to science in the years to follow.

TRANSFORMED BACTERIA

If desoxyribonucleic acid is removed from one strain of pneumococci and added to another strain, some of the cells in the second strain are able to transmit characteristics of the first to their descendants

by Rollin D. Hotchkiss and Esther Weiss

If man reproduced his kind the way bacteria do, a grown man at 25 would more or less abruptly become two young men in his own exact image. These two in turn would "divide" in another 25 years, so that after 50 years there would be four young men indistinguishable from the original ancestor. A rather large family could eventually be built up by this process, but all its members would be monotonously alike in appearance, abilities, temperament and vigor. The same would be true of every family. It would be entirely male or entirely female: the two sexes would be aloof from each other. There would be families of burly, competitive athletes, and others made up exclusively of gray-eyed introverts liking nothing better than to write sad poems on the haunting loveliness of subdivision.

After about 20 generations (500 years) we could expect an occasional "mutant" individual to show up, differing from the million other individuals of his family in some one trait such as eye color. In a community so ordered, a means of transferring these rare traits at will from one family to another would have dramatic value indeed. Actually such transformations can be accomplished with bacteria. It is possible to transfer mutations of a particular kind and thereby make controlled studies of heredity.

Only in the last 10 years or so have bacteria become prominent in the study of genetics. Until a little more than a decade ago it was supposed that a bacterial cell did not have a nucleus or the elaborate genetic apparatus characteristic of higher forms of life. The general feeling was that bacteria were simple enough not to need so cumbersome a system for passing along their hereditary characteristics. But in 1944 C. F. Robinow, a British bacteriologist, found signs of nuclei in bacteria. Since then bacteria have gained in complexity the more they have been studied, and their mechanisms have been found to parallel those of cells of higher organisms. The bacterial genetic system has proved to be one of the most fascinating of all to bacteriologists and geneticists alike. Undoubtedly some of the appeal of bacteria for geneticists lies in their rapid rate of multiplication. What other laboratory subject provides a new generation every half-hour? There is no problem of eye-strain involved, either. The tiny creatures take only a few hours to grow to a many-celled colony which is easily visible in the test tube or on a gelatin-like agar plate, and they are much more manageable than the classical fruit flies. When a bacterium achieves a new characteristic, it quickly produces a whole colony of the new type, which can often be readily identified.

Such a new characteristic may turn up in perhaps one in a few million cells in a growing population. The few mutant bacteria may be swamped out as they attempt to grow in the enormous competitive population. Occasionally, however, the environment may favor the rare individuals of a newly arising type, so that they outgrow the usual type. A bacterial geneticist is always on the lookout for these natural events, and he can make detection of them easier by providing a selective environment which allows only certain mutants to grow. For example, if bacteria are put upon agar plates containing penicillin, only the mutants that have resistance to the drug will grow to produce colonies. From a population of a hundred million cells, usually about five to 10 such colonies will emerge, indicating that something like one cell in 10 million of the original population became, mysteriously and suddenly, penicillin-resistant.

The technique of transformation developed in the laboratory permits us to take matters more into our own hands. We can introduce a specific hereditary characteristic into a strain of bacteria by treating the cells with an extract from killed bacteria of a related strain which possess the characteristic in question. The procedure does not create new traits but transfers traits already present in the donor bacteria. In effect we are "robbing Peter to pay Paul."

The transforming material is desoxyribonucleic acid (DNA)—the type of substance now so well known as a fundamental constituent of the chromosomes of higher plants and animals. DNA from the donor cells seems to enter into the recipient bacterial cell and, like a gene, direct part of the cell's internal mechanism. The cell even learns to make more of the directing substance itself. How this controlling substance carries its specific instructions is still a mystery: our most sensitive chemical analyses cannot distinguish any differences between DNA varieties responsible for different traits. But each variety must be chemically distinctive, because the recipient cells repeatedly respond in the same predictable way to a particular extract.

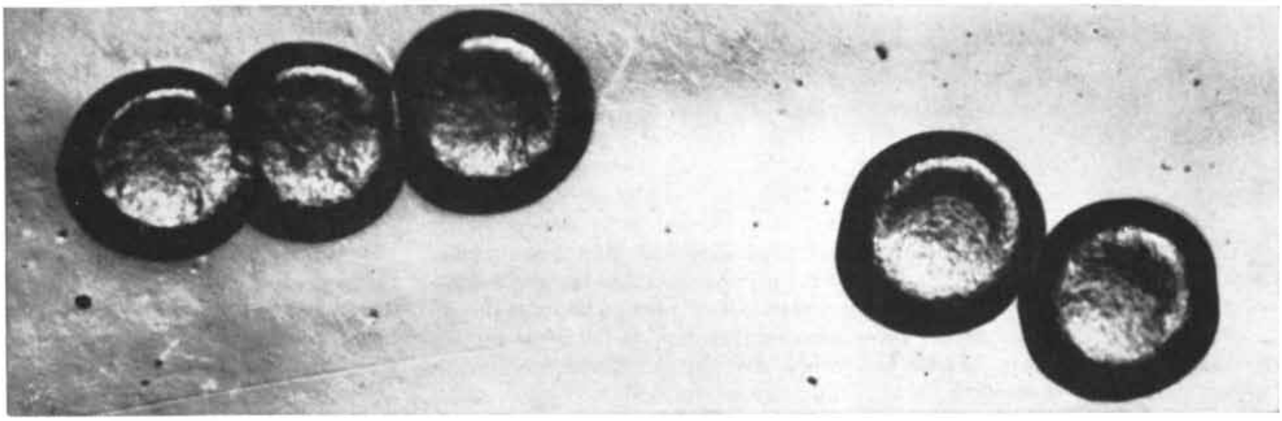
Pneumococci, the pneumonia germs, have been extensively studied by means of laboratory transformation. From about 30 million pneumococcal cells, killed and broken down by sodium desoxycholate (a substance found in bile), we can extract one microgram of purified DNA. This can be preserved for years as a white precipitate in alcohol.

The pneumococci we have used to test the transforming DNA are Type II strains which have lost the ability to produce the sugar capsule that makes the bacteria virulent. On agar plates these strains normally grow as shiny pinpoint colonies. In a broth containing a small amount of antiserum (made from the blood of an animal inoculated with pneumococci) they grow in chains and clumps which settle to the bottom as separate white colonies. By diluting samples of the culture and counting the colonies that develop, we can make quantitative studies of what happens when bacteria are transformed.

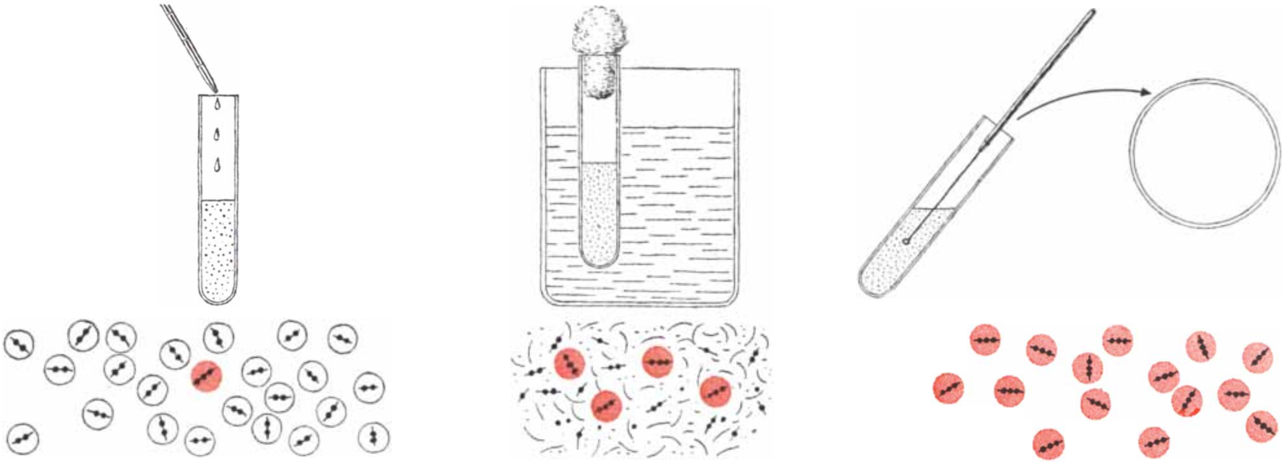
More than 25 specific characteristics have been transferred to this strain from various mutants. They include every sort of trait we can observe: acquisition by the bacterium of various types of capsule coating, development of resistance to drugs, formation of certain types of colonies, and so on. Usually only one trait is passed on to any particular cell, even if the DNA preparation is from a strain having two or three identifiable characteristics. For example, if a million pneumococci are treated with a tenth of a microgram of a DNA which carries three traits—resistance to penicillin and streptomycin and formation of a coat of Type III—some 50,000 of the million may be transformed; of these about 49,000 will acquire only one of the three traits, 800 may have two, and only four will take all three.

The DNA preparation evidently does not carry a complete package of the donor's traits into a recipient cell but only some part of the package. This part is not as small as a gene, however. Certain traits seem to travel together as if they were linked. For example, the DNA factors responsible for the ability of pneumococci to utilize mannitol (a form of sugar found in manna) as a source of energy and for the ability to resist streptomycin tend to be coupled: 20 per cent of cells transformed by a DNA carrying these two markers will show both characteristics.

Experiments in transmission of the mannitol-utilization trait illustrate an-



DIFFERENT STRAINS OF PNEUMOCOCCI grow on the surface of agar in colonies of characteristic form. At the top are the small colonies of pneumococci without capsules. At the bottom are the larger colonies of encapsulated Type III pneumococci. The colonies of Type III produce a sticky sugar; they are larger because they absorb moisture from the agar. If desoxyribonucleic acid (DNA) is removed from pneumococci of Type III and added to the nonencapsulated pneumococci, the latter will acquire capsules.



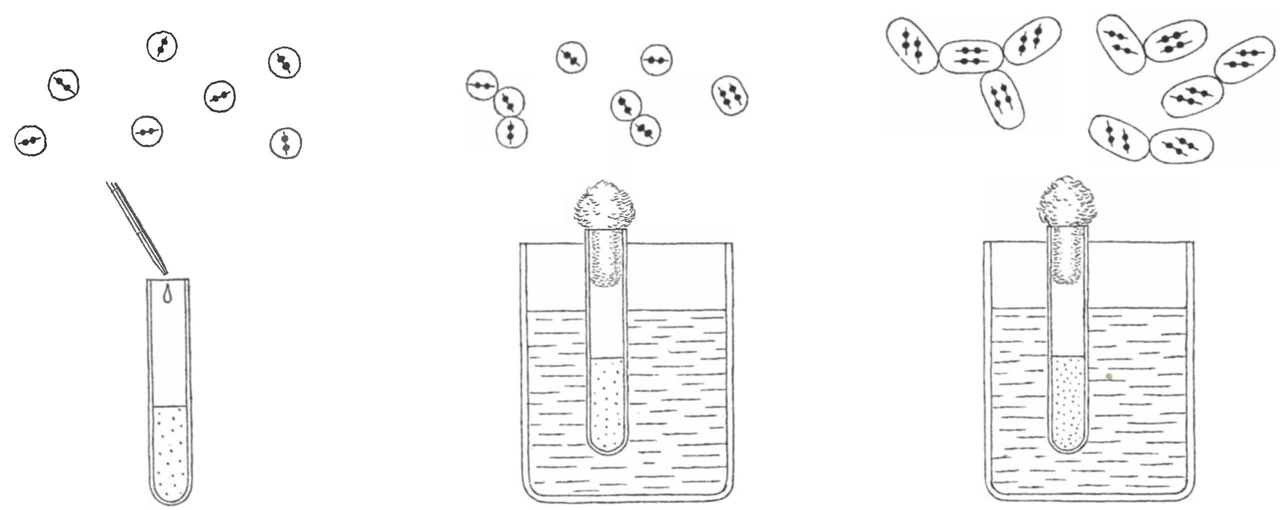
PREPARATION OF DNA from a strain of pneumococci resistant to streptomycin is traced in the drawings at the top of this and the next three pages. First, a broth containing streptomycin is inoculated with pneumococci. One cell (*color*) is a rare mutant resistant to streptomycin. Second, the broth is incubated overnight at 37 degrees centigrade. The mutant multiplies and makes the broth

other important point: namely, that DNA may carry a hereditary trait as a latent ability, regardless of whether or not the ability is developed. Like children who display their innate musical talent only after they have taken some piano lessons, the talented strains of pneumococci do not exhibit their ability to utilize mannitol until they have been exposed to this sugar for a short time. To metabolize it they have to learn to make an enzyme which oxidizes mannitol.

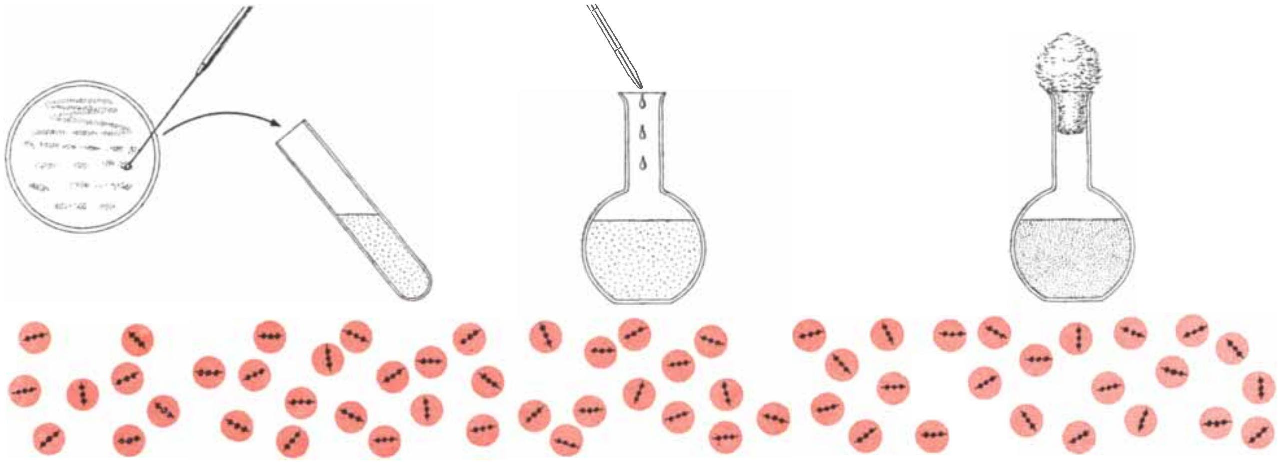
Under the most ideal conditions we have devised up to now, it has been possible to transmit a new trait to 17 per cent of the treated cells. Many factors influence the yield obtained. Foremost of these is the capacity of the recipient strain itself. Some strains seem to be transformed more readily than others, and many seem altogether incapable of responding to DNA. Another factor is the concentration of DNA present: one half of a millionth of a gram per cubic centimeter is an optimal concentration, and one 10,000th of that amount will have some effect. The length of exposure to DNA also is important. We think that the bacteria are most susceptible to transformation just after cell division. After pneumococci have been cooled to a growth-arresting temperature, so that all start out "in step" in the division cycle when they are rewarmed, transformations are exceptionally numerous. About 15 minutes after the rewarming the cells abruptly lose their susceptibility, and just at this time very few cells will be dividing. Still another important factor is the composition of the medium in which the cells grow before and during DNA exposure.

After acquiring the new DNA, a cell multiplies more slowly than the others for a time and is at a disadvantage in growth until its transformation has been completed. Some of the transformed cells are likely to survive in any event, but the percentage transformed is easier to observe if the conditions are adjusted to favor them. For example, in an experiment in which the transformation makes the cells resistant to penicillin, placing the bacteria in a penicillin broth will kill off all but the transformed cells. One must be careful, however, not to challenge the bacteria with the selective agent too soon. The transformed cells require 30 to 60 minutes to manifest their new drug resistance, and it takes still longer for the cells to set up the mechanism necessary to duplicate the new DNA. During this time the new DNA is beginning to perform its genelike functions in the cells.

A transformed pneumococcus remains susceptible to further transformations, even by the same DNA if the DNA



TRANSFORMATION OF PNEUMOCOCCI to a strain resistant to streptomycin from a nonresistant strain is illustrated at the bottom of this and the next three pages. First, young pneumococci are added to a rich broth containing serum albumin. Second, the tube is incubated for three hours at 37 degrees C.; the cells multiply. Third, the tube is cooled to 25 degrees for 20 minutes. This arrests



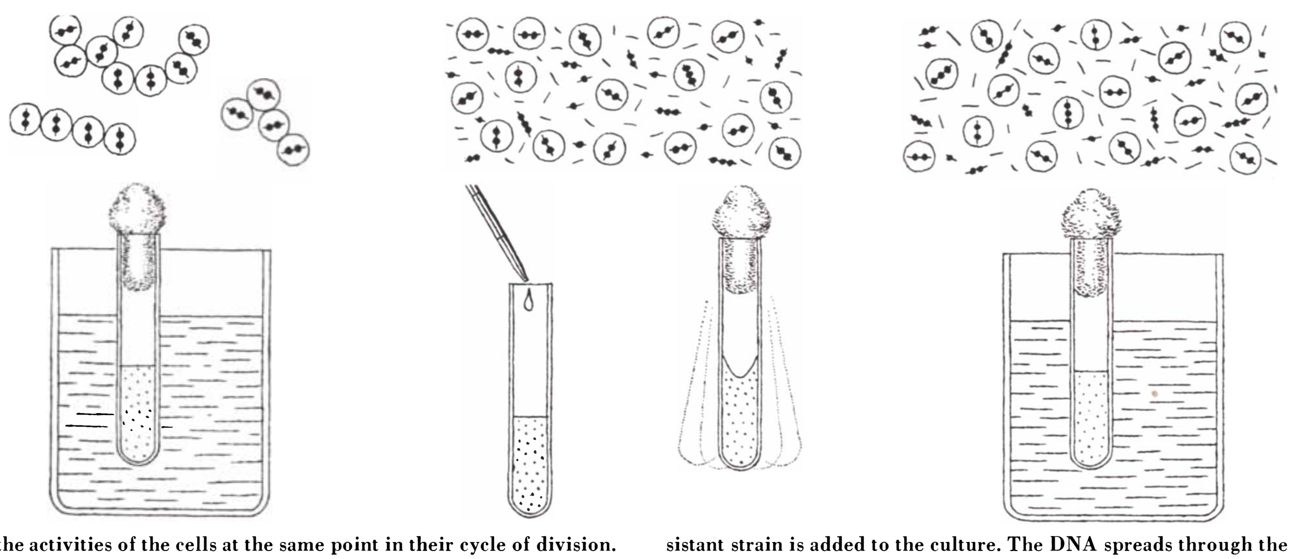
turbid; the other cells are killed by the streptomycin. Third, a bit of turbid broth is removed and spread on an agar medium. Fourth, one of the colonies on the agar plate is transferred to a tube of fresh broth. Fifth, a flask of broth is inoculated with the mutant strain. Sixth, the flask is incubated overnight until the culture is full-grown. This sequence is continued at the top of the next page.

carries more than one trait. Indeed, a particular trait, such as resistance to penicillin, may be developed by a series of stepwise mutations rather than by a single transformation. Beginning with pneumococci that survived exposure to low concentrations of penicillin, we submitted them to successively higher concentrations until we had a mutant strain which was resistant to 30 units of penicillin per 100 milliliters of culture. We then administered the DNA from this strain to pneumococci which were fully sensitive to penicillin. None of the sensitive cells acquired as much resistance to penicillin as the donor strain possessed, and most of those transformed could not resist more than five units of the drug. When these were again treated with the DNA of the highly resistant donor, some became resistant to 12 units of penicillin. It took several such steps to produce transformants able to resist 30 units. We think these indicate the number of spontaneous mutations that must have taken place in the original evolution of the mutant strain.

Experiments with streptomycin produced the same stepwise development of resistance. However, in a large population of cells an occasional cell spontaneously acquired a high level of resistance in just one step, and the DNA from this mutant produced equally resistant cells in a single transformation. Evidently in this case one mutation of a single genetic unit modified the DNA so that it could effect the entire transformation in one step.

Another kind of phenomenon emerges when pneumococci without a capsule are treated with a DNA which confers the ability to form a capsule of Type III. Normally the DNA effects this transformation in one step, but at times it produces cells with intermediate varieties of sugar capsules. Colonies of these cells are smaller than those of the full Type III. Harriett Ephrussi-Taylor, formerly of the Rockefeller Institute for Medical Research and now at the University of Paris, has done many experiments with two such varieties of cells. They seem to differ from each other and from normal Type III only in the quantity of capsule material they produce. If DNA from both varieties is mixed in a single culture, large, juicy colonies characteristic of the normal Type III cells will appear on the agar plates. Dr. Ephrussi-Taylor concluded that the two kinds of DNA could combine in a single recipient bacterium to yield the normal DNA of Type III cells, and this conclusion was strongly supported by other experiments.

The more the action of DNA is studied, the clearer it becomes that each organism's DNA is biologically distinc-



the activities of the cells at the same point in their cycle of division. Fourth, the culture is rewarmed to 37 degrees. Now all the cells start dividing at the same time. Fifth, DNA removed from a resistant strain is added to the culture. The DNA spreads through the broth, and some of the cells react with it. Sixth, the culture is reincubated for five minutes; the cells continue to react with DNA.

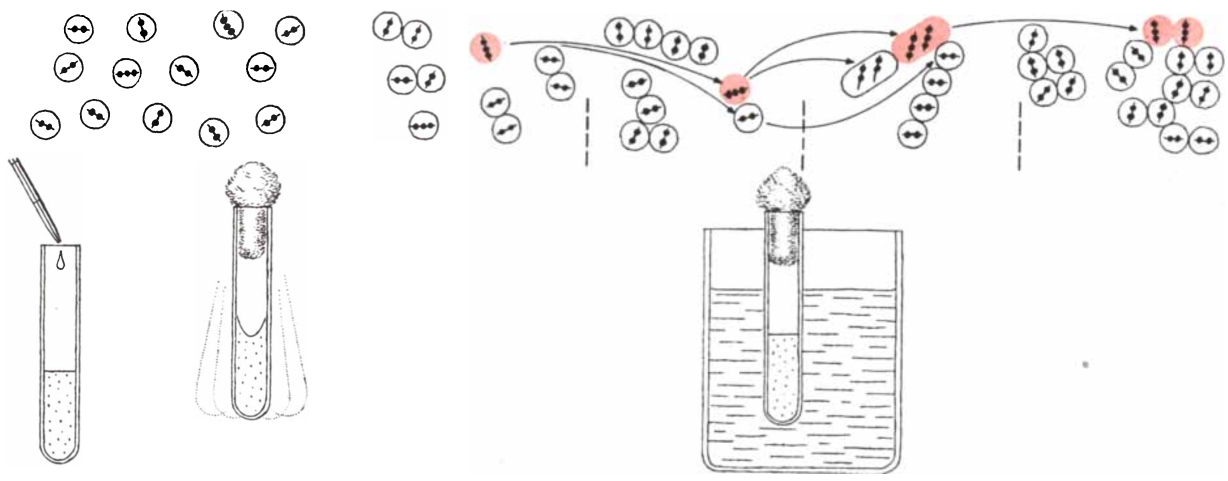
PREPARATION OF DNA IS CONTINUED from the drawings at the top of the preceding two pages. First, sodium desoxycholate is added to the flask containing the full-grown culture of pneumococci. This kills and breaks up the cells; the broth clears. Second, alcohol is added to the cleared flask. This causes the DNA to precipitate in threads. Third, the threads are collected from the flask

tive, even though we cannot detect any chemical difference. Attempts have been made to bring about transformations in pneumococci by injecting DNA from species of bacteria distantly related to them. The attempts have not succeeded. The foreign DNA may enter the cell, but it does not produce any detectable change in the cell's traits. The machinery of the cell apparently recognizes something unusual about the foreign DNA and makes no genetic response to it, so far as we can determine. However, the cell's incorporation of the bogus DNA prevents it from reacting freely with a suitable DNA. (In this respect it behaves something like a fertilized egg: the egg, having accepted one spermatozoon, repels all others.) It seems that the various kinds of DNA are sufficiently alike to penetrate the outer defenses of the bacterial cell. Even DNA from thymus-gland cells of the calf will react with pneumococci, inhibiting their transformation by an appropriate DNA. Indeed, a foreign DNA can compete on about equal terms with pneumococcal DNA for entry into a susceptible pneumococcus. But only the native DNA seems capable of producing a genetic effect on the bacterium.

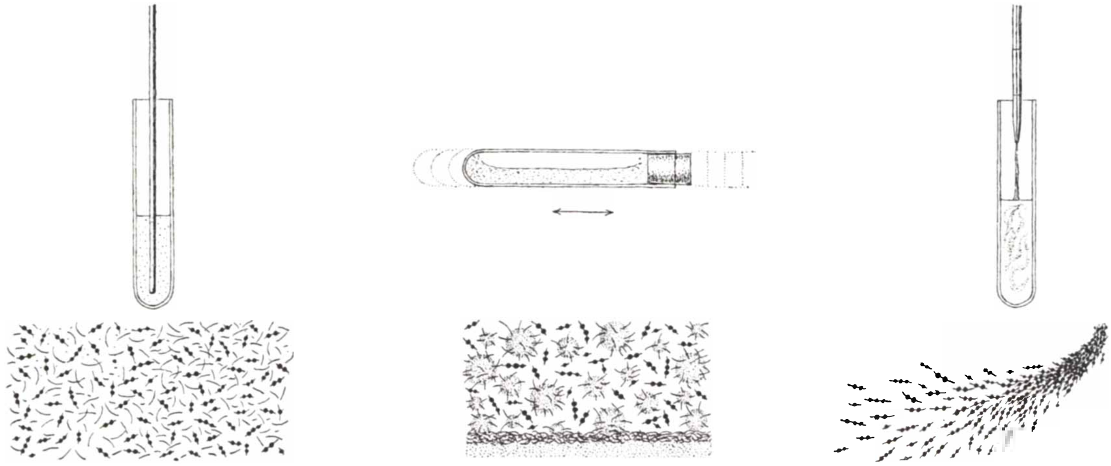
The experiments in transforming bacteria go back to a discovery made in 1928 by Fred Griffith, an English bacteriologist. Pneumonia was then one of the most challenging problems in medical research (the "miracle" drugs having not yet been discovered), and the pneumococcus was as popular a subject of study as the viruses are now. Griffith injected into mice pneumococci without capsules, which are not virulent, together with killed pneumococci of a virulent type (Type III capsules). To his surprise, the tissues of the mice were soon teeming with live, virulent pneumococci of Type III. Since the dead cells could not have come to life, it became evident that their material must somehow have transformed the nonencapsulated bacteria into virulent germs which had the ability to make Type III capsules.

Griffith's discovery was followed up by workers at the Rockefeller Institute, under the great and inspiring leadership of the late Oswald T. Avery. One cannot fail to note that the study of pneumococcal transformation since the initial discovery has been carried out essentially by a single "school," consisting of Avery's students and their followers. This school, now in its second generation and widely spread, can trace its lines of descent as accurately as those of the bacteria it studies.

By 1944 Avery, with Colin M. MacLeod and Maclyn McCarty, had identi-



TRANSFORMATION OF PNEUMOCOCCI IS CONTINUED from the preceding two pages. First, desoxyribonuclease is shaken in the culture, which destroys the DNA that is not inside the cells. Second, the culture is reincubated for two hours. After about 45 minutes some cells show the new trait. These cells are slow to divide; for several generations the new DNA is passed on to only one daughter

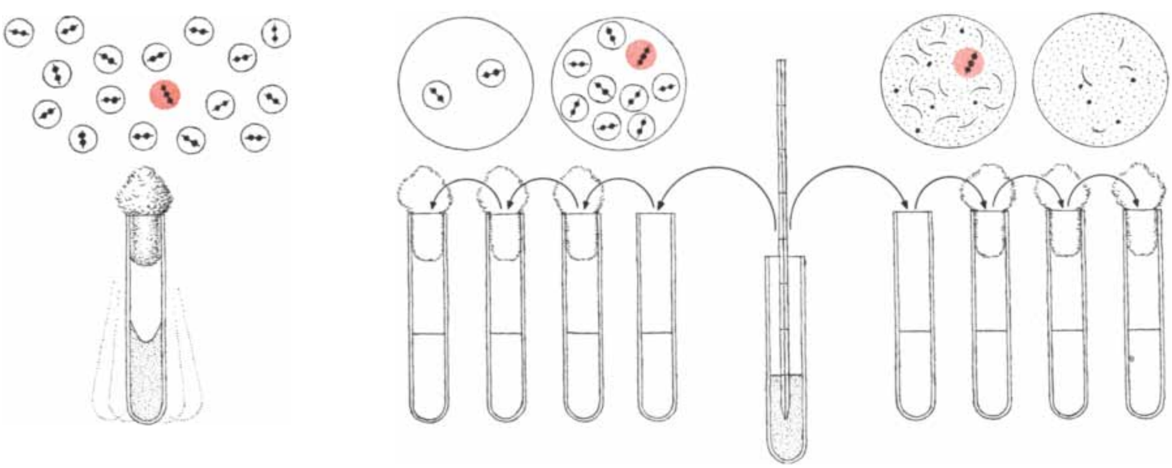


by winding them on a glass rod; this separates the DNA from most of the other substances in the debris of the broken cells. Fourth, the DNA is dissolved in a salt solution. Fifth, impurities are removed by adding various solvents to the solution and shaking it; the solvents tend to precipitate the impurities in particles. Sixth, alcohol is added to the purified DNA, causing it to form threads again.

fied the substance responsible for the transformation of pneumococci as DNA. There followed a long series of transformation experiments, not only on pneumococci but also on other species of bacteria. The germ once thought to be the cause of influenza (*Hemophilus influenzae*) has been studied extensively by Hattie Alexander and her associates at Columbia University, and their findings largely parallel those on pneumococci. Other investigators have reported success in transforming strains of *Escherichia coli*, *Shigella paradysenteriae* and meningococci with DNA.

Over the last 30 years there has been an impressive accumulation of evidence that nucleic acids play a central role in the hereditary mechanism of all living creatures [see "The Chemistry of Heredity," by A. E. Mirsky; SCIENTIFIC AMERICAN, February, 1953]. The transformation work has had a decisive part in that vast investigation. This lead has generated a great number of exciting genetic experiments with animal and plant cells, bacteria and viruses, as the many recent articles on the subject in SCIENTIFIC AMERICAN have made plain. In the nucleic acids biologists at last have definite chemical substances which embody the properties of the somewhat hypothetical units long known as genes. Biochemists have not been slow to take up the challenge to explore the structure of the nucleic acids for the key to the machinery of heredity [see "The Structure of the Hereditary Material," by F. H. C. Crick, SCIENTIFIC AMERICAN, October, 1954; and "The Gene," by Norman H. Horowitz, October, 1956].

Happily, in the mid-20th century we can feel that we are on the threshold of still more exciting discoveries. We can expect to learn new kinds of facts about heredity in the coming years, and also to find theories which will unify the facts. The transformation of bacteria is one of our most promising laboratory tools for further discovery. It means that we can interbreed organisms by transferring a comparatively small and simple genetic unit—much simpler than the intricate apparatus of chromosomes involved in other genetic systems. The simplicity of this process gives many possibilities for controlled manipulation and variation. Transforming agents may be added or withheld at will, used in various concentrations or in combination with other materials, pretreated with chemicals, modified or damaged by exposure to acid, heat or radiant energy. The outcome of the transformations with DNA so treated should do much to throw light upon the still mysterious processes set in motion by the fascinating entities that we call genes.



cell. Then one cell duplicates the DNA and passes it on to both daughter cells, which continue the duplication. Third, the tube is shaken to break up clumps of cells. Fourth, samples of the culture are placed in tubes, some of which (*right*) contain streptomycin. The streptomycin kills the untransformed cells. Later, colonies are visible in the tubes. In higher dilutions they can be counted.

Experiments in Group Conflict

What are the conditions which lead to harmony or friction between groups of people? Here the question is approached by means of controlled situations in a boys' summer camp

by Muzafer Sherif

Conflict between groups—whether between boys' gangs, social classes, "races" or nations—has no simple cause, nor is mankind yet in sight of a cure. It is often rooted deep in personal, social, economic, religious and historical forces. Nevertheless it is possible to identify certain general factors which have a crucial influence on the attitude of any group toward others. Social scientists have long sought to bring these factors to light by studying what might be called the "natural history" of groups and group relations. Intergroup conflict and harmony is not a subject that lends itself easily to laboratory experiments. But in recent years there has been a beginning of attempts to investigate the problem under controlled yet lifelike conditions, and I shall report here the results of a program of experimental studies of groups which I started in 1948. Among the persons working with me were Marvin B. Sussman, Robert Huntington, O. J. Harvey, B. Jack White, William R. Hood and Carolyn W. Sherif. The experiments were conducted in 1949, 1953 and 1954; this article gives a composite of the findings.

We wanted to conduct our study with groups of the informal type, where group organization and attitudes would evolve naturally and spontaneously, without formal direction or external pressures. For this purpose we conceived that an isolated summer camp would make a good experimental setting, and that decision led us to choose as subjects boys about 11 or 12 years old, who would find camping natural and fascinating. Since our aim was to study the development of group relations among these boys under carefully controlled conditions, with as little interference as possible from personal neuroses, background influences or prior experiences, we selected normal boys of homogeneous background who did not know one another before they came to the camp.

They were picked by a long and thorough procedure. We interviewed each boy's family, teachers and school officials, studied his school and medical records, obtained his scores on personality tests and observed him in his classes and at play with his schoolmates. With all this information we were able to assure ourselves that the boys chosen were of like kind and background: all were healthy, socially well-adjusted, somewhat above average in intelligence and from stable, white, Protestant, middle-class homes.

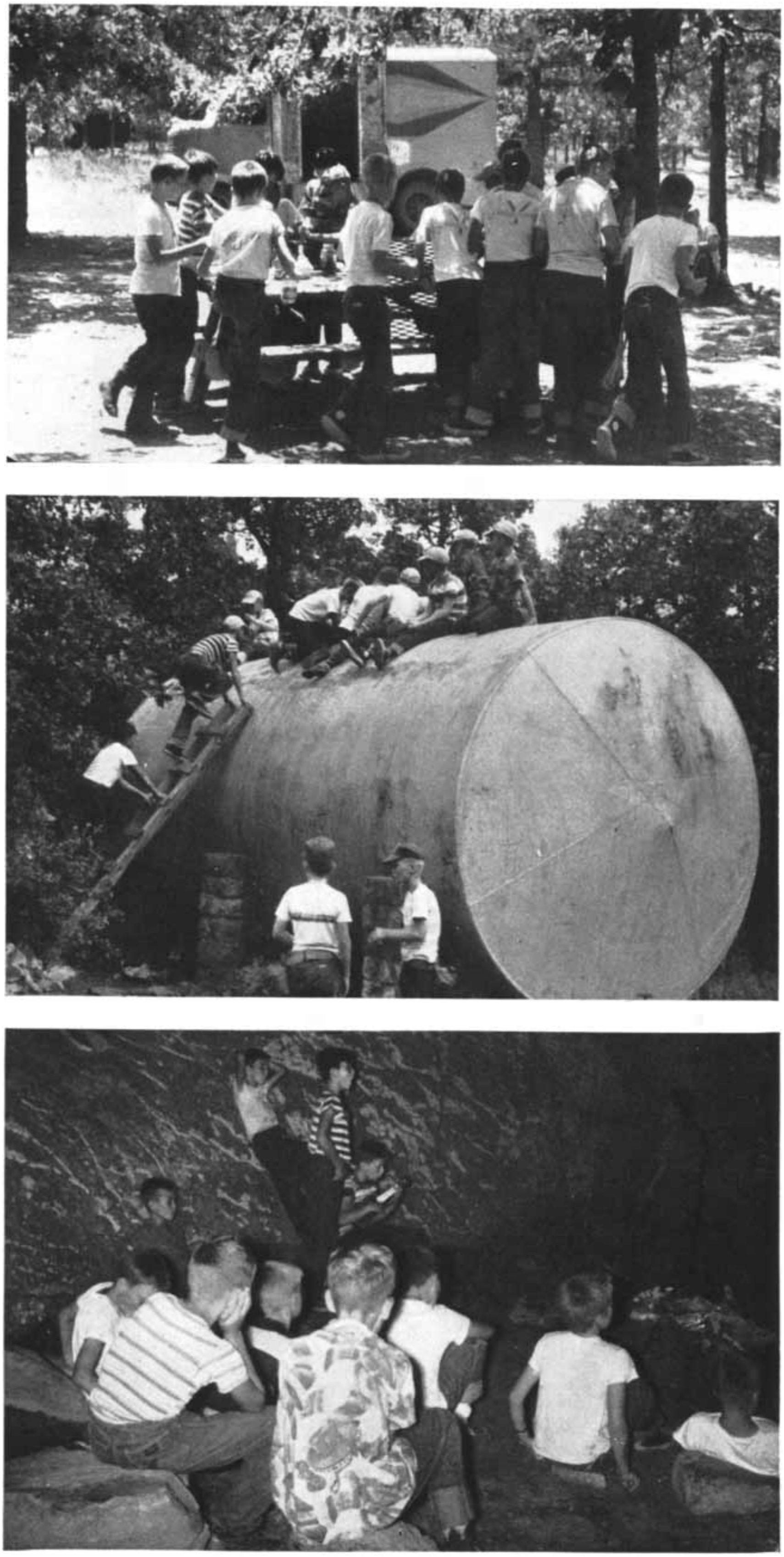
None of the boys was aware that he was part of an experiment on group relations. The investigators appeared as a regular camp staff—camp directors, counselors and so on. The boys met one another for the first time in buses that

MEMBERS OF ONE GROUP of boys raid the bunkhouse of another group during the first experiment of the author and his associates, performed at a summer camp in Connecticut. The rivalry of the groups was intensified by the artificial separation of their goals.

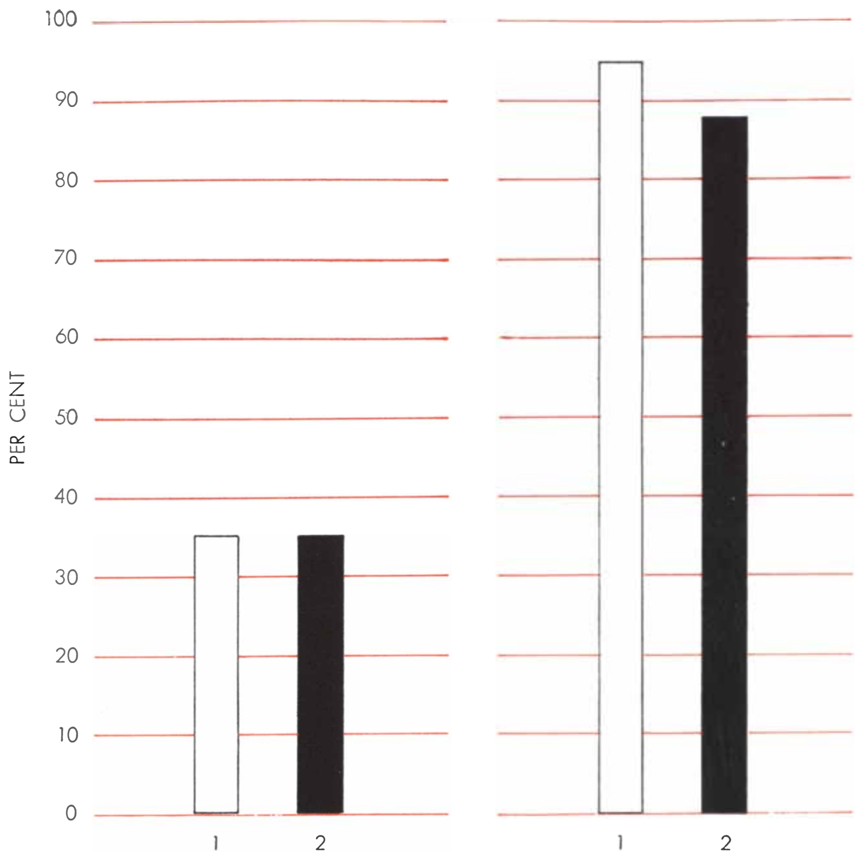
took them to the camp, and so far as they knew it was a normal summer of camping. To keep the situation as lifelike as possible, we conducted all our experiments within the framework of regular camp activities and games. We set up projects which were so interesting and attractive that the boys plunged into them enthusiastically without suspecting that they might be test situations. Unobtrusively we made records of their behavior, even using "candid" cameras and microphones when feasible.

We began by observing how the boys became a coherent group. The first of our camps was conducted in the hills of northern Connecticut in the summer of 1949. When the boys arrived, they were all housed at first in one large bunkhouse. As was to be expected, they quickly formed particular friendships and chose buddies. We had deliberately put all the boys together in this expectation, because we wanted to see what would happen later after the boys were separated into different groups. Our object was to reduce the factor of personal attraction in the formation of groups. In a few days we divided the boys into two groups and put them in different cabins. Before doing so, we asked each boy informally who his best friends were, and then took pains to place the "best friends" in different groups so far as possible. (The pain of separation was assuaged by allowing each group to go at once on a hike and camp-out.)

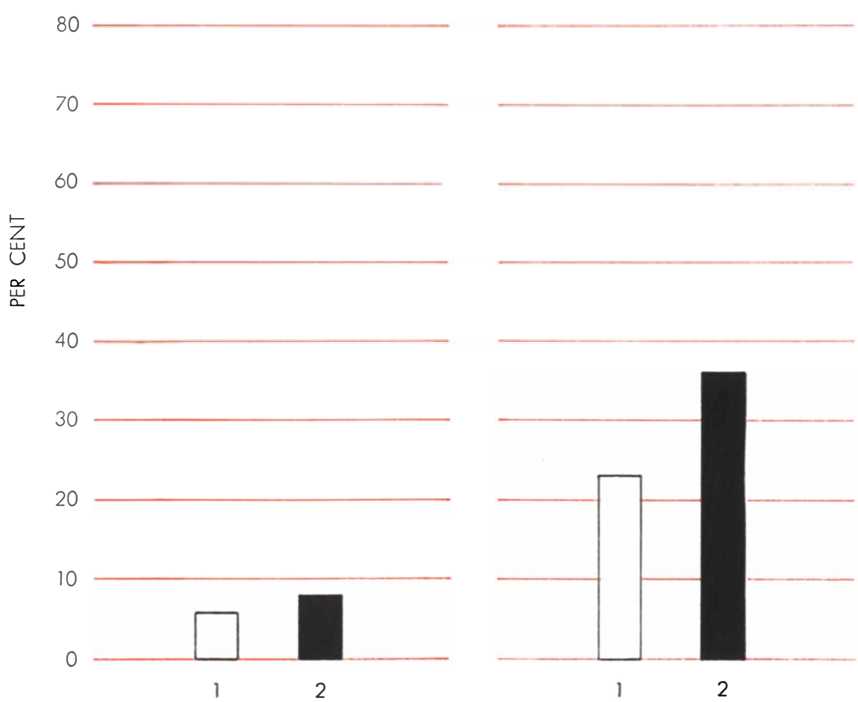
As everyone knows, a group of strangers brought together in some common activity soon acquires an informal and spontaneous kind of organization. It comes to look upon some members as leaders, divides up duties, adopts unwritten norms of behavior, develops an *esprit de corps*. Our boys followed this pattern as they shared a series of experiences. In each group the boys pooled their efforts, organized duties and divided up tasks in work and play. Different individuals assumed different responsibilities. One boy excelled in cooking. Another led in athletics. Others, though not outstanding in any one skill, could be counted on to pitch in and do their level best in anything the group attempted. One or two seemed to disrupt activities, to start teasing at the wrong moment or offer useless suggestions. A few boys consistently had good suggestions and showed ability to coordinate the efforts of others in carrying them through. Within a few days one person had proved himself more resourceful and skillful than the rest. Thus, rather quick-



MEMBERS OF BOTH GROUPS collaborate in common enterprises during the second experiment, performed at a summer camp in Oklahoma. At the top the boys of the two groups prepare a meal. In the middle the two groups surround a water tank while trying to solve a water-shortage problem. At the bottom the members of one group entertain the other.



FRIENDSHIP CHOICES of campers for others in their own cabin are shown for Red Devils (*white*) and Bulldogs (*black*). At first a low percentage of friendships were in the cabin group (*left*). After five days, most friendship choices were within the group (*right*).



DURING CONFLICT between the two groups in the Robber's Cave experiment there were few friendships between cabins (*left*). After cooperation toward common goals had restored good feelings, the number of friendships between groups rose significantly (*right*).

ly, a leader and lieutenants emerged. Some boys sifted toward the bottom of the heap, while others jockeyed for higher positions.

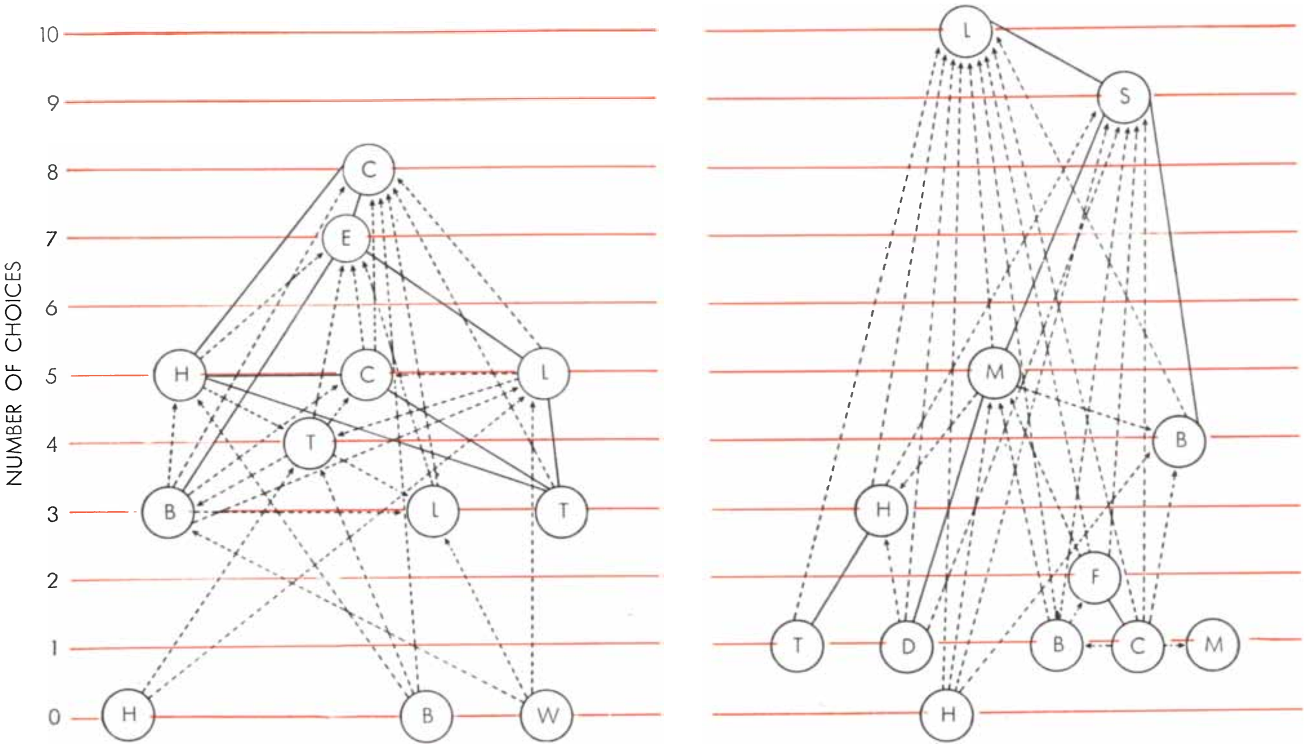
We watched these developments closely and rated the boys' relative positions in the group, not only on the basis of our own observations but also by informal sounding of the boys' opinions as to who got things started, who got things done, who could be counted on to support group activities.

As the group became an organization, the boys coined nicknames. The big, blond, hardy leader of one group was dubbed "Baby Face" by his admiring followers. A boy with a rather long head became "Lemon Head." Each group developed its own jargon, special jokes, secrets and special ways of performing tasks. One group, after killing a snake near a place where it had gone to swim, named the place "Moccasin Creek" and thereafter preferred this swimming hole to any other, though there were better ones nearby.

Wayward members who failed to do things "right" or who did not contribute their bit to the common effort found themselves receiving the "silent treatment," ridicule or even threats. Each group selected symbols and a name, and they had these put on their caps and T-shirts. The 1954 camp was conducted in Oklahoma, near a famous hideaway of Jesse James called Robber's Cave. The two groups of boys at this camp named themselves the Rattlers and the Eagles.

Our conclusions on every phase of the study were based on a variety of observations, rather than on any single method. For example, we devised a game to test the boys' evaluations of one another. Before an important baseball game, we set up a target board for the boys to throw at, on the pretense of making practice for the game more interesting. There were no marks on the front of the board for the boys to judge objectively how close the ball came to a bull's-eye, but, unknown to them, the board was wired to flashing lights behind so that an observer could see exactly where the ball hit. We found that the boys consistently overestimated the performances by the most highly regarded members of their group and underestimated the scores of those of low social standing.

The attitudes of group members were even more dramatically illustrated during a cook-out in the woods. The staff supplied the boys with unprepared food and let them cook it themselves. One boy promptly started to build a fire, asking



SOCIOGRAMS represent patterns of friendship choices within the fully developed groups. One-way friendships are indicated by broken arrows; reciprocated friendships, by solid lines. Leaders were among those highest in the popularity scale. Bulldogs (*left*) had a close-knit organization with good group spirit. Low-ranking members participated less in the life of the group but were not rejected. Red Devils (*right*) lost the tournament of games between the groups. They had less group unity and were sharply stratified.

for help in getting wood. Another attacked the raw hamburger to make patties. Others prepared a place to put buns, relishes and the like. Two mixed soft drinks from flavoring and sugar. One boy who stood around without helping was told by the others to "get to it." Shortly the fire was blazing and the cook had hamburgers sizzling. Two boys distributed them as rapidly as they became edible. Soon it was time for the watermelon. A low-ranking member of the group took a knife and started toward the melon. Some of the boys protested. The most highly regarded boy in the group took over the knife, saying, "You guys who yell the loudest get yours last."

When the two groups in the camp had developed group organization and spirit, we proceeded to the experimental studies of intergroup relations. The groups had had no previous encounters; indeed, in the 1954 camp at Robber's Cave the two groups came in separate buses and were kept apart while each acquired a group feeling.

Our working hypothesis was that when two groups have conflicting aims—*i.e.*, when one can achieve its ends only at the expense of the other—their members will become hostile to each other even though the groups are composed of normal well-adjusted individuals. There is a corollary to this assumption which we shall consider later. To produce friction between the groups of boys we arranged a tournament of games: baseball, touch football, a tug-of-war, a treasure hunt and so on. The tournament started in a spirit of good sportsmanship. But as it progressed good feeling soon evaporated. The members of each group began to call their rivals "stinkers," "sneaks" and "cheaters." They refused to have anything more to do with individuals in the opposing group. The boys in the 1949 camp turned against buddies whom they had chosen as "best friends" when they first arrived at the camp. A large proportion of the boys in each group gave negative ratings to all the boys in the other. The rival groups made threatening posters and planned raids, collecting secret hoards of green apples for ammunition. In the Robber's Cave camp the Eagles, after a defeat in a tournament game, burned a banner left behind by the Rattlers; the next morning the Rattlers seized the Eagles' flag when they arrived on the athletic field. From that time on name-calling, scuffles and raids were the rule of the day.

Within each group, of course, solidarity increased. There were changes: one group deposed its leader because he could not "take it" in the contests with the adversary; another group overnight made something of a hero of a big boy who had previously been regarded as a bully. But morale and cooperativeness within the group became stronger. It is noteworthy that this heightening of cooperativeness and generally democratic behavior did not carry over to the group's relations with other groups.

We now turned to the other side of the problem: How can two groups in conflict be brought into harmony? We first undertook to test the theory that pleasant social contacts between members of conflicting groups will reduce friction between them. In the 1954 camp we brought the hostile Rattlers and Eagles together for social events: going to the movies, eating in the same dining room and so on. But far from reducing conflict, these situations only served as opportunities for the rival groups to berate and attack each other. In the dining-hall line they shoved each other aside, and the group that lost the contest for the head of the line shouted "Ladies first!" at the winner. They threw paper, food and vile names at each other at the tables. An Eagle bumped by a Rattler was admonished by his fellow Eagles to brush "the dirt" off his clothes.

We then returned to the corollary of our assumption about the creation of conflict. Just as competition generates friction, working in a common endeavor should promote harmony. It seemed to us, considering group relations in the everyday world, that where harmony between groups is established, the most decisive factor is the existence of "superordinate" goals which have a compelling appeal for both but which neither could achieve without the other. To test this hypothesis experimentally, we created a series of urgent, and natural, situations which challenged our boys.

One was a breakdown in the water supply. Water came to our camp in pipes from a tank about a mile away. We arranged to interrupt it and then called the boys together to inform them of the crisis. Both groups promptly volunteered to search the water line for the trouble. They worked together harmoniously, and before the end of the afternoon they had located and corrected the difficulty.

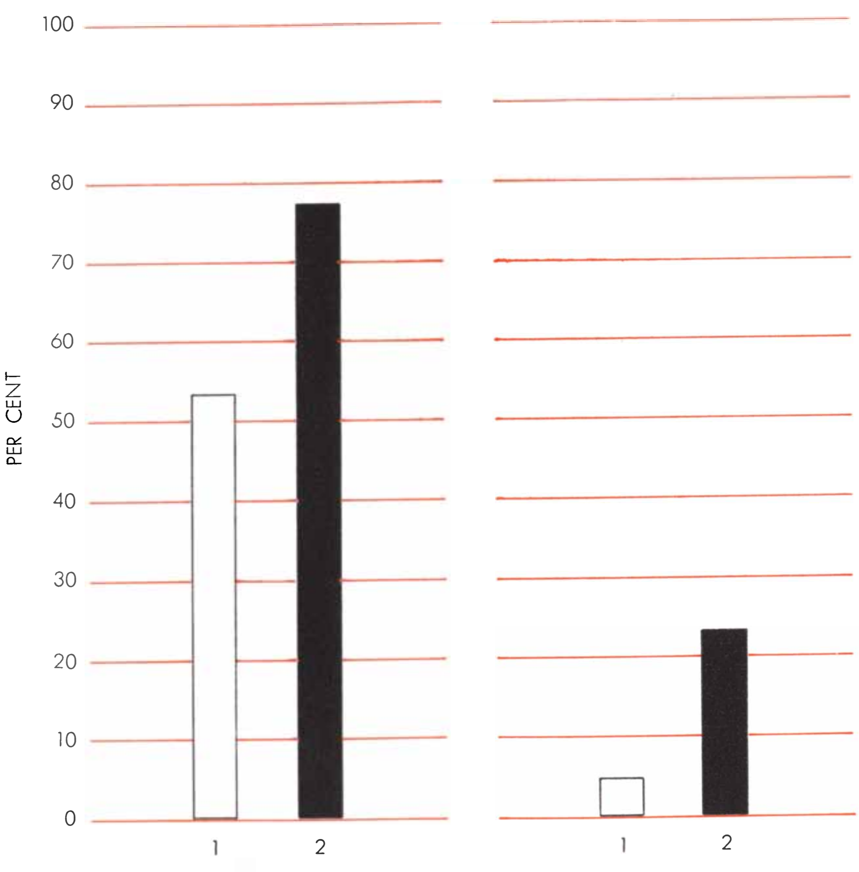
A similar opportunity offered itself when the boys requested a movie. We told them that the camp could not afford to rent one. The two groups then got together, figured out how much each group would have to contribute, chose the film by a vote and enjoyed the showing together.

One day the two groups went on an outing at a lake some distance away. A large truck was to go to town for food. But when everyone was hungry and ready to eat, it developed that the truck would not start (we had taken care of that). The boys got a rope—the same rope they had used in their acrimonious tug-of-war—and all pulled together to start the truck.

These joint efforts did not immediately dispel hostility. At first the groups returned to the old bickering and name-calling as soon as the job in hand was finished. But gradually the series of cooperative acts reduced friction and conflict. The members of the two groups began to feel more friendly to each other. For example, a Rattler whom the Eagles disliked for his sharp tongue and skill in defeating them became a "good egg." The boys stopped shoving in the meal line. They no longer called each other names, and sat together at the table. New friendships developed between individuals in the two groups.

In the end the groups were actively seeking opportunities to mingle, to entertain and "treat" each other. They decided to hold a joint campfire. They took turns presenting skits and songs. Members of both groups requested that they go home together on the same bus, rather than on the separate buses in which they had come. On the way the bus stopped for refreshments. One group still had five dollars which they had won as a prize in a contest. They decided to spend this sum on refreshments. On their own initiative they invited their former rivals to be their guests for malted milks.

Our interviews with the boys confirmed this change. From choosing their "best friends" almost exclusively in their own group, many of them shifted to listing boys in the other group as best friends [*see lower chart on page 56*]. They were glad to have a second chance to rate boys in the other group, some of them remarking that they had changed their minds since the first rating made after the tournament. Indeed they had. The new ratings were largely favorable [*see chart on this page*].



NEGATIVE RATINGS of each group by the other were common during the period of conflict (*left*) but decreased when harmony was restored (*right*). The graphs show percent who thought that *all* (rather than *some* or *none*) of the other group were cheaters, sneaks, etc.

Efforts to reduce friction and prejudice between groups in our society have usually followed rather different methods. Much attention has been given to bringing members of hostile groups together socially, to communicating accurate and favorable information about one group to the other, and to bringing the leaders of groups together to enlist their influence. But as everyone knows, such measures sometimes reduce intergroup tensions and sometimes do not. Social contacts, as our experiments demonstrated, may only serve as occasions for intensifying conflict. Favorable information about a disliked group may be ignored or reinterpreted to fit stereotyped notions about the group. Leaders cannot act without regard for the prevailing temper in their own groups.

What our limited experiments have shown is that the possibilities for achieving harmony are greatly enhanced when groups are brought together to work toward common ends. Then favorable information about a disliked group is seen in a new light, and leaders are in a position to take bolder steps toward cooperation. In short, hostility gives way when groups pull together to achieve overriding goals which are real and compelling to all concerned.

Kodak reports to laboratories on:

the 40th edition of the Eastman Organic Chemicals Catalog . . . films for dosimetry . . . outwitting the law of probabilistic adversity

Our sweet laborers *have finished the task of preparing the address labels. By now "Eastman Organic Chemicals, List No. 40," should have reached all who have in years past indited a desire to keep receiving each new edition of the catalog of the 3500-odd reagents and other organic compounds quickly available in laboratory quantities from a single source of known integrity. Others who want the new catalog should address* Distillation Products Industries, *Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Monitoring the person

For better or worse, consumption of horseshoes, coal scuttles, and 1-gallon kerosene cans falls, and that of film badges steadily rises. As ever more men earn their daily bread by the care and feeding of nuclear reactors or the manipulation of reactor products, the time has come for us to systematize the nomenclature of the various materials we make that go into the badges worn for a working week and then turned in for recording how much radiation the worker has received.

The simplest of the materials is *Kodak Personal Monitoring Film, Type 1*, with a layer of the most sensitive of all x-ray emulsions on each side of the base. It comes in 1¼″ x 1⅝″ size, just like dental x-ray film, in a little packet that comes apart with the pull of a tab in the processing room. Its function, largely, is to establish that the wearer has not been exposed to more β-, γ-, or X-radiation than is considered permissible.

Now, however, the new *Kodak Personal Monitoring Film, Type 2*, goes a step farther. *Type 2* has the highly sensitive emulsion on one side only. The other side bears a low-sensitivity emulsion that is just barely affected by exposures that drive the high-sensitivity side to full density. If the film should emerge from processing a sinister heavy black, one can quickly remove the high-sensitivity emulsion and assess the full measure of the misfortune from the density of the slow emulsion. Fortunately, this happens very seldom. The previous practice of packing separate pieces of fast and slow film into the badge had seemed extravagantly pessimistic in its waste of film and processing labor. The way was clear for the genius who conceived *Type 2*.

Kodak Personal Neutron Monitoring Film, Type A, is read with a microscope. One counts within a given area the number of tracks left by protons recoiling from fast neutrons or generated in the nuclear $N^{14}(n,p)C^{14}$ reaction.

Kodak Personal Neutron Monitoring Film, Type B, is a complex sandwich of nuclear track film between aluminum shields and paper proton radiators, all contrived to make the track counts correspond more quantitatively to the dosage effect of fast neutrons such as occur around accelerators.

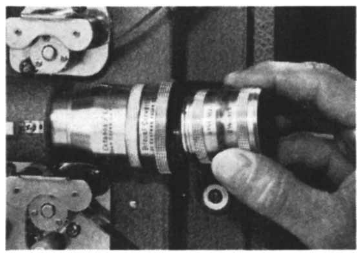
Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y., quotes prices, gives hints on processing and calibration, and arranges delivery through Kodak dealers. (*Secretaries to the contrary notwithstanding, the word is "personal," not "personnel."*)

Want your focal length changed?

You are to show movies. You bring the projector in and set it up in the logical place. Screen's all set. You thread the film. The projector lamp goes on. As you bring the lens to focus, you are confronted with one of the following three situations: 1) the rectangle of light neatly fits the screen, and the screen is big enough for all to see comfortably; 2) the picture is too small, and the room isn't long enough to get it any bigger; 3) the picture is too big for the screen, and it is inconvenient to move the projector any closer.

In cases 2) and 3) there is generally a fellow present who knows all about geometrical optics. He advises that you need the shorter or longer focal length. You look in the case. Of course, there is no other lens there; but if there were, the law of probabilistic adversity would guarantee it to be a longer lens if your difficulty is too small an image and a shorter lens if the image is too big.

All this was before the era of the *Cine-Kodak Bifocal Converter*, which



commenced several months ago. This small cylinder is a telescope of 1.25× power. It slips over the *Kodak Projection Ektanon Lens, 2-inch f/1.6*, that is standard on all 16mm projectors we make. Put on one way, it can expand the projected picture from about 6½ square feet to 10½ square feet for a 16-foot throw. Turned the other way for a large room, it can keep the picture within an 8-foot width when the projector is 10 feet farther from the screen than without the converter.

The proposition is appealing in its simplicity. For $26.50, a dollar less than the price of a single Ektanon lens, your Kodak dealer is in effect selling you two supplementary focal lengths. And the optical performance is good at all three focal lengths, because the designers of the converter knew exactly what projection lens it was to go on.

Price quoted is subject to change without notice.

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

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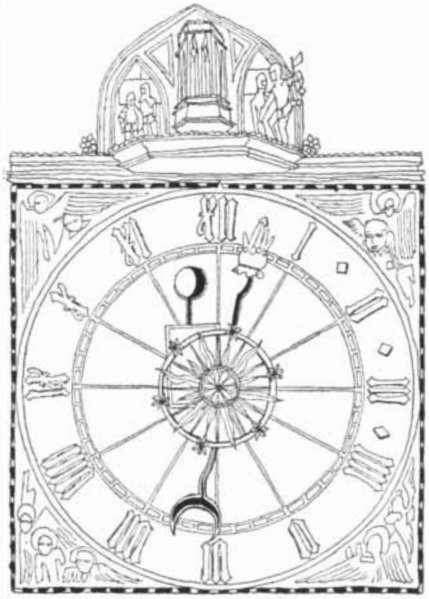


Fusion Power

The thermonuclear power program of the U. S. has been conducted from its beginning in almost complete silence. Recently, however, there came a break in the stillness. Richard F. Post, a physicist engaged in the program at the University of California, published a long article on "Controlled Fusion Research" in *Reviews of Modern Physics.* He describes the paper as "a distillation of the work of the many physicists who have been contributing" to the research.

Post says that the study of fusion power began even before the end of World War II (although the very existence of Project Sherwood, the code name for the program, was announced only a year ago). The first experiments were undertaken at the Los Alamos Scientific Laboratory, following up theoretical studies by Edward Teller, Enrico Fermi, James Tuck and others. In 1951 Lyman Spitzer, Jr., an astrophysicist at Princeton University who did not know about the Los Alamos work, conceived a different approach to the problem. The Atomic Energy Commission set up a second research group at Princeton to work on it. Then Herbert York of the University of California heard about the Los Alamos and Princeton ideas and came up with several new ones of his own. He formed an experimental team at the Livermore laboratory, with Post at its head, to pursue them.

All of the approaches, Post explains, are concerned with the dual problem of (1) heating a gas of light elements enough so that its particles can overcome their electrostatic repulsion, collide, fuse and release energy; (2) holding the heated gas within a confined space so that the reaction can continue. The necessary temperatures are so high that the gases become completely ionized "plasmas," *i.e.*, mixtures of bare nuclei and the electrons that have been stripped from them. Physicists have had comparatively little experience with plasmas and do not yet understand them very well. A good deal of the Sherwood research is concerned with the basic theory of this unfamiliar state of matter.

One of the specific problems discussed in the article is the question of density. If a gas as dense as sea-level air began to undergo fusion, it would release energy at the rate of 15 million kilowatts per cubic centimeter and its pressure would be some 150 million pounds per square inch! It might be possible to work with such a gas by limiting its fusion reaction to very short, occasional bursts. For any continuous system, however, the gas must be very rare—not much denser than a good laboratory vacuum.

Among the possible fusion reactions under consideration are those between pairs of deuterium nuclei and between deuterium and tritium. The D + D reaction may produce a helium 3 nucleus, a neutron and 3.25 million electron volts of energy, or, with equal probability, a tritium nucleus, a proton and 4 Mev. The D + T reaction always yields helium 4, a neutron and 17.6 Mev. The apparent energy advantage of D + T is offset by the fact that most of the energy goes off with the neutrons, which are very hard to capture. On the other hand, the lowest temperature at which deuterium nuclei could possibly react is about 400 million degrees centigrade. D + T could go at about 46 million.

At such temperatures, obviously, the gas cannot be enclosed in any material container. The only plausible means of confinement, according to Post, is an electromagnetic field. Under one reasonable set of operating conditions the field would have to exert a pressure of about 15,000 pounds per square inch.

One attractive idea is to make the plasma generate its own containing field through the so-called "pinch-effect." A current passing through a tube of plasma is analogous to a current through a bundle of parallel wires. It is a familiar fact that parallel conductors carrying current in the same direction tend to move together because of their surrounding magnetic fields. Similarly, a plasma carrying a current tends to shrink and to pull away from the walls of its container. To develop an inward pressure of 15,000 pounds per square inch requires a current of millions of amperes. But even if it could be achieved, the simple pinch will not work. The pinched current tends to develop kinks which, because of the shape of the magnetic field, enlarge themselves until the magnetic sheath breaks up.

The problems of controlling a fusion reaction are so many and so difficult, says Post, that "some physicists would not hesitate to pronounce [them] impossible of solution." But many of the workers on the project have the "firm belief" that all the problems "will be mastered—perhaps in the next few years."

More Money for NSF

Congress has granted an appropriation of $40 million to the National Science Foundation for the fiscal year 1957. This is almost 2½ times the appropriation the NSF received in 1956.

The new budget breaks down into these major categories: support for research projects, $16.25 million; education and fellowships, $14.5 million; scientific facilities, $5.8 million; communication of information (including translation of Soviet publications), $900,000; policy studies and surveys of U. S. research, $750,000; operating expenses, $1.8 million. Most of the money in the education category ($9.5 million) will go to finance summer institutes for high-school teachers. The largest item on the scientific facilities bill is $3.5 million for the national radio observatory in West Virginia, plans for which were described by Bart J. Bok in last month's Scientific American.

Federal Science Establishment

Of the 80 agencies in the executive branch of the Federal Government 36 engage in some scientific activity. In carrying out its research and development program the Government spends $2 billion annually and directly employs more than 130,000 scientists. A guidebook to this vast scientific enterprise called *Organization of the Federal Gov-*

ernment for Scientific Activities has been published by the National Science Foundation.

The present pervasive program has evolved a long way from the simple "observation and collection of data about natural phenomena" that began in the early 19th century. Among noteworthy developments in the past decade of rapid expansion the report cites the increase in agricultural research; establishment of the Atomic Energy Commission, the Office of Naval Research, two new Institutes of Health (for dental and heart research) and the National Science Foundation; the development of research centers operated by private contractors for the Government; the inauguration of a large program of medical research by the Veterans Administration.

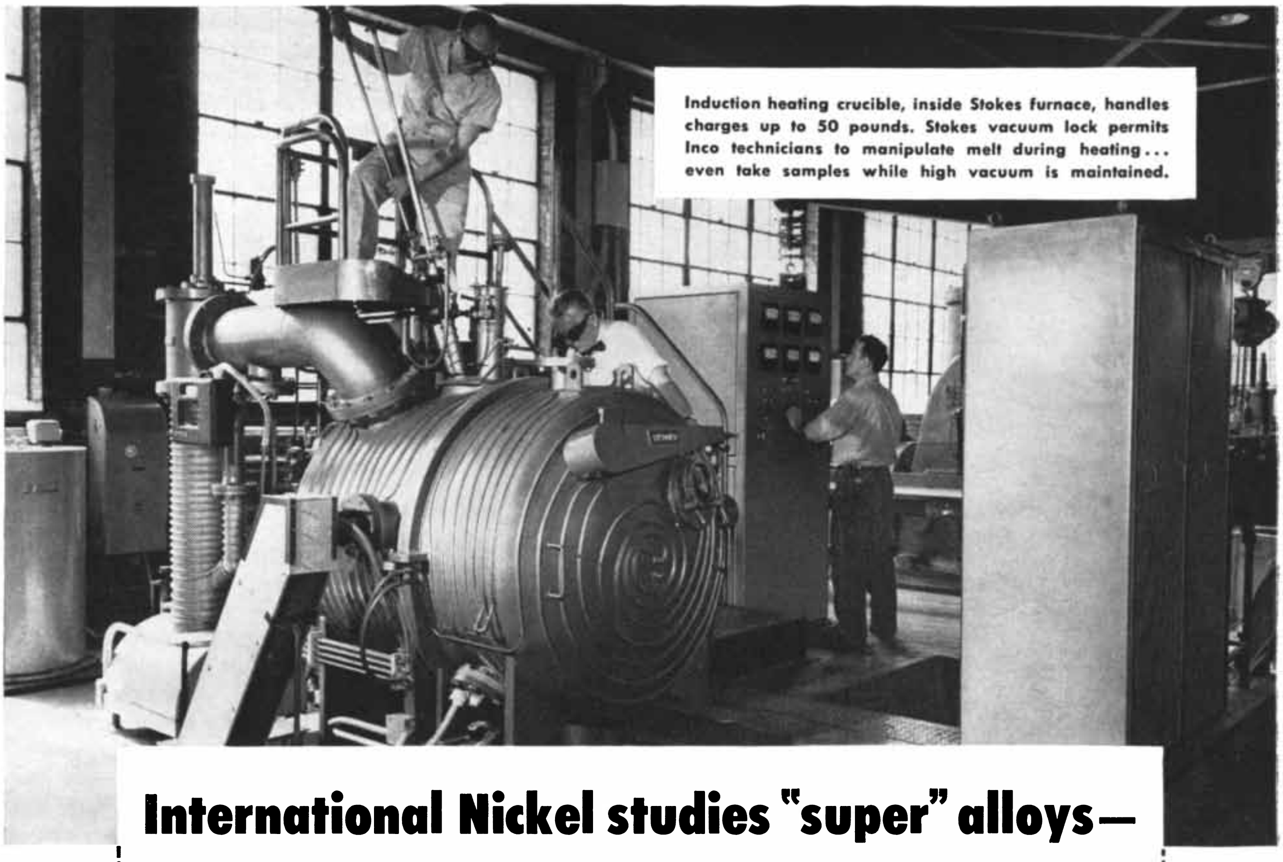
The main section of the publication is devoted to a detailed description of the Federal research establishment. The responsibilities of various branches of various agencies are listed, and research topics are indexed to tell which laboratories or agencies are working on them.

Making More Scientists

A $200-million program of undergraduate scholarships is "needed immediately" to help end the waste of this country's intellectual resources. So recommends the College Entrance Examination Board in a report to the National Science Foundation entitled *Encouraging Scientific Talent.*

A Board survey of high-school students indicates that only half of those ranking in the top 30 per cent in scholastic aptitude currently continue their formal education. Each year there are 60,000 to 100,000 superior students who want to go to college but who cannot afford to. Another 100,000 do not even want to go.

Adequate scholarship help would at once salvage the youngsters who are both able and willing. Not all of them would become scientists. But the Board's survey shows that a large proportion of high-standing students, especially boys, are interested in scientific work. Furthermore a considerable percentage of the others would abandon a preferred major subject if they received a scholarship in science or engineering. Ideally, says the report, financial aid should be offered "across the board" to encourage intellectual talent in general. If the scholarships are limited, *e.g.* to science, they should restrict the recipients as little as possible. The report concludes that a program of the necessary size—about 100,000 new scholarships



Induction heating crucible, inside Stokes furnace, handles charges up to 50 pounds. Stokes vacuum lock permits Inco technicians to manipulate melt during heating... even take samples while high vacuum is maintained.

International Nickel studies "super" alloys—melted and cast in Stokes Vacuum Furnace

The "thermal barrier" may be pushed even higher, as the result of investigations in vacuum processing of alloys in a Stokes furnace, at International Nickel's Research Laboratory.

Exclude air and remove gases from metals, and you can create extra properties that are unattainable by conventional techniques. This is one of the metallurgical developments that International Nickel Company, Inc. is investigating at Bayonne, New Jersey.

Using a Stokes Vacuum Furnace, the company is studying the effects of vacuum melting and casting on a variety of nickel base alloys such as Inco 700 and 713, destined for jet engines and other extreme temperature service. They also plan to examine the possibilities of vacuum melting of special nickel alloys containing oxidizable elements, stainless steels, cast iron and copper base alloys.

Stokes vacuum furnaces range in capacity from laboratory sizes to those capable of melting and casting charges of 3000 pounds on a production basis. The combination of Stokes high capacity Microvac mechanical pumps and "Ring-Jet" Oil-Vapor Booster Pumps gives fast pump-down and dependable maintenance of required vacuum down to the low micron ranges.

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each year—will have to be largely supported by the Federal Government.

But scholarships alone cannot recover all the potential scientists, the report declares, even among the group that wants to go to college. It is equally important to prepare students better for college scientific work, to interest them in a science career and to inform them of its opportunities and rewards. Such efforts should begin early; the sixth or seventh grades may be the "crucial point" where many able children are lost to science. Higher pay and recognition must be accorded science teachers in order to reduce the present acute shortage in that profession; the "well-trained, stimulating high-school science teacher" has almost disappeared.

The Antineutron

The inventory of "reversed" matter is growing. Now the antineutron has been made, caught and identified by a group of physicists working at the University of California Bevatron.

Anti particles are marked in general by a reversal of the properties that identify their ordinary counterparts. The anti particles corresponding to charged particles like the electron and proton are oppositely charged. The neutron is uncharged, but it does have a magnetic field. The antineutron's field is reversed. That is, if a neutron and an antineutron were lined up so as to spin in the same direction, their magnetic fields would be in opposite directions. But the essence of "anti-ness" is annihilation. When an ordinary particle and its anti particle collide they both disappear, turning into energetic radiation.

This is what happens when an antiproton bumps into a proton. Theory shows, however, that if the two merely pass near each other, the antiproton may flip a negative pi meson to the proton in a sort of lateral pass. This leaves both particles electrically neutral: the proton becomes a neutron and the antiproton an antineutron. If the antineutron subsequently meets another neutron, the pair will annihilate.

The California research team, consisting of Bruce Cork, Glen Lambertson, Oreste Piccioni and William Wenzel, set up an experiment to manufacture antineutrons and to detect their annihilation. They directed antiprotons at a sample of liquid hydrogen. A few (three per thousand) were converted to antineutrons. These were made to hit a lead glass target where some of them annihilated with neutrons. The resulting energy bursts were detected and meas-

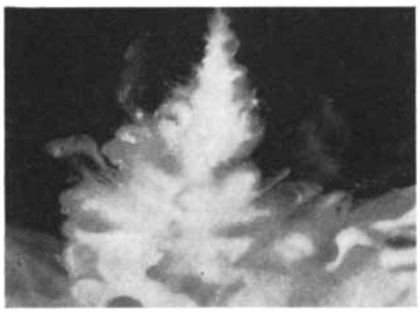
DOW CORNING

SILICONE NEWS

Aid for Maintenance-Weary Plants

- **New Silicone defoamer kills production bug-a-boo, reduces downtime**
- **Higher vacuum, lower cleaning costs . . . with Silicone diffusion pump fluid**
- **Motors insulated with Silicones give more mileage per maintenance dollar**

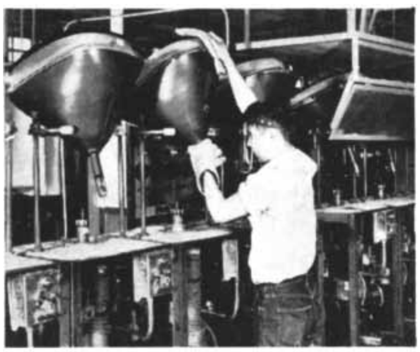
KILLING A BIG HEADACHE—Foam steals valuable production space, breeds costly maintenance problems. During the past decade, Dow Corning silicone defoamers have flattened foam during processing of products ranging from Fudgsicles to auto parts. Now are generally conceded to be the most versatile and efficient foam killers available.



Enter Antifoam B, a new Dow Corning silicone defoamer . . . kills foam with all the deftness of its contemporaries but adds a new measure of convenience. Speedy dispersibility is the important key, as illustrated by the underwater photo above. Other features—ready to use, no delays for diluting or mixing—excellent stability, long storage life—stays uniform even if frozen or boiled. No. 35

CORROSION BOWS OUT—More and more maintenance engineers plagued by the high cost of finishing and refinishing metal surfaces are standardizing on protective coatings made with Dow Corning Silicones. A typical example: Reynolds Metals Company has found that silicone based aluminum paint lasts at least 8 times longer than a conventional aluminum paint on diesel exhaust stacks where temperatures average 950°F to 1100°F. Consumers, too, want products that stay good looking longer. That's why foresighted appliance manufacturers are trending toward silicone based product finishes. No. 36

LOW COST HIGH VACUUM — When Thomas Electronics began making TV picture tubes, organic oils were used in the 400 high vacuum diffusion pumps on the production line. Opening and closing these pumps 5 times every 8 hours caused rapid evaporation and breakdown of the oils. Result: Carbon deposits required costly, time-consuming cleanings. In 1951 Thomas switched to Dow Corning silicone pump fluids. Maintenance costs were sharply reduced, because semi-inorganic silicone fluids do not break down to form carbonaceous deposits. Thomas also found that oil consumption dropped 30% with silicone fluid. No. 37



SALVE FOR VALVES—Effective at temperatures from —40°F to 500°F and resistant to many chemicals, "Valve Seal," a salve-like silicone compound, protects valve stems from corrosion, seals against leakage of process fluids. Impressed with the freedom-from-maintenance provided by Valve Seal, the Foxboro Valve Co. now offers its well-known "Stabilflo" valves equipped with a lubricator for injecting this versatile Dow Corning silicone lubricant. Other Valve Seal applications — flow meter bearings, pump packings, plug cocks. No. 38

MORE MUSCLES FOR LESS MAINTENANCE—New dimensions of efficiency in electric motors have been

realized through the use of insulating materials made with Dow Corning Silicones. More power per pound and greater reliability are part of the story. Smoother production and lower maintenance costs are additional reasons why silicone insulated electrical equipment is getting the nod from utilities like the Philip Sporn plant on the American Gas and Electric System.

Philip Sporn's first silicone insulated motor, a 1000 hp, 1190 rpm fan motor, has been operating over 4 years in ambient temperatures up to 120°F. Starting against cold air 4 times a day, it is overloaded by 30% bringing its total rise to 250°F with an output of 1300 hp. Built by the Elliot Co., this motor has coils wrapped with "R Tape," made from Silastic*, Dow Corning's silicone rubber. No. 39

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ured in a special counter arrangement which discriminated against all bursts not caused by annihilation of neutral particles.

Because the production of an antineutron is so rare an event, the experiment became feasible only after the Bevatron's output of antiprotons was stepped up. In the original antiproton experiments only 300 were counted over a period of weeks. Now, when everything goes right, 6,000 can be made in a day.

Source of Immunity

The immune response, by which living organisms "learn" to recognize and destroy foreign protein or other materials, is one of the leading puzzles of biochemistry. An important clue to the initial step in the process has been uncovered by a group of British researchers. They are tracing the antigen that "teaches" an animal to reject a graft.

When skin from one mouse is grafted onto another of a different genetic strain, the transplant does not last. The first time the experiment is tried, the patch takes hold and grows for a time but then withers away and falls off in about 10 days. Subsequent grafts between the same animals never begin to grow, and are completely destroyed in six days. The first transplant has made the mouse immune against later ones.

Immunity can also be produced by injecting some tissue, not necessarily skin, from the donor mouse into the donee. After such an injection even a first skin transplant is destroyed in six days. Exactly what substance in the injected tissue is responsible for immunity has been unknown. It has been generally supposed that only living cells could call forth the response.

Now R. E. Billingham, L. Brent and P. B. Medawar of University College, London, have shown that killed cells can give immunity and have traced the active agent to the nucleus. They report in *Nature* that they broke up tissue samples by ultrasonic vibration and separated the cell nuclei from cytoplasm. The nuclei produced immunity when injected into mice, cytoplasm did not.

Treating nuclei with an enzyme which digests desoxyribonucleic acid (DNA) destroyed their power to give immunity. Other enzymes, even one which completely dissolved the nuclei, did not impair the potency of the material. These and other chemical tests indicate that the active agent is a compound of DNA and protein. The investigators suspect, and are trying to prove, that the activity

Leak detection

New Profit Opportunities

- **Scientific leak detection cuts complaints in packaging industry.**
- **Refrigeration systems made leak tight; service costs reduced 85%.**
- **Vacuum systems' down-time reduced.**

A NEW LEAK DETECTOR, especially designed for continuous production-line testing of pressurized cans which use Freon* or a similar propellant, has recently been announced by the General Electric Company. Designed for use by manufacturers of insecticides, hair lacquers, paints, plastic sprays, shave lathers, shampoos, etc., the new Fixed-head Leak Detector accurately leak checks every can on the filling line. This 100% leak test helps protect the quality of the product throughout

its shelf life and sizeably reduces complaints and returns caused by deterioration on dealer's shelves.

Automatic testing can be accomplished and rejection of faulty cans can be initiated by the new system. Manual testing of cans or containers is eliminated and this new method is more sensitive and much faster than conventional "hot water" methods.

Tolerance limits for quality control can be set and maintained through use of General Electric's new Leak Standard. Experience with your product will show the maximum size leak which can be permitted without reducing shelf life below the desired minimum. The Leak Standard makes possible quantitative measurement of the leak and proper calibration of the detector to predetermined limits.

ANOTHER UNIT CUT SERVICE COSTS 85% for a user in Michigan who installs air conditioning equipment. These savings were achieved by using General Electric's Type H-1 portable detector to check new units for leak tightness during installation and to speed service calls. This detector is also popular for checking piping systems, gas sealed transformers, radiant heating systems, instruments, double glass windows, laboratory apparatus, gas tanks and other closed vessels and systems.

Existing light has no effect on the efficiency of your leak detection procedure since this unit does not depend on the changing color of a flame as a leak signal. With the Type H-1 halogen leak detector, even an unskilled operator can find a leak so small that in 100 years, only one ounce of Freon* gas would escape. A true leak signal is assured because the unit automatically offsets slow changes in background concentrations of halogen gases. Leaks are indicated by an instrument dial as well as by a variable-pitch loudspeaker or earphones.

FOR CRITICAL APPLICATIONS, requiring extreme sensitivity, General Electric's Mass Spectrometer Leak Detector is ideally suited. Used for testing vacuum tubes, refrigeration systems, transistor housings, mercury boilers, vacuum furnaces, uranium processing equipment,

altitude chambers, distillation equipment, cyclotrons and gas cooled generators, the unit will detect helium leaks of as small as 1×10^{10} standard cubic centimeters of air per second. At a slight sacrifice in sensitivity, hydrogen can be used as a tracer gas instead of helium. Rugged industrial construction, simplicity of design, and extensive use of plug-in type components make the General Electric device easy to operate and maintain. For example, the spectrometer tube of the detector can be removed without having to shut down the leak detector vacuum system. It is possible to resume operation within five or ten minutes after the tube is replaced. Features such as these are typical of General Electric's family of leak detection apparatus.

Whenever leaks can be expensive, in terms of money, safety, or reputation, call your General Electric Apparatus Sales Office for consultation about the best solution to your problem of leak detection. Or write Section 585-47, General Electric Company, Schenectady 5, New York, for information on the Fixed-head Leak Detector, the Leak Standard, the Halogen Leak Detector or the Mass Spectrometer Leak Detector.

**Reg. trademark of "Kinetic" Chemicals Div. of E. I. Du Pont de Nemours and Co., Inc.*

ACCURATE LEAK DETECTION MEANS PROFITS

GENERAL ELECTRIC

actually resides in the DNA—the genetic material itself.

Oldest City

Radiocarbon dating methods have greatly enhanced ancient Jericho's claim to be man's oldest city. A preliminary report on materials from Kathleen M. Kenyon's excavations [see her article "Ancient Jericho"; SCIENTIFIC AMERICAN, April, 1954] show that a level above that of the first walled town dates from the period 8000-6000 B.C. This pushes the beginning of civilization back to a time when the Ice Age had not yet ended in northern Europe. Jericho was already twice as old as Rome is today when the Israelites razed her in the second millennium B.C.

The radiocarbon dates have a qualitative as well as quantitative importance, according to an article by Sir Mortimer Wheeler in *Antiquity*. Up to now, historians have believed that civilization began about 3500 B.C. in the "Fertile Crescent" formed by the valleys of the Nile and the Tigris-Euphrates. It now seems that desert oases such as Jericho were permanent agricultural settlements long before man knew how to cope with the cultivation of seasonally flooded river valleys.

Frozen Radicals

Free radicals, which normally exist only fleetingly in hot gases, can now be solidified and stored for hours. In this form their properties can be investigated, conveniently and at leisure, by means of optical spectroscopes. The storage technique was developed by H. P. Broida and several colleagues at the National Bureau of Standards.

Broida creates his free radicals by first passing various gases through a high-frequency electric discharge and then piping them into an evacuated chamber immersed in liquid helium at 4.2 degrees above absolute zero. As soon as they strike the walls of the chamber they condense. An added advantage of the technique is that the electric discharge raises the gas atoms to an excited state. After the radicals freeze they gradually drop back to the ground state, emitting light energy. Thus emission as well as absorption spectra can be studied. The substances solidified so far include hydroxy (OH) molecules, and atomic nitrogen, oxygen and possibly hydrogen.

When frozen radicals are heated a few degrees they react suddenly. Study of the light and heat given off can tell much about these reactions. Also, by freezing

various radicals together and then heating them, it may be possible to create entirely new chemical compounds.

Hormone Anatomy

The first complete isolation of intermedin, a pituitary hormone which controls pigmentation, and the determination of its structure have been reported by Irving I. Geschwind, Livio Barnafi and C. H. Li, of the University of California. Even more significant is their discovery that a well-defined section of the intermedin molecule is identical to a section found in the hormone ACTH. The biochemists believe that this fragment probably contains the specific biological activity of intermedin and explains the fact that ACTH can also induce pigmentation. The finding tends to confirm the idea that large pituitary hormones like ACTH are, in effect, several hormones rolled into one. The various effects of ACTH (it stimulates the adrenal glands, produces pigmentation, and increases the amount of red cells in the blood) may each depend on a specific portion of its molecule.

Calculus of Clean-and-Jerk

The bigger you are, the more weight you should be able to lift (*ceteris paribus*). This qualitative rule has now been reduced to mathematical exactness by M. H. Lietzke, a chemist at Oak Ridge National Laboratory with a penchant for arithmetizing athletics. Writing in *Science*, Lietzke suggests that weight-lifting ability should be proportional to the 2/3 power of body weight. When he plots the world records for various weight classes, his formula is strikingly confirmed.

He extends the graph only as far as the 198-pound class because athletes in these limited classes generally train down to make the weight. They therefore represent pure bone and muscle, the only material that counts. Extrapolation of the curve shows that the heavyweight (unlimited class) record of 1,130 pounds (total for three lifts: the press, the snatch and the clean-and-jerk) should be within reach of a 232-pound lifter. The record-holder, Paul Anderson, weighs in at a supererogatory 350.

Not all the class records lie exactly on the line. The farther they are above the line, the more exceptional a performance they represent. On this basis, Lietzke concludes, the 148-pound champion, Kostilev of the U.S.S.R., is the world's best weightlifter.

The famous, lightweight *Talgo*, originally field-proven in Spain, is now pioneering a new era of railroad transportation in the U. S. Prototypes of these new Talgos, as well as the original ACF-built Spanish version, were all road-tested with Consolidated Electrodynamics instruments to evaluate design features and riding comfort.

Whenever you need fast, accurate data for new-product development, product improvement, or quality control, CEC can help you. The instruments, equipment, and systems available through Consolidated will place you in command of any analytical, control, or data-processing problem. How CEC can help improve your own products, competitive position, *and profits* is told in Brochure 43—"Your Next Move for Profit and Progress." *Send for it today.*

Most significant move in modern railroading

FIRST ACF-TALGO in revenue operation in the U.S. is Rock Island's "Jet Rocket". Its prototypes were road-tested with CEC Recording Oscillographs. Strain gages, accelerometers, travel gages, and three-way ride recorders completed the test equipment.

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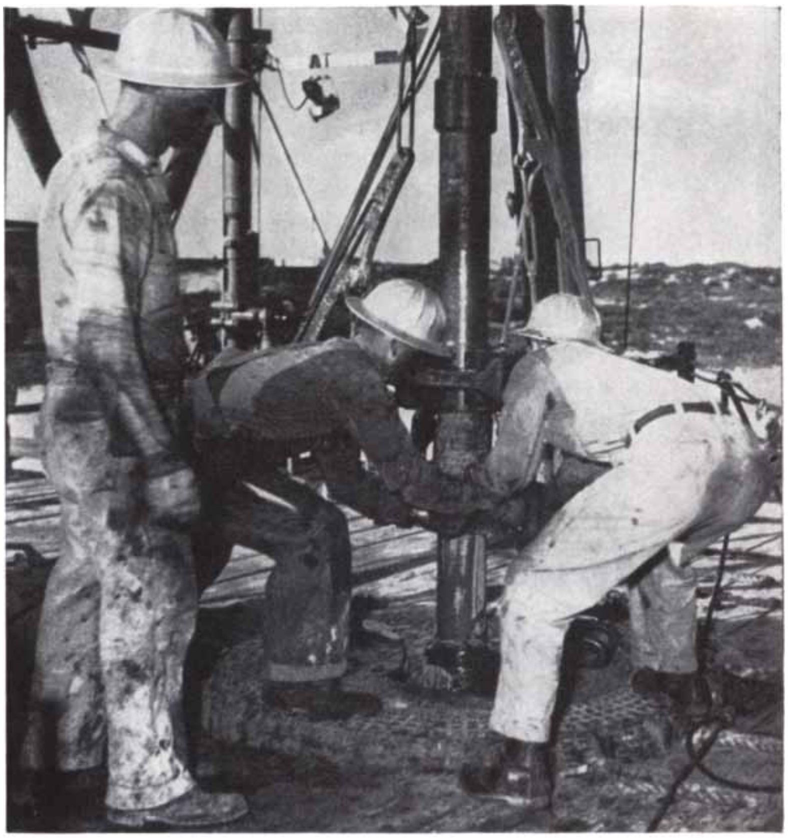
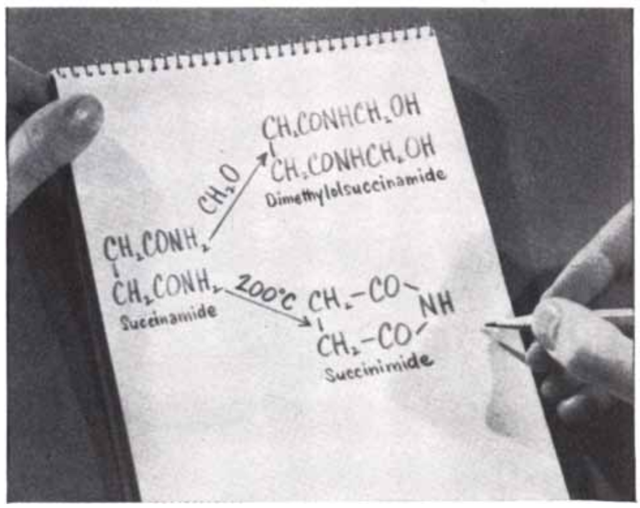
Life on the Chemical Newsfront



FIELD TESTS OF CYPAN® Drilling Mud Conditioner, a new organic water-loss control reagent, have produced excellent performance reports. As wells go deeper, a steady flow of special muds is needed to carry away cuttings, lubricate drill bits and maintain hydrostatic pressure. These muds must stand up under increasingly severe heat and contamination conditions. CYPAN stabilizes muds even at temperatures as high as 350° F. It resists contamination by salt, which otherwise would flocculate the colloidal clays present, and retards water loss so that muds maintain gel strength, lubricating and caking properties. A high molecular weight, acrylic-type polymer, CYPAN is readily soluble in water and can be added easily to mud systems. **(Industrial Chemicals Division, Dept. A)**

THERE'S A SOFTER FEEL AND BETTER DRAPE in the blouse this lady is examining, for it has been treated with Cyanamid's new CYANATEX® 3119 Softener. Both natural and synthetic fibers are lubricated and softened by this general purpose non-ionic textile finishing agent, making cloth easier to handle during processing as well as improving the appearance and "hand" of the finished garments. CYANATEX 3119 can be used alone, or in conjunction with other textile chemicals without any adverse effect on desirable characteristics such as crease retention and shrinkage control. **(Organic Chemicals Division)**



A DIAMIDE, Cyanamid's succinamide is now available for your investigation as an intermediate in which both terminal groups offer typical amide reactivity. For example, reaction with formaldehyde yields the dimethylol derivative which has possible interest in the modification of cellulose or starch. Heating produces succinimide, useful as an intermediate in the preparation of an unusual brominating agent, N-bromosuccinimide. Cyanamid's newly developed process for producing succinamide opens the way for increased acceptance of this intermediate for commercial use. **(New Product Development Department, Dept. A)**

Interior Designer: Michael Greer, A.I.D.

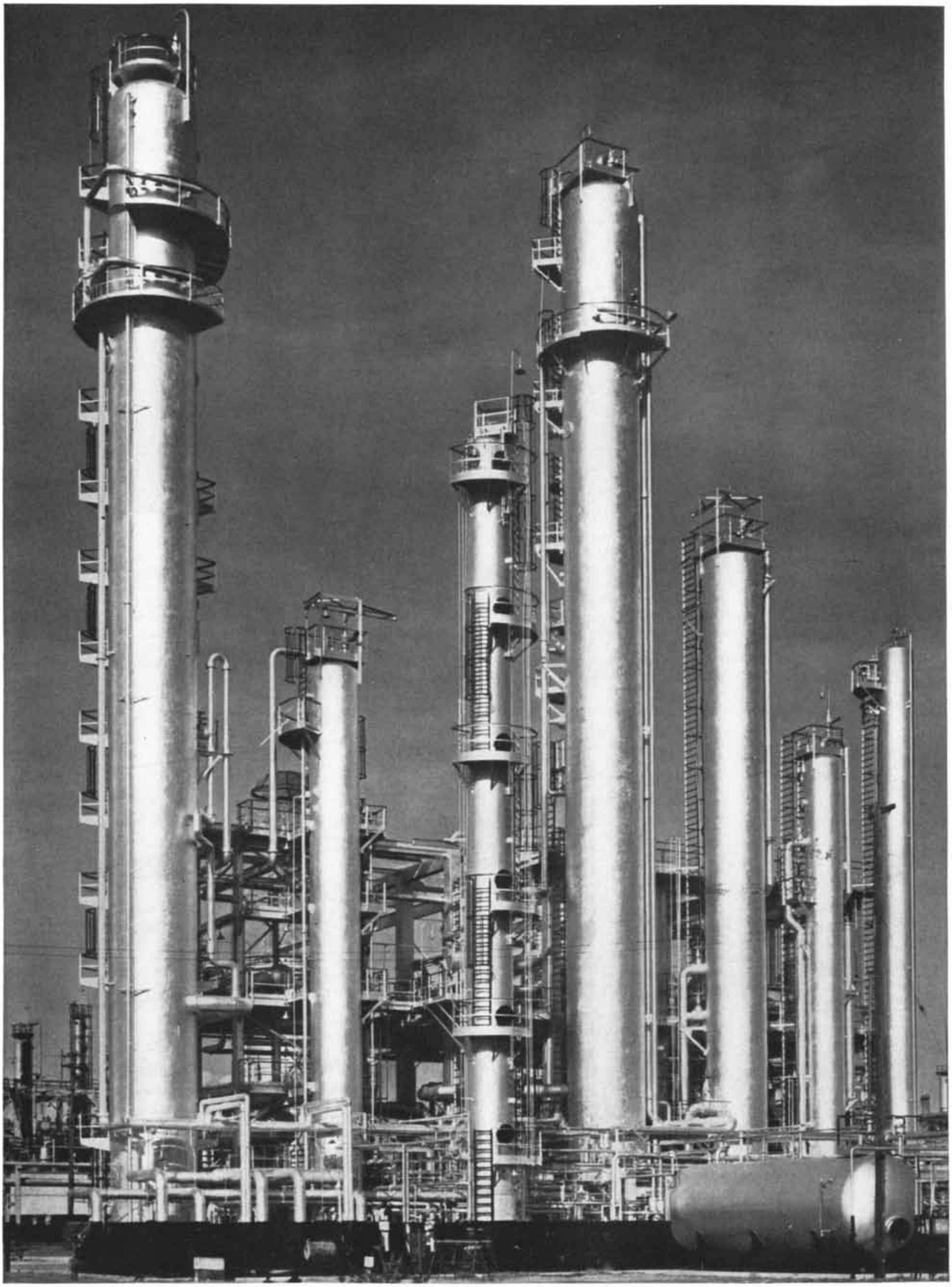
CONTINUED BEAUTY UNDERFOOT is assured in this living room, one of many rooms in a group of apartments decorated by members of the New York Chapter, American Institute of Decorators, in the Royal York Apartments, New York City. Wall-to-wall carpeting has been treated with CYANA® Soil Retardant to keep the rug new-looking between cleanings. Wool, cotton or synthetic fibers are treated at the rug mill. An invisible protective barrier is formed so that dirt particles can no longer readily adhere to the carpet fibers. Normal on-floor maintenance keeps rugs treated with CYANA in excellent appearance. **(Organic Chemicals Division)**

24 MILLION POUNDS OF ANILINE A YEAR is the goal of a new Cyanamid plant to be constructed at Willow Island, W. Va. The plant will use an entirely new process developed by Cyanamid research. For almost forty years a major supplier of aniline, Cyanamid is expanding its capacity in response to steadily increasing demand for products and intermediates dependent upon this building block of organic chemistry. Current data sheets on Aniline Oil, giving properties, specifications, uses and test methods are available on request from American Cyanamid Company. **(Organic Chemicals Division)**

HIGHER FIDELITY MUSICAL TONES are reproduced by a new phonograph designed by Pickering and Company of Oceanside, N. Y. The delicate mechanism of the Fluxvalve Pickup is sturdily housed in a unique one-piece head molded from Cyanamid's LAMINAC® Polyester Resin. The stylus is ingeniously supported in a separate LAMINAC molding, easily inserted into the head. The excellent frequency response of the Fluxvalve is protected indefinitely by the moisture-resistant and dimensional stability of LAMINAC. Another advantage is greater economy in production through the elimination of assembly problems, thanks to its integral construction. Precision molding to within .001" tolerance with LAMINAC Resins has solved critical alignment problems. **(Plastics and Resins Division)**

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

Building for the Future Through Chemistry



BUTADIENE is made in this section of the Baytown, Tex., petroleum refinery of the Humble Oil and Refining Co. Elsewhere in the refinery area the butadiene is mixed with isobutylene to make Butyl rubber, which is largely used for the manufacture of inner tubes.

RUBBER

Natural rubber is now supplemented by a remarkable variety of synthetic rubbers. The trend is culminated by the production of a synthetic rubber which is identical with natural rubber

by Harry L. Fisher

Vulcan was the Roman god of fire and metalworking. When Charles Goodyear, over a century ago, found a way to improve natural rubber by heating it with sulfur, he compared his method with the process of tanning to convert "perishable hide into beautiful leather," and the process of "baking iron" with carbon to change it into steel. These processes evidently had intrigued Goodyear and given him the thought that, just as raw iron and hides could be transformed, so it should be possible to change rubber into something with better and more useful properties. The process Goodyear developed for rubber was given the name "vulcanization" not by Goodyear himself but by a Mr. Brockedon, a friend of Thomas Hancock, the Englishman who rediscovered the method four years after Goodyear had prepared the first samples in 1839.

Natural rubber had been known, of course, long before Goodyear discovered a way to "change" it. The word rubber had come from its use in rubbing out the marks of a lead pencil, and it was mentioned as available for this purpose in a preface of a book by Joseph Priestley published in 1770. The English still call natural rubber "India rubber," because it came originally from the West Indies, which Columbus and his contemporaries thought was India. The French word for rubber, *caoutchouc*, probably comes from the native expression *caa o-chu* or *cahuchu*, which means "weeping wood," according to a reference to the matter by the Frenchman Charles Marie de La Condamine in 1736. Nowadays, more in keeping with the properties and uses we know today, rubber sometimes goes by the name "elastomer"—a term which I suggested in 1939 when the editor of *Industrial and Engineering Chemistry* asked for a more descriptive nomenclature for the rubbers. This name applies to any substance which can be stretched readily to at least twice its length and which retracts rather rapidly to approximately its original length when the stress is released.

The word rubber has in fact come to mean not a particular chemical substance but a type of material. When we speak of synthesizing a substance such as camphor or quinine, we mean duplicating the natural product, but synthetic rubber can mean a substance with rubber-like properties.

Supply and Demand

Before Goodyear discovered how to make rubber really useful, the traffic in natural rubber was slight. In 1834 the imports of natural rubber into the U. S. had reached 540 long tons, but the rubber-business "bubble" soon burst and imports dropped to 260 tons. Fifteen years after the discovery of vulcanization they still amounted to only 2,150 tons. (Compare this with the 635,332 long tons of natural rubber imported and the 982,304 tons of synthetic rubbers produced in the U. S. in 1955.)

However, the demand later rose by leaps and bounds, and very early in the game attempts began to be made to produce rubber synthetically. Aside from the uncertainties of the overseas supply, the price of natural rubber has been a nightmare to manufacturers of rubber goods because of its great fluctuations. A hundred years ago the average price was 62 cents a pound. During the next 50 years it varied widely. In 1910, with the new demand for automobile tires and tubes, it went as high as $3.12 a pound. Five years later, thanks to increased production of plantation rubber, it was down to 66 cents again. In 1932 the average price fell to 2.6 cents a pound, the lowest in history. It rose to 20 cents in 1940 and now is around 36 cents a pound. The principal synthetic rubbers are around 25 cents a pound.

Most people thought that synthetic rubber was new during World War II. Was it? As early as 1879 a Frenchman named G. Bouchardat heated natural rubber to a high temperature and obtained a volatile substance, called isoprene, which he succeeded in converting into a rubber-like material. The important point of Bouchardat's reasoning is that he conceived that isoprene might be a building stone of rubber—which in fact it is. Three years later W. A. Tilden in England obtained isoprene from turpentine, and then, by Bouchardat's method, converted it into a "tough substance resembling caoutchouc." Seven years later Tilden noted that isoprene standing in a stoppered bottle had changed spontaneously to a rubber, and he found that it "unites with sulfur in the same way as ordinary rubber, forming a tough elastic compound." And by 1910 S. V. Lebedev in Russia had made a rubber-like compound from butadiene, the simplest of all the hydrocarbons related to rubber.

Polymers

These hydrocarbons, compounds consisting only of carbon and hydrogen, have what the chemist calls "a conjugated system of double bonds," which readily link to many other substances or join molecules of the same kind. Butadiene [*see formula on page 78*] forms long chains of many times its own molecular weight. Such substances are known as polymers, and the method of producing them is called polymerization. The term comes from two Greek words meaning "many parts." When two different substances unite to form long polymers the product is called a copolymer.

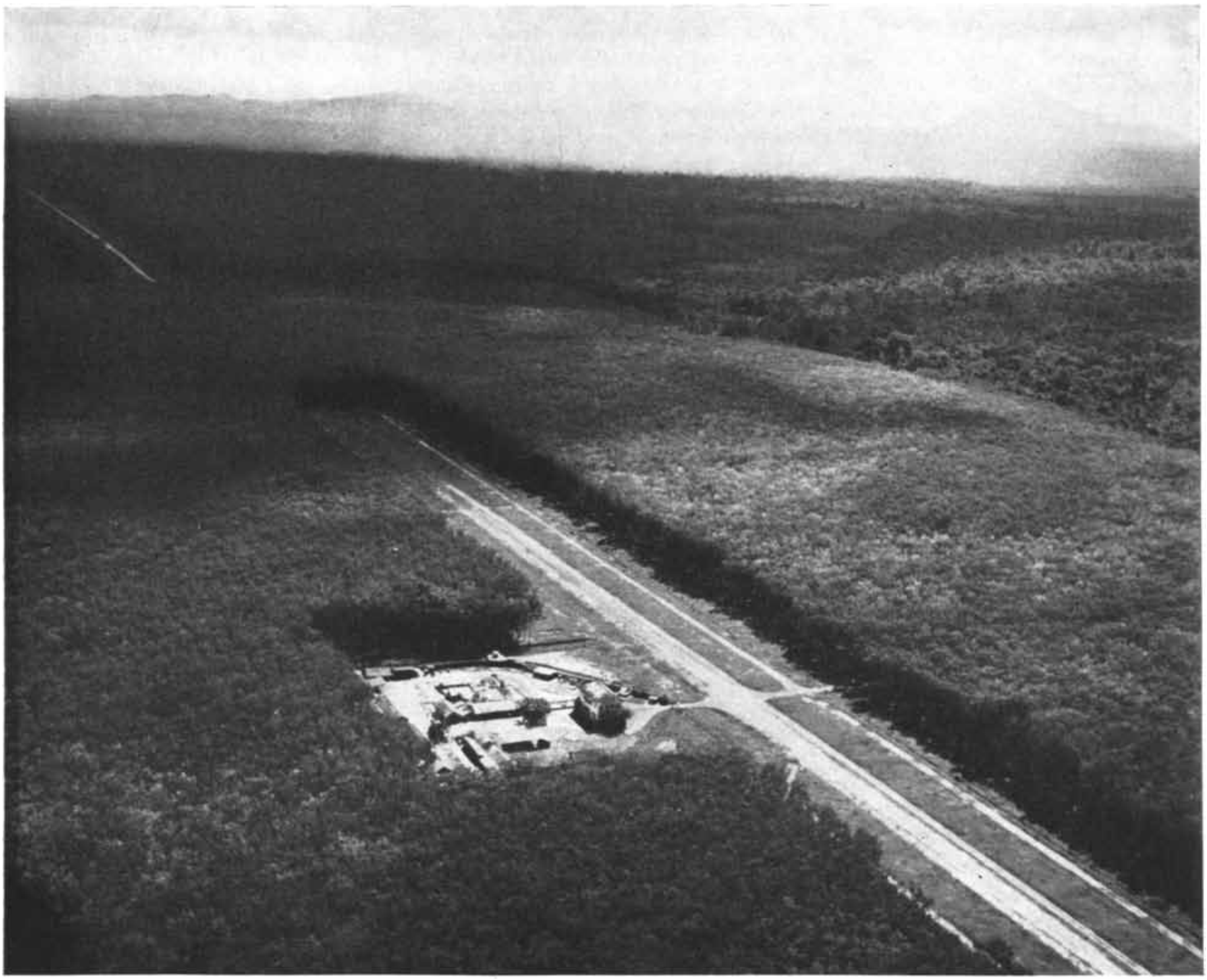
Polymerization is an interesting reaction. It is started in the presence of catalysts and the reactive chemical entities known as radicals. Among the good catalysts are peroxides, and Tilden's spontaneous performance was probably the result of a peroxide formed by the action of oxygen of the air on the isoprene.

Natural rubber is a high polymer consisting of units made up of two molecules of isoprene [*see formula on page 78*]. Isoprene has a molecular weight of only 68, and the natural rubber molecule (average molecular weight: one million) contains approximately 14,706 molecules of isoprene. Just how the hydrocarbon chain of natural rubber is formed is not known, beyond the fact that it comes from an acetate. Isoprene itself has never been found in any rubber tree or plant.

Practically all the natural rubber of commerce comes from trees on plantations in the Far East and in Liberia. These trees are all descendants from seeds gathered from rubber trees (*Hevea brasiliensis*) in the upper Amazon Valley in Brazil by Sir Henry Wickham in 1876. The steamer *Amazonas*, which happened to be on the upper Amazon with no return cargo, took a load of 70,000 seeds to England, and they were planted in Kew Gardens. Of the 2,700 that germinated and produced seedlings, about 2,000 were taken to Ceylon and allowed to grow in botanical gardens there. Thus were the Far Eastern plantations started.

Rubber is found in an emulsion known as latex in microscopic tubes in the bark. The bark is tapped with a U-shaped blade, and the latex oozes out of the cut. It is collected, coagulated by the addition of diluted formic or acetic acid, then squeezed between corrugated rolls and hung in a smokehouse to dry. About 80 per cent of the natural rubber comes on the market as tough, smoked sheet. Another form is pale crepe, which is washed on mills and allowed to dry without smoking.

Crude rubber is too tough to be mixed with other substances in its natural state. In the early 1800s substances were mixed into it by dissolving it in turpentine, which was then allowed to evaporate. A Scotsman named Charles Macintosh had the idea of putting the material between layers of cloth to make raincoats, and raincoats are still called mackintoshes. A big step forward came in 1820 when Thomas Hancock in England discovered that when rubber was worked, or "masticated" (he used a nail-studded machine), it became soft, and then all kinds of substances could be mixed into it. It is now known that the change is brought about by oxygen in the air. Apparently the working of the rubber shears the long molecules into



NATURAL RUBBER is grown on the Cambodian plantation of Loc Ninh, here viewed from the air. The smooth area of woodland that covers most of the photograph is planted with *Hevea brasiliensis*. In the middle of the photograph is the plantation's own airstrip.

fragments, free radicals, which unite with oxygen and form smaller molecules, so that the rubber becomes softer. The softening of rubber on a mill takes only a few minutes. If milled for 90 minutes or longer, the rubber is reduced to the softness of putty and finally to a heavy syrup. Rubber is not milled longer than necessary, because the longer the time of milling, the poorer are the properties of the final product.

Vulcanization

Natural rubber is vulcanized by heating it with sulfur, usually at temperatures of 250 to 307 degrees Fahrenheit. In the early days eight parts of sulfur were mixed into 100 parts of rubber and the mixture vulcanized for three to four hours. In 1906 George Oenslager discovered that the addition of aniline shortened the time and gave the rubber high tensile strength, good elongation and better resistance to aging. This was the first use of an organic accelerator of vulcanization. Aniline is poisonous, so nonpoisonous accelerators were soon substituted. Nowadays there are about 50 different types, and they give remarkably fine properties. Only about one part of accelerator per 100 parts of rubber is needed, and the proportion of sulfur has dropped to three parts or less. This is helpful because sulfur is only slightly soluble in rubber at room temperature, and an excess of it will crystallize on the surface as a yellowish powder, known as "bloom." Furthermore, low-sulfur compounds age more slowly.

Aging, which makes rubber goods hard, cracked and finally useless, is caused chiefly by oxygen, especially ozone (O_3). Ozone, though present in the atmosphere only in very small proportions, is the great enemy of rubber. It acts rapidly, especially when the rubber is stretched by 20 per cent or more of its length. To slow down aging, a small amount of antioxidant is usually added to rubber.

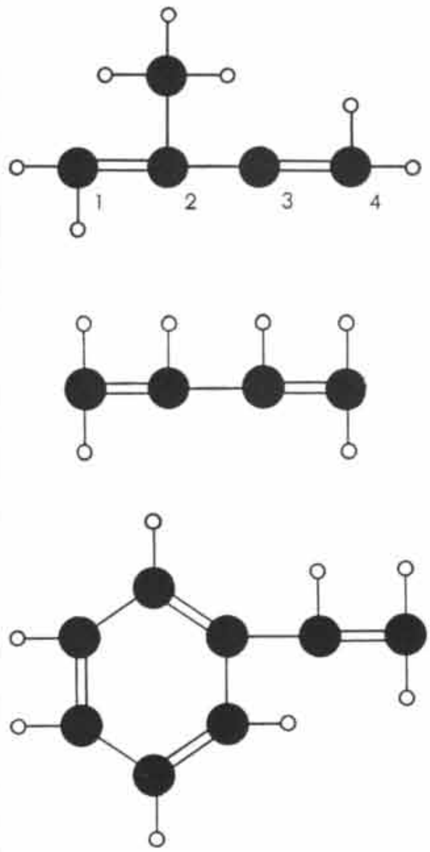
Vulcanization changes natural rubber from a plastic to a nonplastic material, makes it insoluble and enhances its properties. Vulcanized rubber can be stretched to six to nine times its usual length, depending on the load. A vulcanizate maintains its shape and always returns to that shape even though deformed in use. Witness a tire. Rubber vulcanizates have remarkable strength. Their tensile strength approaches that of mild steel. The carbon blacks used in rubber for tire treads give it a tensile strength of 4,500 pounds per square inch. One new synthetic rubber has a tensile strength of 11,100 pounds per square inch.

Natural rubber is a remarkable material, but man has improved on nature. He has made synthetic rubbers which do not swell in oils and greases, as natural rubber does. Natural rubber burns easily; chemists have produced synthetics which do not burn at all. They have synthesized white rubbers which can easily be colored to any hue, even pastel shades. Natural rubber vulcanizates have good impermeability to air, but the synthetic rubber Butyl (now used for inner tubes or the lining of tubeless tires) has 10 times their impermeability. Vulcanized natural rubber holds its properties over a wide range of temperatures, but the silicone synthetic rubbers stand up over more than twice the span—from 130 degrees below zero to as high as 600 degrees F. There are synthetic rubbers which are not affected by ozone. The new polyurethane rubbers have even greater resistance to tear than that of treated natural rubber, which is excellent. They make tire treads twice as tough. And because they give out less heat when stretched than natural rubber, they should eventually replace natural rubber even in tires for large trucks and buses. The day is coming when passenger car tires will last 100,000 miles—the lifetime of an ordinary car.

Chemistry

What is synthetic rubber, chemically speaking? We should ask first: What is natural rubber? Natural rubber contains a number of things—some protein, organic acids, sterols, fats, salts and so on—but primarily it is a long-chain hydrocarbon, and it is this hydrocarbon, making up about 95 per cent of the material, that interests us. Through the years intensive efforts were made to synthesize it, but they did not succeed until very recently. Meanwhile many synthetic rubbers were made via other approaches. The history of rubber research therefore follows two paths: the making of rubber-like materials, generally by trial and error, and the long search for chemical understanding and synthesis of natural rubber itself.

As we have seen, the early attempts to make rubber started with hydrocarbon building blocks, first isoprene and finally butadiene. Between about 1909 and 1912 isoprene was synthesized in Germany. The Germans converted it into a rubber and made it in such quantity that the tires on the Kaiser's automobile were manufactured of it. One of these tires



STRUCTURE of isoprene (*top*), butadiene (*middle*) and styrene (*bottom*) is indicated by these formulas. The large black balls are carbon atoms; the small white balls, hydrogen atoms. The single lines are single chemical bonds; the double lines, double bonds. The position of the four carbon atoms in isoprene are numbered according to the convention described in the text of this article.

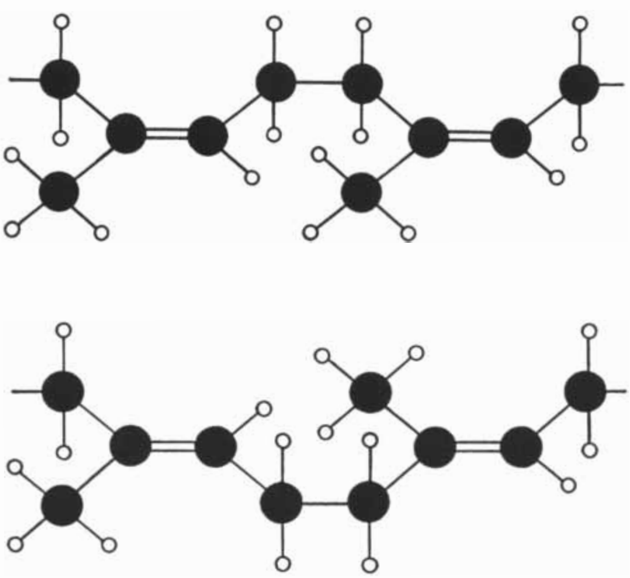
was proudly exhibited in a lecture at the Eighth International Congress of Applied Chemistry in New York City in 1912. Then during World War I the Germans, finding themselves rather suddenly cut off from supplies of natural rubber, rushed precipitately into the manufacture of "methyl rubber" from dimethylbutadiene, which can be considered as isoprene with an extra methyl group (CH_3). The method required six to eight months at temperatures up to 150 degrees F. They manufactured 2,350 long tons of this methyl rubber and found its best use in hard rubber battery jars for submarines. Tires were produced, but they were very poor. The cost of the rubber was about $3.25 a pound.

The Germans' effort was the forerunner, however, of a train of developments in production of synthetic rubbers from simple hydrocarbons. To this day the rubbers in greatest production are made with such substances. But as it happens, the first commercial synthetic rubber did not start from a hydrocarbon.

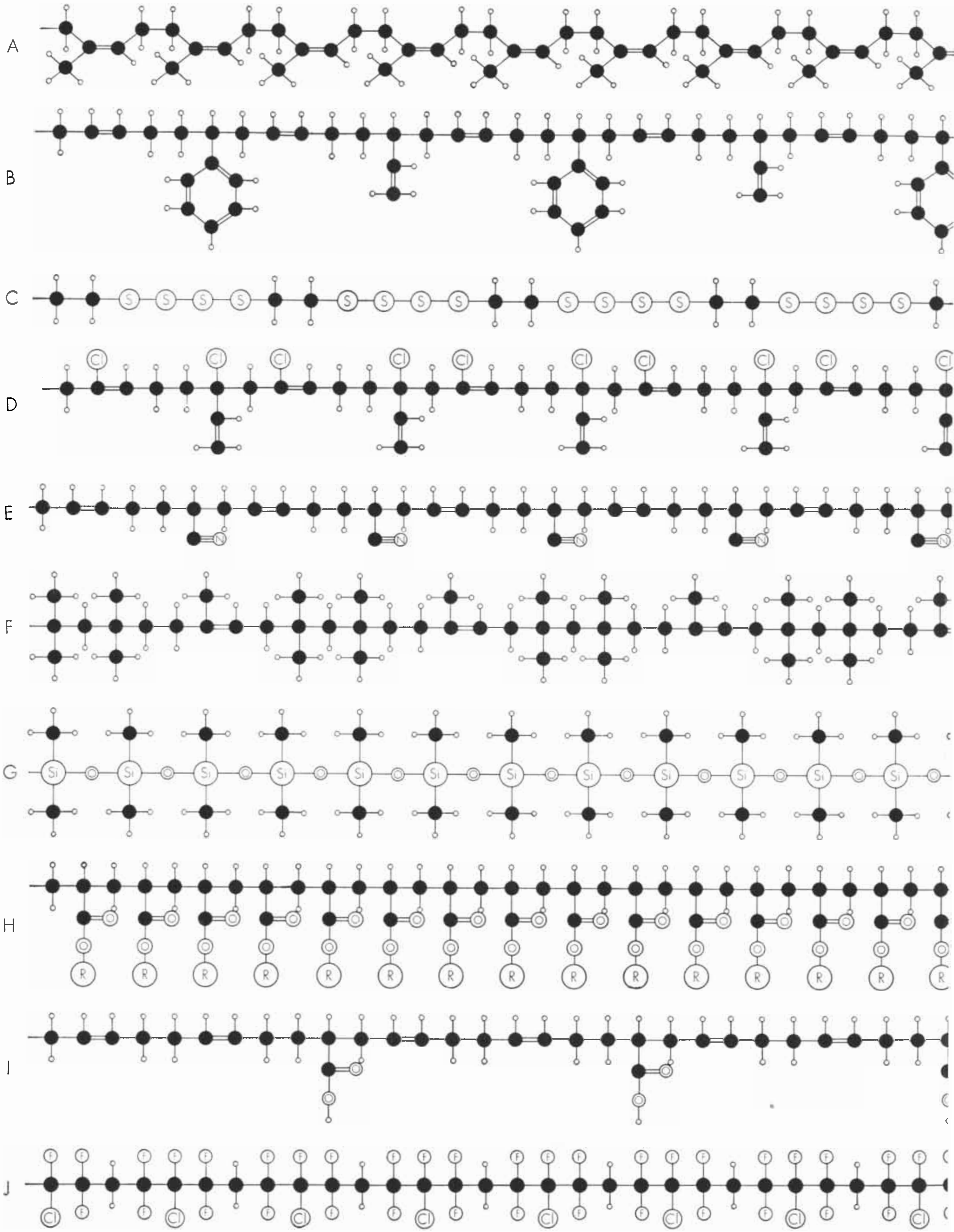
During the First World War, I was teaching organic chemistry at Columbia University, and early in the winter of 1917-18 I received a request from E. Emmet Reid of a special section of the Bureau of Mines to prepare about 20 substances for testing as chemical warfare agents. With the help of students I prepared 12, and then started to prepare dichloroethyl sulfide (which later became known as mustard gas). My co-worker, Meyer Moskowitz, and I decided to use what looked like a shorter method than the conventional one. We heated a mixture of ethylene dichloride and potassium sulfide. To our surprise we obtained a rubber-like product. Not long afterward I left teaching and went into industry. Our vice president in charge of research thought my product was poor, and unfortunately it had a rather bad odor. Eleven years later this material became the first commercial synthetic rubber—Thiokol. J. C. Patrick developed it about 1924 and put it on the market in 1929. J. Baer developed similar products at the same time in Switzerland. Thiokol is of importance because it swells very little in solvents, oils and greases and is not affected by ozone. But it is perhaps of equal interest because it was the first synthetic rubber not made from a hydrocarbon.

The Rubber Chain

From the beginning the aim of chemists working with the hydrocarbons was to synthesize the hydrocarbon chain of natural rubber. Not only was the structure of the chain unknown but there were no methods of distinguishing its structure from that of other rubber-like polymers. The efforts to make the rubber hydrocarbon chain began, as we have seen, with isoprene as the building block. A leader in this work was the firm of Strange and Graham, Ltd., in London. The late Chaim Weizmann, a member of the group, undertook to try to produce isoprene itself from an isomer (dimethylallene) of isoprene. Isomers are compounds which have the same atomic composition but differ in structure. Weizmann tried to convert dimethylallene into isoprene by the use of sodium as a catalyst. This was good organic chemistry, but instead of isoprene he obtained another isomer—an acetylene. At the same time F. E. Matthews, working in the same laboratory, was trying the reverse—to convert isoprene into an isomer of it. He sealed some isoprene and sodium wire in a glass tube to note any effect of the sodium on isoprene itself. In a month's time he observed that the contents of the tube had become viscous, and in two months the contents were converted into a solid mass of amber-colored rubber. Thus Matthews discovered that sodium could catalyze the synthesis of an elastic polymer from isoprene. Around the same time C. D. Harries, a consultant for the chemical firm of F. Bayer and Company in Germany, made the same discovery. Harries advised his firm to take out a patent, but unfortunately for him he lost the patent



CHAIN OF ISOPRENE MOLECULES has either the *cis* (*top*) or *trans* form (*bottom*). The hydrocarbon of natural rubber has *cis* form; the hydrocarbon of gutta-percha, *trans.*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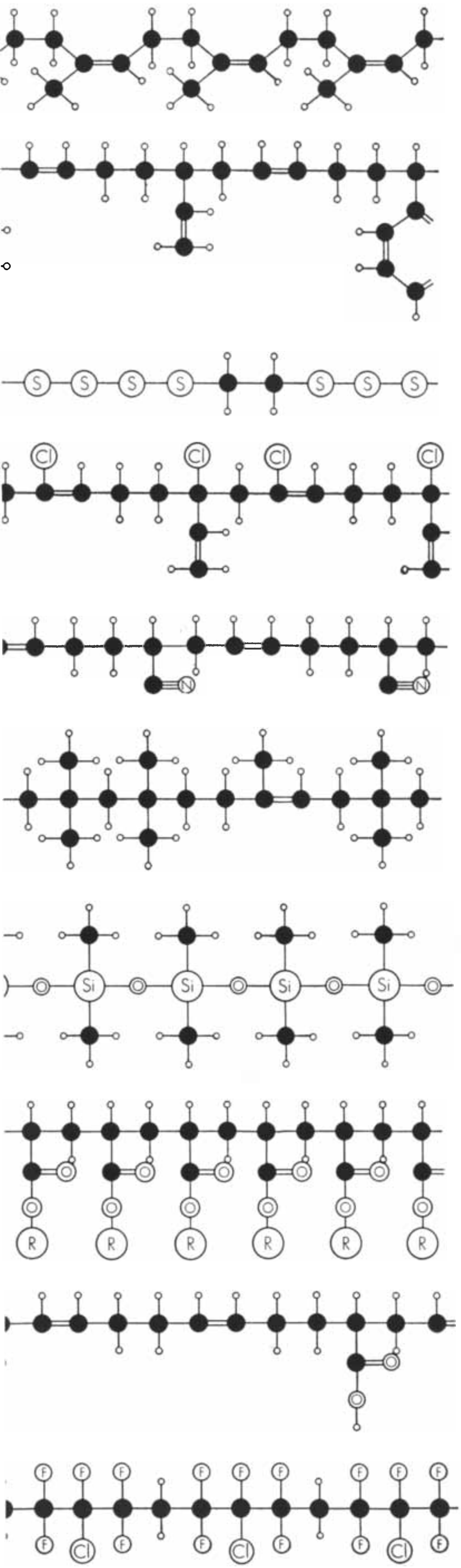


TEN RUBBERS are composed of relatively simple molecules repeated in long chains. Shown at the left are the chains of natural rubber (A), GR-S rubber (B), Thiokol (C), neoprene (D), nitrile rubber (E), Butyl rubber (F), silicone rubber (G), polyacrylate (H), carboxylic rubber (I) and Kel-F elastomer (J). Here again the carbon atoms are represented by black balls and the hydrogen atoms by small white balls. The other atoms are indicated by letters: S (sulfur), Cl (chlorine), N (nitrogen), Si (silicon), O (oxygen) and F (fluorine). The letter R in the chain of polyacrylate indicates that various radicals, or groups of atoms, may be attached at this point.

because Matthews had already applied for one.

W. H. Perkin, Jr. (son of the discoverer of mauve, the first synthetic dye), who worked with the Strange and Graham firm, gave a paper on the making of synthetic rubber from isoprene at the 1912 International Congress at Columbia that I have already mentioned. I was secretary of the organic section of the meeting and was an enthralled member of the audience. Perkin showed glass tubes containing the synthetic rubber. He left them with me, and I was a happy instructor to show them to my classes at Columbia whenever I reached the subject of olefins and rubber. I studied this method of polymerizing isoprene in the laboratory but had only very small amounts of isoprene which I had to synthesize myself. I also synthesized a methyl derivative (dimethylbutadiene) and had considerable success in preparing a polymer of it by the action of sodium. Manufacturing companies had little interest at that time, however, in the synthesis of rubber-like products, because they were inferior to natural rubber and much more expensive.

I cannot discuss the further developments in synthesis of rubber without entering the forbidding realm of organic chemistry, but I will try not to make the subject seem too difficult. As indicated above, no one could explain the differences between the synthetic polyisoprene prepared with sodium and the natural rubber hydrocarbon. Even Harries, who had done so much excellent work in studying the structure of the rubber hydrocarbon and in synthesizing rubber-like products, could not do so. But chemical tests showed that the molecules were not alike.

Cis and Trans

A tremendous amount of research work was done before it was possible to understand the structures of rubber-like materials and what their differences are. Organic chemistry, physical chemistry, physics and mathematics all took part. More than 30 years ago H. Staudinger of Zurich (later a Nobel laureate) proved that rubber molecules were like ordinary organic substances, united by primary valences in very long chains. He did not then realize just how long rubber molecules were, yet he did show high molecular weights.

Harries showed that the natural rubber hydrocarbon is a group of isoprene units—polyisoprene. Later it was demonstrated that the structure has to be described by the term *cis*-poly-isoprene. What does that *cis* mean? In a hydrocarbon compound any element or group attached to a carbon atom by a single bond is free to revolve on that bond. However, groups attached to a pair of carbon atoms linked by a double bond cannot revolve; they may be considered to be rigid. Now there are compounds which have the same groups attached to carbon atoms but held in different positions: they are called position isomers. In 1874 the Dutch physical chemist J. H. van't Hoff predicted that in certain double-bonded compounds there should be *cis* and *trans* isomers. Those who have studied Caesar will remember his discussion of cisalpine Gaul and transalpine Gaul, *cis* being the portion on the Roman side and *trans* the portion on the opposite side. Similarly a compound is the *cis* form when the same or similar groups are on the same side of the double bond, and the *trans* form when they are on the other side.

The two forms are well illustrated in nature by the structures of the hydrocarbon of rubber and the hydrocarbon of gutta-percha [*see diagrams on page* 79]. Rubber is the *cis* form, whereas gutta-percha is the *trans* form. One has to look sharp to see the difference. But the substances are distinctly different in properties. One is a rubber and the other a plastic. Much more could be said about this feature of chemical structure, but let us go on.

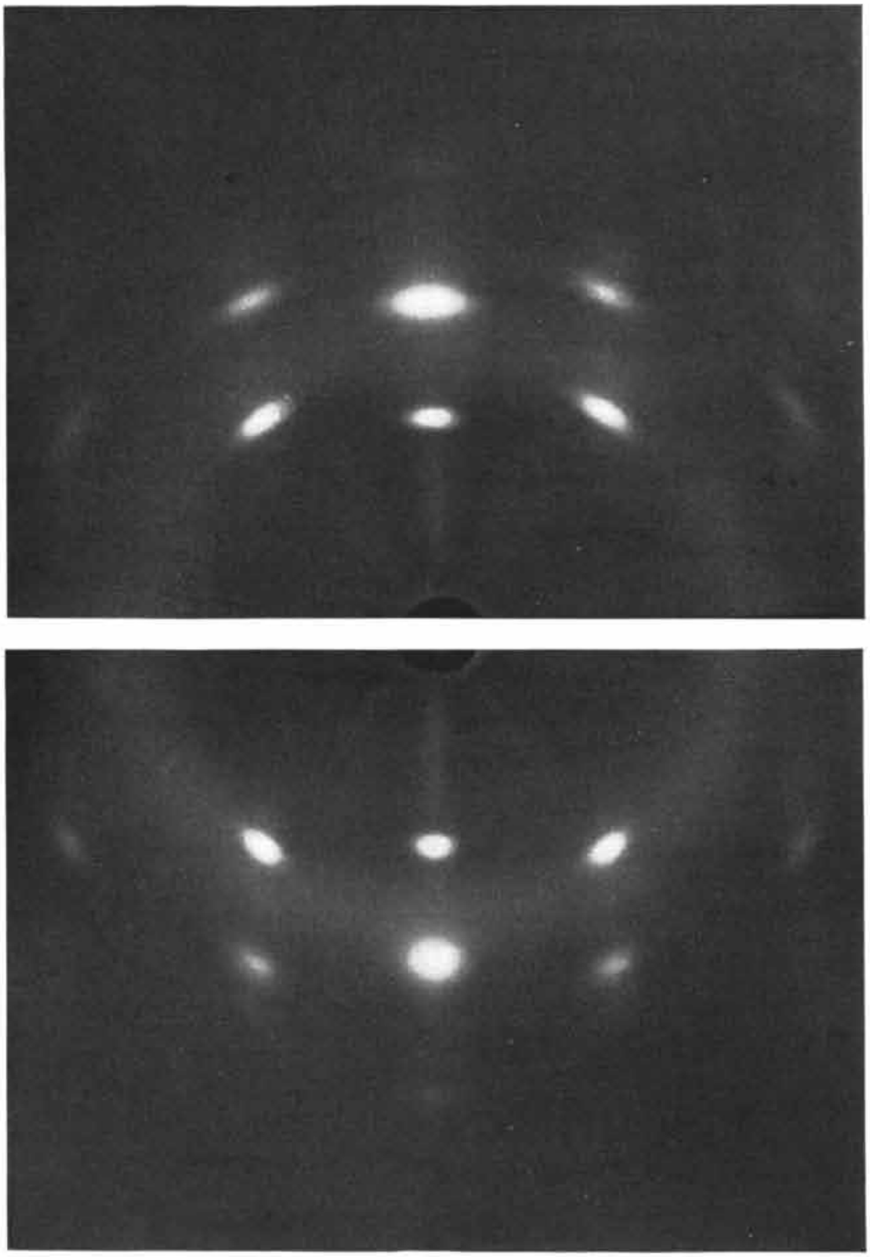
We must next consider the structure of the chain itself. To make the natural rubber hydrocarbon the molecules of isoprene must be linked to one another end to end, or at what are called the 1 and 4 positions [*see upper diagram on page* 78]. The action of sodium, however, causes isoprene molecules to attach themselves to each other not only at the 1, 4 positions but also at the 1, 2 and 3, 4 positions.

The big problem in synthesizing the natural rubber hydrocarbon was to make the isoprene molecules unite always at the 1, 4 positions and to produce the *cis* structure. This problem has only recently been solved, probably in two ways. Research groups of the B. F. Goodrich Chemical Company and the Gulf Oil Corporation have announced that they have solved the synthesis by use of a catalyst prepared by a method used by K. Ziegler in Germany. Their rubber product is called Ameripol S-N. No details have yet been given on the catalyst, nor is it stated whether isoprene is the starting substance.

The Firestone Tire and Rubber Company also has synthesized the natural rubber hydrocarbon and has published its method. The catalyst is finely divided lithium, in the proportion of one part to 1,000 parts of purified isoprene. They are treated at a temperature of 104 degrees F. The product is called Coral rubber. The average molecular weight of Coral rubber is 669,000; that of Ameripol S-N is lower–248,000. These rubbers will cost about the same as natural rubber and will be produced soon in pilot plants.

Thus the long-looked-for synthesis of the natural rubber hydrocarbon has at last been accomplished.

Now there has just been published an



X-RAY DIFFRACTION PHOTOGRAPHS indicate that natural rubber and Coral rubber, a new synthetic product made by the Firestone Tire and Rubber Company, are identical. At the top is the diffraction pattern of natural rubber; at the bottom, that of Coral rubber.

announcement of the synthesis of a rubber with an even simpler building block than isoprene—namely, butadiene. It is *cis*-poly-butadiene, the simplest possible type of rubber polymer. The synthesis is achieved by means of a new catalyst, butyl lithium, in titanium trichloride, in octane solution at 176 degrees F. This rubber's average molecular weight is 220,000; its vulcanizates have a tensile strength of 5,240 pounds per square inch, and they have excellent stretching and recovery qualities and a low heat build-up. Furthermore, butadiene is cheaper than isoprene.

Buna

Sodium and potassium butadiene rubbers were manufactured on a small scale in Germany before 1930. The Germans called these rubbers Buna, from the first two letters of butadiene and of *natrium* (New Latin for sodium). They added numbers, *e.g.*, Buna 85, to indicate the viscosity and molecular weight of the rubber. The U.S.S.R. also has manufactured sodium butadiene rubber, in much larger amounts.

The Germans, finding that these rubbers had considerably poorer properties than natural rubber, tried another direction in the 1930s. They went back to old patents on a process for polymerizing isoprene and butadiene in water emulsions. It appears that the inventor wished to imitate the aqueous condition of natural latex. By the method of aqueous polymerization the Germans soon produced two new types of synthetic rubbers: Buna S, a copolymer of butadiene and styrene, and Buna N, a copolymer of butadiene and acrylonitrile. They used the term Buna even though no sodium was involved.

Buna S is an all-purpose rubber and can replace natural rubber in most of its applications. During the war the Germans' production of Buna S reached 108,800 tons in 1943. But in the U. S. comparatively little was known as to how to manufacture it before our entry into the war. In August, 1942, President Roosevelt appointed a Rubber Survey Committee consisting of Bernard M. Baruch, James B. Conant and Karl T. Compton. The committee and its experts recommended development and manufacture of a general-purpose rubber similar to Buna S. Under the leadership of William M. Jeffers, president of Union Pacific Railroad, who was appointed rubber director, a staff of chemists and engineers, with only a general idea of how Buna S was produced, swiftly set up a process. In December, 1943, the new

rubber began pouring out of a new plant in Institute, W. Va. This rubber was prepared from butadiene and styrene, and was called GR-S (Government Rubber-Styrene). In 1945 the production was 791,197 long tons.

Recently the plants were sold to private companies, each of which now uses a different name for its product. The recipe for the GR-S made during the war was: 75 parts (by weight) of butadiene, 25 parts of styrene, 180 of water, 5 of soap, .3 of potassium persulfate and .5 of Lorol mercaptan. The last two were the catalysts. The butadiene and styrene were emulsified in water in the presence of the soap and then copolymerized with the potassium persulfate and the dodecyl mercaptan. The synthetic latex was coagulated, washed, dried and then baled.

How did the ingredients work? The persulfate starts the reaction by oxidizing the mercaptan to form a free radical. The free radical, on colliding with a molecule of butadiene or styrene, attaches itself to the molecule. The combination, still a free radical, in turn goes on adding one butadiene or styrene molecule after another until a long chain is formed. The chain is closed when perchance it collides with a free molecule of mercaptan. The mercaptan controls the size of the rubber molecules: the greater the proportion of mercaptan in the mixture, the lower the average molecular weight and the softer the rubber. The Germans knew of this modifying action of mercaptan but did not put it into effect. They made very tough rubber and then plasticized it by heating it in air in ovens.

The reactions take place at a temperature of 122 degrees F. GR-S has been carefully analyzed, and it is known that at this temperature the chain consists of about 59 per cent of *trans*-poly-butadiene in 1, 4 positions, 15 per cent *cis*-poly-butadiene in 1, 4 positions, and 25 per cent of a polymer of butadiene joined at the 1, 2 positions. At lower temperatures the proportions change.

It was known early in the war that GR-S rubber made at lower temperatures had better properties but the time of conversion ran to three or four days. Near the end of the war the U. S. rubber group learned that the Germans were working in the laboratory on a system which could be used around the freezing point of water. The rubber was better than by the regular method but difficult to handle. No tires were manufactured with it. The method involved reduction and oxidation by special substances. Experiments in this country improved the

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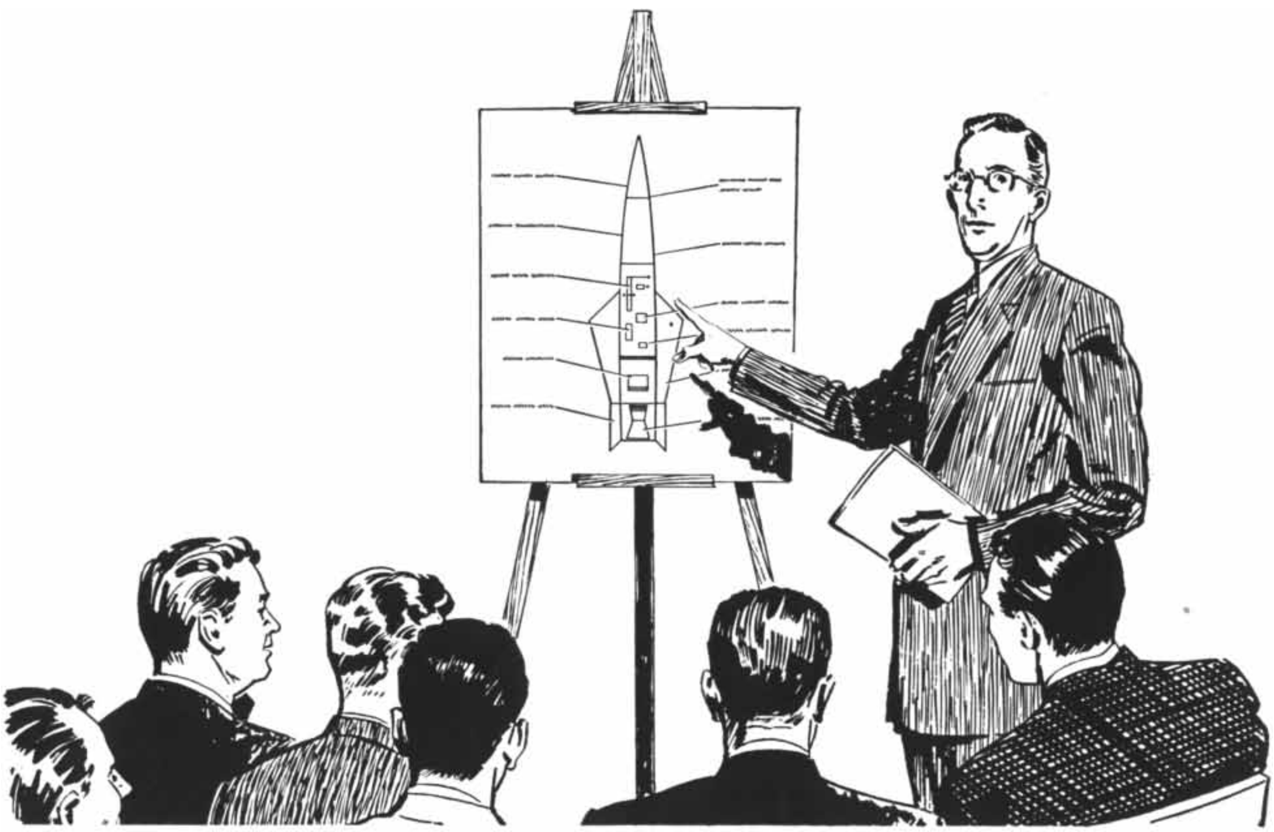


process, and in 1948 a new GR-S was made at 41 degrees F. It was called "cold" GR-S. Cold GR-S works better on rubber mills than the hot version, has stronger properties and with the new furnace carbon blacks gives tires 10 per cent better resistance to abrasion than natural rubber.

The major ingredients of GR-S are at present cheap and plentiful. Butadiene is obtained by cracking petroleum and natural gas. The materials for making styrene are benzene, ethylene and the catalyst aluminum chloride.

Other Rubbers

Now let us look briefly at the other synthetic rubbers. The first synthetic produced commercially, as already mentioned, was Thiokol. By improved methods of synthesis, much of the original unpleasant odor has been removed from these rubbers. They are vulcanized by heating with zinc oxide rather than sulfur. The second commercial synthetic rubber, introduced in 1931, was neoprene. Its synthesis starts from acetylene, and the building block is chloroprene, which may be considered an isoprene with an atom of chlorine in place of the methyl group. Neoprene is more like natural rubber than most of the other synthetics. It withstands ozone and oils better than natural rubber.

Butyl rubber is a copolymer of isobutylene and isoprene, both obtained from petroleum. It consists of 97 parts of isobutylene and three parts of isoprene. Butyl, as I have said, is particularly useful in tire tubes, because of its impermeability to air. Mixed with carbon black, it makes a strong tire tread. It is not affected by ozone. Also, it is the least expensive synthetic rubber on the market.

The nitrile rubbers (Buna N) swell little in oils and greases, withstand heat well (they are useful up to 450 degrees F.) and have good resistance to abrasion. They are vulcanized by a sulfide that is used for natural rubber.

The polyacrylate rubbers, made from esters of acrylic acid, also are resistant to heat and oil, and they have excellent resistance to aging.

The silicone rubbers are, of course, a very unusual class of elastomers. The backbone of their chain consists not of carbon atoms but of silicon and oxygen; hydrocarbon side groups are attached to the silicon. Silicone rubbers retain their properties down to 130 degrees below zero and up to 500 degrees above zero F. This is a most remarkable range of temperatures for a rubber to act as

rubber. The silicones are vulcanized with benzoyl peroxide, show low swelling in many oils and are not affected by ozone. One type is known as Silastic.

Another class of rubbers with exceptional properties is the carboxylic type—a copolymer of butadiene and the carboxyl group (COOH). These rubbers are vulcanized with zinc oxide, and one of them has a tensile strength of 11,100 pounds per square inch, the highest on record.

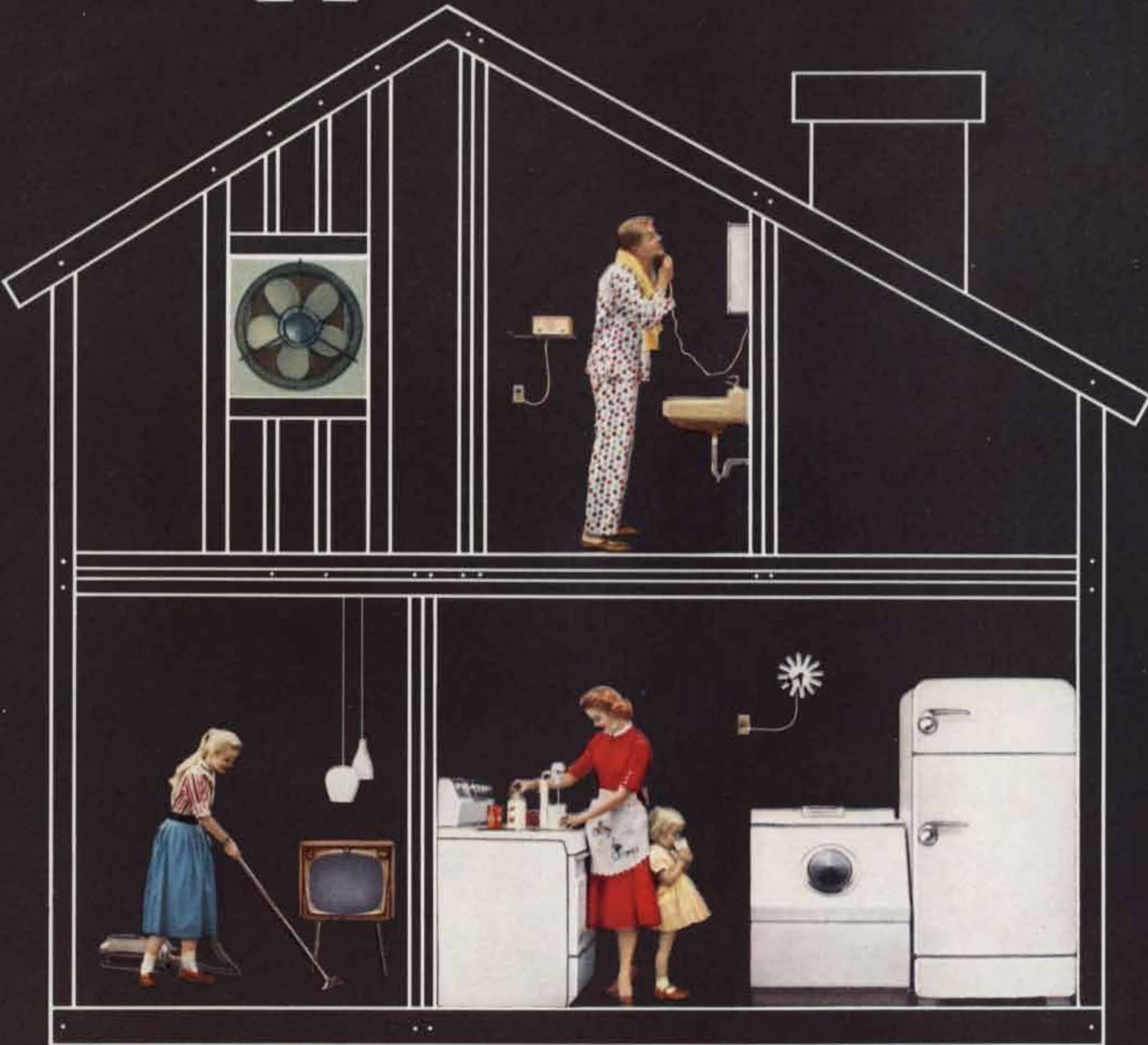
The well-known plastic polyethylene is converted into an interesting rubber by incorporating about 27 per cent of chlorine and 1.5 per cent of sulfur. It is vulcanized with magnesia and moisture. The presence of the chlorine atoms allows easy movement of the molecules and makes it a rubber in place of the original plastic. The rubber, white in color and known as Hypalon, is not affected by ozone, shows low swelling in oils and greases and gives useful mechanical products.

Still another product radically different in make-up from natural rubber is the rubber called Kel-F elastomer. This is a copolymer of two molecules containing carbon and fluorine. It can be vulcanized with benzoyl peroxide and other agents, has a tensile strength up to 3,500 pounds per square inch, and withstands heat, fuming sulfuric acid and fuming nitric acid. It is a special-purpose rubber, still highly expensive, but the price will come down.

The polyurethane rubbers are very interesting and are capable of much further development. They originated in Germany, where they are known as Vulcollan, and were further developed in this country as Chemigum SL. They have great possibilities because of their high tensile strength, high resistance to tear, low loss of heat and excellent age resistance. They start with esters of ethylene and propylene glycols and adipic acid. They can be vulcanized with water, which forms urea derivatives and carbon dioxide. The carbon dioxide gas incorporated in them by this treatment makes them spongy, and the chief use of polyurethane rubber at present is as "foam rubber" for upholstery, mattresses and insulation. But these rubbers will make excellent tire treads, giving 100,000 miles of wear, and will be available in any color because carbon black is not required. They may even not require fabric.

There is a great deal more to be said about rubber, natural and synthetic, but I have already covered much ground. The story is long and this is not the end of the story, but it is of my article.

in appliances...



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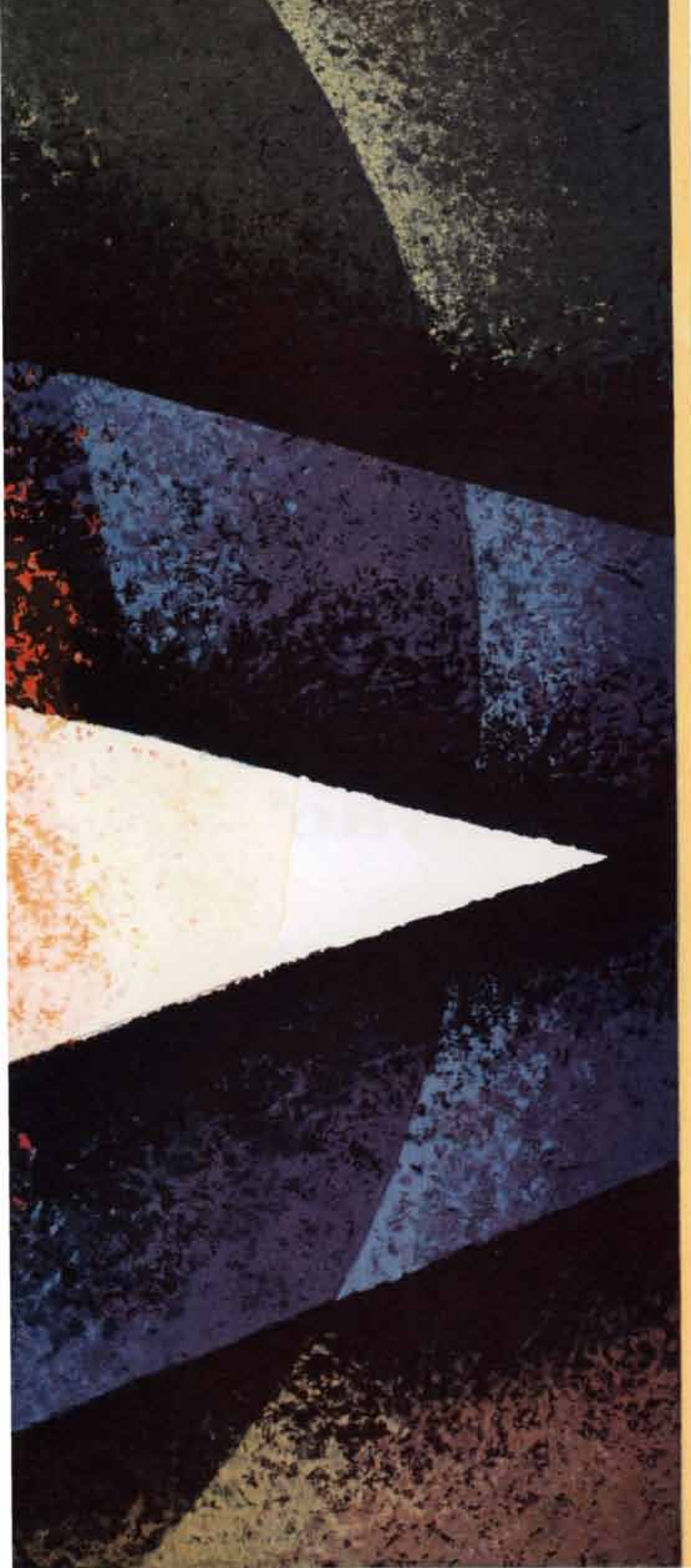


The Birth of the Nuclear Atom

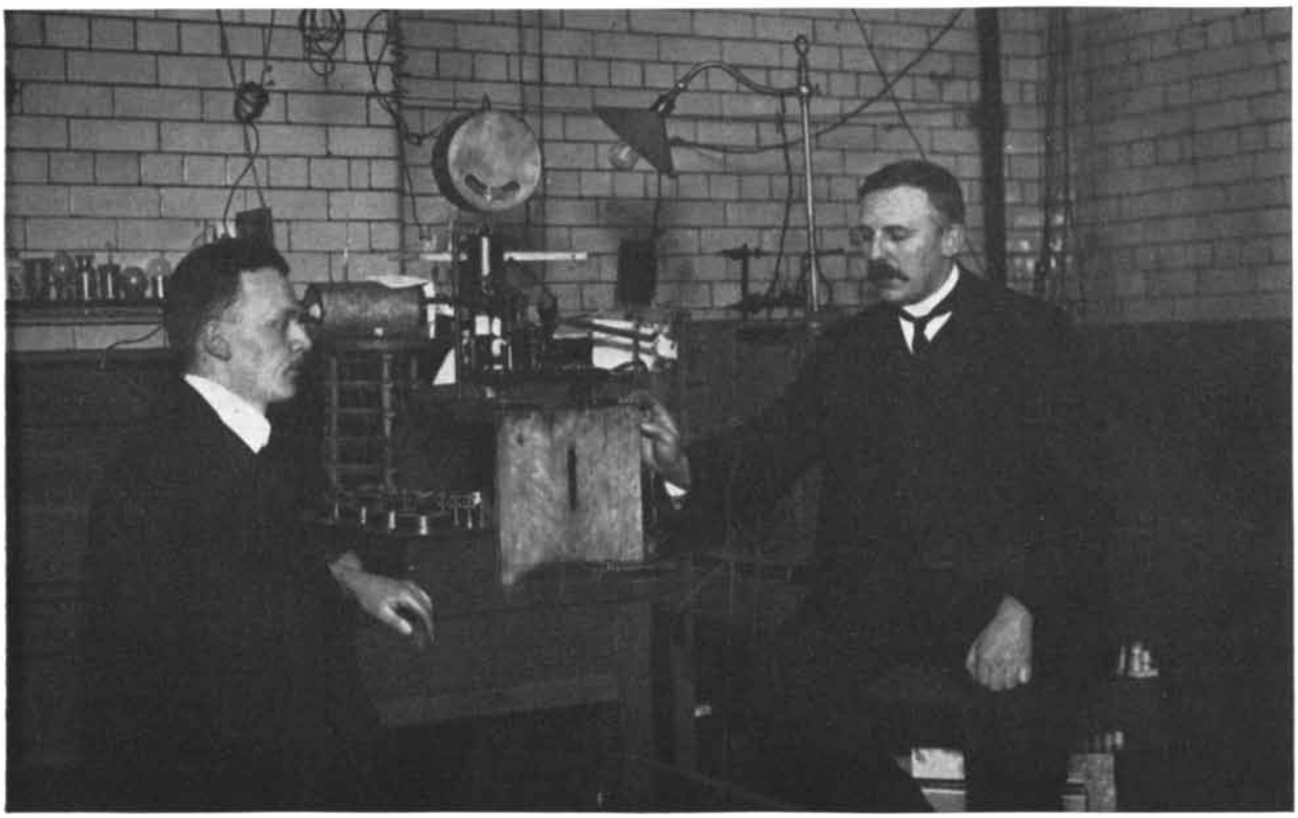
In 1911 Ernest Rutherford published his account of the experiments which showed that the atom has a massive electrically charged core. At the time even he was unaware of the importance of his discovery

by E. N. da C. Andrade

One of the epoch-making events in the history of science was the conception of the theory that the atom contains a nucleus. This fundamental advance, however, caused little comment or discussion at the time when Ernest Rutherford, that great figure who dominated atomic science in his day, first proposed it. The story of the circumstances preceding and attending the birth of the nuclear theory is a strange one, and stranger still is the circumstance that so little has been written concerning it.

When John Dalton first put forward the atomic theory of the elements around 1800, speculation immediately began as to whether all the known elements might not be built of one simple substance. William Prout, an English physician, soon suggested that this prime substance might be the hydrogen atom. His speculation attracted considerable attention and found some support in the circumstance that the atomic weights of a number of the heavier elements seemed to be whole-number multiples of the weight of hydrogen. But accurate measurements later showed that the weights were not exactly whole numbers on this scale, so that the hypothesis became hard to defend. By 1860 it had gone into abeyance.

In 1884 George Gabriel Stokes, a leader of scientific thought, revived the idea of a simple building block. He was led to suppose its existence from a prominent line found in the spectrum of the light from nebulae, which he suggested might originate in matter of a more primitive kind than any known on earth. Two years later the chemist William Crookes, always a bold speculator, went on to propose the existence of a primeval



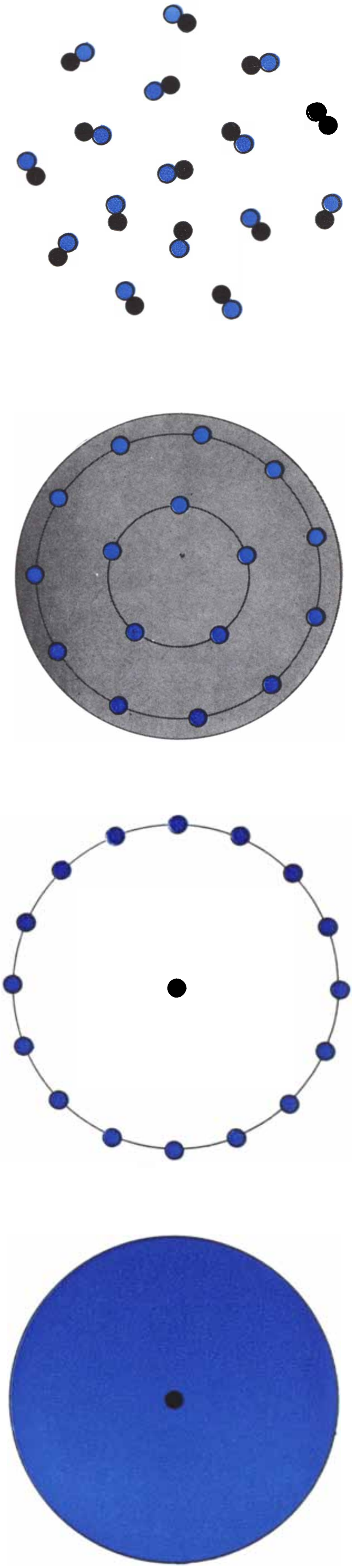
RUTHERFORD (*right*) and Hans Geiger (*left*) were photographed in their laboratory at the University of Manchester at about the time they performed the experiments on the scattering of alpha particles which led to the discovery of the atomic nucleus.

unit of matter to which he gave the name "protyle." Crookes's paper is particularly notable for the fact that he clearly put forward the idea of isotopes of the elements, some 40 years before their existence was actually established. Speaking of the irregularities in atomic weights, he said: "Probably our atomic weights merely represent a mean value around which the actual atomic weights of the atoms vary within certain narrow limits. . . . I conceive, therefore, that when we say the atomic weight of, for instance, calcium is 40, we really express the fact that, while the majority of calcium atoms have an actual atomic weight 40, there are not a few which are represented by 39 or 41, a less number by 38 or 42, and so on."

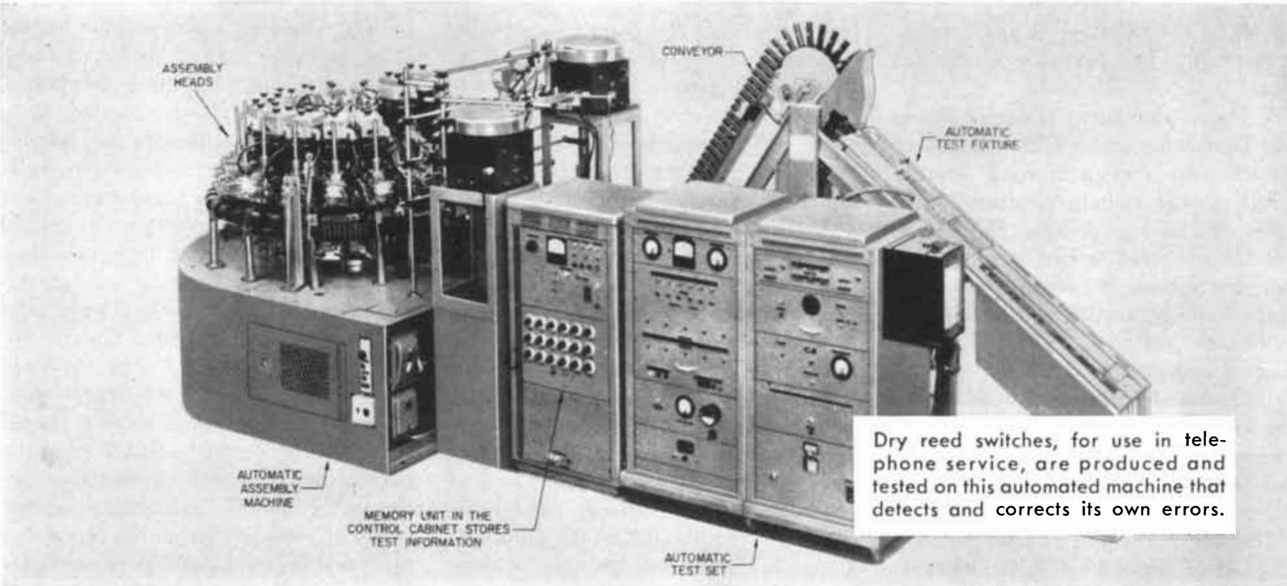
These speculations were not taken very seriously in the scientific world. Before long, however, experimenters supplied the speculative atom builders with their first definite brick—the electron. By the closing years of the 19th century it had been established that electrons formed part of the structure of every atom. The Dutch physicist Hendrik A. Lorentz, studying the Zeeman effect (the splitting of spectral lines by a magnetic field acting on the atomic light source), had even deduced that electrons circulated in orbits within the atom, though there was still no detailed picture of how many electrons an atom might contain, how they were arranged or how they behaved.

Philipp Lenard, professor of physics at the University of Heidelberg, took the matter much farther. He showed that the absorption of electrons of a given speed by matter was roughly proportional to the mass of the matter traversed, whether it was air or gold, to take an extreme contrast. This suggested that all atoms contained some common component (almost certainly an electrified particle) which was present in each atom in proportion to the mass of the atom. Moreover, Lenard discovered that while a very small part of the atom stopped swift cathode rays, the major part must be transparent to them. This was the first proof of the emptiness of the atom—which today is so familiar a conception. To explain the results of his experiments Lenard supposed that the atom contained minute centers of force (which he called "dynamids"), each composed of an electron and a positive charge in very close proximity to the electron. He calculated the radius of the impenetrable dynamid to be 3×10^{-12} of a centimeter or less—a value which is not far from the present measured radius of the nucleus of an atom. Lenard was not sure whether hydrogen contained one or more dynamids, but he seemed to incline to one.

At about the same time Joseph John Thomson (J. J., as he was always called in England) proposed another model. Adopting a suggestion of Lord Kelvin, he pictured the atom as consisting of electrons embedded in a sphere of positive electrification which occupied the entire volume of the atom. The electrons were treated as moving masses, like planets. This scheme got over difficulties raised by the classical laws of electrodynamics, according to which a system consisting of stationary charged particles attracting or repelling one another could not be stable. Thomson, who was intent on explaining the periodic chemical properties of the elements on the basis of atomic structure, proceeded to construct a hypothetical atom made up of rings of electrons rotating within a positively charged sphere. He showed that the number of electrons in each ring must be limited if the system was to remain stable and not collapse. After the first ring had been built up to five electrons, a sixth electron would start a second ring; after 16 electrons, the 17th would start a third stage of ring building, and so on. An atom with 70 electrons, for instance, would have six concentric rings. This development of rings in stages gave an obvious analogy to the periodic system, and Thomson followed it out in some detail. He succeeded not only in obtaining a rough picture of some aspects of the chemical behavior of ele-



VARIOUS MODELS OF THE ATOM were proposed in the period after the discovery of the electron. At the top is a schematic drawing of the atom suggested by the German physicist Philipp Lenard. He proposed that the atom might consist of small "dynamids," each of which was an electron (*blue dot*) in close proximity to a center of positive charge (*black dot*). Second from the top is a drawing of the atom suggested by the famous English physicist J. J. Thomson. He saw the atom as a sphere of positive electrification in which the electrons were embedded. He also suggested that the electrons were arranged in rings. Third from the top is the atom of the Japanese physicist Hantaro Nagaoka, in which the electrons are marshaled in a single ring around a central positive charge. At the bottom is the atom of Rutherford, in which the central electric charge is surrounded by a sphere of electrification of the opposite charge. Rutherford did not specify whether the central charge was positive or negative.



Dry reed switches, for use in telephone service, are produced and tested on this automated machine that detects and corrects its own errors.

Solved: Automatic Production of a New Switch

Switches to connect and disconnect the circuit elements in talking paths are used by the millions in the Bell System telephone network. There would be, quite naturally, a significant story to tell if ways are found to improve them and at the same time shrink their cost. This is Western Electric's part of just that story.

A few years ago our associates, the Bell Telephone Laboratories, designed a new type of switch having great advantages over conventional designs. Called a "dry reed" switch, it consists of two reed-like elements made of magnetic alloys whose contact ends are sealed in a gas-filled glass tube. Thus sealed, the contacts are permanently protected from moisture, dust and other factors which reduce contact reliability.

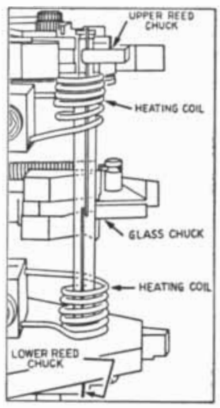
DRY REED SWITCH (3/5 Actual Size)

In use, the new switch is mounted within a coil which creates a magnetic field to close the contacts. The operating speed of the closely spaced contacts is remarkable: they can make and break a circuit 250 times per second. The dry reed switch is much smaller than previous designs and requires less power. These features, combined with increased reliability and freedom from maintenance, make the new switches desirable components for modern switching systems.

Initially, dry reed switches were produced on a manual assembly line. Application was limited, however, unless they could be produced economically in volume.

So a challenge went to the engineers of Western Electric, manufacturing and supply unit of the Bell System: Can you design a machine to make this improved switch in large volume, at low cost and at the high quality level required by the Bell System?

The Western Electric engineers responded with an automated machine capable of turning out many hundreds of thousands of units annually, at 1/20 the cost of those produced by manual assembly—an answer not given, to be sure, before many difficult engineering problems had been solved!



A study of automatic machinery then used in the glass industry disclosed that no available machine could approach the required precision in positioning the metal reeds inside glass tubes so the gap between them would not vary more than ±.0005 inch from the established value. A radically new type of machine had to be designed. In addition, conventional gas filling processes were not suited to automatic production or were prohibitive in cost.

In the final machine evolved through teamwork of Western Electric engineers, the parts are picked up by eighteen assembly heads mounted on a rotary table which turns at ⅓ r.p.m. The reeds are automatically positioned, the tubes filled with gas and sealed, and 100% checks are made on the operating characteristics of the finished switches.

An interesting feature solves the delicate problem of reed alignment. At one point in its circular journey, each assembly head reaches a magnetized section which causes the two reeds to lock in the overlap area. One of the reeds is then released by its chuck, leaving it in perfect alignment with the opposing reed as it is sealed to the glass tube. Then the gap is set—and it is here that true automation is used.

Accuracy at this point determines how well the switch will function, so it is necessary to know whether the gap-setting mechanism (a cam-controlled slide which positions one of the reed-holding chucks) is performing within specifications at all times. To do this, the "feed back" principle is employed. If a test indicates that the space between reeds is not exact, this information is fed back by means of an electronic circuit and a correction is automatically made to the gap-setting of the next switch.

This is another imaginative solution by Western Electric engineers of the problem: "We don't have it, can't get it – go ahead and invent it!" This is a recurring problem as new frontiers are opened in telephone research and new, improved instrumentalities and facilities must be manufactured within rigid precision limits and to low cost objectives.

That our engineers succeed in such solutions is one of the big reasons why the Bell System can continue to offer dependable telephone service at low cost.

Yes, we welcome employment applications from qualified engineers who see, as we do, rewarding accomplishment in work of this kind.

Western Electric

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM ments but also in accounting for certain aspects of the behavior of atoms in response to incident particles, X-rays and light.

A major difficulty, however, hung over Thomson's model. Classical laws of physics said that a moving electric charge should radiate electromagnetic waves and so lose energy. This meant that the electrons would steadily lose energy of motion; as a consequence their orbits would get smaller and smaller and eventually collapse. This difficulty haunted and distressed not only Thomson but also all other atom builders before Niels Bohr.

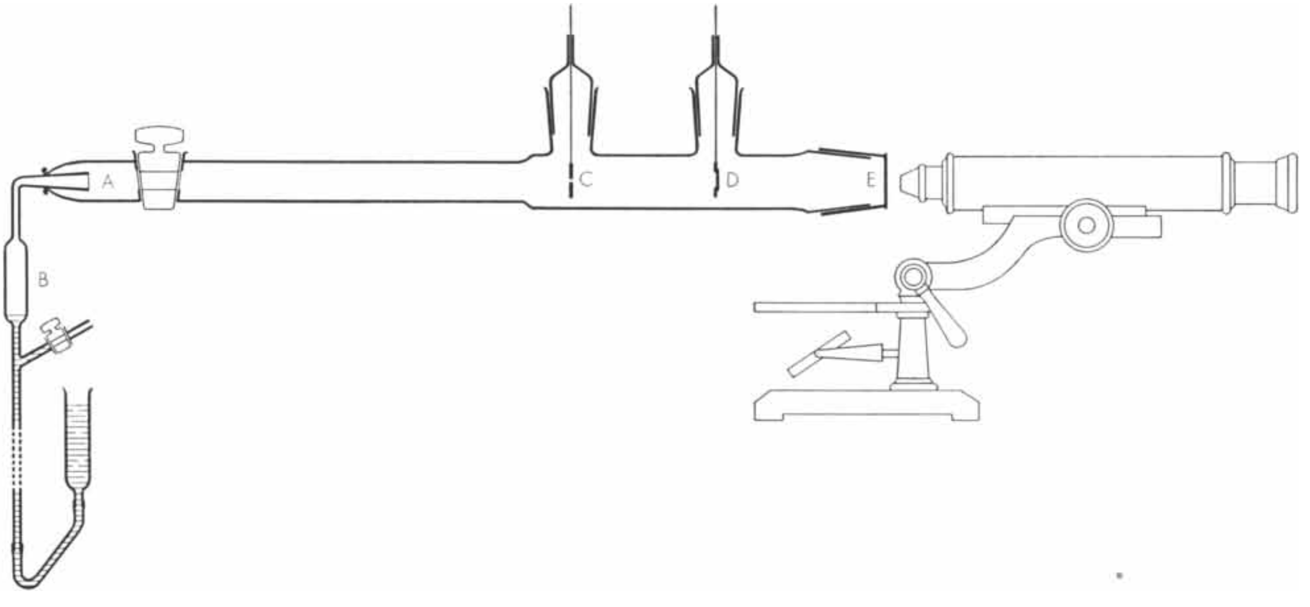
Lenard, then, had built a model of the atom made up of nearly empty space with dynamids widely dispersed through it. Thomson had made a round pudding of positive electricity with currants (electrons) circulating in it. Other well-known physicists also tried their hand. Hantaro Nagaoka of Japan pictured an atom consisting of a central positive charge surrounded by a single ring of electrons. Johannes Stark of Germany showed great ingenuity in constructing atomic models. But most of the models had failed to show much power to mimic the actual behavior of atoms.

Such was the position in May, 1911, when Ernest Rutherford, then professor of physics at the University of Manchester, published the epoch-making paper that put the nuclear atom before the world. The paper was entitled "The Scattering of Alpha and Beta Particles by Matter and the Structure of the Atom." Its chief concern was to account for the results of a series of experiments on the bombardment of metal foils with beams of particles.

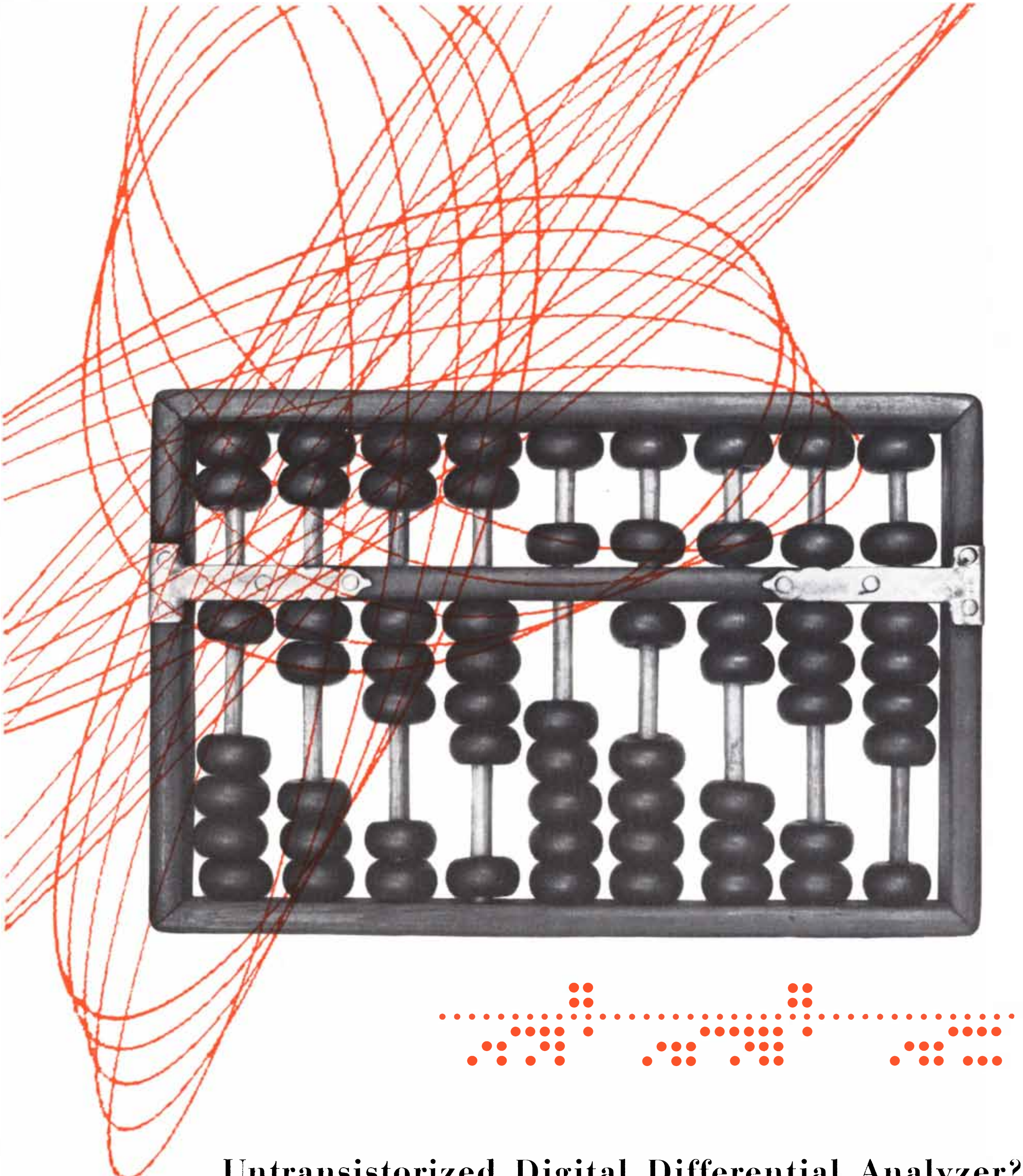
The question at hand was to explain the unexpectedly large deflection of some of these particles by the bombarded matter. When a stream of alpha particles was fired at a thin foil of metal (*e.g.*, gold), most of the particles passed right through. Some were turned aside slightly and emerged at a small angle from their original path. But a few were deflected by large angles, and an occasional particle actually came back, emerging from the foil on the same side it went in! Describing later how strange he found it that a few of these enormously energetic particles should be turned back by a thin foil that most of them could penetrate, Rutherford said: "It was quite the most incredible event that ever happened to me in my life. It was almost as incredible as if you had fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

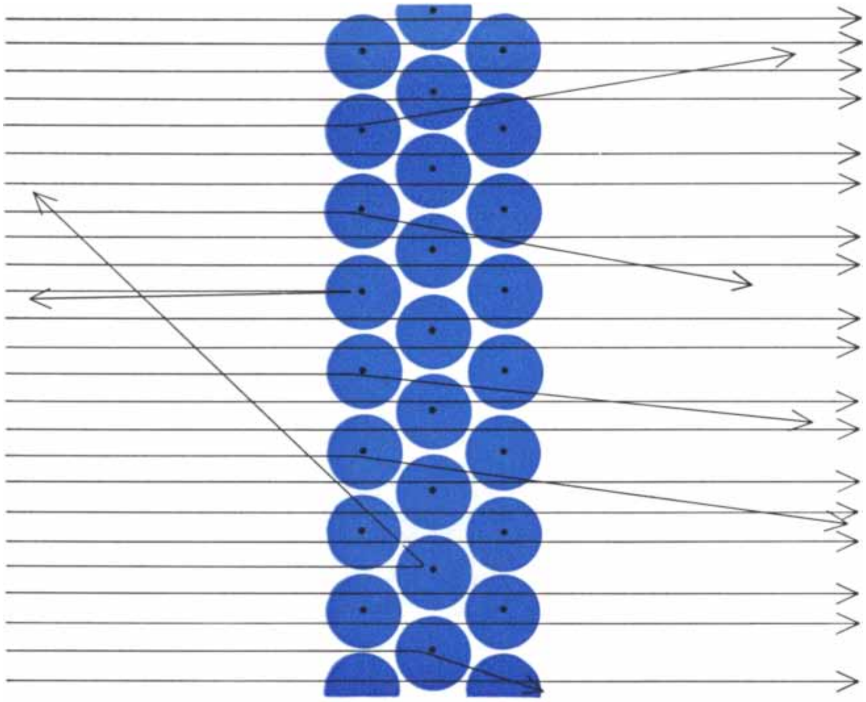
The deflections in question were much larger than could possibly be accounted for by the Lenard or Thomson models of the atom, in either of which the bombarding particles would have been subjected to a number of random small deflections. To explain his results Rutherford postulated a new scheme for the atom, picturing it as consisting of a central charge (later, but not in this paper, called the nucleus) surrounded by a sphere of electrification of equal but opposite charge. So far as deflection of the bombarding particles was concerned, it made no difference whether the central charge was positive or negative: they would be deflected in either case, by repulsion or by attraction backward after they had passed a nucleus. "For convenience," said Rutherford, "the sign will be assumed positive." He then worked out what the scattering pattern should be, on the basis of the probabilities of the bombarding particles encountering nuclei in the foil. His calculations agreed well with experiments, and he found also that the number of particles turned back by a foil was proportional to the atomic weight of the material and the thickness of the foil—both very strong arguments for the concept of the nuclear atom. Part and parcel of his discovery was the assumption that the magnitude of an atom's central charge was proportional to its atomic weight.

The salient points of Rutherford's paper were succinctly summarized in an abstract written by his student Ernest Marsden, who with Hans Geiger performed some of the fundamental scattering experiments. Rutherford had shown, said Marsden, that the scattering of al-



EARLY EXPERIMENTS of Rutherford were performed in this apparatus. Radium emanation (the radioactive gas radon) was introduced into the conical tube at A, which was closed by a thin window of mica. After the radioactive gas had remained in the tube for several hours, it was removed by allowing it to expand into the vessel at B. The radioactive decay of the emanation had coated the walls of the tube with a thin film of radium C, which emitted alpha particles that traveled down the evacuated tube to the right. A pencil beam of alpha particles was obtained by means of a narrow slit at C. The beam then passed through a metal foil at D. Finally each alpha particle produced a scintillation in a zinc sulfide screen at E. The scintillations were observed visually by means of the microscope at the right. Only those particles which were scattered at small angles to the right of the foil could be detected by this apparatus. Later Rutherford built an apparatus which also detected those particles which bounced backward from the foil.





METAL FOIL in the apparatus depicted on page 96 is schematically represented by the colored disks in this drawing. Each disk is an atom with a positively charged nucleus in its center. The lines beginning at the left represent the beam of alpha particles, which are also positively charged. Most of the alpha particles go straight through the atoms, but those that pass close to nuclei are repelled. Some are deflected; others actually bounce backward. The scattering was observed by Rutherford and his colleagues on their zinc sulfide screen.

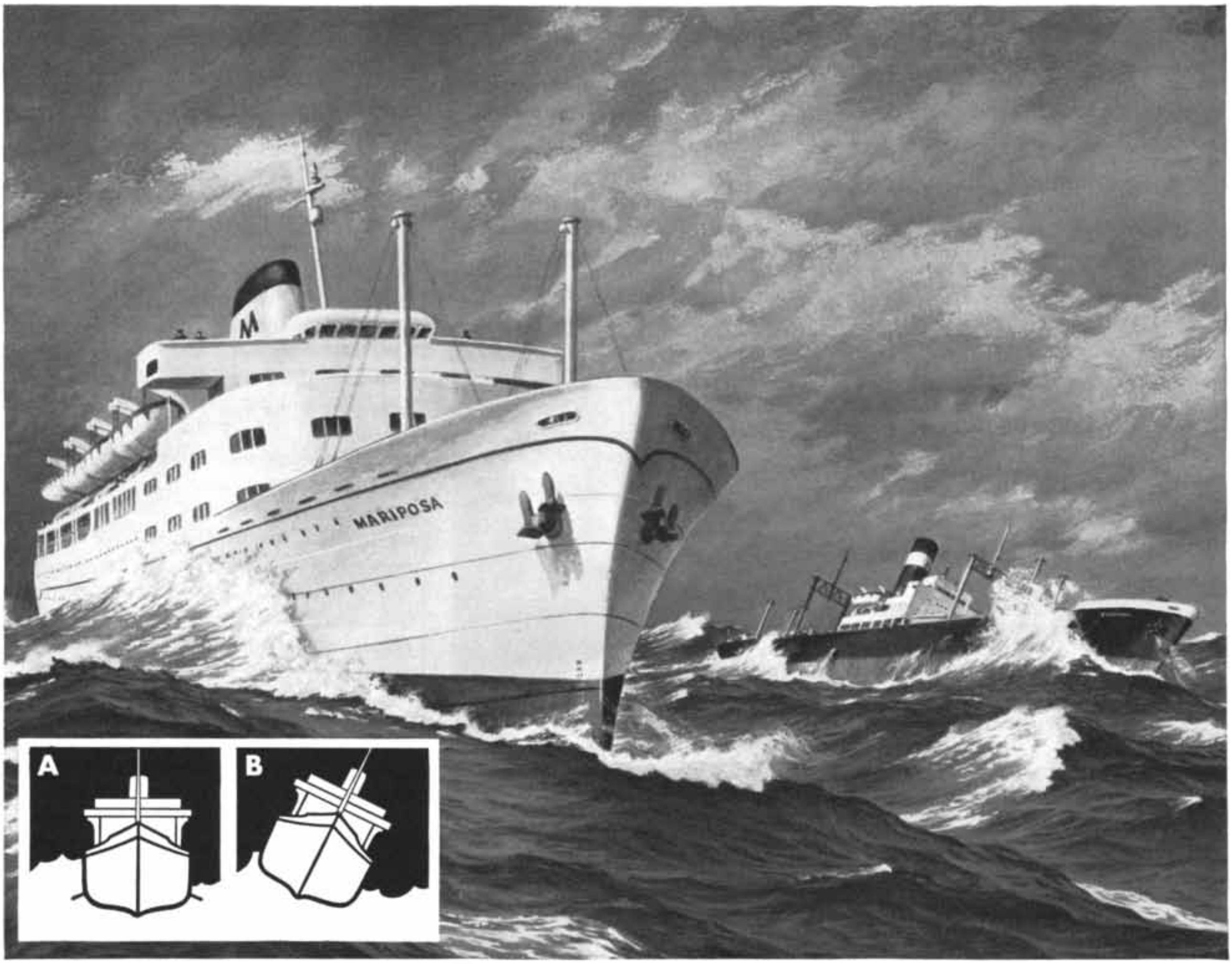
pha and beta particles by matter could be explained by assuming that the atom consisted of "a strong positive or negative central charge concentrated within a sphere of less than 3×10^{-12} centimeter radius, and surrounded by electricity of opposite sign distributed throughout the remainder of the volume of the atom of about 10^{-8} centimeter radius." As a general description of the atom this does not need to be fundamentally amended today.

And what did it all arise from? Just the fact that when alpha particles were fired at a metal foil, a few were turned aside through unexpectedly large angles or actually came back from the foil. It would have been easy to dismiss these few oddities as of no particular consequence—the result of contamination or suchlike. Rutherford, however, saw them for what they were, events of startling significance.

Yet he remained cautious in interpreting them, in this paper and later. He said nothing in the first paper about the electrons surrounding the nucleus. He did not consider at all chemical, spectral or isotopic aspects of the elements. He was only concerned, as his title suggests, with scattering of particles by matter. He was quite definite about the results, but there is nothing to indicate that he realized at the time the supreme importance they were to have.

The paper produced no kind of sensation in the world of physics. I was then studying at Heidelberg, with Lenard as my professor, and the interest there in atomic and electronic physics was very keen. Great excitement was caused by C. T. R. Wilson's first publications on the cloud chamber, but I do not remember any talk at all about Rutherford's paper. Turning to *Nature* for 1911, I find no mention of this paper and only one reference to the particle-scattering work—a brief, routine summary of a talk giving a preliminary account of it which Rutherford delivered on March 7 to the Manchester Literary and Philosophical Society. In *Science* likewise his epoch-making paper went unnoticed.

The fact is that the structure of the atom was not taken terribly seriously by most physicists in 1911. It seemed a rather inaccessible and speculative problem, something like that of life on other planets. Different atom models had been put forward to do different things: here was a new model which dealt with the scattering of alpha particles, very well



In rough sea, stabilized ship (A) extends fins to halt roll. It holds course without reducing speed. Unstabilized ship (B) rolls and is forced to cut speed. First two commercial installations of the Gyrofin are on the Matson Lines, Mariposa and Monterey. Randolph Sevier, President of Matson Lines, says, "In addition to added passenger comfort, we expect to realize savings in fuel and time because the ships will be able to maintain course and speed in heavy weather."

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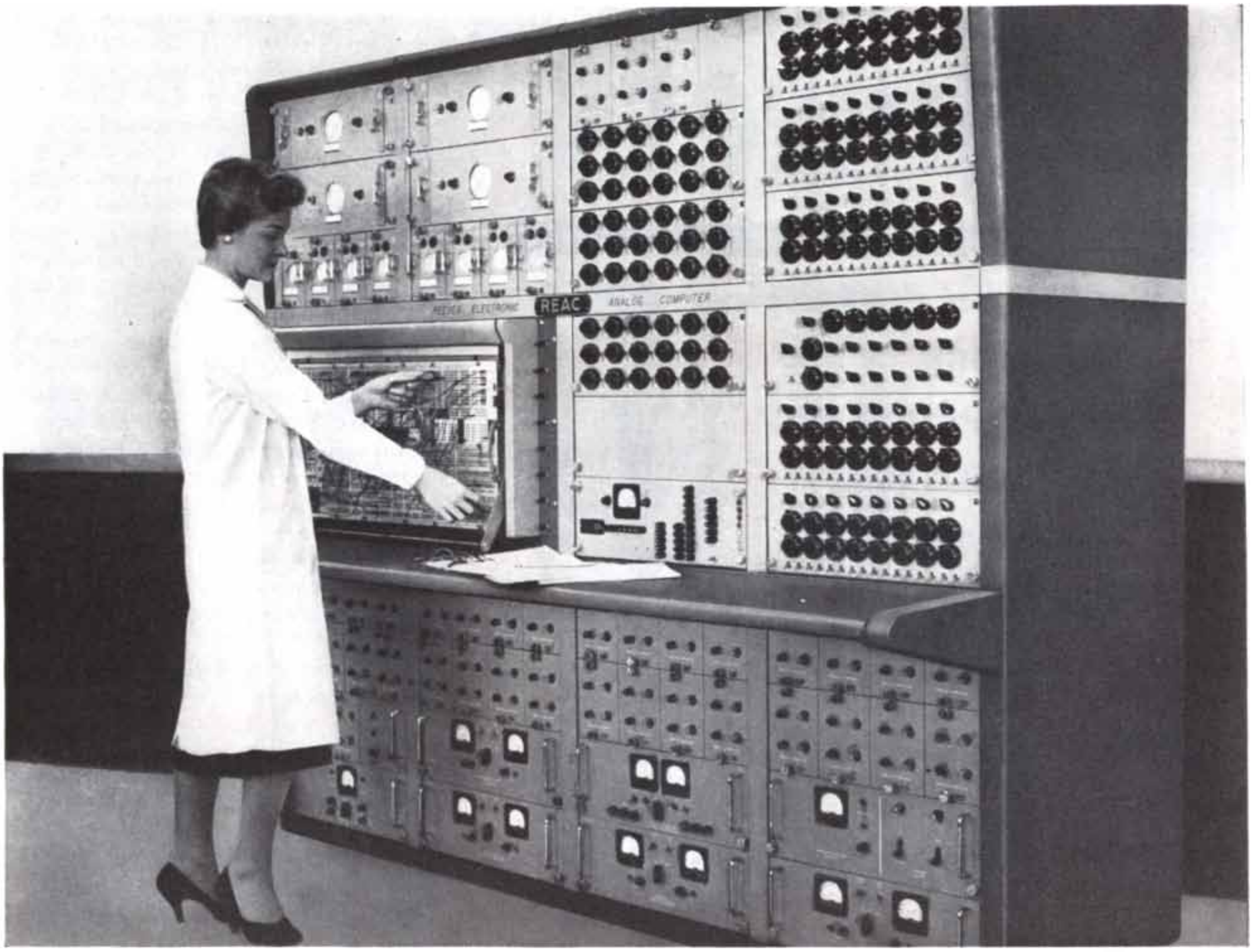
perhaps, but not everybody was interested in the scattering of alpha particles.

Rutherford's own reticent attitude may also have been one of the reasons that the birth of the nuclear atom caused so little commotion. In his book *Radioactive Substances and Their Radiations*, published two years after his 1911 paper, Rutherford had only two passages about the structure of the atom. The first was merely a two-page summary of the paper; here Rutherford used the word "nucleus" once but generally referred to it only as the "central charge," and still gave the sign of the charge as either positive or negative. The second passage, at the very end of the book and so presumably written later, went somewhat farther. Rutherford now gave the charge as definitely positive and spoke of the rest of the atom as a distribution of electrons; in particular, he described the helium atom as consisting of a minute center with two positive charges, two remote electrons when in its neutral state. He also raised the question of the structure of the nucleus for the first time: "No doubt the positively charged center of the atom is a complicated system in movement, consisting in part of charged helium and hydrogen atoms." Rutherford followed this remark with an observation of characteristic simplicity and insight: "It would appear as if the positively charged atoms of matter attract one another at very small distances, for otherwise it is difficult to see how the component parts at the center are held together." Thus Rutherford raised the question of the mysterious forces holding the nucleus together, which is still, more than 40 years later, one of the most difficult of all problems in atomic physics.

If the rest of the world of physics took the discovery of the nuclear atom calmly, in Rutherford's laboratory, where there was always excitement, it generated a special ferment. In the spring of 1912 Niels Bohr of Copenhagen came to the laboratory in Manchester and found its members full of enthusiasm for the wide prospects opened by the discovery. Bohr himself became fired with the same excitement and spent some months working in Rutherford's laboratory. Convinced of the general correctness and the great possibilities of the nuclear model of the atom, he soon began to demonstrate the power of the model to explain the reactions of the atom to light.

In his first paper after his stay at Manchester, published in July, 1912, Bohr firmly established the structure of the



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atom as consisting of a nucleus surrounded by electrons. From his calculations he concluded that hydrogen had a positive nuclear charge of one unit, and helium two units. Shortly afterward Antonius van den Broek of the Netherlands put forward the theory that the nuclear charges followed such a sequence right through the table of elements: that is, each atom had a nuclear charge equal to its order in the table, or its atomic number (not atomic weight). At about the same time Casimir Fajans in Germany and Frederick Soddy and Alexander Russell in England independently formulated the law that holds when atoms are transformed by radioactive decay: namely, when an atom emits an alpha particle (containing two positive charges), it goes down by two places in the periodic table; when it emits a beta particle (with one negative charge), it goes up by one place. Soddy also coined the word "isotopes," to denote varieties of an element having identical chemical properties but different masses.

The orderly relation between nuclear charge and atomic number was finally clinched by the beautiful work of the English physicist H. G. J. Moseley (who in 1915, at the age of 27, was killed in battle at Gallipoli). By systematic experiments Mosley showed that each element, when excited to X-ray emission, emitted X-rays of characteristic wavelengths, determined by its atomic number. Moseley concluded: "We have here a proof that there is in the atom a fundamental quantity, which increases by regular steps as we go from one element to the next. This quantity can only be the charge on the central positive nucleus." (As a personal note I may perhaps be allowed to add that further proof that the X-ray wavelength was determined by nuclear charge and not by atomic weight was given when Rutherford and I showed in 1914 that gamma and X-ray emissions by two isotopes of lead had the same wavelength.)

In 1913 Bohr published three revolutionary papers which applied the quantum theory to the orbits of electrons in atoms and explained the emissions of light and X-rays by atoms in terms of their structure. As I have mentioned, atom builders up to that time had been persistently troubled by the difficulty that, on the accepted laws of electrodynamics, electrons lost energy by radiation and nevertheless continued to circulate in unchanging orbits in the atom. Bohr boldly proclaimed that the classical laws of electrodynamics did not apply within the atom. Electrons in atoms, he

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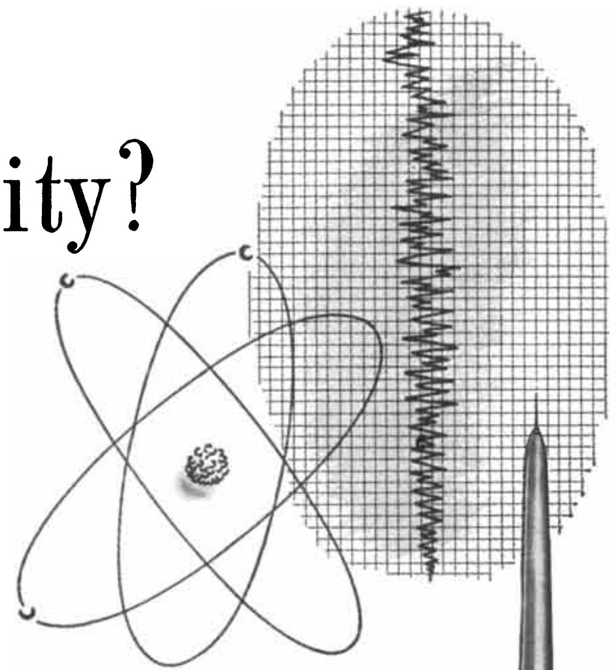
said, sent out their radiant energy not continuously but in packets, or quanta. He assumed that only certain classes of orbits were possible, and radiant energy was emitted in a burst when an electron changed orbits. In short, Bohr laid down new quantum laws for the minute world of the atom and showed how they could be made to account for the observed facts. He is the Newton of atomic astronomy.

Bohr's model of the atom gave the first precise explanation of the spectra of simple atoms, and later it clarified the periodic chemical properties of the elements. Today Bohr's theory of orbits has been replaced by a picture in which the electron is not regarded as a point moving in an orbit but is considered to be spread out as a kind of cloud, which represents the probability of its being found in any specific position. However, the atomic scene is still ruled by quantum conditions of the kind that Bohr originally laid down.

By the time the First World War broke out, the nuclear atom had developed into a lusty infant. Its importance was not yet, however, widely realized. In Norman B. Campbell's well-known book *Modern Electrical Theory*, published in 1913, a chapter called "The Structure of the Atom" made no mention of Rutherford's atom, then nearly two years old. Pieter Zeeman, discoverer of the Zeeman effect, in an article in 1915 referred in a sentence to atom models put forward by James Jeans, Joseph Larmor, Lenard, Nagaoka and Bohr, adding that in explaining light spectra the models of Thomson and W. Ritz seemed the most successful. And Owen Richardson in his *Electron Theory of Matter*, a standard work, devoted nearly all of a long chapter on the structure of the atom to Thomson's atom. In the last few pages he mentioned the nuclear atom and briefly considered Bohr's work. His comment, not unsympathetic, was to the effect that while the conclusions conflicted with accepted principles in physics, so did those arising from certain other newly observed phenomena. Here, then, is one of the acutest brains in the physics of the time, certainly not condemning, but certainly not suggesting that a new epoch in physics had been opened. But then I doubt that Rutherford himself realized at the time—as Bohr undoubtedly did—the vast potentialities of the nuclear atom. Years afterward he wrote to Geiger: "They were happy days in Manchester, and we wrought better than we knew." I fancy that he may have had the nuclear atom particularly in mind.

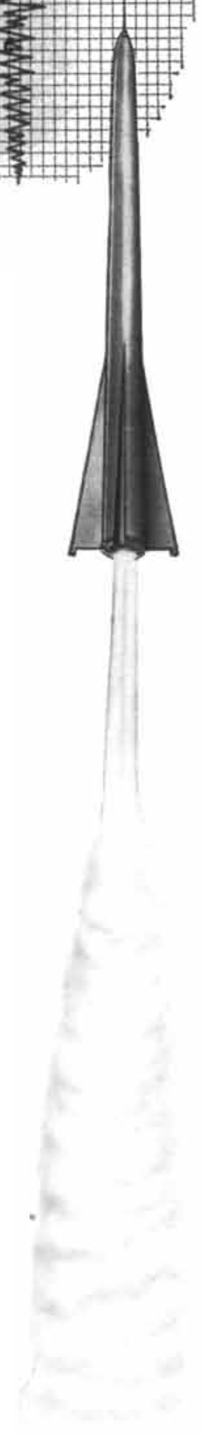
F I R S T   O F   A   S E R I E S

What is reliability?



Industry in the United States is becoming more and more complex... we're getting automated ... computers are computing... the missiles are flying... the digits are digitizing...

And the word "Reliability" takes a new and different meaning... what does it mean to you?



It's time to stop and take a look! Ask three of your friends how they define "reliability." You'll be surprised at the different answers you receive. And when you quiz them further on how much reliability is needed in a particular product... how they would control the design and manufacture of that product to obtain the amount of reliability they want... you'll be even more surprised by the variety of the answers.

So... let's define reliability. Let's start off with a definition that is gaining the most acceptance in the technical field...

The reliability of a particular component or system of components is the probability that it will do what it is supposed to do under operating conditions for a specified operating time.

Looks simple enough!

But what hazards it presents! The first important challenge is that word "probability"... it takes you seriously into the field of data collection and statistical analysis. Then you check into the phrase "do what it is supposed to do"... someone must define these objectives. And, look at the "operating conditions"... pause briefly and reflect on the many different conditions under which products operate. And, finally, note the phrase "for a specified operating time"... does one normally, consciously, define reliability in terms of time?

These considerations pose problems for all of us... the manufacturers of components, those who assemble components into other products, systems personnel, designers, industrial engineers, production workers, purchasing agents, quality control... *and users!*

Let's look at the word "probability."

Picture a chain, with its successive links. Many of today's systems, simple or complex, comprise such a chain of components. However, as we all know, that chain will be only as reliable as its weakest link. And, statistically, the over-all reliability of the chain or system is the mathematical product of the reliabilities of the individual links expressed as...

Over-all Reliability, $R_0 = r_1 \times r_2 \times r_3 \ldots r_n$

As an example, assume a product has a chain of 100 components in which each component has a reliability of 99 per cent... which assumes that only one out of a hundred units of each component will fail. These are relatively high standards established by past practices. But what happens? Multiplying .99 by itself one hundred times ($.99^{100}$), note that our chain of components will have a reliability of only 36.5 per cent! Two out of three of our chains would probably fail!

As another example, let's look at contacts in a multi-contact electric connector. If, for instance, we are to assemble connectors containing 25 similar contacts from a 1% defective contact population, we can expect 22% of the connector assemblies to contain one or more defective contacts! See how the multiplication of probabilities presents a major challenge to both designer and manufacturer?

But all is not lost! There is another side of the picture. With proper care, analysis, and control, our organization at Cannon has actually achieved, in special "missile quality" contacts, a known level of only 2.85 x 10^{-3}% defective... or one defective part in 35,000! Naturally, we don't achieve

that with all our contacts . . . but we do try to design and manufacture the utmost in reliability required for specific applications.

However, to return to your problems and to go a step further in demonstrating "probability" of uncontrolled contacts . . . and the challenges it poses to you and to us . . . consider the case where we have three groups of contacts, each group with contacts of different sizes. Let us assume, also, that each group has different percentage defective populations and that the three groups are assembled in a 90-contact connector as follows:

50 No. 16 contacts with a population reliability of .59; 25 No. 12 contacts, reliability .60; and 15 No. 8 contacts, reliability .64.

Then . . .

$$R_c \text{ (90 contact connector)} = r_{\#16} \times r_{\#12} \times r_{\#8}$$

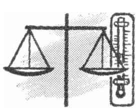
or,

$$R_c \text{ (90 contact connector)} = (.59)\ (.60)\ (.64) = .23$$

It is apparent from the above that connector contact populations must be maintained at extremely low values of percentage defective. This is of extremely vital importance if we are to produce connector assemblies which will perform satisfactorily in systems utilizing series circuitry, where the failure of one contact pair can cause failure of the entire system.

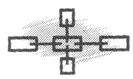
We have been talking only about *a contact* . . . just one of the many different materials and parts (such as contact pins, insulators, shells, and couplings) going into the more than 20,000 different connector and electrical items we manufacture. Think of the "product of reliabilities" rule in systems comprised of tens, hundreds, or thousands of electrical components connected by connectors such as ours. Regardless of whether they design, manufacture, sell, or use washing machines or guided missiles, everyone faces the same problem. That's why we're taking some of your valuable time to present the important subject of reliability here.

*



All of us, when we specify materials, parts or components must constantly keep in mind the (a) "probabilities," (b) what the part is supposed to do, (c) the operating conditions, and (d) the time it must operate satisfactorily. Let's see what we can do to increase reliability in relation to these four factors:

(a) Probabilities. To increase the reliability of any component, and thereby the system as a whole, it is necessary to think in terms of statistical distribution of important physical properties. From field reports of failure and laboratory test results, we must first isolate those properties which most frequently cause trouble. It is then necessary to determine whether poor performance is due to lack of process control to keep the product within specified tolerance limits, whether the dollar sign has entered into the picture too far—cutting reliability down for the



sake of a few cents here or there—or whether the design itself is inadequate for an end-use application. In any case, the use of the statistical approach to problem solution offers a positive method of obtaining known levels of reliability.

(b) Definition of Function of Product. Each component and each system . . . both civilian and military . . . in each different field of endeavor, in each product produced, has different functions. None of us should "over-build". . . nor should we "under-build." We should look at our specifications closely.

(c) Operating Conditions. Temperature and pressure, humidity, corrosive atmospheres, stray electric and magnetic fields, low and high frequency noise, shock and vibration . . . all must be considered plus conditions prior to product use.

(d) Operating Time. This varies both for different products and different fields of application. Have you set reasonable lengths of operating time for your product or system, from the viewpoints of both usage and economics?

*

We at Cannon Electric are proud of our historical emphasis on quality and reliability. Since our inception in 1915 we have consistently adhered to a design philosophy embracing the highest quality and reliability in each Cannon Plug for the specific application for which it is to be used. *If we cannot design to that principle, we don't make it!* In manufacture, we are proud of our know-how in depth, proud of our fine quality control systems, proud of our personnel, and proud of our reliability control group. The "Cannon Credo". . . part and parcel of the everyday life of each Cannon employee . . . is posted in all offices and all departments of all eight Cannon plants around the world. Three of its sections read as follows:

To develop an organization of exceptional people possessed of respect for the dignity of the individual and imbued with the spirit of the team.

To provide a facility with which we can produce to our utmost in an efficient and pleasant environment.

To develop and produce products of such quality, and render such service, that we may always be proud of our efforts.

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Whenever *you* have an electric connector reliability problem . . . in design, engineering, production or prototype phases . . . we would welcome the opportunity of discussing it with you.

Cordially,

Robert J. Cannon *President*

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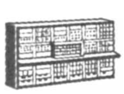

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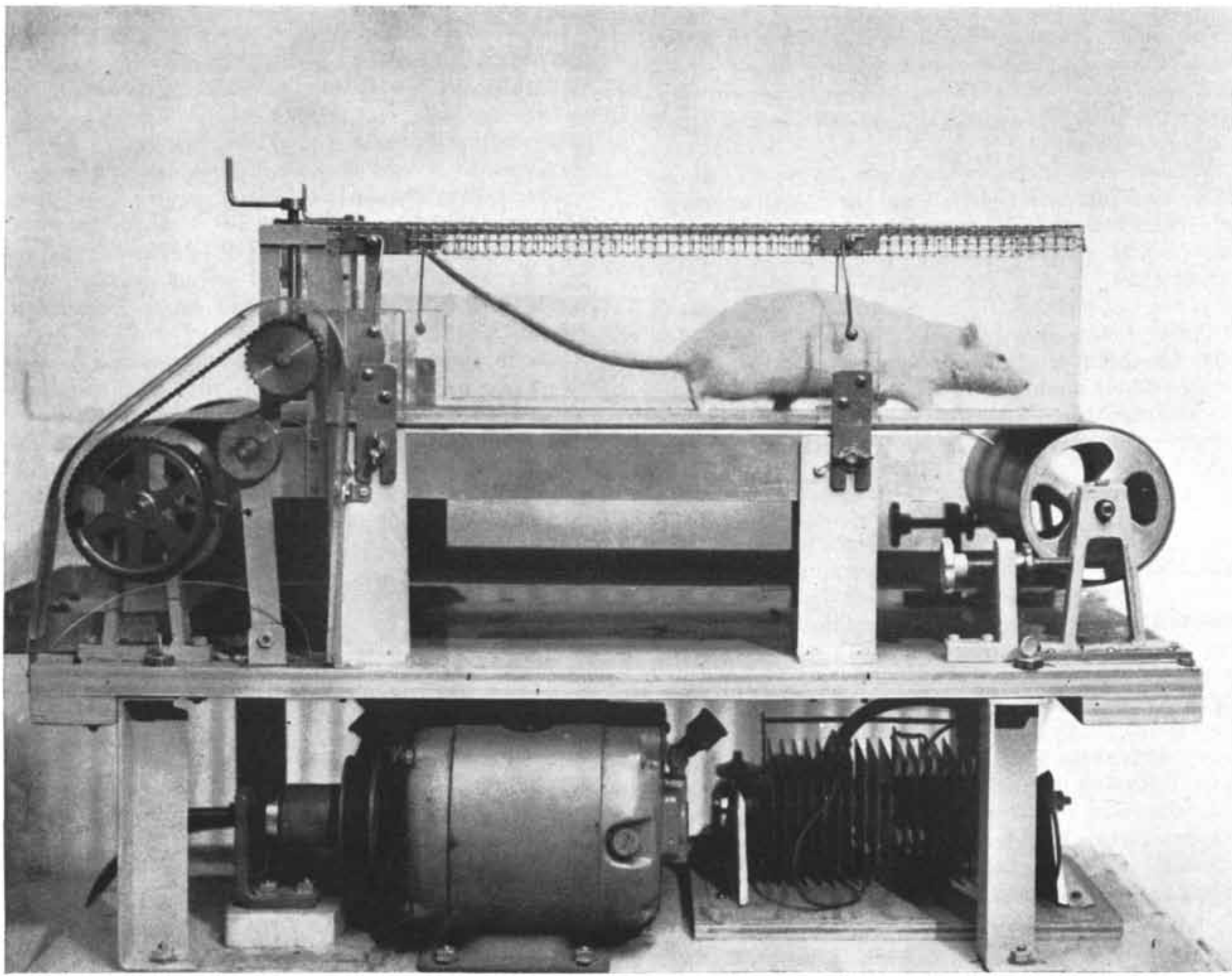
APPETITE AND OBESITY

It is often said that obesity is caused simply by overeating. But what causes people to overeat? The answer to the question is sought by the physiological experiments described herein

by Jean Mayer

Obesity has been called the "Number 1 Nutrition Problem," if not the "Number 1 Health Problem," in Western countries at the present time. All recent statistical studies agree that overweight is associated with a shortening of life. For example, Louis I. Dublin found that among men and women insured with the Metropolitan Life Insurance Company, overweight persons show a 50 per cent greater than normal mortality between the ages 20 and 64. The mortality rate among them increases with the degree of overweight: deaths among moderately obese men, for example, are 42 per cent above the standard risk, and among the markedly obese, 79 per cent. By and large their higher death rate reflects a greater susceptibility to "degenerative" diseases, notably diabetes, cirrhosis of the liver, and heart, kidney and



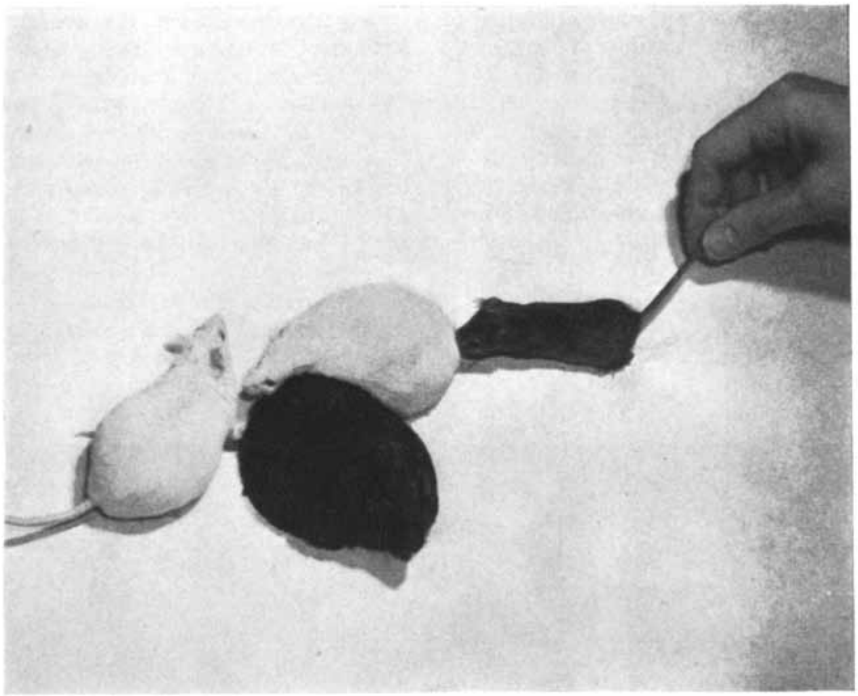
RAT EXERCISES on a treadmill in the author's laboratory at the Harvard University School of Public Health. It was discovered that exercising rats in this manner two hours a day prevented the progressive obesity usually suffered by rats confined in small cages.

circulatory diseases. Overweight increases the risk of death from cardiovascular or kidney disease by more than 50 per cent. (On the other hand, the death rates from tuberculosis, ulcers and suicide are actually lower than average among obese persons.)

Unhappily the underlying causes of obesity are still largely unknown. To say that obesity is due to overeating is not much more illuminating than to say that alcoholism is caused by overdrinking. The real question is: Why do people overeat? What factor (or factors) disturbs the mechanism of regulation of food intake in such a way that the balance between intake and energy output is tipped in favor of excessive consumption? This article summarizes some of the recent efforts to discover the disturbances that lead to obesity in animals and in man.

The first problem to be tackled is to get a clearer concept of how appetite is normally regulated. A number of years ago the most popular theory, advanced by the late Walter B. Cannon of Harvard University and Anton J. Carlson of the University of Chicago, held that contractions of the stomach were the main signal arousing the sensation of hunger (sometimes in the form of the so-called "hunger pangs"). While there is no doubt that such contractions exist and may play a part in awareness of hunger, the notion that they played a basic role had to be abandoned when it was demonstrated that denervation of the stomach or even its total removal by surgery did not fundamentally alter the regulation of food intake. The influence of bulk in the diet, of "filling up the stomach" as such, was shown to be minor. It may delay hunger pangs but it does not eliminate the over-all feeling of hunger.

Carlson made the interesting suggestion that a low level of sugar in the blood was the cause of stomach contractions, but this was discarded when several workers failed to find any regular relation between sugar level and hunger sensations. The well-known ravenous appetite of diabetics with high blood sugar also seemed to invalidate the idea.



THREE FAT MICE demonstrate obesity due to three different causes. At the right is a normal black mouse for purposes of comparison. The other black mouse is the littermate of the normal mouse; it is fat because it carries the hereditary obese-hyperglycemic gene. The white mouse at the left became obese after a lesion was surgically made in its hypothalamus. The other white mouse became obese after it was injected with gold thioglucose.

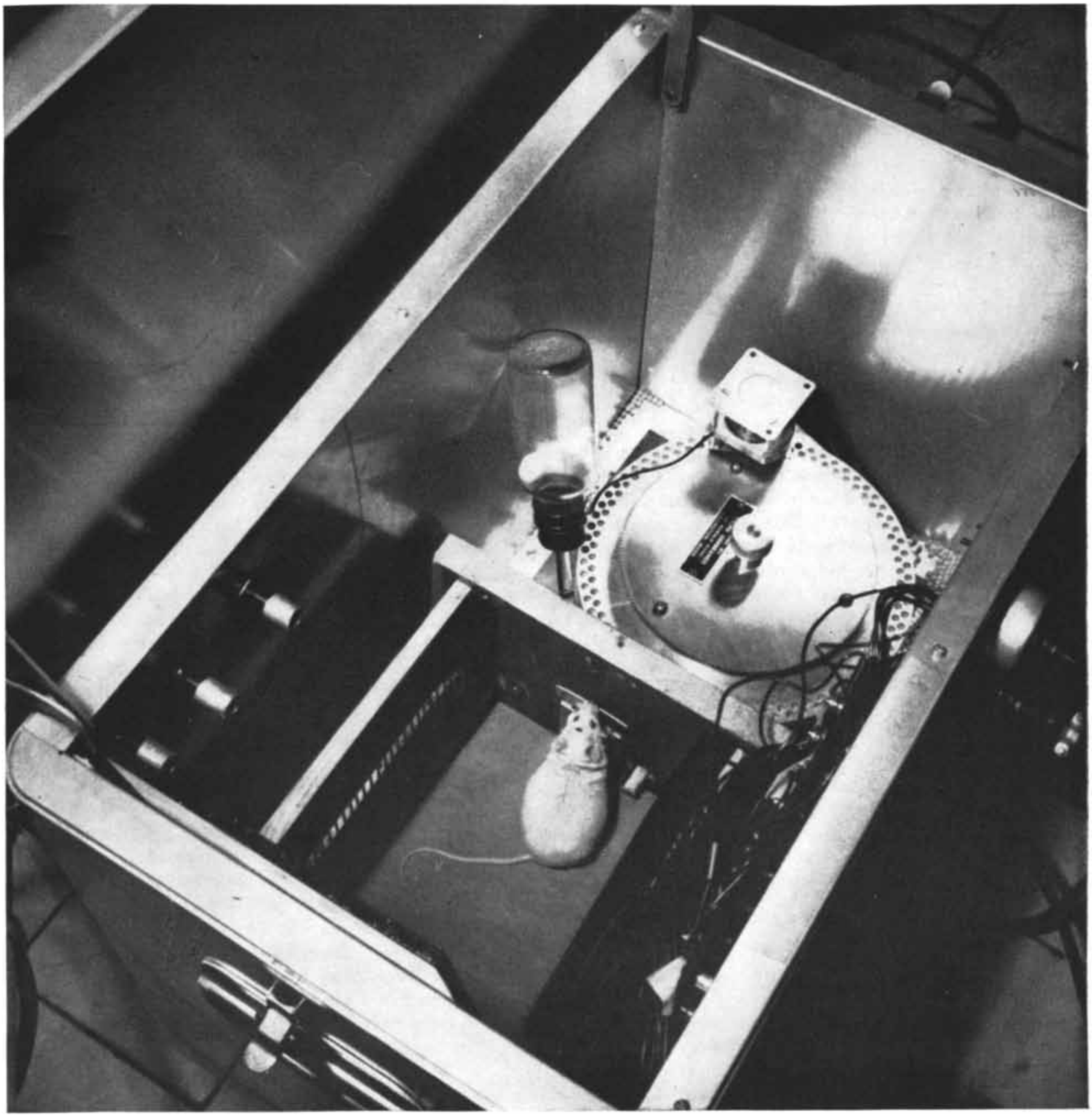
The first productive clue to how food intake is regulated came in the early 1940s when S. W. Ranson and his colleagues at Northwestern University discovered that animals became obese after destruction of the central area of the hypothalamus, an important part of the mid-brain. John R. Brobeck and an associate at Yale University then showed that destruction of side areas of the hypothalamus caused animals to refuse food. José M. Delgado, working at Yale on monkeys, and Stig Larsson, working at the University of Stockholm on goats, found that electric stimulation of the same area induced their animals to eat.

Pursuing these findings in our laboratory in the department of nutrition at the Harvard University School of Public Health, we began with a systematic exploration of how the regulatory centers in the hypothalamus operated. We used the very convenient technique developed by the Harvard psychologist B. F. Skinner for measuring animal responses and behavior. The essential feature of the method is that the animal itself produces a reward (*e.g.*, a small pellet of food) by pressing a lever, and the strength of the rewarding effect, or the intensity of the animal's desire, is measured by the frequency with which it presses the lever [see "Pleasure Centers in the Brain," by James Olds; SCIENTIFIC AMERICAN, October]. In our experiments the animal had to press the lever a certain number of times to obtain a food pellet, and a record of its behavior was registered automatically by an electrical recorder.

Application of this method showed that the feeding behavior of normal animals exhibits a clear-cut daily cycle. The animal feeds rapidly and frequently for several hours; there follows a "satiety period" during which it eats very much less and in a desultory fashion. However, if the central area of the animal's hypothalamus is destroyed, it does not taper off in this way but goes on eating at the same high rate. Our experiments demonstrated that the central area of the hypothalamus is a satiety center which normally acts as a brake on the lateral area, where stimulation to eat is constantly present. In other words, what is "regulated" is not hunger but satiety.

The next question was: How do the satiety centers in the hypothalamus determine when the body's hunger for food has been satisfied? It appeared improbable that they could use as an index the body's content of fat or protein, which between meals declines by only a very small amount in proportion to the total. The sugar reserves, on the other hand, would provide a sensitive index. The stores of sugars carried by the organs of the body are limited. In the liver of man, for example, the content of glycogen after a meal amounts to only about 300 calories (a moderately active man spends 3,000 calories of energy a day). Furthermore sugar, in the form of glucose, is the sole fuel of the central nervous system. It seemed reasonable to assume, therefore, that the satiety centers of the central hypothalamus might be sensitive to the availability of sugar from the blood, and that their utilization of sugar might be a measure of hunger.

An elaborate program of experiments was carried out to test this hypothesis. In the first series of experiments we found that the rate of food intake by animals did indeed correlate well with the rate of utilization of sugar by the body as a whole. Next we conducted tests with human subjects, using as a measure of sugar utilization the difference between the sugar level in arteries and in veins. The results further supported the hypothesis: the subjects' feelings of hunger appeared appeased when the rate of sugar utilization fell. These observations were confirmed and extended by Albert Stunkard of Cornell University. He studied "hunger" contractions of the stomach, employing a stomach balloon technique of Cannon and Carlson. Stunkard found that when the difference between the sugar levels in the arteries and veins was small (indicating reduced availability of sugar), the subject showed contractions of the stomach and had subjective feelings of hunger, while a large difference (indicating appreciable reserves of sugar) accompanied satiety. Very recently two findings have brought convincing confirmation of our hypothesis concerning the role of sugar. Stunkard and a colleague found that administration of glucagon, a pancreatic hormone, which raises the blood sugar level without decreasing utilization of sugar, invariably eliminated gastric contractions and hunger feelings. A particularly striking illustration of this effect was given by a patient who had lost the use of his brain



OBESE MOUSE PRESSES A LEVER in a special cage designed to study the feeding behavior of small animals. The large disk at the upper right is part of an automatic feeder that discharges pellets of food into a tray at the right of the mouse whenever it presses the lever a predetermined number of times. To the left of the lever is a tube from the water bottle suspended above the disk.

cortex after an accident and whose central nervous system was therefore reduced to the lower centers of the midbrain. The only treatment (aside from intake of food) that eliminated hunger contractions of the stomach in this patient was glucagon, raising the level of available sugar.

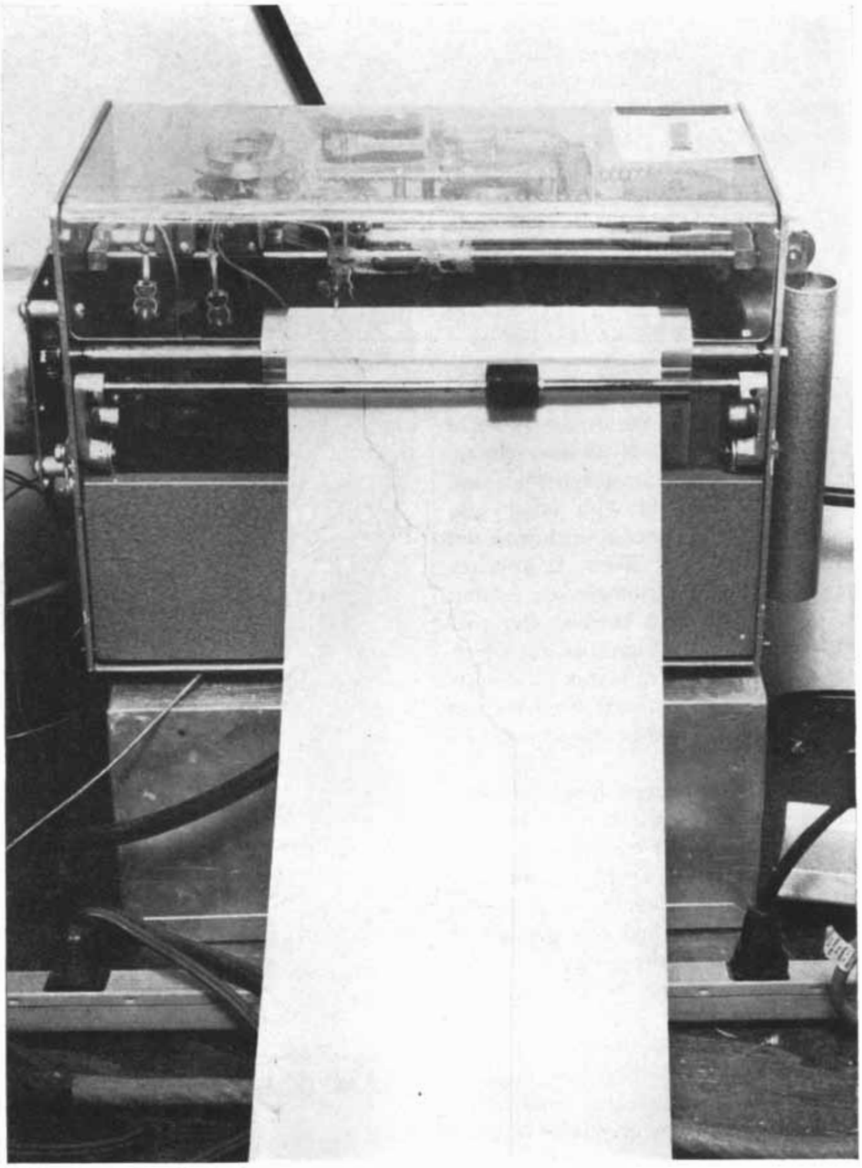
The other recent finding gives a more direct "proof" of the theory. My associate Norman Marshall and I experimented on mice and rats with a chemical called gold thioglucose—a compound of glucose and gold linked together by a "sulfur bridge." A single dose of gold thioglucose induces overeating and obesity in animals. We established that the substance selectively destroys the satiety area of the central hypothalamus. Compounds of gold with other substances, even very similar to glucose, did not produce these effects. It appears, therefore, that gold thioglucose exerted its destructive effect because the gold was "dragged in" by glucose, for which the satiety cells have a special affinity. The experiment demonstrates that these cells do indeed act as sensitive receptors of glucose.

Once the cells have taken in glucose, they must translate this fact into an electrical signal to other centers in the central nervous system. Tracer studies show that potassium generally accompanies glucose into cells, and the passage of potassium ions into the glucose-receiving cells may account for the generation of electrical impulses.

The impulses from the hypothalamus satiety cells, on reaching the cerebral cortex, are interpreted there and translated into sensations of satiety or hunger. But other factors—psychological as well as physiological—may intervene to modify appetite, at least temporarily. Conditioned reflexes and habits, in particular, have to be reckoned with. The whole scheme is one of great complexity, and therefore it is to be expected that any one of a number of dysfunctions may cause a person to overeat. The dysfunction may affect either the regulatory centers or the general metabolism of the body. Hence we conclude that there are both "regulatory" and "metabolic" roads to obesity.

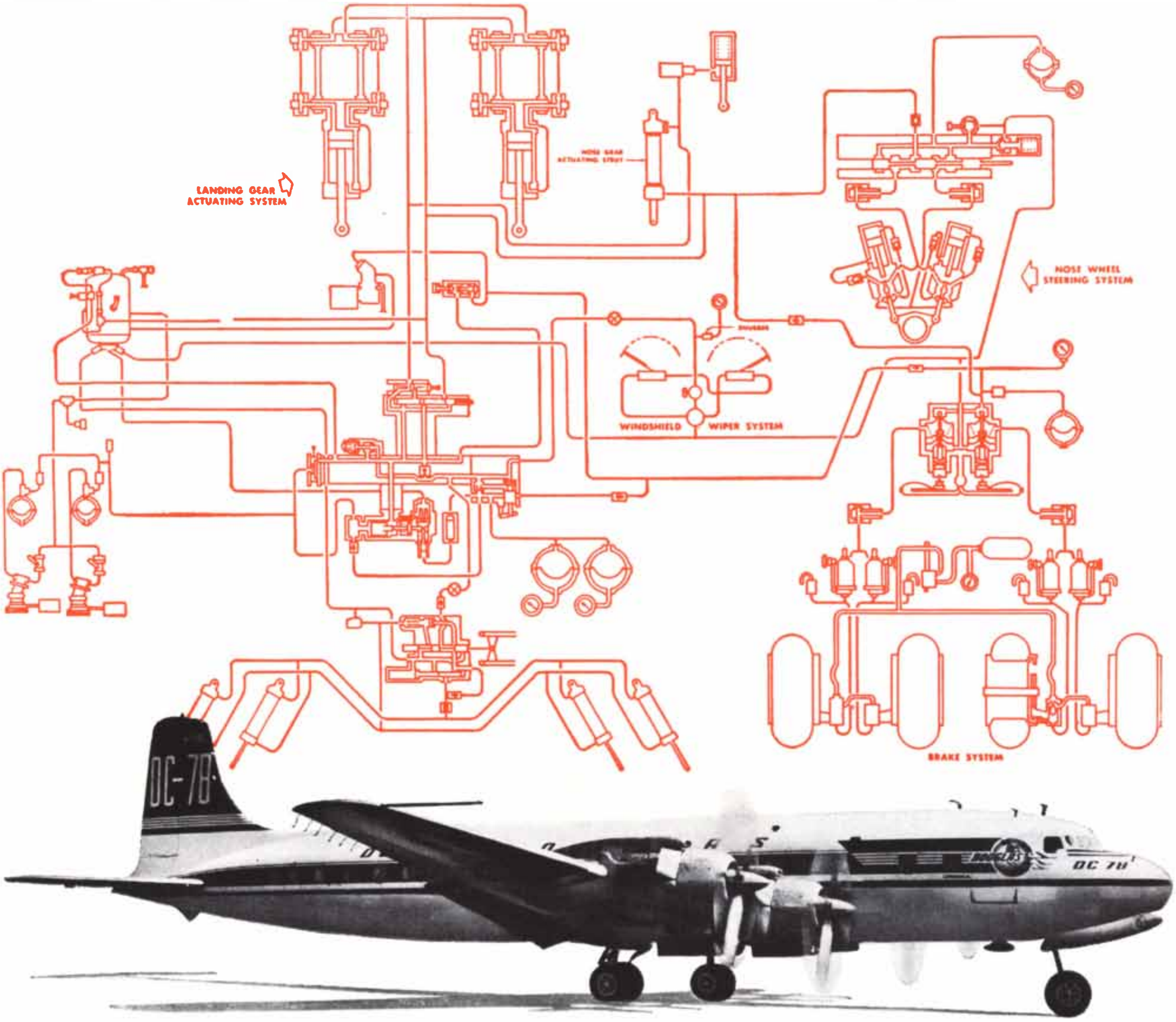
Thinking in terms of first causes, we can trace obesity to three sources: heredity, injury and unfavorable external factors (*i.e.*, relating to nutrition or exercise).

Genetic obesity has been studied in particular in the mouse. There is a form called "yellow" obesity, because it is associated with a yellowish coat color. This


INTAKE OF FOOD by an animal in the cage on page 110 may be continuously recorded on a strip of paper. The curve shows the number of times the animal pressed the food lever.

mutation has been known for half a century, and it affects a dominant gene; only when a yellow mouse is mated to a nonyellow one do the offspring survive. Those offspring of the mating that inherit a yellow coat also become obese. Another interesting form of obesity in the mouse was discovered five years ago at the Jackson Memorial Laboratory in Bar Harbor by Margaret M. Dickie and has been studied intensively in our laboratory. These mice weigh three to five times more than normal ones, are inactive and have poor resistance to cold. Their distinguishing marks are high levels of sugar and cholesterol in the blood. Even when restricted to the same amount of food as their normal littermates, they manufacture more fat; reduced to an insufficient diet, they lose mainly protein rather than fat. This last trait, incidentally, is characteristic of the "metabolic" forms of obesity. We have been able to elucidate the primary mechanism responsible for the overeating and obesity of these mice: they secrete unusual amounts of the two hormones produced by the pancreas—insulin and glucagon. Their hypersecretion of these hormones has been substantiated by measurements made in collaboration with the Toronto laboratory of Charles H. Best, the codiscoverer of insulin.

Other forms of genetic obesity have been found in mice, rats, the Shetland shepherd dog and a strain of chickens. And of course certain strains of domestic animals, hogs in particular, have been bred for centuries because of their tendency to obesity. The evidence for genet-


LANDING GEAR ACTUATING SYSTEM
NOSE WHEEL STEERING SYSTEM
WINDSHIELD WIPER SYSTEM
BRAKE SYSTEM
DC-7B

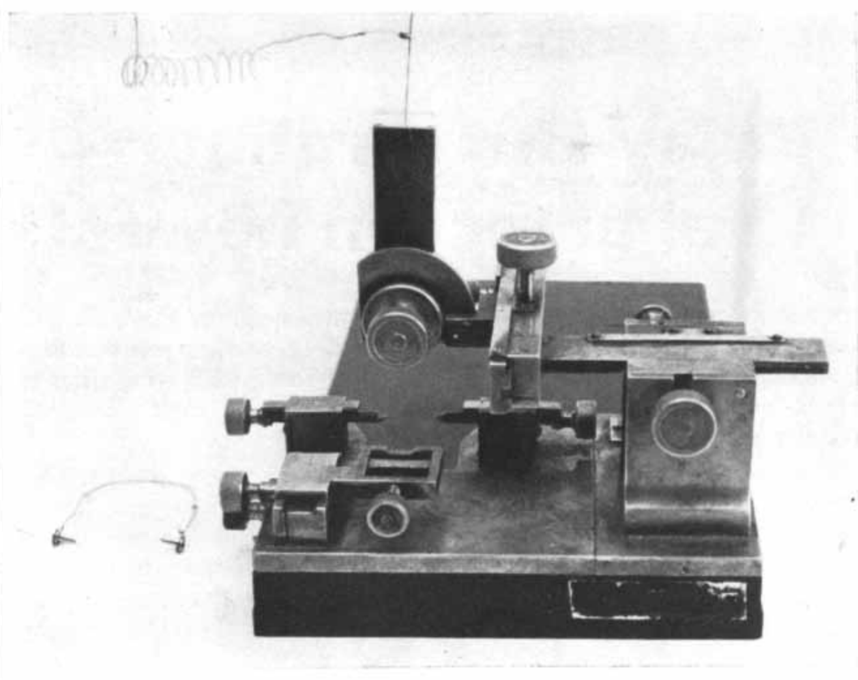
ic obesity in man is far less clear-cut, but a number of studies very strongly suggest that children of overweight parents exhibit a much greater tendency to obesity than children of normal-weight persons, and that this is not entirely due to factors of upbringing.

Traumatic obesity has been produced in the laboratory by several different means. We have induced it in the mouse by destroying centers in the hypothalamus, by implanting specialized tumors and by injecting, or causing the animals to secrete, excessive doses of certain hormones. In the type of obesity caused by destruction of the regulatory centers, the animal synthesizes an excessive amount of fat only if it is allowed to overeat. If it is underfed, its body composition becomes normal when it has been reduced to normal weight. We have studied metabolic obesities in rats in collaboration with Jacob Furth, of the Children's Cancer Research Foundation in Boston. Injection of tumorous tissue from the pituitary gland will induce such an obesity; it is traceable to excessive secretion of the pituitary hormone ACTH. In some species of animals it is possible to induce obesity by injecting long-lasting insulin, alone or in combination with a substance that depresses the activity of the thyroid gland. Castration, as is well known, also may lead to obesity.

Besides these "constitutional" obesities—genetic or traumatic—obesity can be produced by tampering with the environment. Paul Fenton of Brown University has shown that certain strains of mice become very obese when placed on high fat diets. Olaf Mickelsen at the National Institutes of Health in Bethesda, Md., observed the same effect with a strain of rats.

The influence of exercise is important. We found that exercising rats on a treadmill for two hours a day prevented the progressive "creeping" obesity which is typical of normal animals restricted in small cages. Exercise on the treadmill also cut down considerably the rate of weight gain of mice with a traumatic or hereditary tendency to obesity. An amusing natural illustration of this point is furnished by the "waltzing mouse"—a breed with a gene which causes it to turn constantly in its cage, as if it were chasing its tail. If this type is crossed with a genetically obese mouse, the offspring never reach anything like the weight of the fat parent: their exercise holds their weight down to only 30 per cent above normal, instead of the potential three or four times normal weight.

Our studies have shown that the effect of exercise also applies to human beings. Many overweight youngsters eat no more than their contemporaries of normal weight, but are characterized by a very limited spontaneous physical activity, if not total avoidance of exercise. The



STEREOTACTIC APPARATUS is used to make experimental lesions at exactly the same place in the brains of several animals. Animals of a standard size are used. The head of the anesthetized animal is fixed in the frame at the left side of the apparatus. The lesion is made by an electrode which is accurately located in the brain by turning the three upper knobs.

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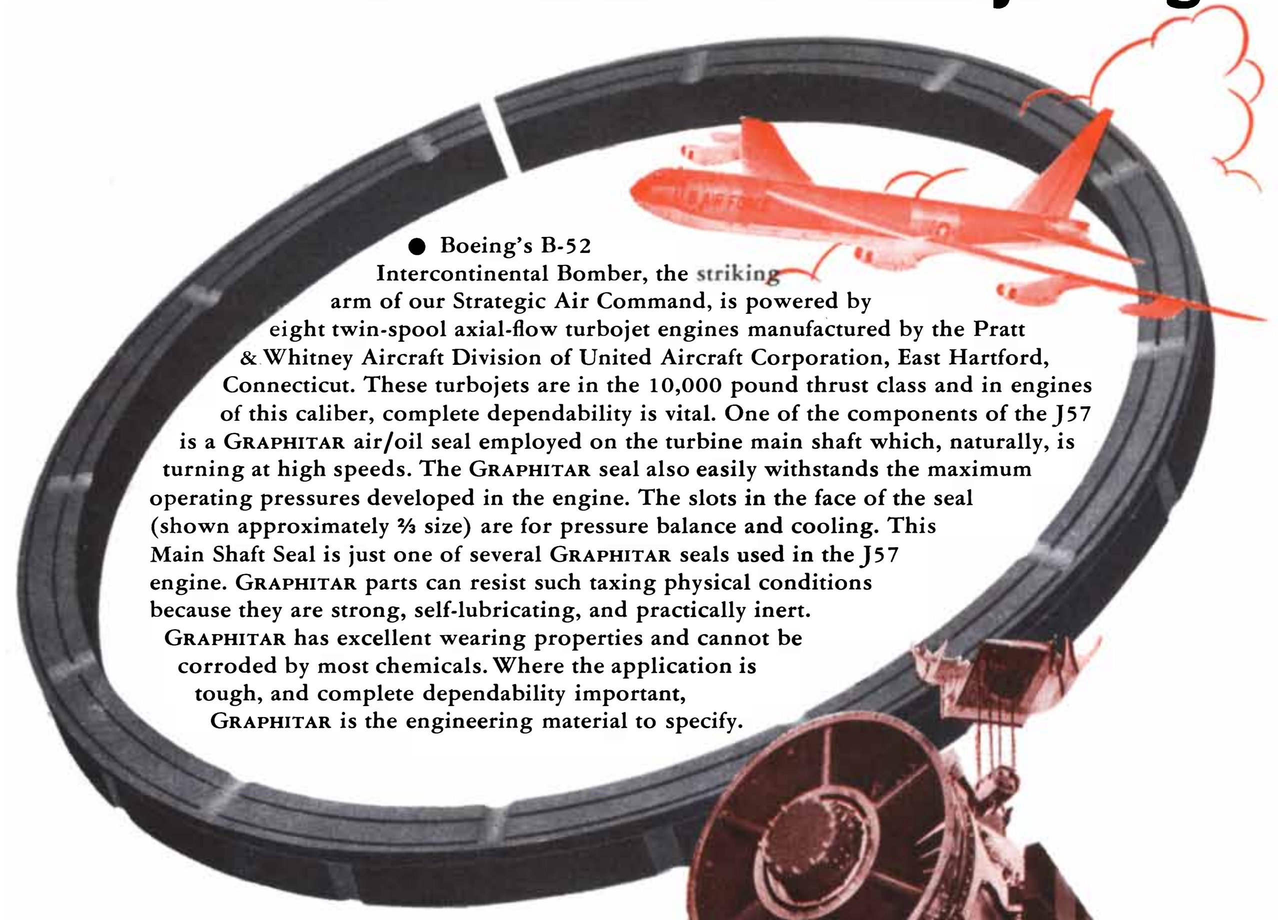

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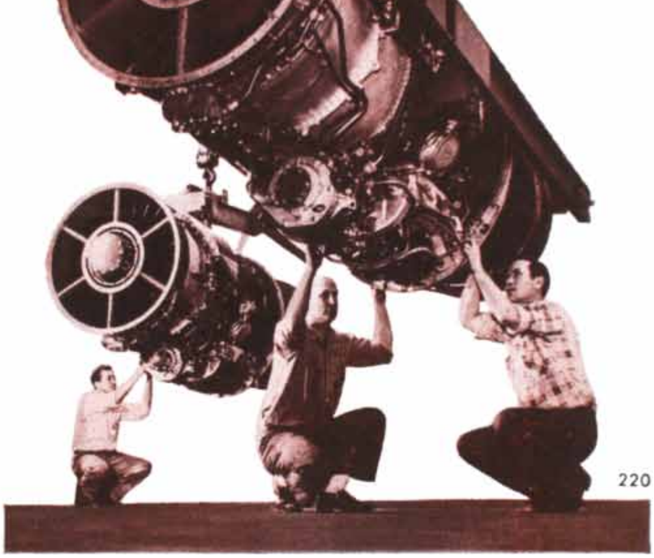

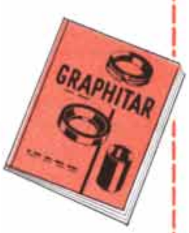

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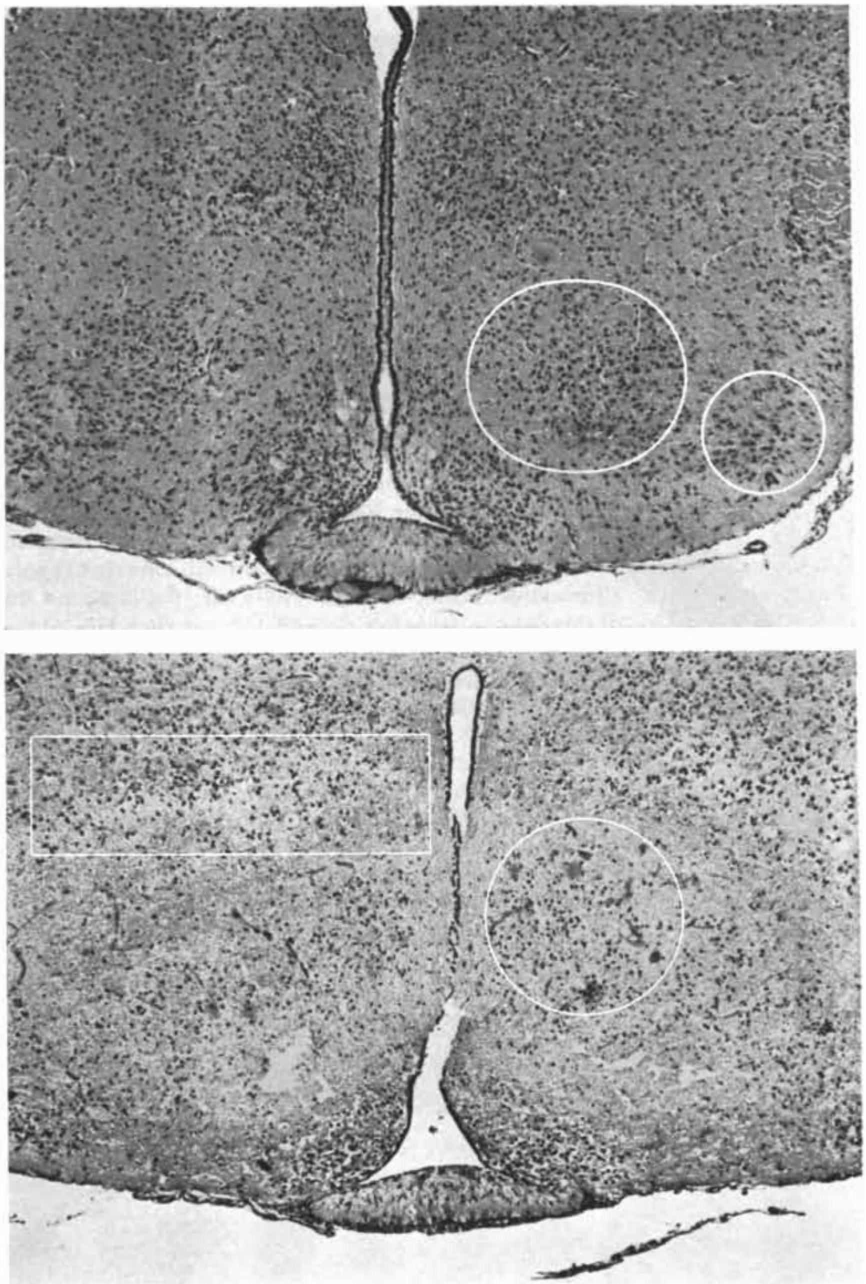
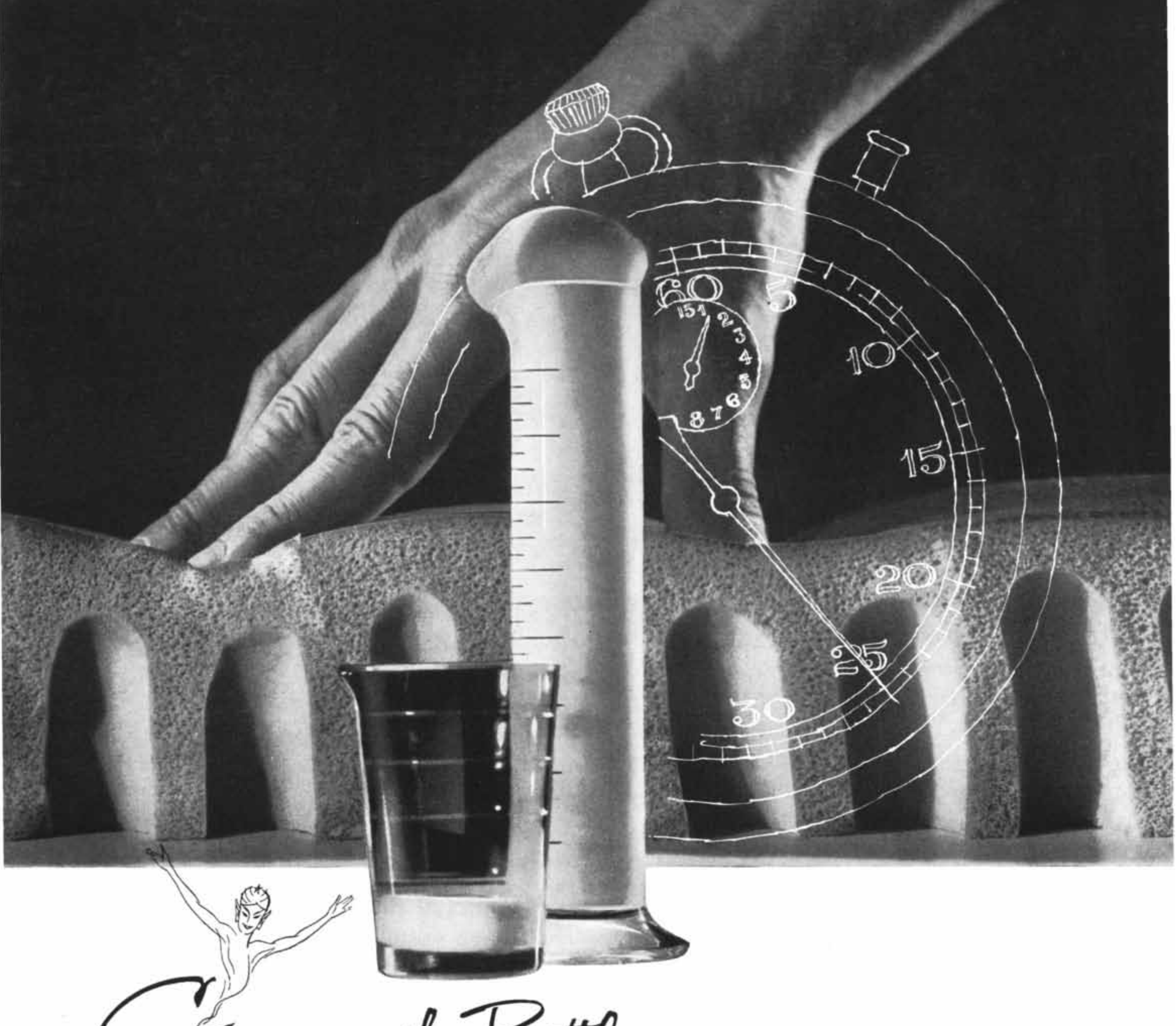


HYPOTHALAMUS of the mouse brain is shown in these photomicrographs of sections through the brain. The larger loop in the photomicrograph at the top surrounds the ventromedial nucleus, which is the center of the "satiety" cells. The smaller loop surrounds the lateral area, which contains the "feeding" centers. If the cells in the ventromedial nucleus are destroyed, the animal becomes obese. If the lateral areas of both brain hemispheres are destroyed, the animal stops feeding. The photomicrograph at the bottom shows the hypothalamus of a mouse which three days earlier had been injected with gold thioglucose. Many cell nuclei (*black dots*) have disappeared; the whole area is disorganized and "thinned" due to the death of cells and edema. The small blots in the circle at the right are hemorrhages. The rectangle shows the line of demarcation between normal and abnormal tissue.

same is true of adults. People who do not exercise usually eat as much as those who are moderately active.

We are still a long way from understanding all the complexities of the mechanism regulating appetite, or from being able to cure a basic tendency to overweight or underweight (which may be even more dangerous than obesity). It can safely be said, however, that progress in the last decade has been highly encouraging and that advances of our knowledge in this important field should take place even more rapidly in the near future.



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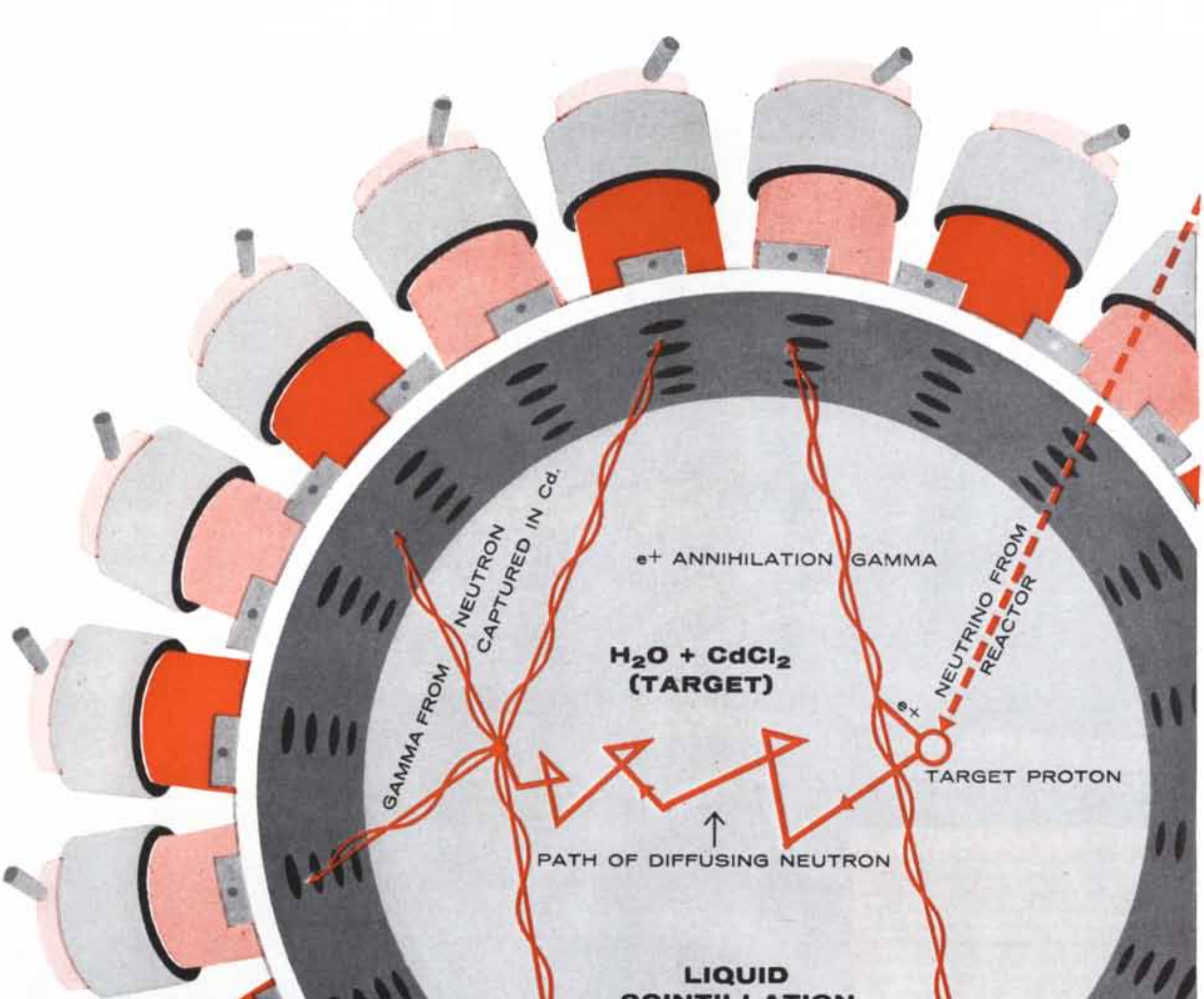
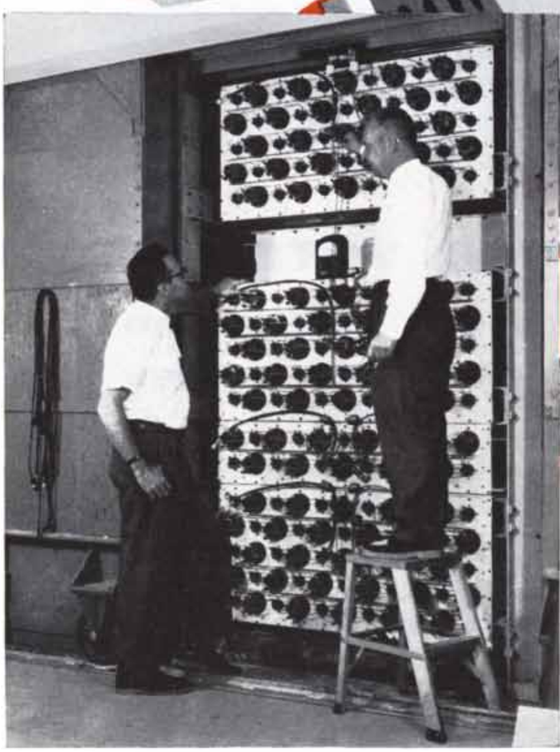
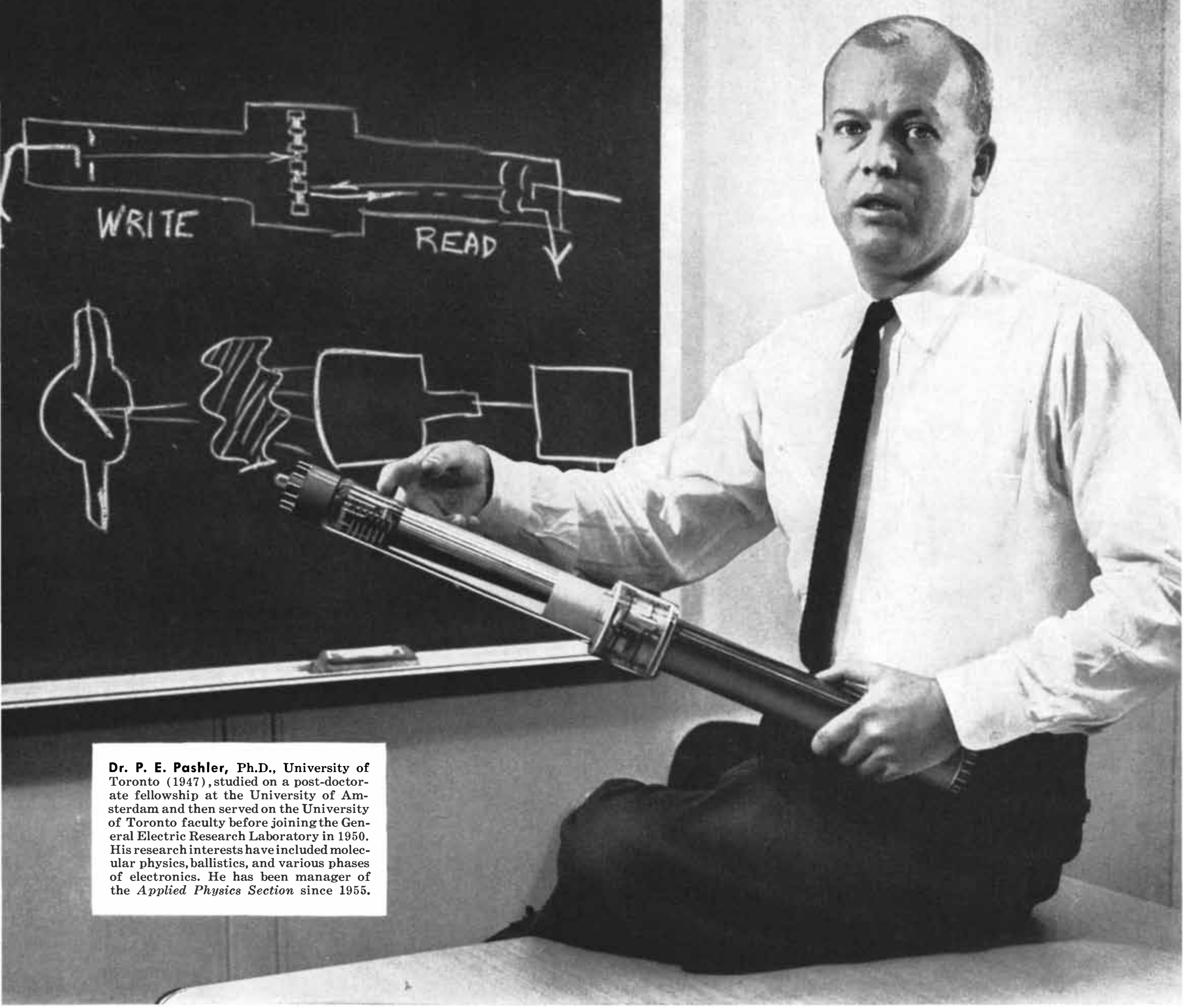




Bank of photomultiplier tubes used in the neutrino experiment.



Dr. P. E. Pashler, Ph.D., University of Toronto (1947), studied on a post-doctorate fellowship at the University of Amsterdam and then served on the University of Toronto faculty before joining the General Electric Research Laboratory in 1950. His research interests have included molecular physics, ballistics, and various phases of electronics. He has been manager of the *Applied Physics Section* since 1955.

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Unorthodox Methods of Sperm Transfer

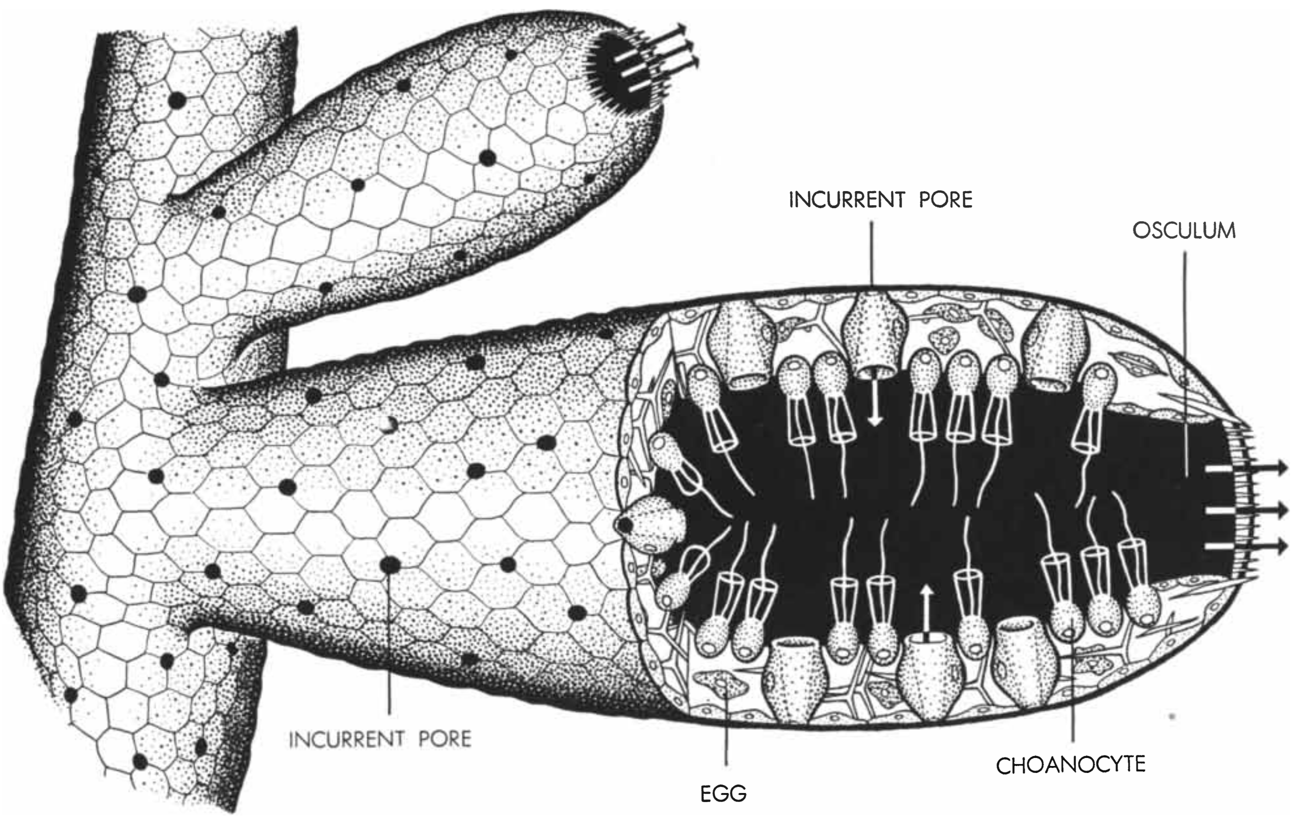
The eggs of some animals are not fertilized by the usual methods, which raises a number of interesting questions. Consider the sponge, the bedbug, the spider and the leech

by Lord Rothschild

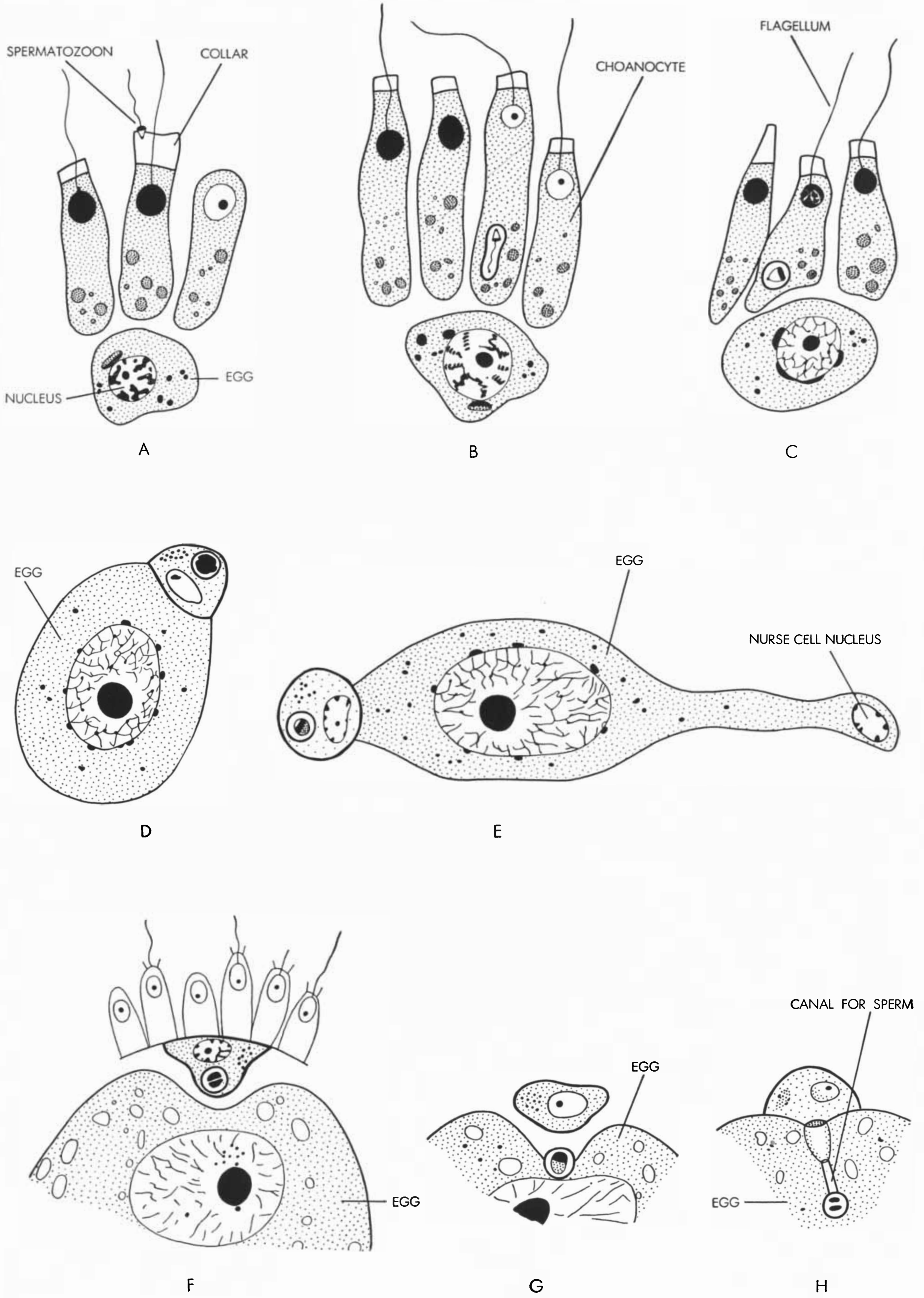
In the study of life, as in other affairs, it is often the unusual that provokes the keenest curiosity. The example discussed in this article concerns a simple and fundamental requirement of animal reproduction—the meeting of the egg and the spermatozoon. Examination of various unusual ways in which this is accomplished raises several questions of general biological interest.

Probably most people are under the impression that there are only two methods by which eggs and sperm are brought together: (1) by deposition of the sperm in the female's reproductive tract, or (2) by the liberation of eggs and sperm near each other in water, as in the case of spawning fish. Fertilization then occurs after a moving spermatozoon collides with an egg, either by chance or because it is attracted toward the egg.

However, in some groups of animals the sequence of events does not conform to this "normal" pattern. Sponges, spiders, leeches and bedbugs, for example, effect the union of the egg and the spermatozoon by less direct means. Some of these animals do not employ the usual reproductive organs for copulation; some use cells other than the germ cells to convey sperm to eggs; while others submit the spermatozoa to apparently unnecessary hazards. In certain



PART OF A SIMPLE SPONGE COLONY is depicted in this semi-schematic enlargement adapted from *Animals without Backbones*, by Ralph Buchsbaum. The lower sponge has been cut away to show its internal structure. Water is pumped out of the sponge by the flagella of the choanocytes; it enters by way of the incurrent pores. The choanocyte transfers the spermatozoon to the egg (*next page*).


SPERMATOZOON
COLLAR
NUCLEUS
EGG
A
CHOANOCYTE
B
FLAGELLUM
C
EGG
D
EGG
NURSE CELL NUCLEUS
E
EGG
F
EGG
G
CANAL FOR SPERM
EGG
H

cases, such as spiders, the unorthodox methods are clearly advantageous, but in others they seem pointless. Most of these peculiar methods appear to be inefficient. But the training of biologists prevents them from accepting the concept of inefficiency in living organisms. If these habits had not had some survival value, we are taught, the species in which they evolved would have become extinct, having been edged out of existence by animals with more efficient methods. The unusual methods of sperm transfer are therefore worth some study from this point of view, quite apart from the intrinsic interest of the subject.

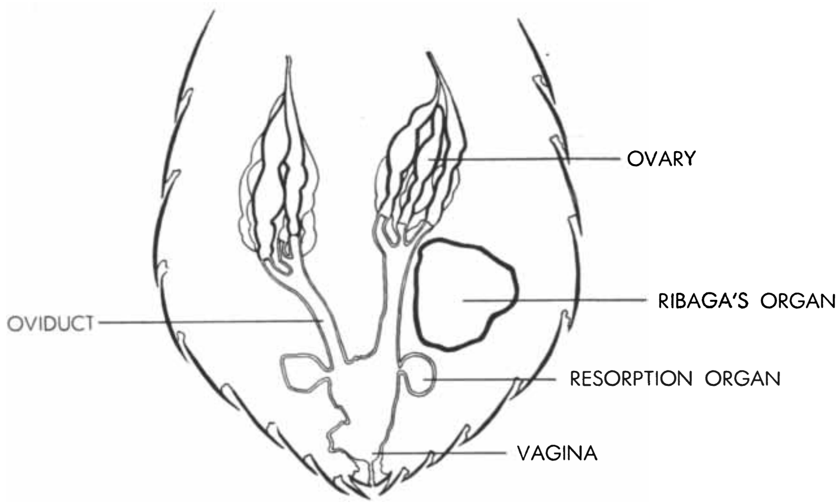
In the sponge, sexual reproduction depends on an activity in which this animal is continually engaged—the intake and expulsion of water. The sponge sucks water into its body through pores in its body wall and expels the water through its "osculum" [*see drawing on page 121*]. When sponges reproduce sexually and not by budding, sperm are produced in the body wall and discharged into the water through the osculum. With luck, these sperm will enter another sponge through its pores. But they do not unite directly with eggs in the second sponge. Instead they invade cells of a unique kind which are aligned on the body wall of the sponge. These cells, called choanocytes (from the Greek word for funnel), have a collar or funnel through which protrudes a flagellum; it is the constant whiplike motion of the choanocytes' flagella that sucks water into the sponge and expels it through the osculum. Once a spermatozoon has penetrated a choanocyte, the

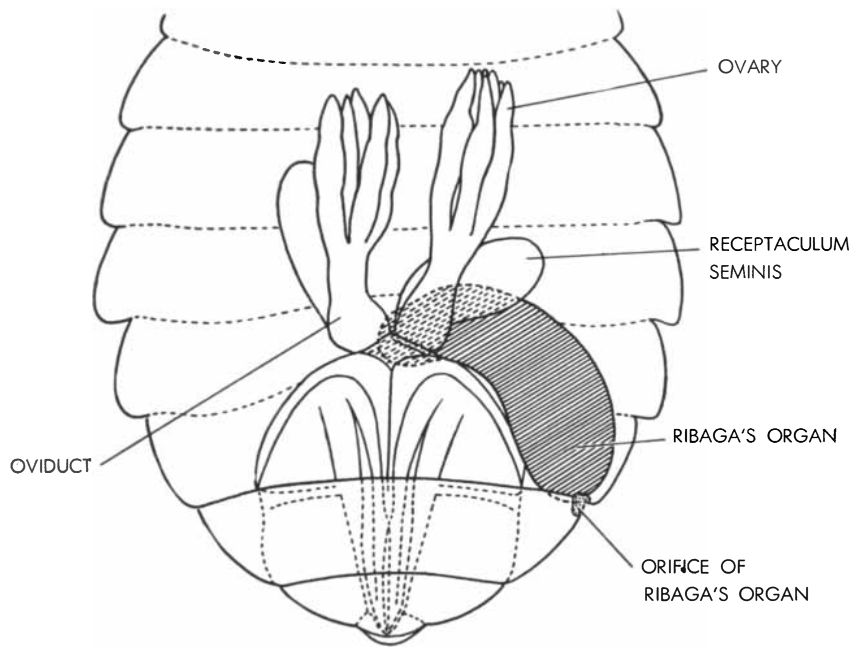
SPERMATOZOON OF THE SPONGE *Sycon raphanus* is transferred to the egg by the sequence of events depicted on the opposite page. In A the spermatozoon enters the collar of the choanocyte. In B the spermatozoon is contained in a spermiokyst near the bottom of the third choanocyte from the left. In C the spermatozoon within the spermiokyst has lost its tail. In D the choanocyte has turned into a sperm-transit cell, and is pressed to the upper right surface of the egg. In E the egg has ingested two "nurse" cells. The nucleus of one nurse cell is at the right; the sperm-transit cell is at the left. In F the sperm-transit cell is about to eject the spermiokyst into the indentation at the top of the egg. In G the spermiokyst has been ejected from the sperm-transit cell. In H the spermiokyst is within the egg. The scale may be gauged from the fact that the tail of the spermatozoon is .05 millimeter long. The drawings are adapted from Odette Tuzet.

latter loses its collar and flagellum and becomes a carrier whose function is to transfer the spermatozoon to an egg. The tail of the spermatozoon degenerates, while its head and middle piece (the sperm's power station) swell to about three times their normal size [*see illustration on page 122*].

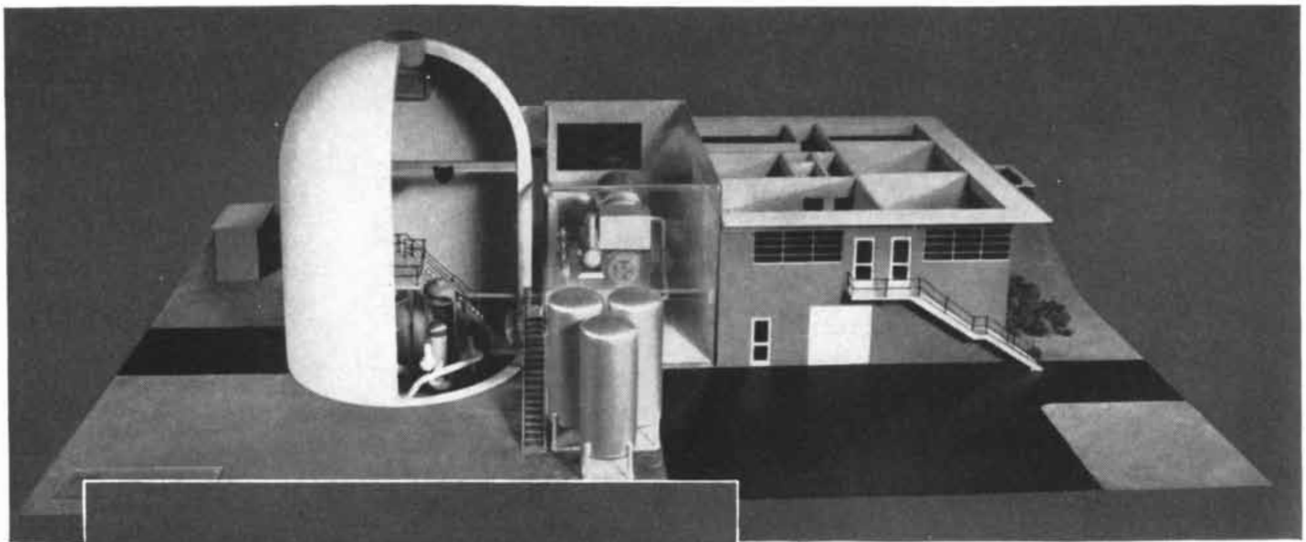
It is a striking fact that a spermatozoon will enter a choanocyte only if the latter happens to have an egg near it. When the spermatozoon has entered the choanocyte, the nearby egg wanders away, absorbs two "nurse cells" and then returns to the carrier cell. The latter then attaches itself to the surface of the egg and injects the spermatozoon into it. The fertilized egg proceeds to develop in the usual way.

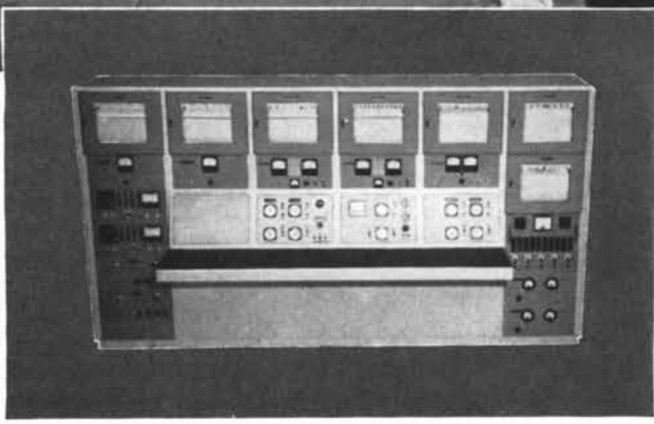
This extraordinary sequence of events poses several puzzling questions. Why does the spermatozoon enter a cell which





FEMALE BEDBUG has a cavity called Ribaga's organ; the spermatozoa are deposited in this cavity and not in the vagina. The spermatozoa pass between the cells lining Ribaga's organ and travel up the oviduct to the eggs. The drawing at the top, adapted from R. Abraham, is a cross section of the abdomen of the female bedbug *Cimex lectularius*. The drawing at the bottom, adapted from J. Carayon, is a similar section of a close relative of the bedbug.





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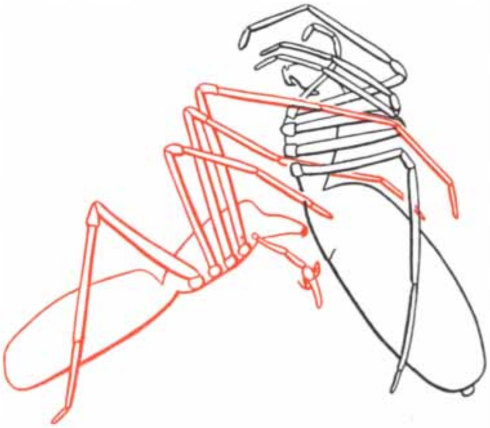

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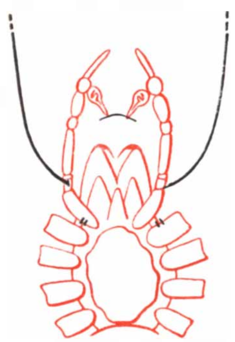

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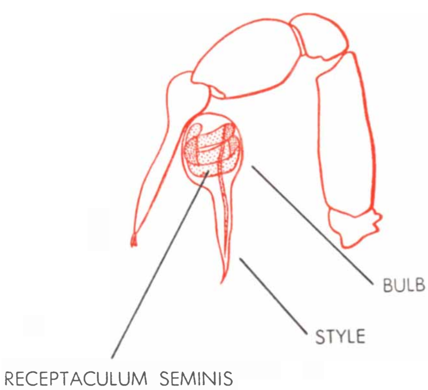

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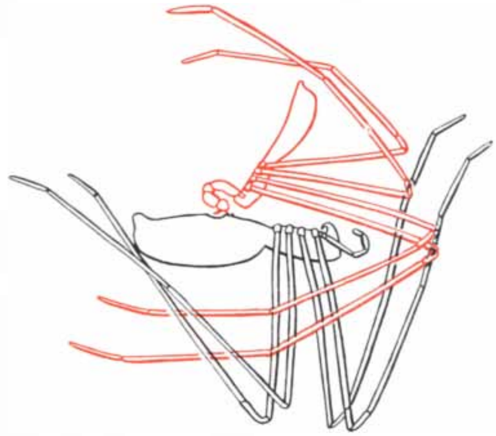

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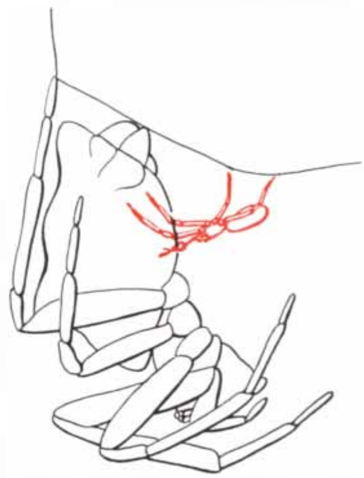

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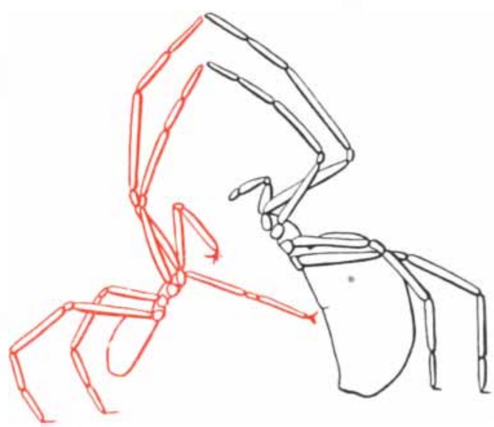


F

is not an egg? Invasion of body cells by sperm occurs elsewhere in the animal kingdom, and it has been suggested that they confer some benefit on the somatic cells they penetrate. This cannot apply here, because the choanocyte simply acts as a vehicle for transfer of the sponge spermatozoon to the egg.

Again, how is it that a spermatozoon is attracted only to a choanocyte which is near an egg? If the attraction is chemical, how can a chemical gradient be maintained when the water within the sponge is kept in continual motion by the choanocytes' lashing flagella?

The bedbug's method of sperm transfer is even more odd. The male bedbug does not inject sperm into the female's genital tract but into an entirely separate structure, known as Ribaga's organ, on the right side of the female's body. Since this organ has no connection with the oviducts or the ovaries, it is not immediately obvious how the sperm get to the eggs. The difficulties encountered by the sperm are exacerbated by the fact that Ribaga's organ and the female's body cavity contain cells which eat sperm. Nonetheless some of the spermatozoa manage to survive and to fertilize eggs. Passing between the cells lining Ribaga's organ, they enter the body cavity, travel up the walls of the female's reproductive tract and ultimately reach the ovaries.

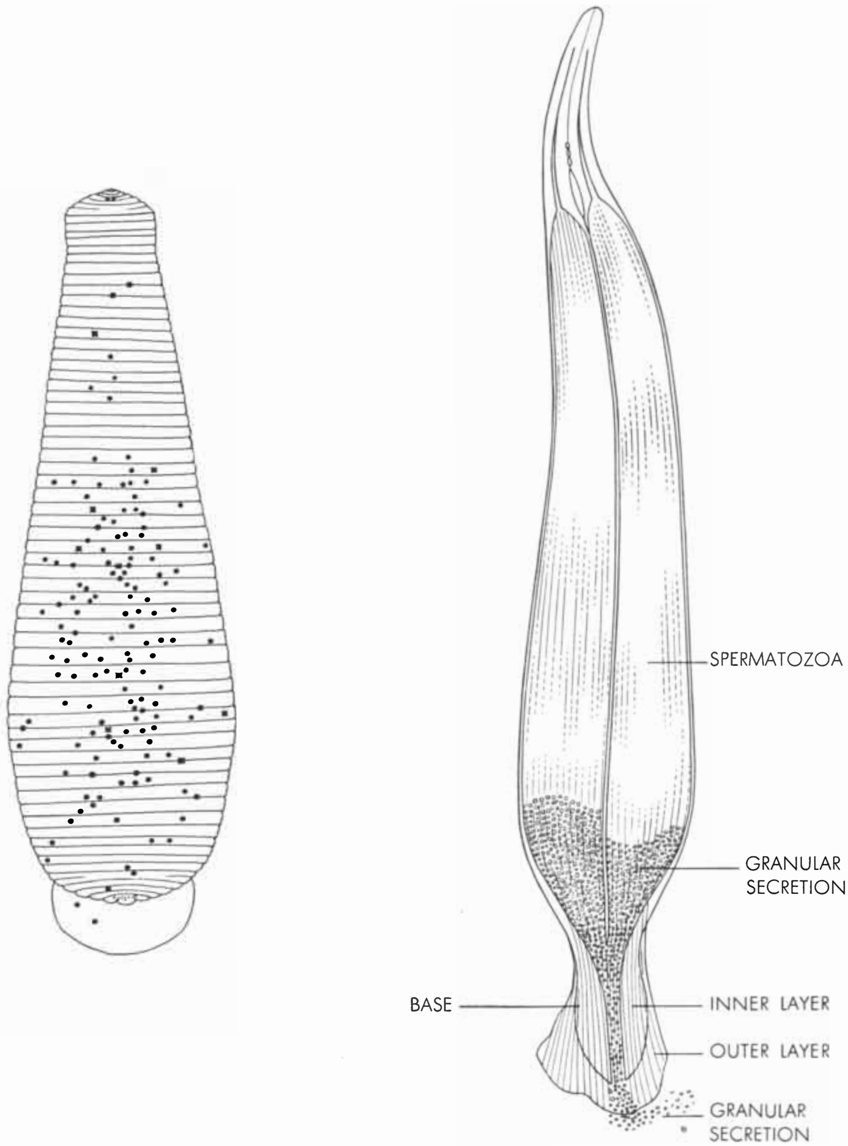
Normal copulation is impossible in the bedbug, because the organ of the male, a large, inflexible, lopsided structure, cannot fit into the female genital opening. Without the mutation responsible for the evolution of Ribaga's organ, bedbugs would have become extinct—to the advantage of the human race.

In spite of being useful, Ribaga's organ

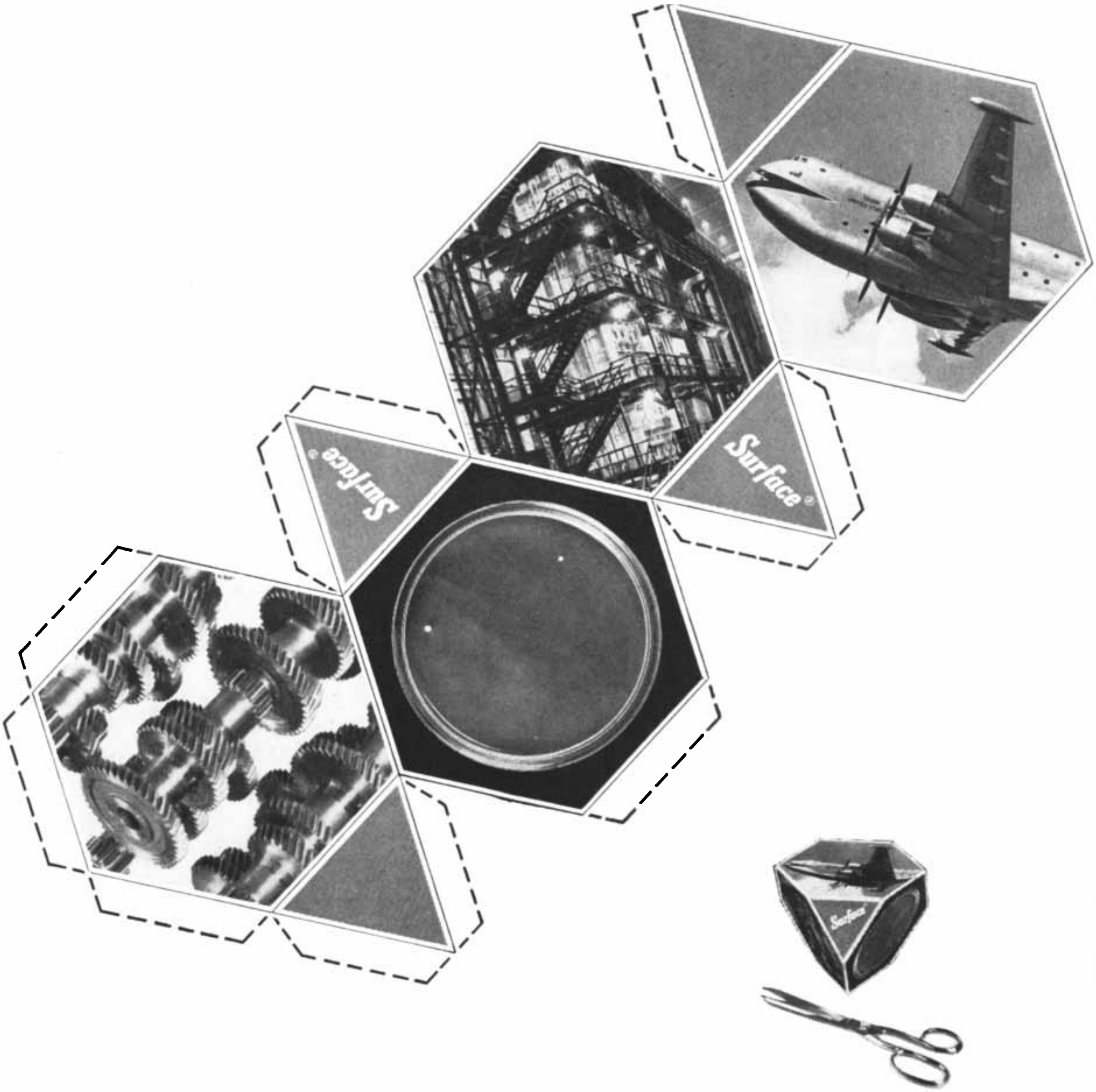
TRANSFER IN THE SPIDER may be adapted to the cannibalism of the female, depicted in black on the opposite page. The male, shown in color, spins a small web and deposits a drop of semen on it. The semen is then transferred to the female in small receptacles on one of his six pairs of "legs." At A the male of the species *Segestria senoculata* transfers sperm to the female. The drawing is adapted from U. Gerhardt. At B is a detail of A, seen from below. At C is an enlarged view of the semen receptacle in a single palp of the spider *Scytodes lesserti*, adapted from Pierre-Paul Grassé. At D is sperm transfer in *Pholcus opilionoides;* at E, in *Cyrtophora citricola;* at F, in *Filistata insidiatrix.* The last three drawings are also adapted from Gerhardt.

is a cumbersome solution of the bedbug's problem. It is therefore all the more difficult to understand why the bedbug has evolved additional obstacles to survival of the sperm on their way to the eggs. If and when we do understand, some of the other problems discussed in this article may well become clarified.

The spider injects sperm into the female by means of one of the six pairs of appendages with which this animal walks, fights and eats. The third to sixth pairs are concerned mainly with walking. The first pair are poison fangs, with which the spider paralyzes and holds its prey. It is the second pair, the palps, which the male uses for sexual intercourse. In the female the palps are mainly sensory, though she also uses them to hold her victim and squeeze juice out of it. In the male the palps are modified to serve as receptacles for semen and as organs for introducing the semen into the female. They are not, however, connected to the male's ordinary reproductive system. Before sexual intercourse the male spider spins a special web, sometimes called the "spermatic web." He then deposits a drop of semen on the web and dips each palp in the drop. By capillarity and perhaps by suction semen



LEECH, which is hermaphroditic, transfers its sperm in a capsule called a spermatophore. The spermatophore is deposited on the surface of another leech. At the left is a schematic drawing of the leech *Placobdella parasitica*. The drawing, adapted from R. J. Myers, enlarges the leech about 15 diameters. The round spots show the distribution of 135 spermatophores implanted on the upper side of the leech; the square spots, the distribution of 11 spermatophores on the under side. At the right is a drawing of a spermatophore. The drawing, adapted from C. O. Whitman, enlarges the spermatophore about 45 diameters.



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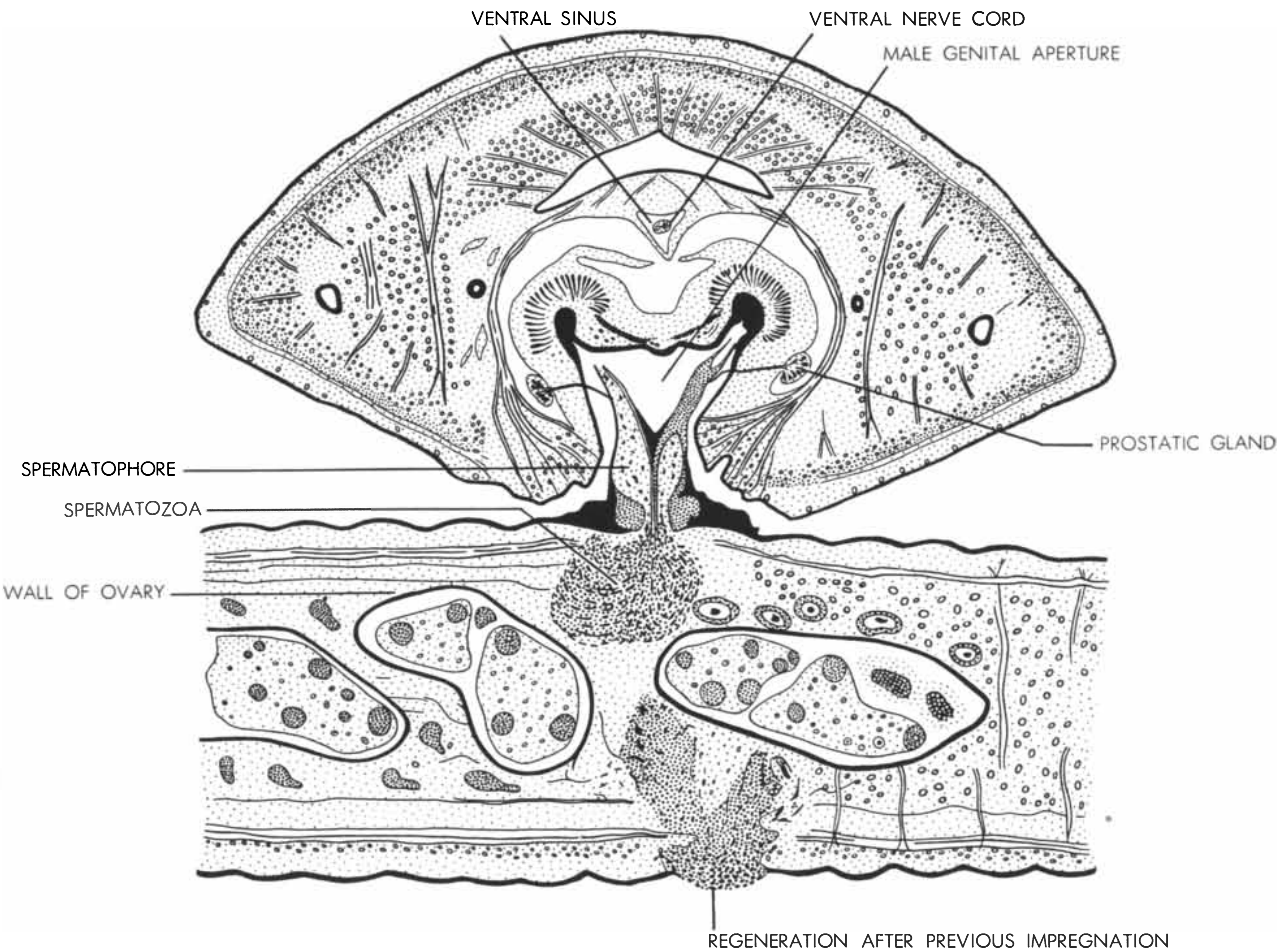
is drawn into a small receptacle at the tip of the palp. The process is repeated a number of times, each palp being inserted alternately into the drop or drops of semen.

The male spider then looks for a female. Having found one, he often engages in complicated nuptial dances, or communicates his presence by tugging at the female's web. He usually approaches with circumspection, for, as the French zoologist Pierre-Paul Grassé has remarked: "Copulation is always for the male a sporting adventure which has its dangers." Grassé was referring, of course, to the well-known cannibalistic habits of female spiders. It may be that the extraordinary method of sperm transfer evolved by male spiders increases their chances of engaging in sexual intercourse without being eaten. When the male is near enough, he inserts his palps into the female genital orifice. Muscular contractions operating on the body fluid in the palp expel the semen into the female reproductive tract, after which fertilization occurs in the normal way.

Leeches are hermaphrodites. The individual playing the male role in a union does not inject its sperm into the female reproductive tract of the other leech. Instead it deposits a capsule containing semen on the surface of the recipient leech. This capsule, called a spermatophore, may be deposited almost anywhere on the upper surface of the body. The capsule not only contains sperm but also a granular material which is concentrated at the end of the spermatophore that is attached to the recipient body [*see illustration on page 128*].

The function of this granular secretion is to breach the layers of tissue in the body wall and create an aperture for entry of the sperm. It contains enzymes which exert a violent destructive action on these tissues. Pressure exerted by the distended walls of the spermatophore also assists in creating the breach, as was shown in an experiment carried out by R. J. Myers. He cut open the end of the spermatophore farthest away from its point of attachment to the surface of the leech. This relieved the pressure, and in these circumstances there was no breakdown of the recipient leech's tissues.

Ordinarily within one hour after the deposition of the spermatophore most of the sperm have entered the body of the recipient, where, as in the bedbug, they may be eaten by special cells. If they escape this hazard, they have a good chance of being carried by the body fluid to the ovaries, where they pass through the walls and fertilize the eggs inside.



TWO LEECHES of the species *Herpobdella atomaria* are shown in cross section during copulation. The body of the leech at the bottom runs from left to right. The leech at the top is at right angles to the leech at the bottom. The drawing is adapted from E. Brumpt.

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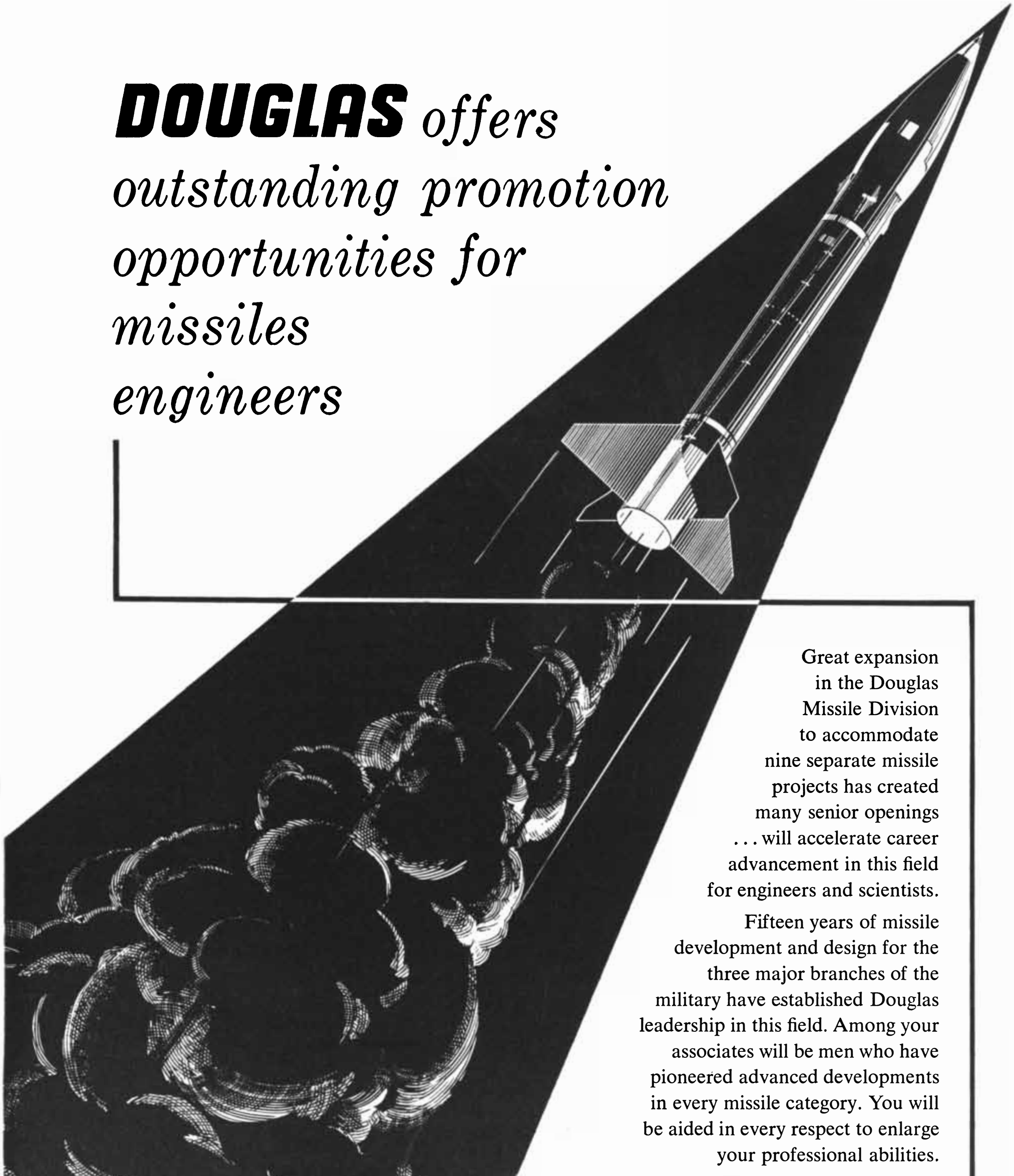

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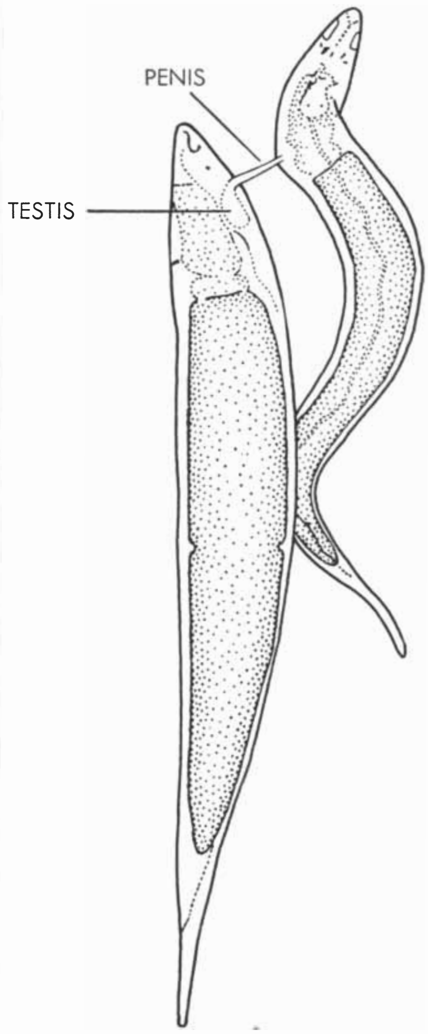
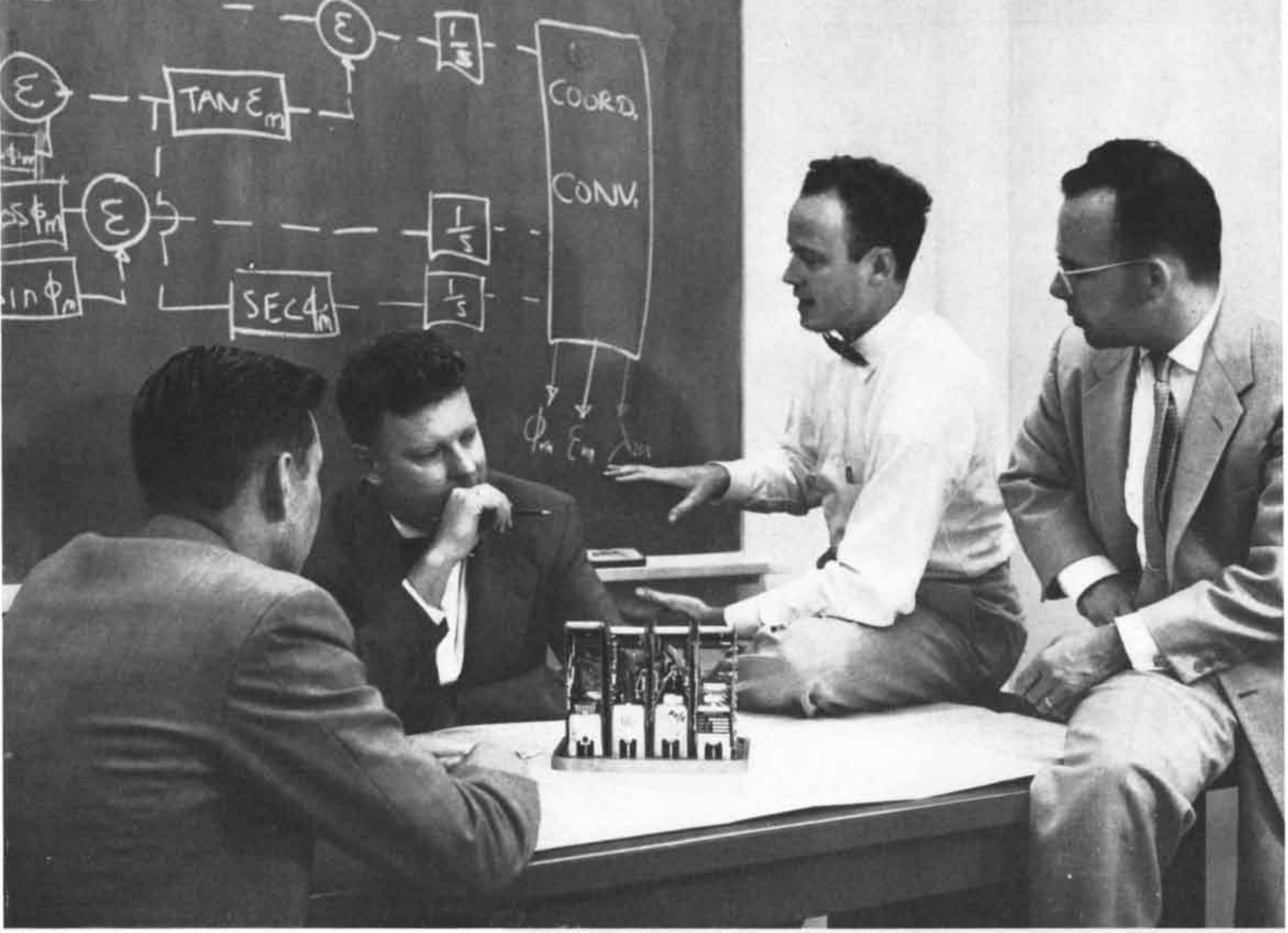
Meanwhile the damaged tissues of the recipient leech repair themselves within about three days after copulation.

This method of insemination is called "hypodermic" impregnation. It not only occurs in leeches but also in certain worms and probably in rotifers and some arthropods.

The examples given in this article do not exhaust the list of unorthodox methods of sperm transfer in the animal kingdom. They pose provocative problems for biologists. Bizarre as they may appear, these peculiar habits must have survival value; otherwise they would not have persisted. This type of situation, which makes biology so fascinating, compels us to carry out more experiments if we are to unravel the paradoxical mysteries of nature.



TURBELLARIAN WORM *Stenostomum oesophagium* transfers its sperm by a method resembling that of the leech. The sperm are injected into the body cavity of the animal. This drawing enlarges the worms about 15 diameters. It is adapted from W. A. Kepner, Jeanette S. Carter and Margaret Hess.



G. D. Schott (second from left), Flight Controls Dept. Head, discusses new techniques in the mechanization of autopilots with R. D. Wertz (left), Flight Controls Research Engineer; R. J. Niewald, Flight Controls Analysis Section Head, and B. C. Axley, Servomechanisms Analysis Group Engineer.

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RADIOACTIVE TUBERCULOSIS DRUGS

Three drugs are now used to control the tubercle bacillus, though none is completely effective against it. Their mode of action is investigated by inserting radioactive atoms into their molecules

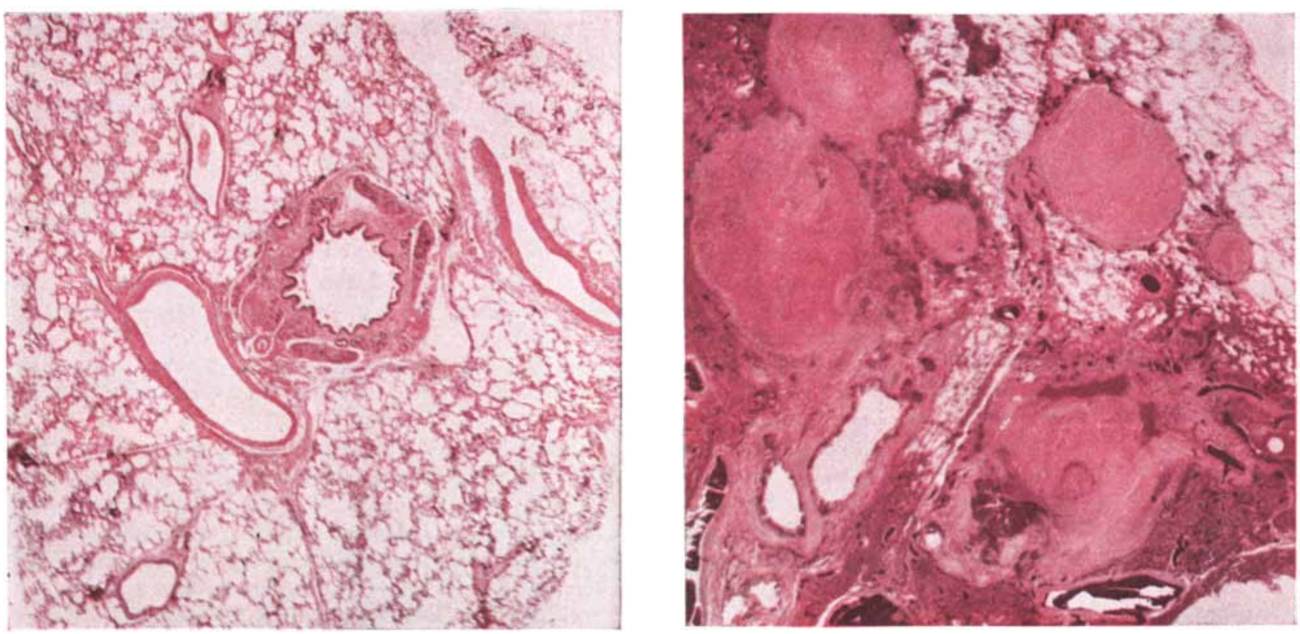
by Lloyd J. Roth and Roland W. Manthei

In the short space of 10 years a profound change has come about in the attitude of medical research toward tuberculosis. A decade ago, although progress had been made in treatment and in reduction of the TB death rate, the prospects for finding a definite cure for this ancient plague of mankind still looked unpromising. The stubborn tubercle bacillus had resisted every drug that had been tried, and it seemed invulnerable to the possibility of successful chemical attack. But in the past decade, as everyone knows, its resistance has partly yielded to three new drugs—streptomycin, para-aminosalicylic acid (PAS) and Isoniazid. While none of the three is completely effective in eradicating the microbe, they give good control over the disease and have provided investigators with an opening wedge for determining how the tubercle bacillus can be attacked and finally conquered.

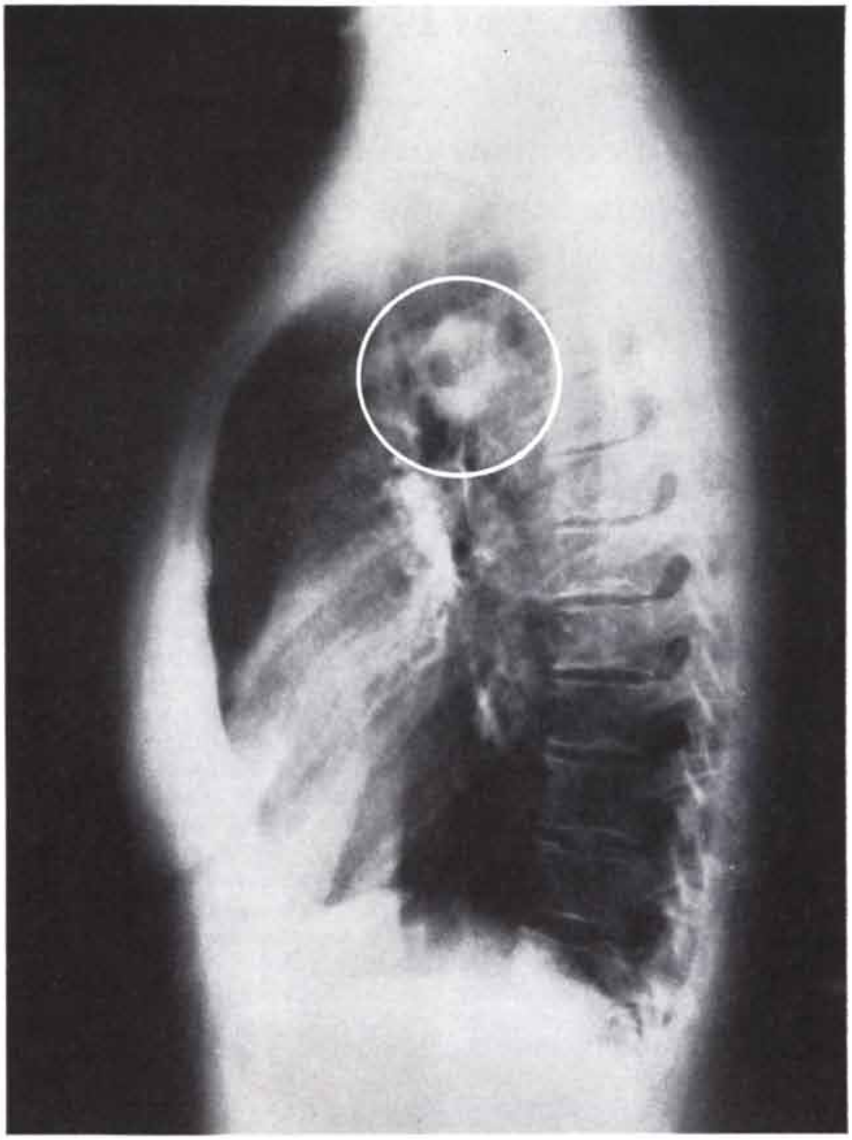
Investigation of the way in which these drugs act against the microbe in the body has only just begun. We shall report here what has been learned so far from radioactive tracer studies started four years ago at the University of Chicago School of Medicine.

Very soon after Isoniazid was introduced as a TB drug, Arthur Murray and Wright H. Langham of the Los Alamos Scientific Laboratory succeeded in labeling it with radioactive carbon 14 for tracer work. We therefore began with this drug. Our first objective was to find out how it reached the tubercle bacilli in the body. There was good reason to believe that the drug acted directly on the bacilli, because it was effective against the organisms in the test tube. However, these microbes are unusually difficult to reach with drugs in the body: they collect in pockets out of the bloodstream and are entrenched in fortresses (tubercles) walled by tough scar tissue [see "The Germ of Tuberculosis," by Esmond R. Long; Scientific American, June, 1955]. It was long thought that the resistance of the tuberculosis germ to drugs was due to inability of the drugs to penetrate the tubercle.

To follow Isoniazid in the body we performed a series of tracer experiments with mice and guinea pigs. The animals were placed in special cages where we could trap any radioactive carbon they excreted, including the carbon



HUMAN LUNG TISSUE which has been stained, cut in a thin section and photographed under the microscope demonstrates the difference between healthy (*left*) and tuberculous tissue (*right*). The opaque areas are scar tissue which walls off the tubercle bacilli.



TUBERCULOSIS LESION is revealed by this X-ray from the side of the chest. Experiments with radioactive Isoniazid showed that the drug penetrated the scar tissue of such lesions.

dioxide they exhaled. Then we gave them Isoniazid labeled with radiocarbon, either by mouth or by injection, in a dose equivalent to that given to human tuberculosis patients. The drug spread widely through the animals' organs and tissues, and reached a peak concentration in the tissues in about half an hour. Most of the tissues soon lost the drug, and after eight hours the major part of it had been excreted in the urine. But in certain tissues—the lungs, adrenal glands, liver and skin—the drug persisted for as long as 24 hours at a level sufficient to check tubercle bacilli. In short, the drug lasts for a comparatively long time in the very tissues that are most vulnerable to tubercular infection.

We then tested the penetration of the drug into tubercles. Doses of labeled Isoniazid were given to guinea pigs infected with a strain of bacilli which causes human tuberculosis. Within a short time the drug appeared inside the capsules in amounts sufficient to stop the bacilli from multiplying, and it remained there in effective concentration for many hours. When repeated doses of the drug were given, Isoniazid actually accumulated in the tubercles in increasing concentration.

With the cooperation of Robert H. Ebert of the University of Chicago, we extended the tracer studies to human volunteers who had tuberculosis of the lung and were to be operated upon for removal of the lesion. Two hours before the operation they were given a therapeutic dose of Isoniazid containing a nonhazardous amount of radiocarbon. After the operation, tubercles in the excised section of lung were measured for

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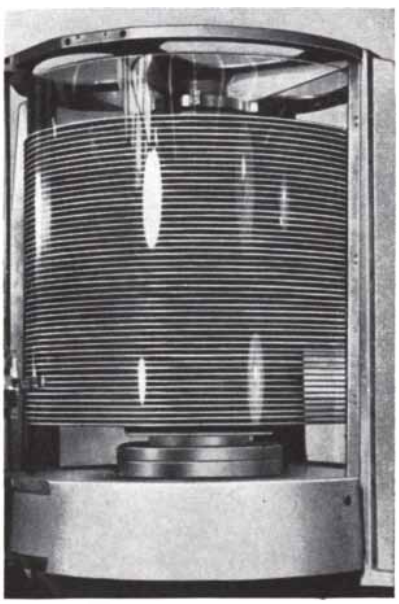

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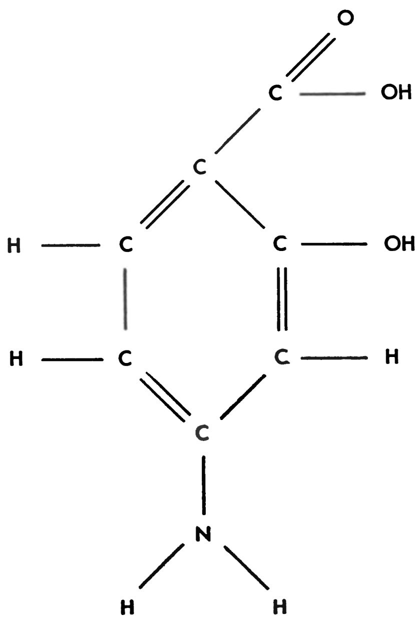
radioactivity. All of the tubercles had enough radioactive Isoniazid to halt the growth of bacilli.

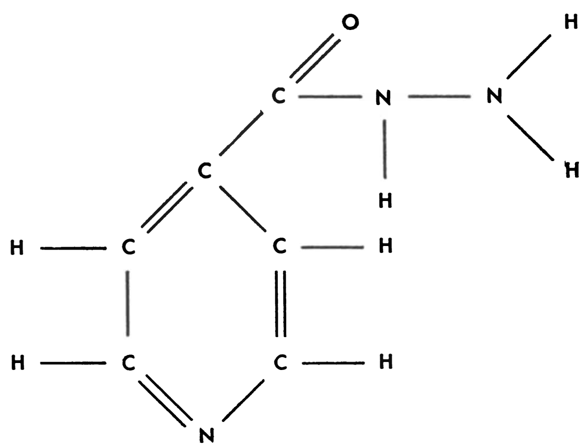
The tubercle is, of course, a critical element in the progress of tuberculosis. It is formed at a battleground where the bacilli have been fought by the body's defending cells. The virulent germs are walled off in a pocket enclosed by dead cells and scar tissue. If the tubercle softens, it provides an excellent medium in which the bacilli may multiply. In any case the tubercle remains a dangerous nest of infection unless it goes on to calcify and ultimately destroy the germs. It is encouraging to learn that Isoniazid can pass into the tough tubercles containing active bacilli.

Apart from tracking the drug to tuberculous lesions, it was a matter of great interest to follow its fate in other tissues, particularly the brain. Isoniazid does not often produce side effects in patients who receive the drug. But in about 10 per cent of the patients, especially the older ones, it may generate disturbances of the nervous system: they complain of headaches, dizziness or altered sensations of touch. We found that the drug quickly moved into brain tissue in our experimental animals. After a delay, amounting to about the same length of time it had taken the drug to reach peak concentration in the brain tissues, the animals showed symptoms of stimulation of the central nervous system. The delay may represent the time it takes for the drug to arrive at a synapse or to produce some stimulating chemical reaction; just how the drug stimulates the nerve cells is not known. To locate the areas where the drug collected in greatest concentration, we placed sections of cat and rat brains on films and kept them in a deep freeze for 30 days, allowing the radioactive tissues to record autoradiograms on the film. The developed film showed that the drug tends to concentrate in the gray matter of the brain in a manner not directly related to the circulatory system of the organ. This information may lead to clues concerning how the drug acts on the central nervous system.

Isoniazid soon disappeared from the brain tissues of living animals. The experiments indicate that if physicians space out doses of the drug at intervals of at least eight or 12 hours, disturbances of the central nervous system may be less likely to occur.

It appears from examination of the human patients who took the radioactive drug that Isoniazid achieves much the





STRUCTURAL FORMULAS of para-aminosalicylic acid (PAS) and Isoniazid are shown in these drawings. In the tracer experiments with PAS (*top*) the compound was tagged with a radioactive carbon atom either in the carboxyl group or in the central ring. In the experiments with Isoniazid (*bottom*) only the carboxyl group was labeled with radiocarbon.

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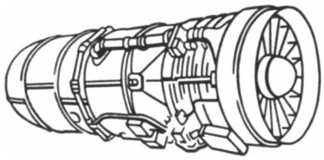

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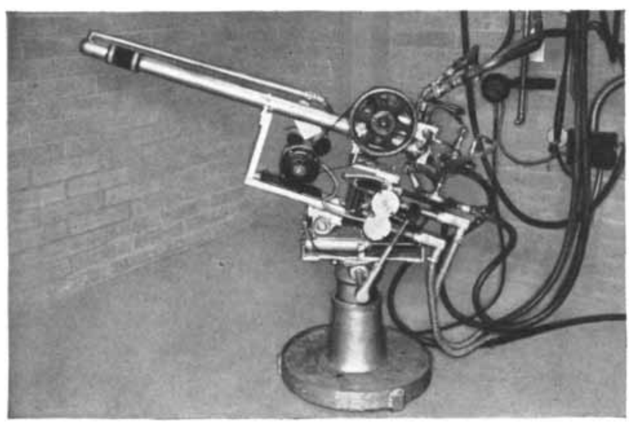

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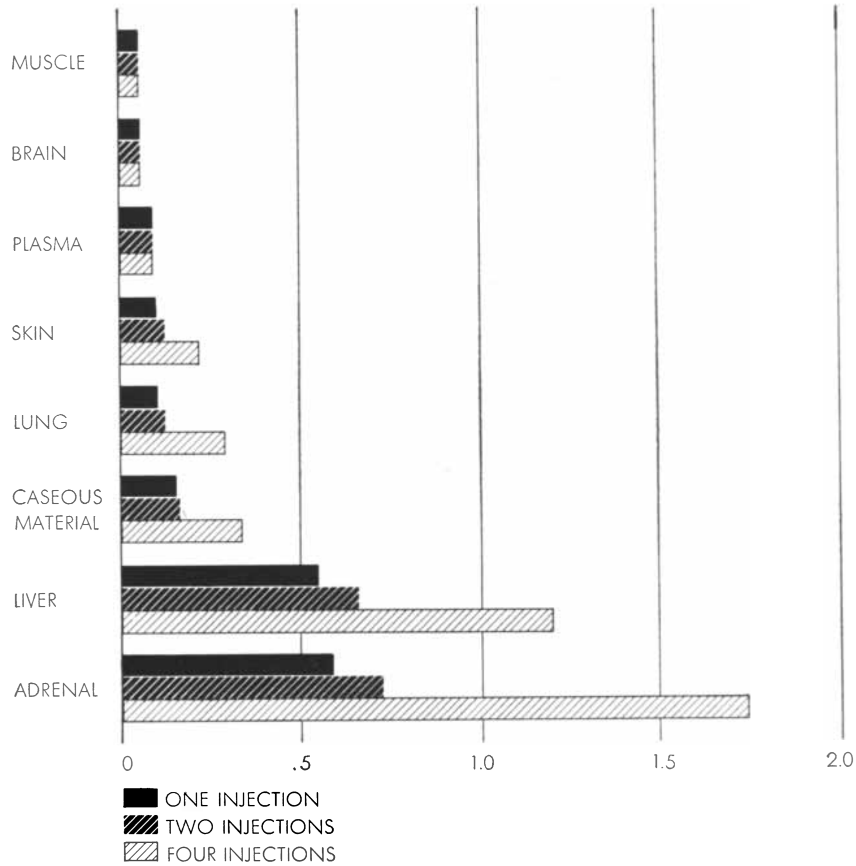


CONCENTRATION OF ISONIAZID in various tissues of guinea pigs was measured 24 hours after the animals had received their last injection of the labeled drug. The units of the scale at the bottom of this chart are millionths of a gram of Isoniazid per gram of guinea-pig tissue. Most of the Isoniazid was retained in the lungs, the liver and the adrenal glands.

same distribution in the human body that it does in laboratory animals. The drug was found in the spinal fluid, among other places, and this has a practical bearing for clinical practice. Isoniazid has proved effective in preventing the spread of bacilli into the meninges—membranes of the brain and spinal cord—which is a grave threat in tuberculosis.

Tracer experiments with PAS and streptomycin were delayed by the fact that these substances were more difficult than Isoniazid to label with radiocarbon. Pure PAS labeled with carbon 14 was synthesized some months ago by chemists in our laboratories, and we have performed experiments parallel to those with Isoniazid. Like Isoniazid, PAS quickly penetrates into tubercles. But unlike Isoniazid, it does not remain there long: it disappears from the infected organs about as rapidly as it does from the bloodstream.

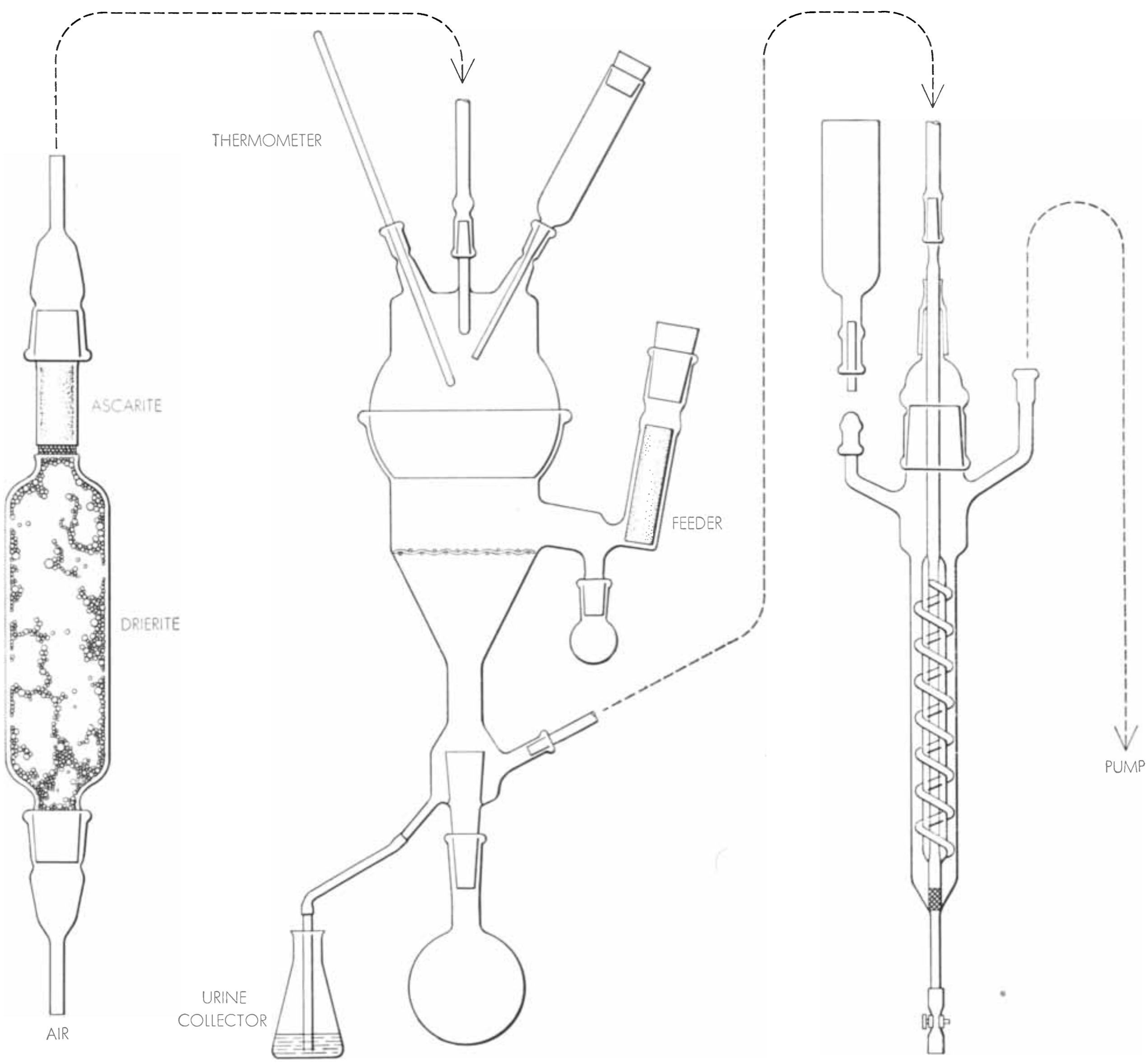
The major aim of the work with these radioactive drugs is not merely to follow their travels in the body but to discover what happens to them chemically and how they act against the bacillus. Both Isoniazid and PAS are rather simple compounds consisting of a benzene ring with a side group or two attached [*see diagrams on page 138*]. The first question was whether the compound lost its carboxyl side group (COOH) in the body. The drug was labeled with radiocarbon at this position. If it was decarboxylated in the body, the radiocarbon would be expected to appear in the carbon dioxide exhaled by the animal. In the case of Isoniazid, no appreciable radioactivity turned up in the carbon dioxide. That is to say, there was little or no decarboxylation of the drug in the body.

PAS presented an interesting problem. It was known that the compound, when decarboxylated, was ineffective against the tubercle bacillus. Furthermore, it was also known that PAS readily lost its carboxyl group under acid conditions. Consequently it was important to find out to what extent and under what circumstances the drug would be decarboxylated in the body. Doses of PAS carrying the radiocarbon label in the carboxyl group were administered to guinea pigs in a special metabolism cage.

When the drug was injected into the animals, less than 1 per cent of the radiocarbon showed up in their exhaled carbon dioxide in the following 24 hours. But when the animals received the drug by mouth, this figure rose to 4 per cent, and when the drug was kept in the acid stomach by a surgical operation which blocked discharge into the duodenum, the amount of radiocarbon excreted in carbon dioxide increased further to 11 per cent in eight hours. However, in human subjects only 1.5 per cent of the radiocarbon was found in the expired air. In view of these results, it seems that the relatively low effectiveness of PAS against tuberculosis when used alone is not due to decarboxylation of the drug.

What is responsible for the antitubercular effect of Isoniazid? Is the active agent the whole molecule, part of the molecule or a modified compound produced by metabolism of the drug in the body? This question was investigated by chemical analysis of the radioactive material in tubercles in the lung tissue removed from tubercular patients. The material was extracted from the tissue and separated into its component compounds by paper chromatography. This process separates the different compounds in different spots or bands on a paper strip, and each substance can be identified. The paper strip was then placed on photographic film to record radioactivity. The compounds that contained radioactive carbon produced dark spots or bands on the film. Two radioactive substances were found in the extract from the tubercles. One was Isoniazid itself, which accounted for the major share of the radioactivity, and the other was isonicotinic acid, a metabolic product derived from Isoniazid.

Analyzing the patients' urine in the same way, we isolated seven metabolic



OPERATION OF THE MOUSE METABOLISM CAGE depicted on the cover is traced by this drawing. The mouse stands on the screen in the vessel in the center. Water vapor and carbon dioxide are removed from the air flowing into the apparatus by Drierite and Ascarite in the column at the left. Carbon dioxide exhaled by the mouse is recovered in the alkaline absorption column at the right. The urine and feces of the mouse are collected at the bottom of the vessel in the center; thus all the metabolic products of the mouse are recovered. The radioactive carbon in these products is a clue to the manner in which the mouse has metabolized labeled drugs.

● Manufacturing ●● Manufacturing and product development ●●● Manufacturing, product development and research □●● Pilot manufacturing, product development and research

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	GPE CAPACITIES
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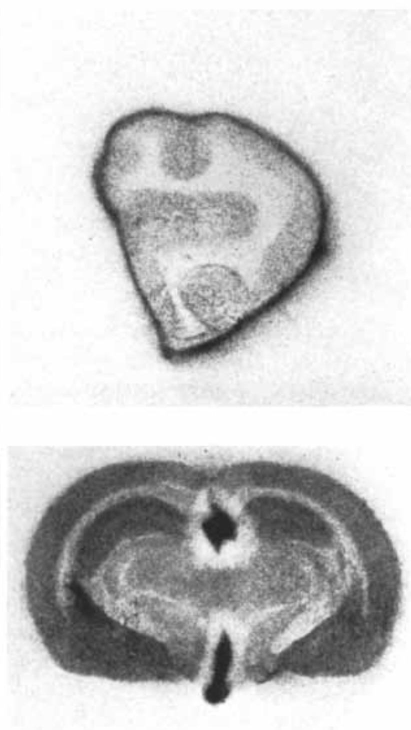
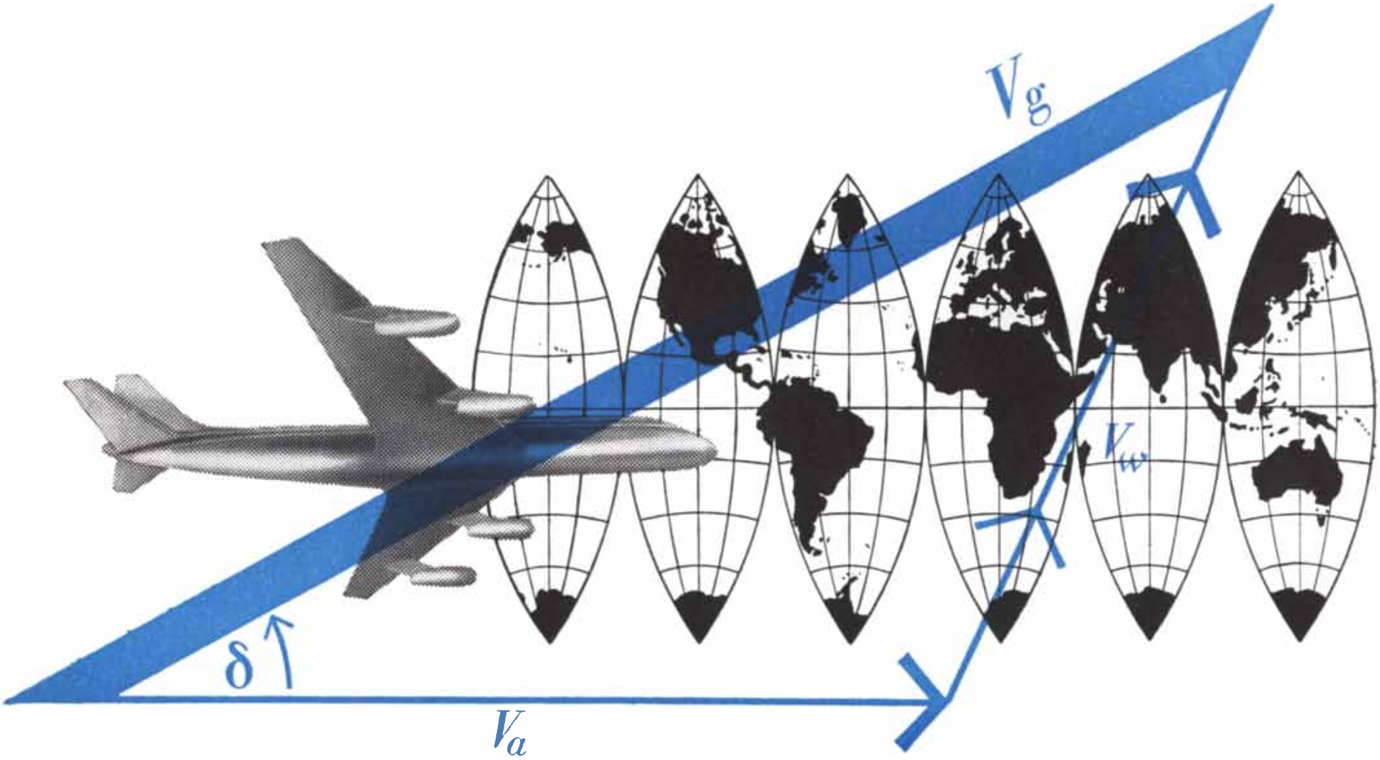
products of Isoniazid. None of these is nearly as effective against tubercle bacilli as the parent compound. Hence we must conclude that the therapeutic effect of the drug lies either in the Isoniazid molecule as a whole or in a conversion product which undergoes some further change before it is excreted in the urine.

The next question is to determine how the drug works against bacilli. Isoniazid is a very reactive chemical. It reacts with material in the red blood cells, with vitamins and with many other substances in the body. Some of the mild side effects that develop after the drug has been taken for a long time may be due to its interaction with vitamins such as ascorbic acid or pyridoxine.

A number of laboratories are now investigating the action of Isoniazid and the other antitubercular drugs, and there is hope that we may finally find the Achilles heel of the formidable tubercle bacillus.



RADIOAUTOGRAPHS indicate how Isoniazid is concentrated in brain tissue. Radioactive Isoniazid was administered to cats and rats; sections of their brains were then placed on photographic film. The radioactivity of a section of cat brain exposed the film in the pattern shown at the top; the radioactivity of a section of rat brain, in the pattern shown at the bottom. Both patterns demonstrate that Isoniazid tends to concentrate in the gray matter. The two darkest spots in the middle of the rat brain are experimental artifacts.



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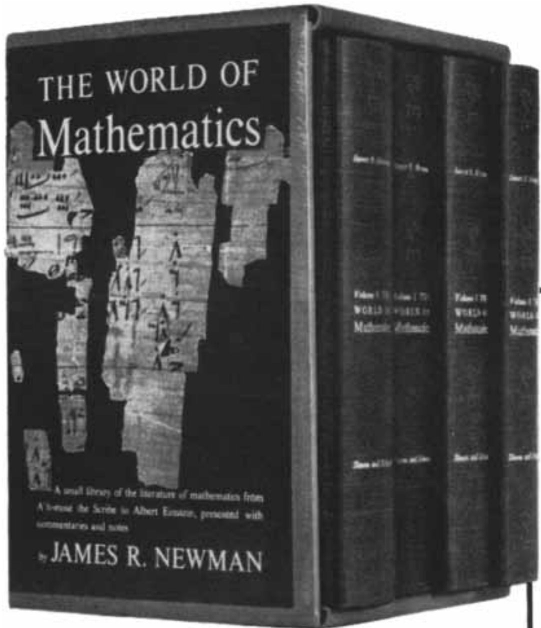

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BOOKS

A massive new collection of mathematical writing of interest to the general reader

by Max Black

The World of Mathematics, edited by James R. Newman. Simon and Schuster ($20).

This colossus of a book may be briefly described as an unrivaled anthology of writing on the nature of mathematics, its history and philosophy, and its bearing upon science, literature and human affairs. Its 2,535 pages (in four volumes) provide, according to my estimate, something like a hundred hours of the most exciting, stimulating, tantalizing, exasperating, mystifying and generally delightful reading that a man could ask for.

James Newman is well known to readers of Scientific American as a man of wit and learning with a gift for writing about science in a style that is clear but not superficial, entertaining without facetiousness or condescension. These qualities have characterized his previous books, including the well-known *Mathematics and the Imagination,* which he wrote in collaboration with the late Edward Kasner, and his writings for this magazine. In *The World of Mathematics* Newman's talent for popularization in the best sense of the word finds full scope.

The book would be well worth reading if only for the 90 essays with which Newman introduces the various selections. His commentaries range from brief accounts of the selected authors' lives and times to concise and elegant summaries of the main points of their works. I can think of no more knowledgeable or urbane guide to the treasures of mathematical literature.

Of the various sections in the book, the one on "Mathematics and Logic" is an especially good example of effective popularization of technical thought. In an introduction four pages long Newman manages to give a lucid exposition of the real point of using symbols in logic. He tells us enough about George Boole to bring that charming man to life. The selections open with a few pages from Boole's epoch-making *The Laws of Thought.* There follows a masterly sketch of the development of symbolic logic from C. I. Lewis and C. H. Langford's well-known text. It was a happy thought to choose this summary: I know of no other brief account that reviews the history of the main discoveries in logic as well. Next comes a remarkable article by Ernest Nagel, written especially for this collection, bearing the title "Symbolic Notation, Haddocks' Eyes and the Dog-Walking Ordinance." Here Nagel performs the feat of explaining the basic constituents of modern logical notation for persons without previous knowledge of the subject—something I would have thought impossible in the space provided. Nagel translates into logical symbolism a passage from Lewis Carroll (about "Haddocks' Eyes") and an amusing extract from the imaginary minutes of a town-council meeting. Turning to more serious affairs, he leads us through the early theorems of *Principia Mathematica* to the point where "$1 + 1 = 2$" has been shown to follow from principles of pure logic. Nagel's piece is followed by a substantial extract from Alfred Tarski's logic text, possibly the best book of its kind yet written. The whole section adds up to one of the best introductions to modern logic that I know. I have dwelt upon this section because it shows the difficulties Newman had to surmount, and the skill displayed in overcoming them. But there are a score of other sections that satisfy the same high standards.

In 80 pages or so the book gives a short course on probability, a subject notoriously hard to present to nonspecialists without distortion. The selections are from Pierre Simon de Laplace, Charles S. Peirce, Henri Poincaré and John Maynard Keynes, with Nagel again offering a summary of the main issues. This section, by the way, contains a fine appreciation of the life and works of Keynes, who is obviously one of Newman's heroes.

In the section on statistics are several classic papers, including Jacob Bernoulli's discussion of "The Law of Large Numbers," and more frivolous essays by Sir Ronald A. Fisher ("Mathematics of a Lady Tasting Tea") and Bernard Shaw (on gambling and insurance). I don't think anyone could learn very much about statistics from this section, but he would certainly get a very fair impression of the aims of the subject, its historical background and its importance in science and everyday affairs.

Do mathematicians seem enigmatic, or possibly inhuman? Anyone who thinks so should read Newman's extracts from G. H. Hardy's *A Mathematician's Apology*—a wonderful little book which most readers are unlikely to have come across. Or read about the strange and sad life of the great Indian genius Srinivasa Ramanujan. Nor should one miss the fascinating glimpses of the authors given in Newman's biographical sketches: Augustus De Morgan refusing an honorary degree because "he did not feel like an LL.D."; Lewis Carroll's habit of photographing his young friends in the nude; D'Arcy Wentworth Thompson lecturing to an Indian audience with an angry hen tucked under his arm; Johannes Kepler gloating over the discovery of his third law ("He was number-intoxicated, a variety of religious experience not restricted to the weak-minded," says Newman).

From curiosity about the life and character of great mathematicians, it is but a step to wonder about the nature of mathematics itself. Is it true that "mathematical reality lies outside us," as Hardy and any number of others have held? Does a mathematician discover, or does he invent? Is mathematics merely a sophisticated play with symbols? Can the "pure entities" of mathematics have any meaningful relation to the provisional, imprecise, approximate world of sensuous experience? How *can* mathematics be useful? The answers remain as controversial as in the days of Plato and Aristotle. Schools adhering to different answers—"formalists," "intuitionists," "logicists"—remain locked in bitter combat.

The World of Mathematics provides

a comprehensive guide to these intricate battlegrounds. An excellent introduction to the subject is P. E. B. Jourdain's little book *The Nature of Mathematics*, long out of print, and here reproduced in full. The discussion is carried on in essays by William Kingdon Clifford on the exactness of mathematical laws, by Richard Dedekind and Bertrand Russell on the definition of number, and by Peirce, Poincaré, J. J. Sylvester, Hermann Weyl, Richard E. von Mises and others. There are also first-rate discussions of the nature of geometry by Hermann von Helmholtz, von Mises and several more. Non-Euclidean geometry, once so mysterious, nowadays can be understood by an intelligent layman. The sections concerned (for these discussions are not all in one place) are topped off by three fine recent articles by Carl Hempel and Douglas Gasking, in which the perennial problems of the philosophy of mathematics receive precise formulation and the hope of ultimate solution.

The gem of this part of the book, to my mind, is an essay by Newman and Nagel on "Gödel's Proof," first published in SCIENTIFIC AMERICAN. Gödel's theorem, with the insight it provides on the limitations of formalism, may well prove to be the most important single mathematical result of the century. It is, however, one of the hardest to render comprehensible, and I have sometimes thought of it as the supreme test of efforts to explain mathematics to the million. I may be wrong in thinking that even these two gifted writers do not quite succeed in explaining what Gödel was up to. At least they bring the reader very close to the original line of argument, even if nobody is going to find Gödel easy.

If the going in this book is tough at times, it is a merit of Newman's plan that he does not shirk the hard questions. The sections on mathematical philosophy impress me as being on the whole a brilliant vindication of this ambitious policy.

My guess is that most lovers of mathematics are more interested in "pure" than in "applied" mathematics, and find their chief pleasure in the esthetic and philosophical aspects of the subject. Certainly many have felt something mysterious about the power of mathematical thought to emerge from the inner consciousness (or so it seems), bringing results at once certain, necessarily true and "inexorable." If God is a mathematician, as some think, men feel most godlike when they feel the thrill of mathematical discovery. Russell has written eloquently of the fascination of pure mathematics. It transports us, he says, "into the region of absolute necessity, to which not only the actual world, but every possible world, must conform; and even here it builds a habitation, or rather finds a habitation eternally standing, where our ideals are fully satisfied and our best hopes are not thwarted."

However, the applications of mathematics—to practical affairs and to the sciences—also have a powerful appeal, and Newman's book does not neglect the literature of applied mathematics. I was delighted to find that he had rescued from the obscurity of a philosopher's symposium a splendid autobiographical sketch in which Russell speaks on this aspect of the subject. He says that his early interest in mathematics was "partly mere pleasure in discovering that I possessed a certain kind of skill, partly delight in the power of deductive reasoning, partly the restfulness of mathematical certainty; but more than any of these (while I was still a boy) the belief that nature operates according to mathematical laws, and that human actions, like planetary motions, could be calculated if we had sufficient skill."

Happily we are still a long way from being able to calculate the orbits of human actions. But mathematicians have not been slow to try their hands at the social sciences or anything else. These days they can provide a geometry of foreign affairs (as in Lewis Fry Richardson's "Mathematics of War and Foreign Politics"); they undertake to hunt submarines in incredibly sophisticated ways; they apply a theory of games to open up an entirely new approach to economic questions; and they even have the audacity to try to compute ethical and esthetic values. Newman has assembled the best writing in these fields. And he has an excellent section (nearly 600 pages long) on the more conventional applications of mathematics to physics and biology. My own favorites here are Dmitri Mendeleyev on the periodic table of the elements, Gregor Mendel on the mathematics of heredity and J. B. S. Haldane's delightful essay "On Being the Right Size." But there are many other wonderful things—a fine essay on the discovery of Neptune, Werner Heisenberg and Erwin Schrödinger on the uncertainty principle, Weyl on symmetry, George Polya on how to solve mathematical problems, A. M. Turing on the theory of computing machines, and so on and on. For lovers of fun and whimsy there is some fascinating nonsense by Stephen Leacock, and a collection of just about all the mathematical puzzles, games and paradoxes that anybody has ever heard of. I must add a

special word of gratitude for the section called "Mathematics in Literature." Here are included two of my own favorite pieces: Sylvia Townsend Warner's idyllic geometry lesson in the South Seas (from her unjustly neglected book *Mr. Fortune's Maggot*) and Russell Maloney's poker-faced fantasy on the possibility of Shakespeare being typed at random by a gang of monkeys. Surely there must be things in this book to satisfy every appetite and fastidious taste.

In no other field of learning has popularization been undertaken by men of greater distinction—or with happier results—than in mathematics. But Newman has succeeded in doing what none of his eminent predecessors quite managed to do—convey unforgettably an impression of the richness and variety of mathematical thought and its long vicissitudes. I look forward to keeping these volumes close at hand, next to Sir Thomas Browne, to dip into when the news over the radio threatens to become unbearable. For mathematics, as well as philosophy, has its consolations.

Perhaps it needs to be said explicitly that nobody ought reasonably to expect to learn much mathematics from Newman's anthology. Its function is to stimulate, to provide background, not to give formal instruction. As I reflect upon its contents, it occurs to me that it contains very little that a mathematician would call "*real* mathematics," *i.e.*, sustained argument about important matters, conducted with an appropriate degree of logical rigor. There is no royal road to mathematics—or, for that matter, to anything else.

As Jourdain says at the end of his little book: "It is best to read the works of the great mathematicians." This means patience, hard work and intense concentration. The great merit of Newman's cornucopia is that it may show many people that such labor can be a joy.

Short Reviews

ALPS AND ELEPHANTS, by Sir Gavin de Beer. E. P. Dutton & Company, Inc. ($2.75). In 218 B.C. Hannibal marched his army of some 50,000 men, 12,000 horses and 50 elephants from Carthaginian Spain over the Alps into Italy. When he entered the plains of the Po and girded himself for battle with Publius Scipio at Ticinus, only half his army was left; the other half had been lost along the way in skirmishes, in crossing rivers and in the ravines and difficult places of the Alps. The elephants were soon to die in the cold of a north Italian winter. Nevertheless the march was a brilliant strategic stroke and was crowned by the victory over the Romans at Cannae, which has remained the supreme example of an annihilating battle. Hannibal's crossing of the Alps has for centuries puzzled historians. Their attempts to trace his route made little headway. This little book by the director of the British Museum of Natural History represents a fresh attempt to unravel the enigma. Sir Gavin devoted many years to his analysis, and he has brought to it his skills as a scientist, classical scholar and historian. Whether or not he has succeeded in retracing the actual route, his fine-screen sifting of evidence, weighing of probabilities and scholarly attack on the problem make an absorbing story. Sir Gavin offers proof that the key river in France which Hannibal crossed was the Aygues and not the Isère, as usually supposed. A nice example of de Beer's method is his demonstration that Hannibal must have crossed the Durance River in its middle reaches, for only at this point was the water level low enough to permit the elephants to wade across. By examining records of rainfall, rates of river flow, temperature changes in the last 2,000 years, the distribution of vegetation, stellar constellations (to fix the time), archaeological remains and other pertinent data, he is able to make a convincing case for Hannibal's line of march running through the Durance basin and across the Col de la Traversette—a 10,000-foot pass affording an unsurpassed view of the plains of Italy. Hannibal's exact track is perhaps not a vital matter, but de Beer's scientific reconstruction of it is fascinating.

THE BUBONIC PLAGUE AND ENGLAND, by Charles F. Mullett. University of Kentucky Press ($9). "Disease," said Jean Charcot, "is from old, and nothing about it changes. It is we who change as we learn to recognize what was formerly imperceptible." The history of the bubonic plague illustrates this apothegm. The plague was known and feared in ancient times; the most famous descriptions were those of Thucydides and Lucretius. For all the progress in medicine, plague has not yet been stamped out, and it still strikes terror whenever there is even a small outbreak. The most massive and dramatic visitations of the disease occurred in England in 1349 and 1665. In the more than three centuries between the catastrophe of 1349 and its dreadful recurrence in the time of Samuel Pepys and Isaac Newton scarcely a year passed that the Black Death did not decimate some English community or devastate an entire region. In this scholarly monograph Professor Mullett has gathered the scattered materials relating to the impact of the Great Pestilence on one country "in order to illustrate the evolution of concepts of public health and preventive medicine." The difficulties of the task were considerable—among them the gross imperfections of the statistics and the imprecise use by contemporaries of the word plague to describe bubonic and pneumonic plague, typhus and other disorders for which no specific names existed. Mullett's skillful evaluation of the data is impressive. His essay is necessarily burdened with detail, but it affords a remarkable panorama of the ravages of the disease and its massive effects on every aspect of life from economics to literature, as well as the reforms in medical practice, housing, sanitation and public health to which it gave rise.

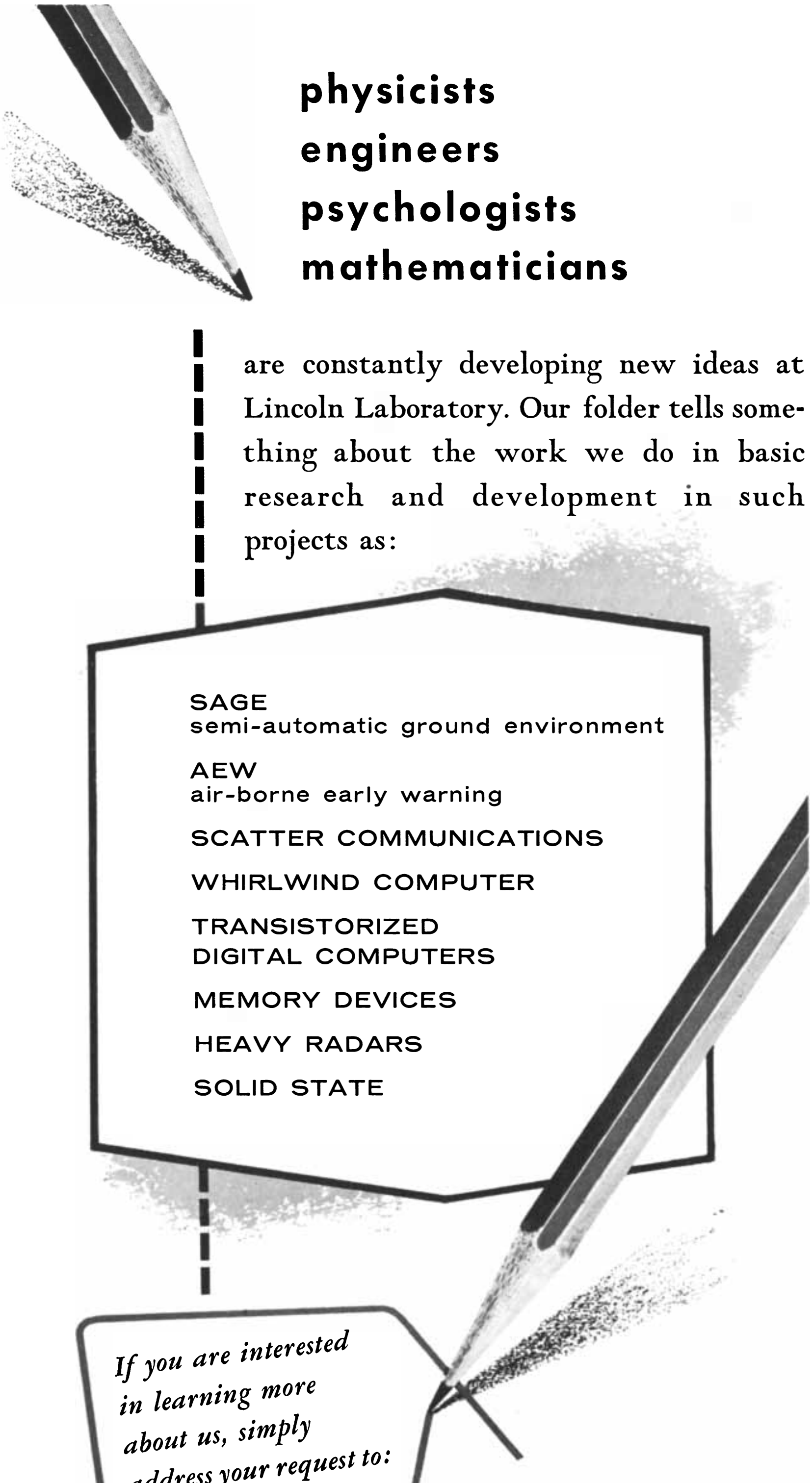
VISTAS IN ASTRONOMY, VOL. I, edited by Arthur Beer. Pergamon Press ($28). This salute to Professor F. J. M. Stratton on his retirement from the chair of astrophysics at the University of Cambridge is a good deal more than a *Festschrift*. A skillful and persevering editor has elicited from 215 authors—astronomers, physicists, geophysicists and historians—contributions representing a remarkable cross section of contemporary astronomical thought. The seven sections of the volume treat almost every phase of dynamics, theoretical astrophysics, instruments, radio astronomy and solar physics. George Sarton writes on "the astral religion of antiquity and the 'Thinking Machines' of today," comparing the present-day adulation of computers to the worship of the planets by the ancients; Hermann Bondi discourses on fact and inference in theory and in observation; Willy Hartner on Renaissance astrology and astronomy; Herbert Dingle on philosophical aspects of cosmology; Georges Lemaître on the three-body problem; E. Finlay-Freundlich on the empirical foundations of the general theory of relativity; E. H. Linfoot on modern telescopic optics; I. S. Bowen on spectrographs; H. M. Smith and G. B. Wellgate on quartz-crystal clocks; W. S. Adams on early solar research at Mount Wilson; J. H. Oort on the 21-centimeter radio waves emitted by interstellar hydrogen. The second volume, now in press, will have sections on solar-terrestrial relations, geophysics, planetary systems, stellar astronomy, photometry, spectroscopy, spectral peculiarities and novae, galaxies, cosmology and cosmogony. This is a magnificent scientific achievement, and a heartening example of international cooperation.

LOGIC, SEMANTICS, METAMATHEMATICS, by Alfred Tarski. Oxford University Press ($9.60). Collected in this volume are the principal papers of a leading Polish-American logician. Originally published in French, German and Polish, and now for the first time translated into English by J. H. Woodger, the various monographs deal with important problems of mathematics and the methodology of the sciences. The collection includes Tarski's highly regarded treatise on the concept of truth in formalized languages. Numerous footnotes direct the reader to the later literature and present information as to advances in the subject during the two decades since Tarski's papers were written.

ANALYTICAL EXPERIMENTAL PHYSICS, by Michael Ference, Jr., Harvey B. Lemon and Reginald J. Stephenson. The University of Chicago Press ($8). This is a revised edition of an immensely successful textbook which covers the whole of classical physics and incorporates enough of the latest concepts to introduce a student to the shape of the science as a whole. The first edition (1943) laid a somewhat greater emphasis upon elementary experiments and used less mathematics; but the revision retains abundant material covering the physical aspects of fundamental phenomena and adds up-to-date information in the discussions of quantum, atomic and nuclear physics, electricity, heat and thermodynamics. There are many satisfactory illustrations, but fewer than in the first edition, and their reproduction is often fuzzy.

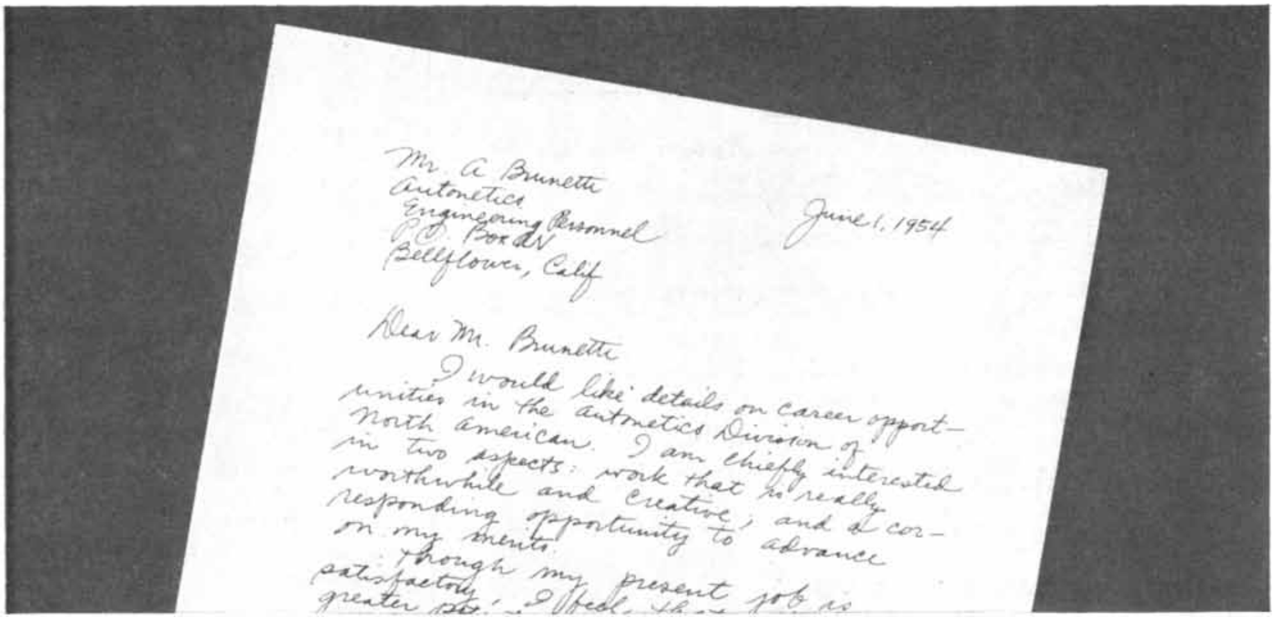
THE AMERICAN ARBACIA AND OTHER SEA URCHINS, by Ethel Browne Harvey. Princeton University Press ($6). The sea urchin is a hedgehog of the sea. It was well known to the ancient Greeks and Romans, was frequently mentioned in their writings as a food and was honored by a full description, some of which is quite correct, in Aristotle's *Historia Animalium*. According to an early English commentary, the botanist Dioscorides said of the species *Echinus marinus* that "it is good for ye stomach, good for ye belly and ureticall; the raw shell of which, being roasted does well to be mixed amongst detergentia medicamenta made for ye psorae [itch]." To this day in various parts of the world sea urchins serve as food. Some Americans, for example, have found the gonads of *Strongylocentrotus franciscanus* eaten raw with French bread "very good—extremely rich, and possibly more subtle than caviar." *Strongylocentrotus dröbachiensis*, another edible species, can be bought in New York City markets and on the streets of Greenwich Village at about five cents apiece. But sea urchins have a nobler function: they are perfect creatures for laboratory research. The *Arbacia* egg is an "ideal cell." It is simple and hardy, therefore suitable for experiments with different chemicals, variable temperature, pressure, light and so on. "The granules in the egg can be moved by centrifugal force, and the egg can be broken into halves and quarters containing different kinds of materials in definite amounts." Sea-urchin eggs have been studied with profit by cytologists, embryologists, physiologists and biochemists. The Marine Biological Laboratory at Woods Hole has a voracious appetite—scientific rather than fleshly—for *Arbacia punctulata*. In a single year 45,000 specimens were used in research. The demand is increasing, but *Arbacia* around Woods Hole are getting scarce. Perhaps they are learning. Mrs. Harvey's book is a model of loving scholarship, the sort of book D'Arcy Thompson particularly would have appreciated. There are many fine plates. A small gem of scientific literature.

THE EXPLORATION OF MARS, by Willy Ley and Wernher Von Braun. The Viking Press ($4.95). Some years ago the late Gertrude Stein gave a lecture at Princeton, in the course of which she outlined a general method for putting every scrap of information in the world on cards. When she had finished writing her syllabus on the blackboard, she suddenly turned to her learned audience and observed: "But now that we know how, why do it?" The authors of this book manage to raise the same question in the reader's mind. Their guide to interplanetary travel is the now familiar mix of fact, conjecture, meretriciously precise engineering specifications and paintings by Chesley Bonestell. After presenting a digest of knowledge, hypotheses and theories about Mars, the authors describe "Operation Space Lift." Getting to the red planet, we are told, is today only an engineering problem. Technical difficulties remain to be solved, a space station has to be built and the cost may run to a national fortune, but it is no longer open to question that "we, the genus homo of Earth, will set foot on Mars within a matter of



decades." The book is crisp in its details. Two rocket ships will be used with a total crew of 12; nine men will land in one ship, three will continue "orbiting" in the other while the explorers spend some 400 days on the Martian sands. The journey will take exactly 260 days each way. The orbital supply ship will have an empty weight of 154 tons, a take-off weight of 1,410 tons, a cutoff velocity of 1.46 miles per second (in the first stage), a specific impulse of 285 seconds (in the second stage), a thrust of 44 tons (in the third stage) and its swivel actuators will weigh .12 ton. Each ship will have eight rigid engines and during maneuver one will cover a geocentric angle of 55.4 degrees. A 12-man crew will require 17.22 tons of food (including a 20-day reserve) for the trip. Personal baggage will weigh 1.32 tons; "research specimens collected on Mars," 5.5 tons. All these and many more data are set down in closely printed tables, expressed in equivalent U. S. and metric figures. A chapter is devoted to "the human aspect" of the expedition. The men will "have to be physically sound," neither "very large" nor "excessively tall." Each one will have to know how to do everything, so that if, for example, the doctor dies, medicine and "simple dentistry" can be practiced by the radioman. The men will be in their "late twenties . . . quietly competent, with an outstanding capacity to learn, an exceptional ability of adaptation, a preference for working in and as a team . . . a sense of humor and a practical outlook [combined] with unlimited imagination." We are warned that the "neighbors' children may think they are dull, in spite of their glamorous jobs." The account of the journey is couched in a style combining White Sands space-travel jargon with Hollywood U-boat commander peremptoriness. The total effect is tiresome as well as inhuman and frightening. It would be better to go to Cannes.

LINCOLN AND THE TOOLS OF WAR, by Robert V. Bruce. The Bobbs-Merrill Company, Inc. ($5). So many Lincoln books have been written that a biographer or historian looking for something new to say has to be pretty ingenious. Dr. Bruce is both ingenious and diligent. Ransacking Army and Navy ordnance bureau files and other large collections of Civil War documents, he has dug up a good story about Lincoln's interest in weapons. Lincoln had a taste and bent for mechanics. He taught himself mathematics and surveying; as a young lawyer riding the circuit he would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AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE stop very carefully to examine any new piece of farm machinery and "shake it, lift it, roll it about, up-end it, overset it, and thus ascertain every quality which inhered in it, so far as acute and patient investigation could do it." He once prepared and delivered a lecture on "Discoveries and Inventions," and even took out a patent of his own on a device for lifting vessels over shoals. As President he was besieged by hordes of inventors, arms contractors, five-percenters, politicians, ordnance officers and other military men, all seeking his help in various phases of the weapons business. He was surprisingly accessible, because he was a friendly man and also because he was deeply interested in the improvement of existing arms and enjoyed testing new ones himself. He fired various species of breechloaders, watched new machine guns being tried, and, not without risk of his life, attended the launching of erratic rockets. He listened to schemes for flame throwers, and gave vigorous support to a program for building immense mortars to be mounted on barges as siege weapons. Among the hundreds of schemes laid before him, "one sees in silhouette almost all the feral implements of modern war," including armored tanks, submarines, poison gases, airborne incendiaries. Lincoln had not only zanies, unscrupulous munitioneers and rascally politicians to contend with, but also unimaginative generals and obstructionist ordnance experts who shuddered at the thought of using weapons not proved in the War of 1812 and who engaged in every chicanery to thwart his wishes. This book, like all other accounts of the man, demonstrates Lincoln's patience, his freedom from pretensions, his generosity, his humor, his wise, sad gentleness, his innocence coupled with a shrewd ability to pierce to the heart of a matter—and his unfailing capacity, when either nonsense or insubordination had dragged on long enough, to crack down.

MEDICAL EFFECTS OF THE ATOMIC BOMB IN JAPAN, edited by Ashley W. Oughterson and Shields Warren. McGraw-Hill Book Company, Inc. ($8). This book is based on the massive report of the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan. The topics considered include the scope of damage and its effects on medical care and facilities, the number and types of casualties, the clinical observations in Hiroshima and Nagasaki, the hematology and pathology of atomic bomb injuries. Unfortunately the book is understandable only to specialists.

An Engineer and his Family Enjoy Life in Upstate New York

where he is associated with the

Electronic Tube Division of

WESTINGHOUSE ELECTRIC CORP.
Elmira, N. Y.

Engineers change jobs for many reasons. Here is a typical example of the reasons why many engineers have selected the Westinghouse Electronic Tube Division in Elmira, N. Y., as the place to advance their engineering careers, and why they like the Elmira area as a place for pleasant family living:

"It took me several years to realize that selecting the right job in the right location is really a 'family affair'. Unless the wife and kids are happy, too, there's not much sense in sticking with a job . . . no matter how interesting the work is.

"About a year ago, we decided that 'big city' life was not doing our family any good. Marge had made a few good friends, but didn't feel she had grown 'roots'. Our two youngsters, Billy and Linda, were nervous and high-strung . . . with no good place to play. My salary was pretty fair, but the high cost of city living ate it up quickly.

"That's when I started looking around for an opportunity that would enable us to live in more congenial surroundings. We checked into several offerings, but none seemed to suit us.

"Then I saw an ad for openings in the Westinghouse Electronic Tube Division in Elmira, N. Y. It sounded like the kind of work I wanted, so I phoned Bob Jarrett, the employment supervisor, and arranged for an interview. That was our lucky day!

"After traveling to Elmira and talking with Mr. Jarrett, I found that my E.E. degree and previous experience qualified me for a position in the Camera Tube Design Section. With a little instruction, I could qualify for several other jobs, too.

"Mr. Jarrett explained about the Westinghouse pension and insurance plan. It was the kind of protection I needed for my family.

"He also told me there would be a 3% general increase in salary each Fall for the next three years, quarterly cost of living adjustments, and periodic review of my work to determine merit increases. Because the Electronic Tube Division is new and expanding rapidly, the chances for promotion are unusually good.

"I liked the looks of the clean little city, the attractive residential areas, and rolling wooded hills all around. About a mile from the plant, I spotted a super golf course!

"When I asked Bob Jarrett about outdoor activities, he said there was wonderful fishing, boating and swimming in the Finger Lakes, about 25 to 30 minutes' drive. (Lots of Westinghouse folks have summer cottages there and commute to work.)

"Well, to make a long story short, I received an offer through the mail in a few days that seemed mighty attractive. When I took Marge and the kids to see what Elmira was like, they fell in love with the place!

"My work at Westinghouse this past year has been richly rewarding. Plenty of design problems to challenge my engineering training and experience. Working together as a team, my colleagues and I are making significant contributions in the field. I'm finally advancing my engineering career.

"As for Marge and the kids, let her tell about that . . ."

"Well, like most engineers' wives, I'd be willing to live wherever Jim's work took him. But when Billy and Linda came along, it was different. I wanted them to grow up in a community where there were good schools, churches, and wholesome surroundings.

"When Jim accepted a position with the Westinghouse Electronic Tube Division and we moved to Elmira, I knew we had found exactly what we wanted.

"Everyone seemed so friendly and anxious to help us get acquainted. The folks at Westinghouse helped us locate a darling little home . . . only 6 minutes' drive from doorstep to plant!

"I was invited to join the Newcomer's Club . . . so I got acquainted quickly. And we were soon made to feel at home in one of the many churches.

"Elmira is large enough to have all kinds of organizations and cultural interests . . . community concerts, Little Theatre, camera club, bird-watching, bowling, sailing, hiking and bridge. Yet it's small enough to be close to fields and forests.

"Jim seems so much more relaxed now. He's working hard at Westinghouse because he loves it, but here he can enjoy the things he was missing in the 'big city'.

"I've found many fine places to shop . . . modern department stores, supermarkets, and everything! Our living costs are down, too. Jim grew a grand vegetable garden in our back yard . . . and I'm getting interested in raising flowers.

"Both the children have grown taller and huskier since we left the 'big city', and they've lost their high-strung temperament.

"This is real family living, and we are all growing 'roots' in the community, thanks to Jim's decision to work at Westinghouse."

If you are interested in advancing your career in the electronics field, we invite you to submit information which may lead to an interview. At present we have opportunities for engineers in Tube Design and Development for Microwave Tubes, Receiving Tubes, Pickup Devices, Power Tubes, Cathode Ray Tubes, Application Engineering, Electrical Equipment Design, Manufacturing Engineering, and Glass Engineering.

In submitting information concerning your background, phone collect to Westinghouse Electronic Tube Division, Elmira 9-3611 and ask for Robert M. Jarrett. (After 5 p.m. or weekends, phone collect Elmira 9-2360.) If you prefer, write a letter to Mr. Jarrett, Dept. W-22, giving basic information, and ask any questions you wish.

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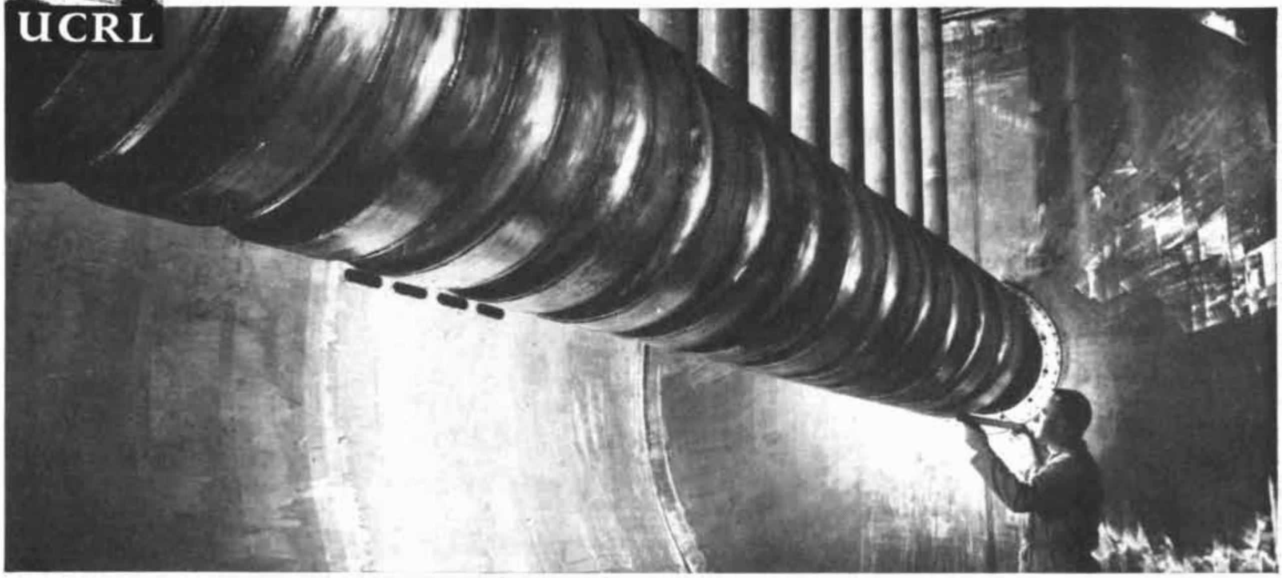

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THE AMATEUR SCIENTIST

A homemade interferometer: the instrument that can be used to measure a light wave

When two rays of light from a single source fall out of step (say after they have taken different paths and met at a common point), their waves reinforce or counteract each other, just as out-of-phase waves in water do. This effect accounts for the blueness of the bluebird, the fire of opals, the iridescence of butterfly wings and the shifting colors of soap bubbles. It also accounts indirectly for the accuracy of watches, the control of guided missiles, the quality of high-test gasoline and myriads of other achievements of technology which would not be possible without precise standards of measurement. All measurements, in the final analysis, depend upon one standard—length. Nowadays the length of the meter is calibrated in terms of wavelengths of light. The most commonly accepted standard for determining the length of the meter is the wavelength of the red light emitted by glowing cadmium in the vapor state. By interferometer methods this wavelength has been measured to a high degree of precision and comes out to be 6438.4696 ± .0009 Angstrom units (an Angstrom unit is one 10-billionth of a meter). The meter is 1,553,164.60 ± .22 times this wavelength.

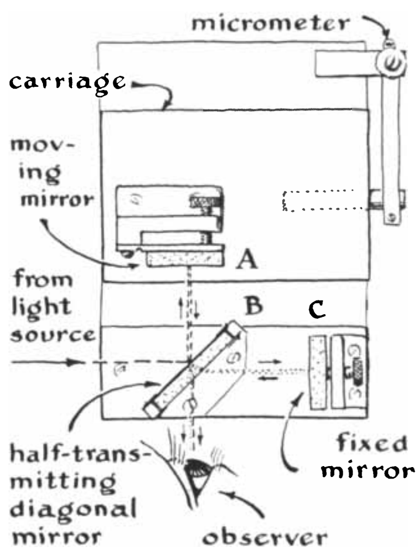
The interferometer, the most elegant of yardsticks, is a singularly finicky and frustrating gadget. A scientist once remarked: "Without a doubt the interferometer, particularly the version of it developed by Michelson, is one of the most wonderful instruments known to science—when it is operated by A. A. Michelson!" In Michelson's hands the instrument certainly established an impressive row of scientific bench marks. It was he who measured the wavelength of the red cadmium line given above.

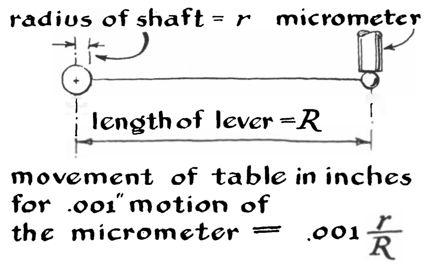
Making measurements with instruments capable of yielding precision of this order is not easy. One can fiddle with the controls of the interferometer for hours without seeing the fringes, or bands of interfering light, that serve as the graduations of length. No amateur would dream of making the instrument primarily for the purpose of using it regularly as a tool of measurement. But in constructing an interferometer and mastering the art of using it, one can learn a great deal about optics.

You can begin by repeating an experiment first performed by Isaac Newton, which demonstrates the basic principle. Simply press a spectacle lens against a glass plate and look directly into the light reflected by the combination from a wide source of light. If you use a magnifying glass, you will see several rainbow-colored rings, surrounding a tiny black spot about 1/64 of an inch in diameter at the point where the lens touches the plate.

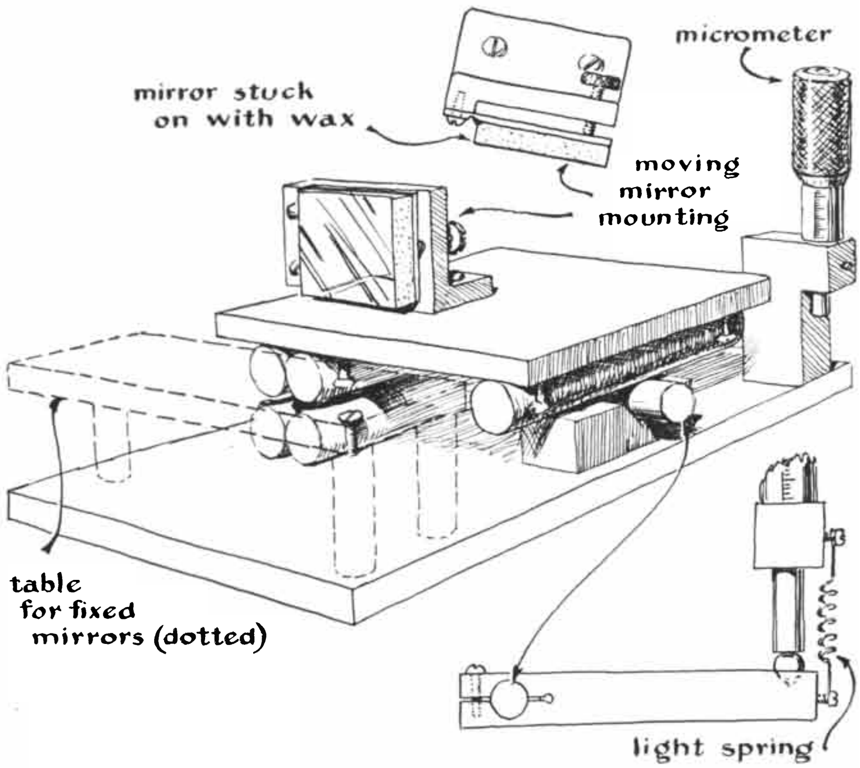
The same effect can be observed with two sheets of ordinary window glass. An irregular pattern of interference fringes will surround each point at which the surfaces of the glasses touch. The pattern will be more distinct if the light source has a single color, *e.g.*, the yellow flame produced by holding a piece of soda glass (say a clear glass stirring rod) in a gas burner. If the glass sheets are squeezed even slightly during the experiment, the pattern of fringes will shift, indicating the minute change in distance between the inner faces of the sheets.

Thomas Young, an English physician, and his French colleague Augustin Fresnel demonstrated in the latter part of the 18th century why interference fringes appear. In so doing they established the wave nature of light. They explained that if two rays of light emitted from the same source encounter reflecting surfaces at different distances from the source, the two sets of waves will end up somewhat out of step, because one has traveled a greater distance than the other. To the extent that the trough of one wave encroaches upon the crest of the other the waves interfere destructively, and the reflected light is dimmed. At various angles of view the apparent distance between the reflecting surfaces will be greater or less, and the intensity of the reflected light will appear proportionately brighter or dimmer, as the case may be. The total energy of the incident light remains unchanged by the interference. It is only the angles at which the energy is reflected that change. Hence the positions of the fringes with respect to the reflecting surfaces appear to shift when the observer moves his head. Similarly, the apparent position of





Path of light in an interferometer made by Eric F. Cave



Details of the interferometer base assembly

the fringes depends on the length of the waves. Long waves of red light may appear to annul one another completely in a certain zone, while the short waves of blue light may appear reinforced. In that case the zone will appear blue, although the light source may be emitting a mixture of both long and short waves. If the source is white light, a blend of many wavelengths, some of the colors are annulled and others are strengthened at a given angle of view, with the result that the fringes take on rainbow hues.

Similarly changes in the distance between the reflecting surfaces cause the fringes to shift, just as though the position of the eye had changed. That is why the fringes move when enough pressure is applied to bend two sheets of glass not in perfect contact.

Another interesting simple experiment is to place an extremely flat piece of glass on another flat piece, separating the two at one edge with a narrow strip of paper, so that a thin wedge of air is formed between them. When the arrangement is viewed under yellow light, the interference fringes appear as straight bands of yellow separated by dark bands which cross the plates parallel to the edges in contact. The number of yellow fringes observed is equal to half the number of wavelengths by which the plates are separated at the base of the wedge. When the paper strip is removed and the plates are brought together slowly at the base, the fringes drift down the wedge and disappear at the base, the remaining fringes growing proportionately wider. By selecting relatively large plates for the experiment, it is possible to produce a fringe movement of several inches for each change of one wavelength at the base. A version of the interferometer is based on this principle.

In short, any change which modifies the relative lengths of the paths taken by two interfering rays causes the position of the resulting fringes to shift. A change in the speed of either ray has the same effect, because the slowed ray will arrive at a distant point later than the faster one, just as if it had followed a longer path. Any material medium will slow light to less than its speed in a perfect vacuum. Air at sea level cuts its speed by about 55 miles per second, short waves being slowed somewhat more than long ones. If two interfering rays are traveling in separate evacuated vessels and air is admitted into one of the vessels, the interference fringes will shift, as if that path had been lengthened. From the movement of the fringes it is possible to determine by simple arithmetic the amount by which the speed was reduced. The ratio of the velocity of light through a vacuum to its velocity through a transparent substance is called the refractive index of that substance. The interferometer is a convenient instrument for measuring the re-

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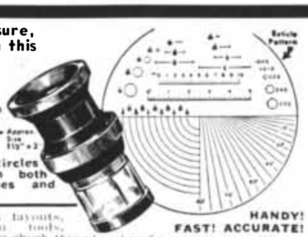

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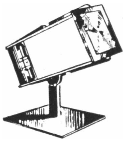

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fractive indices of gases and of liquids.

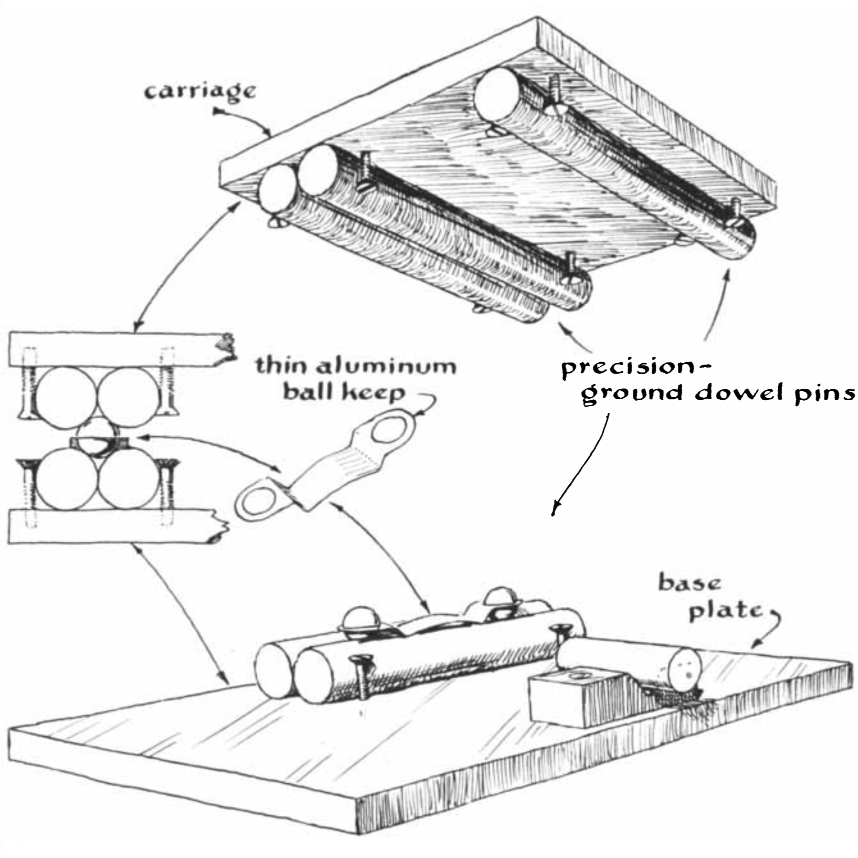
Eric F. Cave, a physicist at the University of Missouri, has designed a simple interferometer which will demonstrate many of these interesting effects and enable even beginners in optics to measure the wavelength of light. With suitable modifications the instrument can be used for constructing primary standards of length, measuring indices of refraction, determining coefficients of expansion and so on.

"The design presented here," writes Cave, "is intended to serve primarily as a guide. Most amateurs will be capable of designing their own instruments once the basic principles are understood. Optically the arrangement is similar to that devised by Michelson. A source of light, preferably of a single color, falls on a plate of glass which stands on edge and at an angle of 45 degrees with respect to the source. This plate serves as a beam-splitter. Part of the light from the source passes through the plate. This portion proceeds to a fixed mirror a few inches away, where it is reflected back to the diagonal plate. The other part of the original light beam is reflected from the surface of the diagonal at a right angle with respect to the source. It travels to a movable mirror, located the same distance from the diagonal plate as the fixed mirror, and it too is reflected back to the plate. Part of this ray passes through the plate to the eye. Here it is joined by part of the ray returned by the fixed mirror [*see drawing on page 161*].

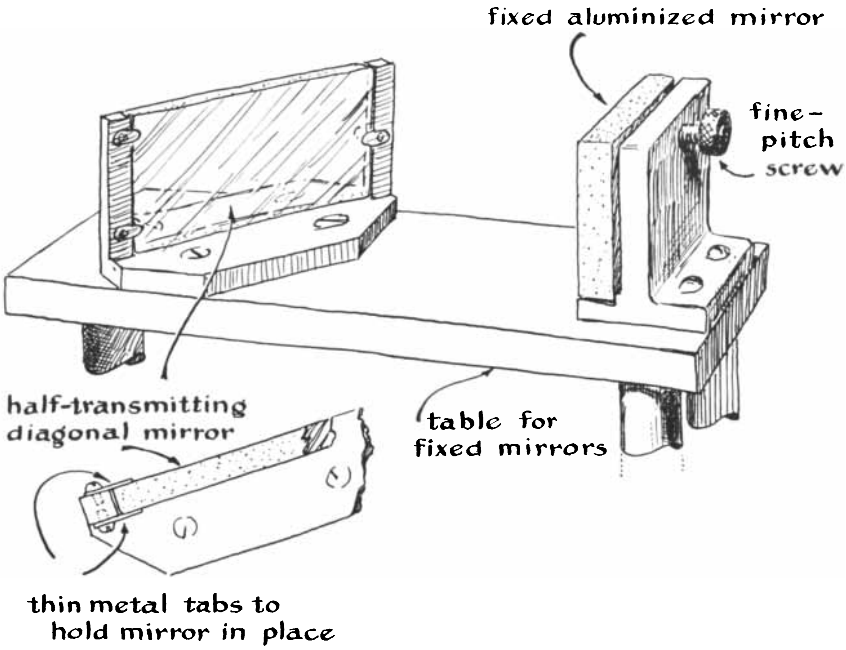
"By adjusting the positions and angles of the two mirrors relative to the diagonal plate it is possible to create the illusion that the fixed mirror occupies the plane of the movable mirror. Similarly, by adjusting the angle of either mirror slightly, it is possible to create the optical effect of a thin wedge between the two mirrors. Interference fringes will then appear, as if the two reflecting surfaces were in physical contact at one point and spaced slightly apart at another. A change in the position of the movable mirror toward or away from the beam-splitter is observed as a greatly amplified movement of the fringes.

"Beginners may expect to spend a lot of time in coaxing the instrument into adjustment. But careful construction will minimize the difficulty.

"The base can be made of almost any metal, although amateurs without access to shop facilities are advised to procure a piece of cold-rolled steel cut to specified dimensions. The instrument can be made in any convenient size. The base



Details of the interferometer carriage assembly



Details of the interferometer beam-splitter and fixed-mirror assembly

of mine is nine inches wide and 14 inches long. You will also need two other plates of the same thickness and width but only about a quarter as long. They become the carriage for supporting the movable mirror and the table on which the diagonal plate and fixed mirror are mounted.

"The carriage moves on ways consisting of dowel pins attached to its underside [*see drawing on page 162*]. The ways are made of commercially ground drill rod, which can be procured in various sizes from hardware supply houses. Each way consists of a pair of rods, one set being attached to the carriage and the other to the base. The ways can be fastened in a variety of arrangements. I fitted them into a milled slot. Flat-headed machine screws will serve equally well as fastenings if you do not have a milling machine. The bearing for the drive shaft can be a block cut with a V-shaped notch. If no shop facilities are available for machining it, you can drill four shallow holes in the base as retainers for four steel balls and simply let the shaft turn between the two sets. The height of the block or ball supports should be chosen so that the top of the carriage will parallel the top of the base when the machine is assembled. The ways move on two steel balls fitted with a ball-spacer made of thin aluminum as shown. In operation the carriage is driven back and forth by turning the drive shaft.

"The shaft may be rotated either by a worm and wheel arrangement or by a 'tangent screw.' The latter consists of a screw pressing on a bearing in a lever arm, the other end of which is attached to the shaft [*see detail at lower right in drawing on page 162*]. A tangent screw permits only a small amount of continuous travel, but it is less expensive than a worm and wheel.

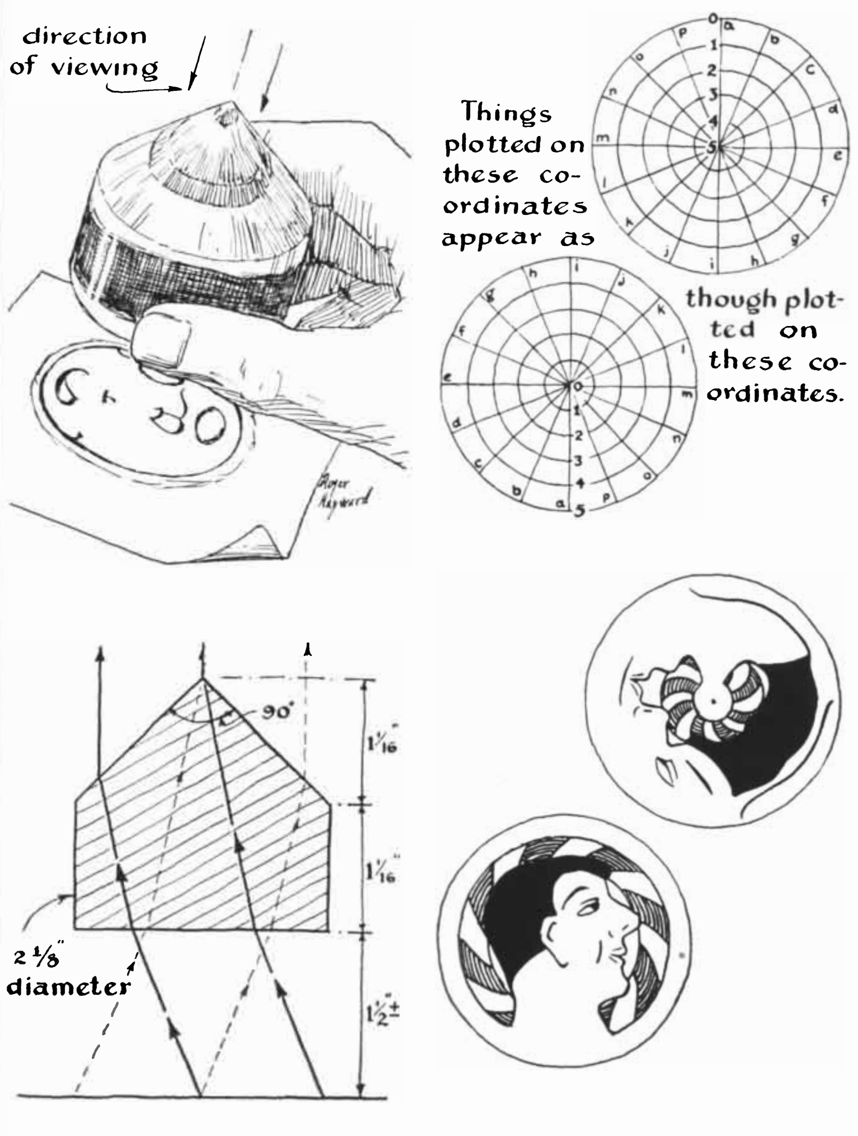
"The lever arm should be rectangular in cross section. One end is drilled for the shaft, split as shown and fitted with a clamping screw. The other end is drilled with a shallow hole for the steel ball-bearing. The screw may be a machinist's micrometer mounted on a bracket as shown. The ball bearing is held in close contact with the micrometer by a spring. The length of the lever and the diameter of the drive shaft determine the amount by which the carriage will move when the micrometer is turned.

"It should be possible to control the movement of the table smoothly through distances equal to at least one wavelength of the light under investigation. The wavelength of the yellow light emitted by glowing sodium is about one 50,000th of an inch. The tangent screw must therefore provide a geometrical reduction to distances of this order. When the machinist's micrometer is turned one division, the screw moves the outer end of the lever arm a thousandth of an inch. By adjusting the effective length of the lever arm (the distance between the center of the ball bearing under the screw and the center of the shaft) with respect to the radius of the shaft, the relative movement of the carriage can be re-

duced by any proportion desired. The reduction is equal to the radius of the shaft divided by the effective length of the lever arm. Thus a 10-inch arm coupled to a 1/4-inch shaft yields a reduction of 80 to 1, and a turn of one micrometer division produces a carriage translation of .0000125 of an inch.

"The quality of the optical parts will largely determine the experiments possible with the instrument and the extent to which it may be worth while later to add accessories and otherwise modify the design. Advanced telescope makers will doubtless prefer to grind and figure the three flats required. Those less skilled in figuring glass may order them from an optical supply house. All three elements should be flat to about a tenth of a wavelength or the resulting fringes will show serious distortion. Small squares can be cut from plate glass and tested for flatness by the method outlined in *Amateur Telescope Making* by Albert G. Ingalls. If the instrument is to be used for testing lenses, mirrors, prisms and so on, the faces of the pieces of glass should be strictly parallel to one another. Both the fixed and the movable mirror should be silvered or aluminized on the front surface, and for best results the face of the diagonal plate also should be silvered slightly, so that it will reflect about as much light as it lets through.

"Mounting brackets should support the optical elements perpendicular to the plane of the base after assembly. They should provide for finely controlled angular adjustment of the mirrors around the horizontal and the vertical axes. In the illustration here [*page 166*] the movable mirror is mounted with wax, but for anything more than an initial demonstration this is not good prac-



Roger Hayward's anamorphic lens

tice, especially if the supporting member is subject to flexure. The diagonal plate and fixed mirror are mounted on a rectangular table fixed to the base, and are located so that the center of the beam of light from the source strikes the center of the diagonal plate and is reflected at right angles to the center of the movable mirror.

"Two important conditions must be fulfilled if the instrument is to function properly. The light must originate from an extended source several feet away, and it must be monochromatic. The yellow flame obtained with soda glass is not strictly monochromatic, because most of the light comes from the brilliant spectral doublet of sodium, but it is adequate for demonstrating the instrument.

"When in operation the instrument should rest on a solid, vibrationless support. The movable mirror is placed as precisely as possible at the same distance from the beam-splitter as the fixed mirror. Preliminary adjustments are then made with the aid of a point source of light—*e.g.*, the highlight reflected from a small polished steel ball 1/16 of an inch in diameter, placed about 10 feet away. The ball should be lighted with a concentrated beam such as that provided by a 300-watt slide projector. The ball is located to the left of the observer when he faces the movable mirror and in line with the center of the beam-splitter and fixed mirror. When you look at the movable mirror through the beam-splitter, you will see two images of the source. You change the angles of both mirrors by means of the adjusting screws until the images of the source coincide. Now you substitute the sodium source of light for the ball. If the distances of the mirrors from the beam-splitter are essentially equal, you should see a number of concentric circles in orange and black like those of a rifle target. The orange color is characteristic of the sodium doublet, while the black circles mark zones of destructive interference between beams reflected by the two mirrors. Remember that you are making exquisite adjustments requiring patience.

"To measure the wavelength of sodium light, first note the precise position of the micrometer and then turn it slowly while counting the number of times the bull's-eye of the target changes from orange to black and back to orange again. From orange to orange or black to black is a half wavelength. Count, say, 100 of these color changes. The carriage has then moved 100 times the half wavelength of sodium light. Read the micrometer setting and subtract it from the first reading. This difference, when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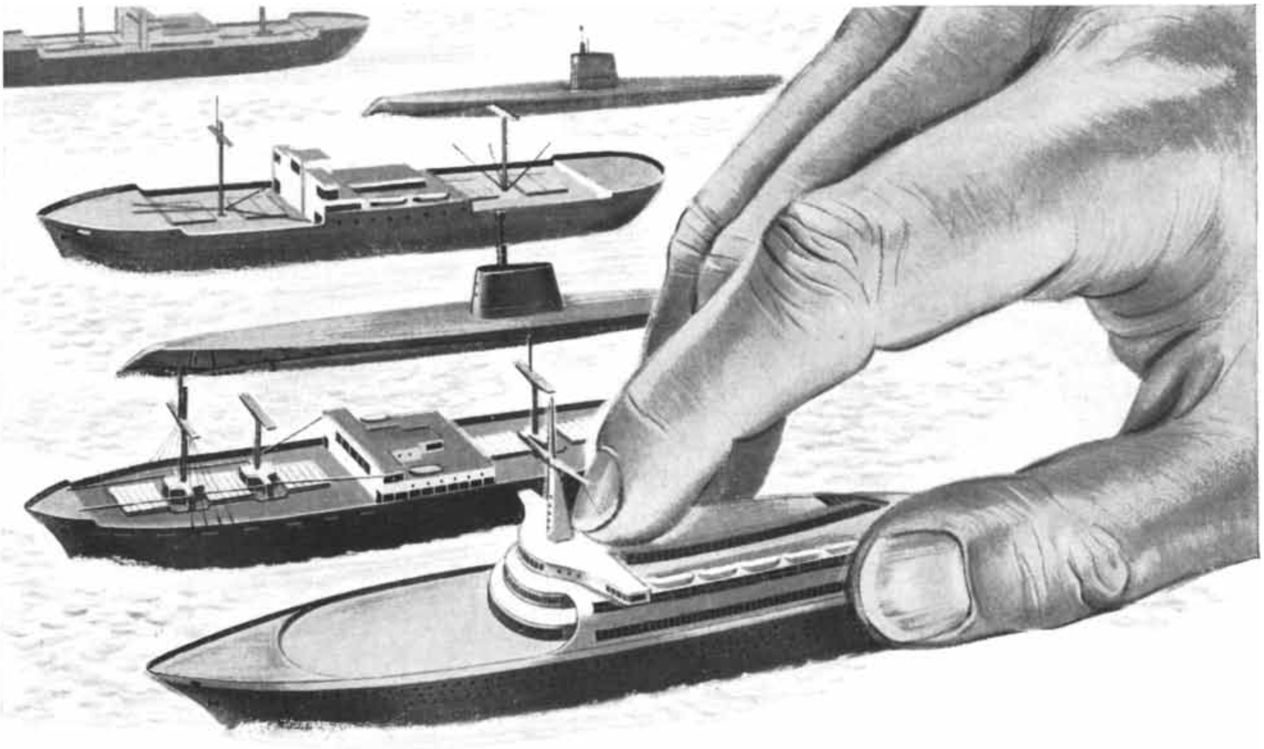
divided by the geometrical reduction provided by the tangent screw, is equal to 50 wavelengths of the light. In reality we are working with the sodium doublet, of course. The wavelength of one of the sodium lines is .000023188 of an inch and the other is .000023216 of an inch. If your experiment comes out correctly, therefore, your instrument will show the average of the two, or .000023202 of an inch. The fact that you are dealing with light of two close wavelengths may cause poor contrast between the orange and dark fringes at certain positions of the carriage. A slight displacement of the carriage from this position will produce maximum contrast.

"This design is intended merely to whet an appetite for interferometry. The instrument and theory discussed here are mere introductions to the subject. Before the instrument can yield results comparable with those achieved by Michelson, it must be provided with a monochromatic source, such as the light emitted by the red line of cadmium. Advanced instruments are provided with a small telescope for viewing the fringes. In addition, Michelson inserted a second diagonal plate in the path between the beam-splitter and the movable mirror. It is unsilvered but otherwise identical with the beam-splitter. This plate equalizes the thickness of glass traversed by the two beams and prevents the short waves in one beam from being retarded more than those in the other.

"Interferometers can be equipped with accessories for measuring the physical constants of solids, liquids and gases. Glass containers provided with optically flat windows can be introduced into the beams. When the air in one is slowly displaced with a gas, the fringes will drift across the field just as if the carriage were being moved. A count can easily be reduced to the index of refraction of the gas. The coefficient of expansion of a solid with respect to changes in temperature can be determined by clamping the specimen, fitted with a thermometer, between the carriage and base. A count of the fringes is then converted into the dimensional change of the specimen. This information, together with the temperature difference, enables an experimenter to compute the desired coefficient."

Since the war much interest has been attracted by the field of anamorphic optics—systems of lenses or mirrors shaped to create distorted images. In the motion-picture industry, for example, most cameras are now fitted with anamorphic lenses which compress images

ENGINEERS, SCIENTISTS...



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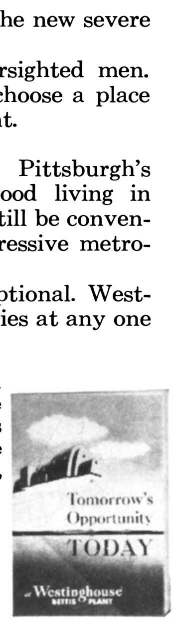

BETTIS PLANT

Westinghouse

in horizontal azimuth. In the resulting pictures actors appear tall and skinny and cylindrical shapes come out as ellipses standing on end. A corresponding lens on the projector then spreads the scene out on a screen as though it had been made with a conventional camera on wide film.

Other forms of distorting lenses are finding increasing use in scientific instruments. They serve to exaggerate some desired observation, such as the position of the bubble in a level or the drift of the pip on a radar screen, while suppressing the images of other objects or movements.

Roger Hayward, who illustrates this department, occasionally dipped into the field of anamorphic optics in his work on the design of instruments for the Armed Forces at the Mount Wilson Observatory during the war.

"Back in the 1930s," he writes, "while trying my hand at a bit of ray tracing, I decided as an exercise to investigate the behavior of a conical lens. As things worked out, the lens proved far easier to make than to compute, so I put away the paper and pencil, chucked a rod of two-inch lucite into my lathe and went to work. The finished element took the form of a short cylinder topped by a 90-degree cone [*see drawings on page 168*]. Subsequent tests disclosed that it was endowed with a remarkable property.

"When one looks through the pointed end at an object facing the base, the image appears reversed and turned inside out! The rays that pass near the edge of the lens create the illusion of coming from the middle of the object, and those from the middle seem to come from the edge, as shown in the sketch.

"I decided it would be interesting to support the lens above a piece of paper and try to draw a recognizable picture through it. This proved to be a weird experience, because the tip of the pencil would move off in totally unexpected directions. The drawing at the upper left (beneath the lens) shows a pattern which, after inversion by the lens, becomes 'Roger.' Similarly the figures at the lower right show the distorted and restored versions of a cartoon. I made a practical application of this lens in a navigation instrument for use in the air during the war; for this, through the good offices of the people at Wright Field, I subsequently received a patent.

"The 90-degree cone shown here can be changed to other angles and dimensions which produce equally interesting effects. The shapes of anamorphic lenses are of course by no means limited to that of the cone."

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BIBLIOGRAPHY

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

THE ARTIFICIAL SATELLITE AS A RESEARCH INSTRUMENT

SCIENTIFIC USES OF EARTH SATELLITES. Edited by J. A. Van Allen. University of Michigan Press, 1956.

TRANSFORMED BACTERIA

THE GENETIC CHEMISTRY OF THE PNEUMOCOCCAL TRANSFORMATIONS. Rollin D. Hotchkiss in *The Harvey Lectures (1953-54)*, Series 49, pages 124-144. Academic Press Inc., 1955.

EXPERIMENTS IN GROUP CONFLICT

GROUPS IN HARMONY AND TENSION. Muzafer Sherif and Carolyn W. Sherif. Harper & Brothers, 1953.

RUBBER

THE CHEMISTRY AND TECHNOLOGY OF RUBBER. Edited by Carroll C. Davis and John T. Blake. Reinhold Publishing Corporation, 1937.

RUBBER AND ITS USE. Harry L. Fisher. Chemical Publishing Co., Inc., 1941.

THE BIRTH OF THE NUCLEAR ATOM

RADIOACTIVE SUBSTANCES AND THEIR RADIATIONS. E. Rutherford. Cambridge University Press, 1913.

APPETITE AND OBESITY

THE PHYSIOLOGICAL BASIS OF OBESITY AND LEANNESS. Jean Mayer in *Nutrition Abstracts and Reviews*, Vol. 25, No. 3, pages 597-611; July, 1955; Vol. 25, No. 4, pages 871-883; October, 1955.

UNORTHODOX METHODS OF SPERM TRANSFER

BEHAVIOR AND MORPHOLOGICAL CHANGES IN THE LEECH, PLACOBDELLA PARASITICA, DURING HYPODERMIC INSEMINATION. Raymond J. Myers in *Journal of Morphology*, Vol. 57, No. 2, pages 617-653; June, 1935.

BIOLOGISCHE STUDIEN AN GRIECHISCHEN, CORSISCHEN UND DEUTSCHEN SPINNEN.

Ulrich Gerhardt in *Zeitschrift für Morphologie und Okologie der Tiere*, Vol. 10, pages 576-675; 1928.

Description of Clepsine plana. C. O. Whitman in *Journal of Morphology*, Vol. 4, No. 3, pages 407-418; January, 1891.

Existence chez certains Hémiptères Anthocoridae d'un Organe Analogue a l'Organe de Ribaga. Jacques Carayon in *Bulletin du Muséum National d'Histoire Naturelle*, Series 2, Vol. 24, pages 89-97; 1952.

La Fécondation des Eponges Calcaires. Odette Tuzet in *Vie et Milieu*, Vol. 1, No. 1, pages 163-177; 1950.

Observation upon Stenostomum oesophagium. William A. Kepner, Jeanette S. Carter and Margaret Hess in *The Biological Bulletin*, Vol. 64, No. 3, pages 405-417; June, 1933.

Reproduction des Hirudinées. Emile Brumpt in *Mémoires de la Société Zoologique de France*, Vol. 13, pages 286-430; 1900.

Spermatophores as a Means of Hypodermic Impregnation. C. O. Whitman in *Journal of Morphology*, Vol. 4, No. 3, pages 361-406; January, 1891.

Traité de Zoologie: Vol. 6. Edited by Pierre-P. Grassé. Masson et Cie., 1949.

Vergleichende Studien über die Morphologie des männlichen Tasters und die Biologie der Kopulation der Spinnen: Versuch einer zusammenfassenden Darstellung auf Grund eigener Beobachtungen. Ulrich Gerhardt in *Archiv für Naturgeschichte*, Vol. 87, Section A, No. 4, pages 78-247; 1921.

Das Verhalten der Spermien in der weiblichen Bettwanze (Cimex lectularius L.) und der Verbleib der überschüssigen Spermamasse. Rudolf Abraham in *Zeitschrift für Parasitenkunde*, Vol. 6, No. 5, pages 559-591; July, 1934.

RADIOACTIVE TUBERCULOSIS DRUGS

Radioactive Tracers in Biology: An Introduction to Tracer Methodology. Martin D. Kamen. Academic Press Inc., 1951.

THE AMATEUR SCIENTIST

Inexpensive Michelson Interferometer. Eric F. Cave and Louis V. Holroyd in *American Journal of Physics*, Vol. 23, No. 1, pages 61-63; January, 1955.

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