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May 1953

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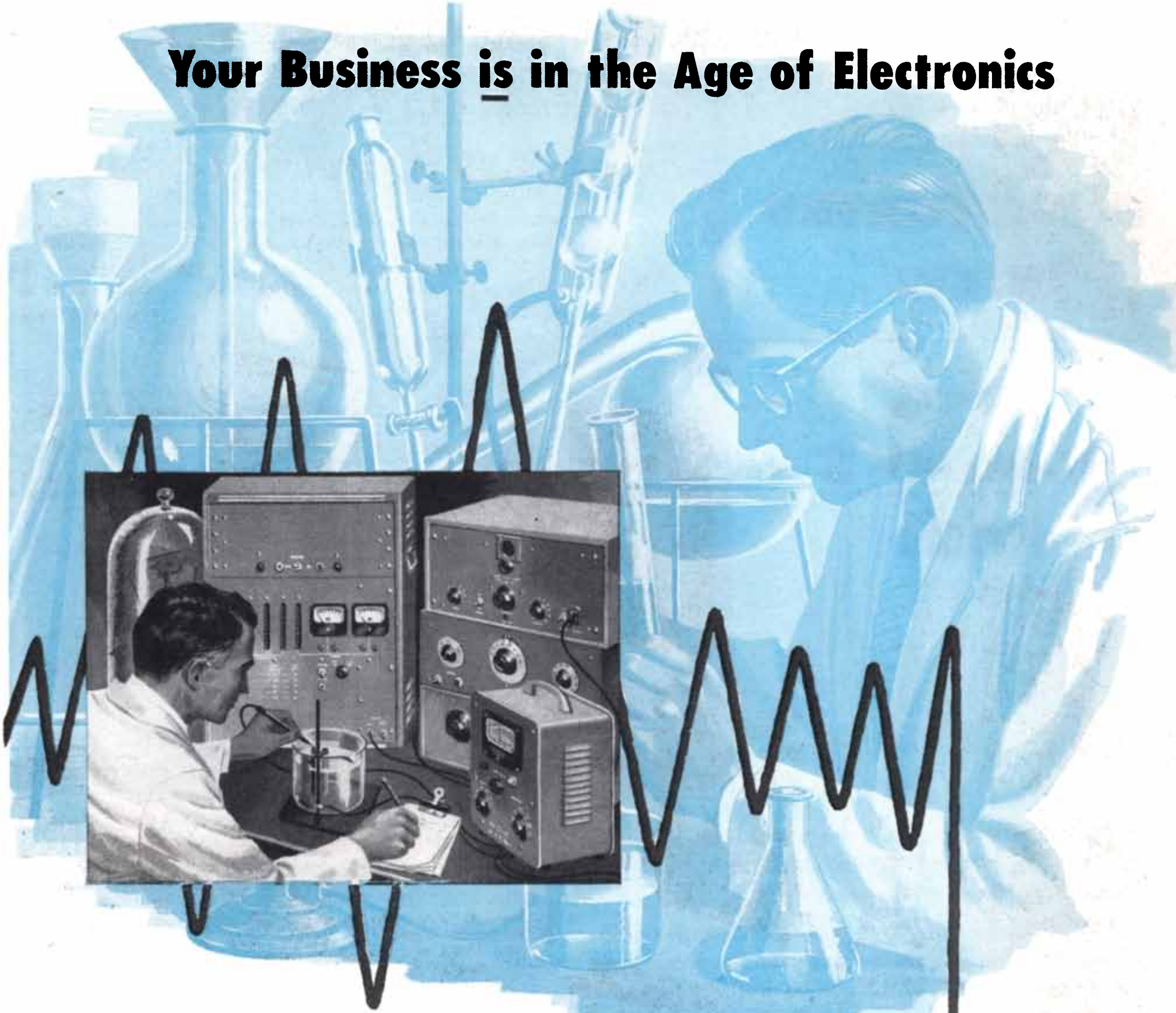

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LETTERS

Sirs:

My article in your March issue entitled "Discoveries in Nitrogen Fixation" contains the statement: "Rhizobium . . . inhabits the root nodules of leguminous plants, such as peas, barley and oats." The end of this sentence should read, "peas, alfalfa and clover." I am indebted to Mr. James H. Murray of Sunset Hill Farm, Valparaiso, Ind., for bringing this error to my attention. I regret any confusion which may have arisen in the minds of those readers of *Scientific American* who have been aware that barley and oats have never been regarded as nodule-bearing. The slip is entirely mine and in no way involves the editorial staff of *Scientific American*.

MARTIN D. KAMEN

Washington University
St. Louis, Mo.

Sirs:

Alfred O. C. Nier wrote a fascinating account of today's work with mass spectrometers in your March issue, but he just missed telling how mass spectrometers might be used to find uranium ores.

He discusses the large variations in the ratio of the two helium isotopes and says: "Hence the problem of explaining the variations is extremely complex."

Part of these variations are not too complex to explain, and, I think, might interest your readers. Helium in the ground comes mostly from uranium de-

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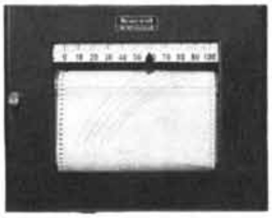

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posits. The variation in isotope ratios from this helium is largely caused by variations in the *concentration* of uranium in the earth. Thus helium-isotope-ratio measurements can be used to differentiate between rich and lean uranium ores by analyzing helium samples from the site—without sampling the ore.

The reason that variations in the uranium *concentration* cause variations in the *isotope ratio* goes as follows: Ore deposits release helium 4 (as alpha particles) and neutrons (from alpha particle-neutron reactions with the gangue material and from spontaneous fission). The neutrons are either captured in the gangue material and make some helium 3 (from lithium, etc.), or they are captured by uranium and make no helium 3. Thus, if there is a large concentration of uranium, there will be little helium 3 made, and therefore a small helium 3-helium 4 ratio. And vice-versa.

Mass spectrometers can help to find uranium ore!

JOHN R. MENKE

Nuclear Development Associates
White Plains, N. Y.

Sirs:

I was dismayed by the correspondence in the letters department of the March *Scientific American.* As you will recall, a gentleman named Max Gruenthal wrote to say that he deplored your article "Psychotherapy for Schizophrenia." You then published a reply from the author of the article, Don D. Jackson.

Although Dr. Jackson competently defended his position, he did not come to grips with an important issue raised by Dr. Gruenthal. Indeed, it may be unethical for a physician to comment on such things. Since I am not a physician, I have no such constraint.

I refer to the whole issue of whether experimental medicine is a subject for articles in newspapers and magazines read by laymen. Dr. Gruenthal seemed to feel that Dr. Jackson's article was unfortunate because (1) it reflected the view of a minority in psychiatry and (2) it aroused the hopes of schizophrenics and their relatives.

Now most articles about new techniques in medicine could be criticized in the same way. I wonder if Dr. Gruenthal suggests that all such articles are bad. He at least implies this, and other physicians have been more explicit in taking a similar position. I, for one, feel that it would be most unfortunate if newspaper and magazine editors agreed with them.

Many physicians find it annoying when a patient asks them about some new medical discovery. I imagine some physicians feel that this challenges their competence. Some must find it a nui-

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Chemical Symbol	O_2
Atomic Number	8
Periodic Group	VI
Atomic Weight	16.00
Molecular Weight	32.00
Molecular Diameter	3.39×10^{-8} cm
Isotopes	16, 17, 18
Allotropes	Ozone (O_3)
Valence	2 and 6
Concentration in Dry Air	20.93%
Boiling Point (atm. press.)	—183.1°C
Melting Point	—218.8°C
Critical Temperature	—118.8°C
Critical Pressure	49.7 atm.
Critical Density	0.430 gm/cc

Vapor Pressure at Various Temperatures:

Pressure mm. Hg	Temperature °C.
0.76	—219.8
7.60	—211.5
76.0	—200.6
190.0	—194.3
380.0	—189.0
760.0	—183.1

Latent Heat of Vaporization	1635.8 cal./mol. @ B.P.
Latent Heat of Fusion	106.0 cal./mol. @ M.P.
Heat of Reaction with Carbon (Coke)	97,000 cal./mol.
Heat of Reaction with Carbon (Graphite)	94,400 cal./mol.
Heat of Reaction with Hydrogen	68,317 cal./mol.

Boiling Points of O_2 - N_2 Mixtures: 1 atm. Pressure

O_2%	BP °K
90	87.7
95	88.9
98	89.9
99	90.0
99.5	90.1

Entropy: 1 Atm.

T °K	Cal / gm mole °K
50	12.52
100	40.58
150	43.31
200	45.36
250	46.84
273.1	47.75
298.1	48.04

Molal Volume: 0° C, 1 atm. (g) 22,397 cc

Specific Gravity:

@ 0° C (g)	1.429
@ —182.9° C (l)	1.14
@ —252.5° C (s)	1.426

Specific Heat:

BP to 25°C (g)	6.98 cal/gm mol.
—183° to —200°C (l)	12.62 cal/gm mol.
—221.8°C (s)	10.74 cal/gm mol.

Coefficient of Thermal Expansion:

0° C to 100° C (g)	3.674×10^{-3}
—195° C (l)	4.10×10^{-3}

Compressibility Factor: PV = 1.0 @ 1 atm., 0° C

P, atm.	0°C	50°C	100°C	200°C
1	1.0000	1.1838	1.3674	
10	0.9913	1.1796	1.3661	
50	0.9569	1.1642	1.3630	
100	0.9234	1.1520	1.3651	
200	0.9140		1.4000	1.8190
300	0.9625		1.4530	1.8850
400	1.0515		1.5320	1.9610
500	1.1560		1.6220	2.0500

$\frac{C_p}{C_v}$ (atm. pressure)

0°C.	$\frac{C_p}{C_v}$
15	1.401
—76	1.415
—181	1.45

Vanderwaal's Constants: a = 1.360 (liter^2, atm. mole^{-2})
b = 0.03183 (liters, mole^{-1})

Solubility in Water:
4.89 cc in 100 cc @ 0° C
2.6 cc in 100 cc @ 30° C
1.7 cc in 100 cc @ 100° C

Viscosity:
@ BP (g) 0.00736 CP
@ MP (l) 0.883 CP
@ 0° C (g) 0.0192 CP
@ —193°C (l) 0.245 CP

Moisture Content of Saturated Oxygen .130 gm/ft^3 @ 0°C

Thermal Conductivity:

	cal. / cm-sec- °C
0°C (g)	5.7×10^{-5}
—78.4°C (g)	4.29×10^{-5}
—191.4°C (g)	1.72×10^{-5}

Index of Refraction: —181°C (g) 1.221

Remember that oxygen is one of the least expensive elements available in pure form, and is finding increasing use in more and more fields. As supplier or user, remember that Chemical Plants builds complete production units in many commercial sizes—based on the processes of Gesellschaft fuer Linde's Eismaschinen, A. G.

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sance to have to explain such things. It is possible to sympathize with these feelings, but one must also consider the viewpoint of the patient. Nothing is more comforting to the patient than to learn that his doctor is fully aware of the latest work in his field. Surely questions by the patient can do no harm, and in many cases they might do some good.

Everyone realizes that some popular articles about medicine are inaccurate or irresponsible. This, however, is not to say that all popular articles are dangerous. In the case of Dr. Jackson's article, I felt that I had learned about an important new study of medicine. If I felt that similar studies were being withheld for the reasons cited by Dr. Gruenthal, I would be rather disturbed. The article by Dr. Jackson was clear and informative, and although Dr. Jackson is apparently a member of a minority in psychiatry, his views are shared by many other serious workers. I hope we will see more such articles, not fewer.

ALBERT R. BRYAN

New York, N. Y.

Sirs:

The article entitled "The Embryologist and the Protozoon" in your March issue was an unusual piece of work. I am referring not so much to its content, though that was interesting enough, but to its narrative form.

One often wonders why there is such a difference between the writing of scientists and what we might call creative writing. To be sure, it would not do for the technical papers of science to be written in the language of the novelist. This presumably would take too much space, and provide less precise information than is required by the readers of such papers. Moreover, scientists are scientists and not writers; it would not do for a creative scientist to spend too much of his time learning to write.

The popular writing of scientists, however, is another matter. Presumably the scientists who write such material do so in order that non-scientists can comprehend their work. If this is the case, why not use the full arsenal of modern writing: the narrative, dialogue, figures of speech and so on. In this way the scientist might really be able to tell us how he works, instead of merely giving us his results.

The author of your article has made a small step in the right direction with his third-person narrative about the embryologist observing the protozoon. I hope other scientists will follow his lead and use similar approaches.

H. R. GOLDSTEIN

Philadelphia, Pa.

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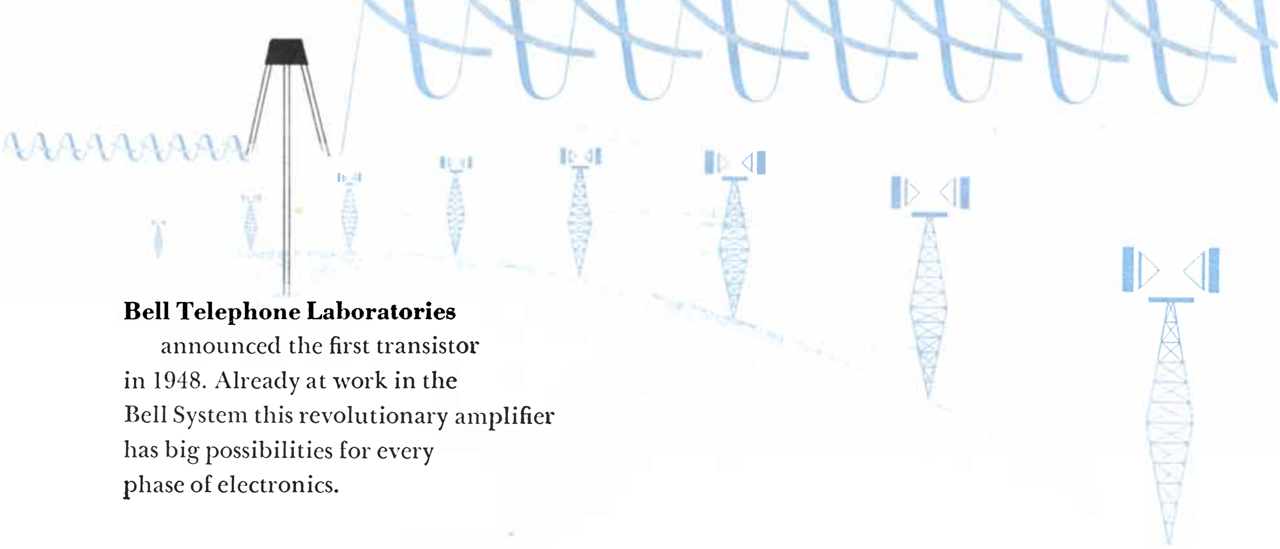

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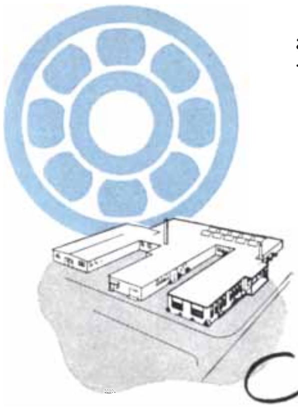

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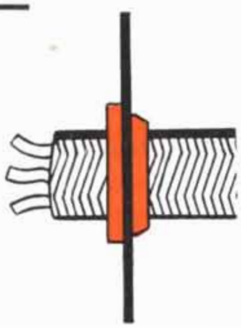
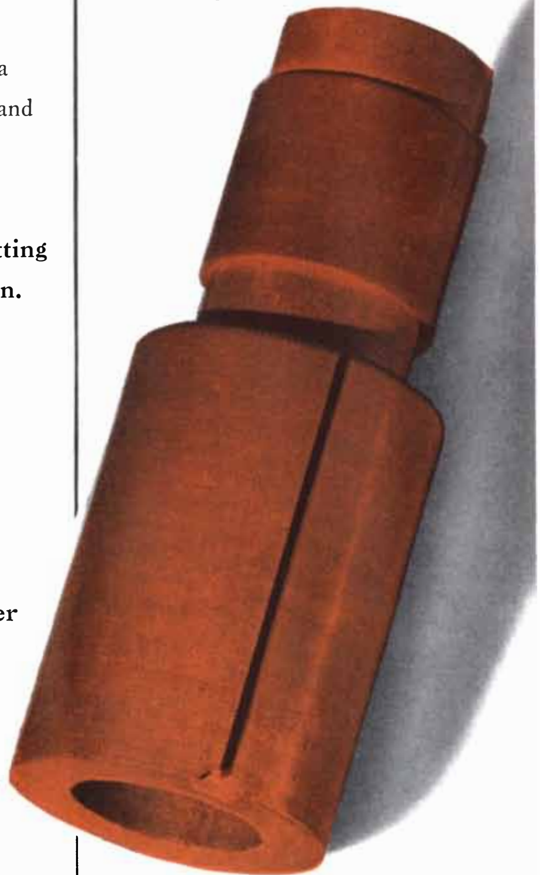


Here's a side-view of a Dilecto grommet, machined to close tolerances from laminated rolled tubing. Sample of grommet and a general catalog will be sent on request.

DILECTO is a C-D-F top quality laminated thermosetting plastic whose uses are limited only by the imagination. Supplied in sheets, rods, tubes, Dilecto answers most electrical and radio needs for a material that is mechanically and dielectrically strong . . . resistant to high heat, hot oil, excessive humidity. It can be punched, stamped, formed and machined to close tolerances. Investigate its possibilities. Available in many grades to meet a variety of requirements. A qualified plastics specialist, your C-D-F sales engineer (offices in principal cities) will help you engineer a better product. Why not call him today!



Another example of a part machined from Dilecto rolled tubing. Notice variety of machining steps and the possible versatility of this mechanically strong material. Only C-D-F makes Dilecto in sheet, tube and rod forms.

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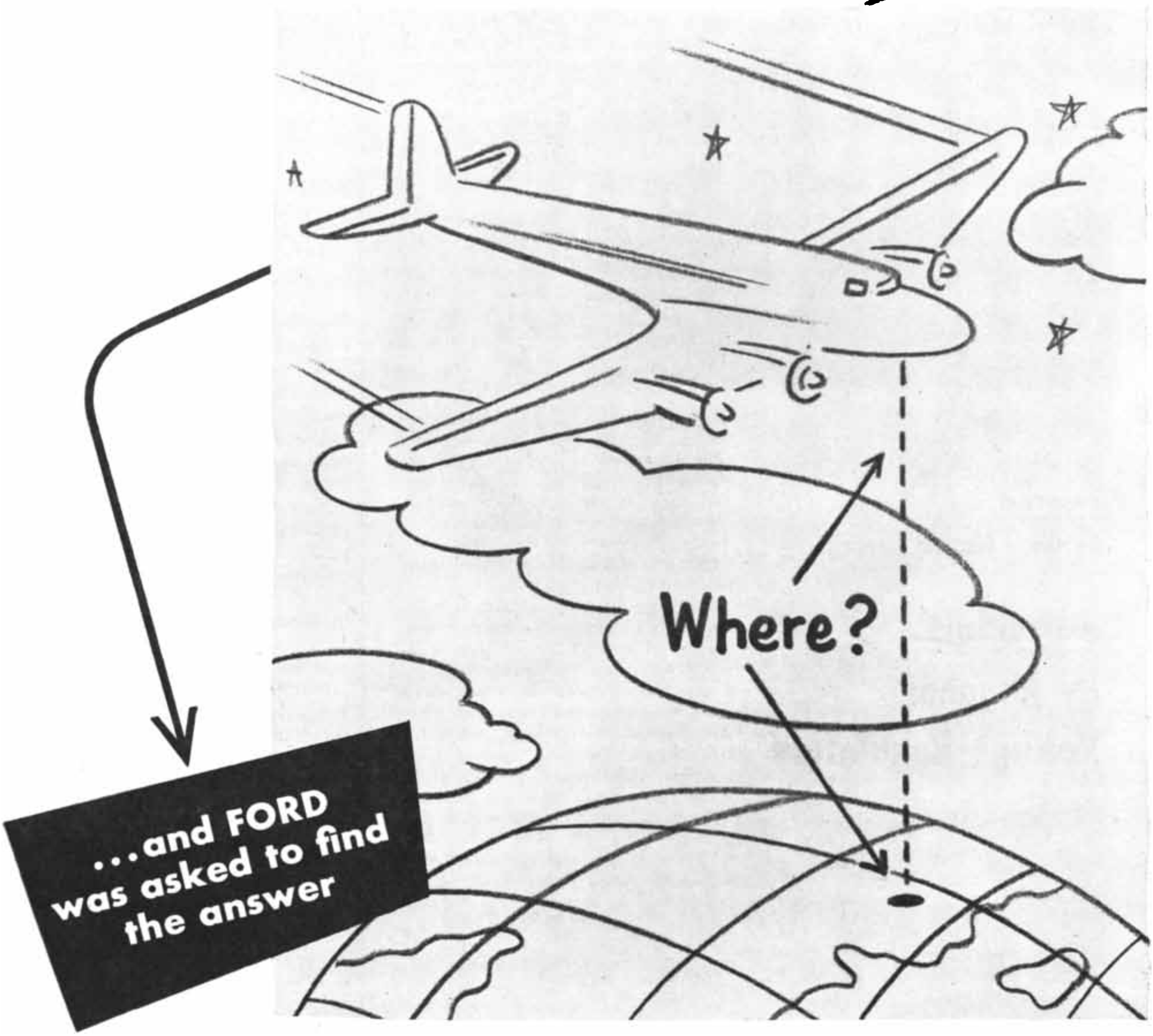

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

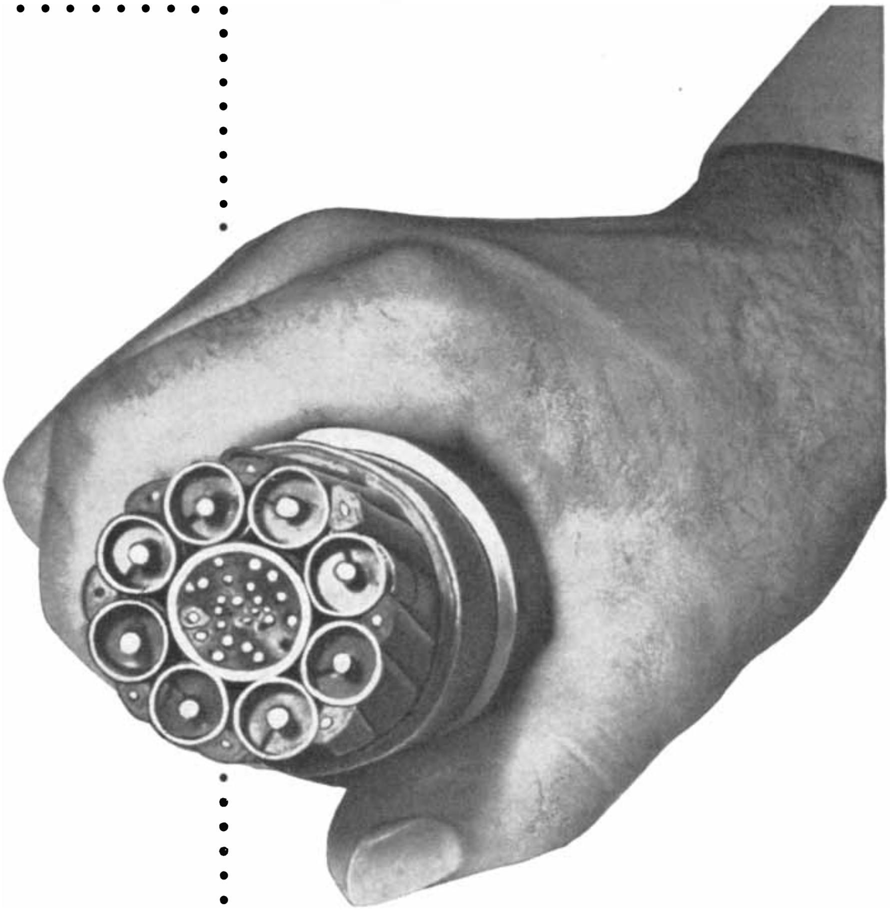
MAY, 1903: "R. Blochmann describes a new system of wireless telegraphy which he calls 'ray telegraphy.' Its distinctive characteristic is that lenses are substituted for antennae. The material of the lenses must have a high dielectric constant, and may consist of resin, glass, paraffin and the like. An important observation made is that the lenses, to be effective in concentrating the electromagnetic rays upon a distant object, need not be very large in comparison with the wavelength used. Thus, mirrors 80 centimeters in diameter suffice for waves 20 centimeters long, and signals can be exchanged over several miles. At the receiving station, a similar lens is used. In fact, the apparatus is practically a heliograph employing invisible instead of visible light. The dark rays have the advantage of being secret and of not being intercepted by fog or by nonconducting solids. Mountains are an obstacle, but this can be overcome by a series of relays. The direction of the arriving waves can be clearly distinguished to within a degree, and many simultaneous messages may thus be received and separated."

"It is announced in Berlin that Count Zeppelin's airship shed on Lake Constance, together with his apparatus, will be sold at auction. The Count is a poor man. He sank over one million marks in the enterprise."

"The other day at the convention of the American Medical Association, in New Orleans, where some 4,000 or 5,000 physicians and attendants were gathered, Dr. Billings drew attention to the decided oversupply of medical men in the United States. He attributed the surplus to the fact that the medical colleges are graduating annually from 10,000 to 12,500 physicians, when the actual needs of the country call for only about 2,500. If Dr. Billings is correct, and there is no reason to doubt his figures, from 7,000 to 10,000 young men are annually entering a profession in which they have but the slimmest hopes of making even the proverbial 'comfortable living.' "

"Mr. Ernest Ruhmer has constructed an apparatus employing the selenium cell to which he has given the name

Pipes that grew without getting bigger



Cross-section of coaxial cable. To triple capacity, Bell Laboratories and Western Electric engineers had to make 1000 amplifiers work perfectly in tandem . . . feed repeater power along the same cable that carries messages . . . put signals on and off the line at numerous cities along the route without distortion.

Pencil-size pipes carry telephone messages and television across country through the Bell System's coaxial cable. Once, each pipe could carry 600 voices, or one television program. Now it can carry 1800 voices, or 600 voices *plus* a broadcast quality television program.

Yet the pipes aren't any larger. They are being made into triple-duty voiceways by new repeaters, new terminal equipment and other transmission advances developed by Bell Laboratories engineers.

The conversion expense is less than the cost of laying extra coaxial cables. But it calls for highly refined manufacturing procedures, made possible only by close co-operation of Bell Laboratories and Western Electric, manufacturing unit of the Bell System.

In improving the coaxial cable system they created more than 20 years ago, engineers at Bell Telephone Laboratories devised a new way to give America still better telephone service, while the cost stays low.

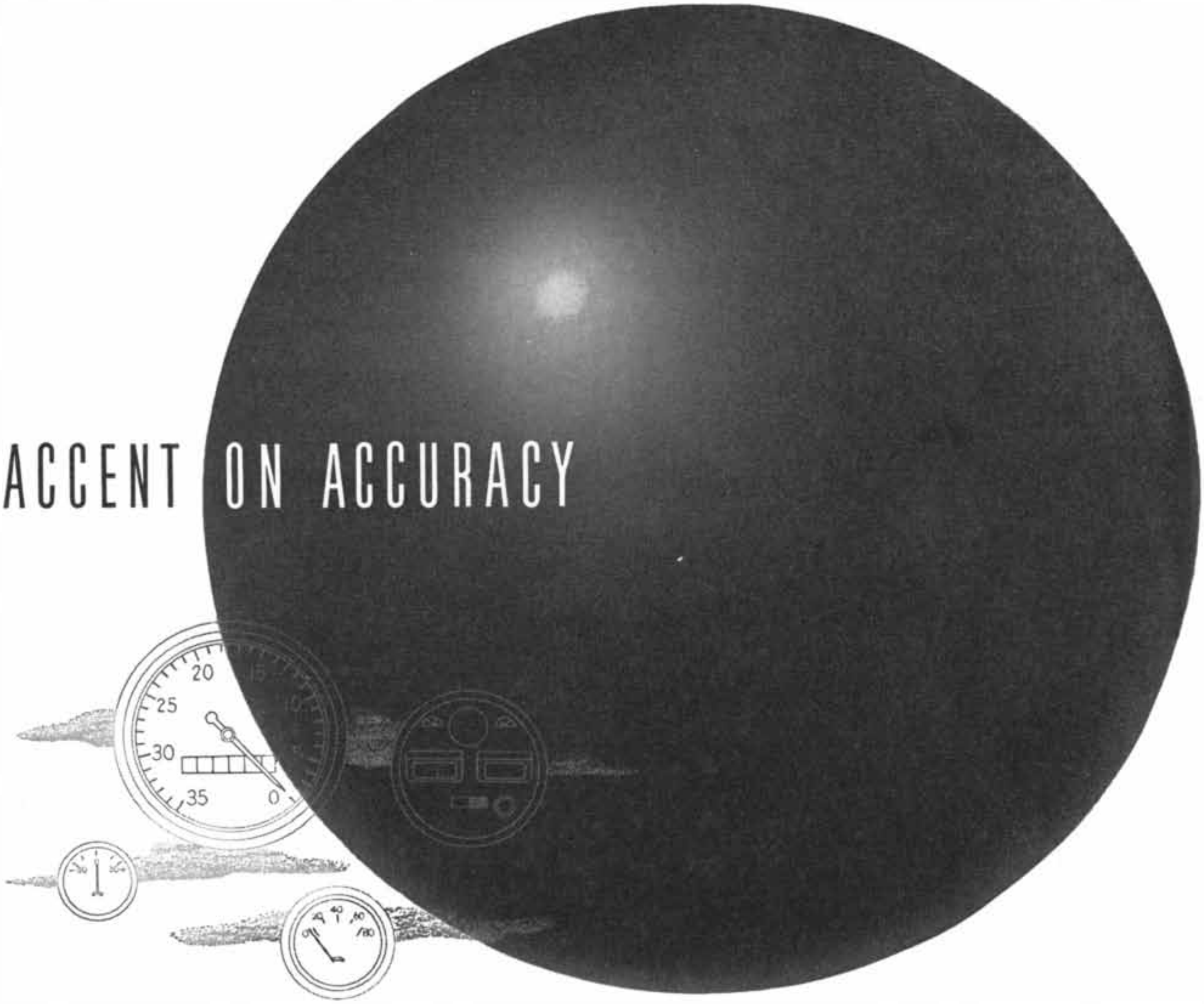
Laboratories engineer tests new triple-duty coaxial system. It marks the first time that telephone conversations and television can travel through the same pipes at the same time. With a wider frequency band being transmitted, big problem was to eliminate interference between the two types of signals.

BELL TELEPHONE LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS FOR CREATIVE MEN IN SCIENTIFIC AND TECHNICAL FIELDS 'photographophone.' It consists of a box containing a gelatine or celluloid film, such as is employed in moving picture machines, and is driven at high speed by means of an electric motor. In the front face of the box is set a cylindrical lens about the size of one's little finger. A short distance away from the box is placed an arc lamp and a telephone. Words spoken or sung into the telephone superimpose the waves in the telephone circuit upon the current flowing in the arc-light circuit, and cause a corresponding variation in the light of the arc. The rays from the arc lamp pass through the cylindrical prism already referred to, and are caused to fall in sharp white lines on the moving sensitive film. This film is then taken out of the box and developed; and then shows a series of perpendicular striations parallel to one another, which are really a photographic record of the sound waves originally entering the telephone. The developed film is next placed back into the box and the motor again started. The arc lamp remains in its original position, but burns steadily as the telephone is not operated. The rays from the arc lamp passing through the lens are therefore quite uniform and the moving gelatine strip acts as a screen to cut off these rays, allowing the light intermittently to fall upon the selenium cell at the back of the box, producing a variation in its resistance and a corresponding effect in the telephone receivers connected thereto. By holding these telephones to the ear, the reproduction of the sound is perfect."

"The final paper read before the last meeting of the Academy of Sciences was 'On the Tetrahedral Principle in Kite Structure,' by Alexander Graham Bell. The chief defect of the box kite, of which Dr. Langley's aerodrome is an elaboration, is that the weight increases with the cube as rapidly as the lifting power does with the square, so that the larger the kite, the less it will lift in proportion. In view of these facts, Mr. Bell had been led, he said, to construct a kite, the frame of which would present the form of a triangle no matter from what side one viewed it. In other words, the frame was a perfect tetrahedron; and in experimenting with the same, he found, as he had expected, that it was self-braced in every direction, and moreover, that the lifting power increased at a greater ratio than the increase in weight. By combining a great number of these kite tetrahedrons he had recently built up an immense kite, with which he successfully lifted not only a man, but a weight of 200 pounds, showing the vast improvement of this over all machines of the same order."

"Sir William Ramsay, who in conjunction with Lord Rayleigh discovered the existence of argon, and subsequently



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NOTHING ROLLS LIKE A BALL

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krypton and xenon, in the atmosphere, has made a computation of the quantity of the two last elements present in the air. The results of his experiments and calculations shows that the air contains .000014 per cent of krypton and .0000026 of xenon by weight."

SCIENTIFIC AMERICAN

MAY, 1853: "The *Augsburg Gazette* published the following news from Munich: 'Professor Liebig was last night giving a lecture on chemistry at the Palace before Queen Maria, Queen Theresa, King Louis, the younger branches of the Royal family and some persons belonging to the court, when a bottle of oxygen gas was improperly handed to him by an assistant, who took it for another bottle. An explosion took place, and the bottle flew into a thousand pieces. Fortunately, the explosion occurred in an inner room, the door of which was open; still some fragments of the glass passed through the door, and slightly wounded some members of the Royal party who were sitting in the front row. Queen Theresa was cut in the cheek, and the blood flowed in abundance. The professor escaped with his life by a sort of miracle.' "

"The clipper ship *Sovereign of the Seas* arrived in New York last month in 82 days from Honolulu (Sandwich Islands), it usually requiring four or five months from these Islands. The run from Honolulu to Cape Horn, a distance of 8,634 miles, was accomplished in 37 days. In 26 of those days, consecutively, the ship ran 6,489 miles, and one of those days was distinguished by an extraordinary run of 430 miles. This is the greatest sailing recorded. A speed of 18 miles an hour for 24 hours—greater than was ever done under canvas."

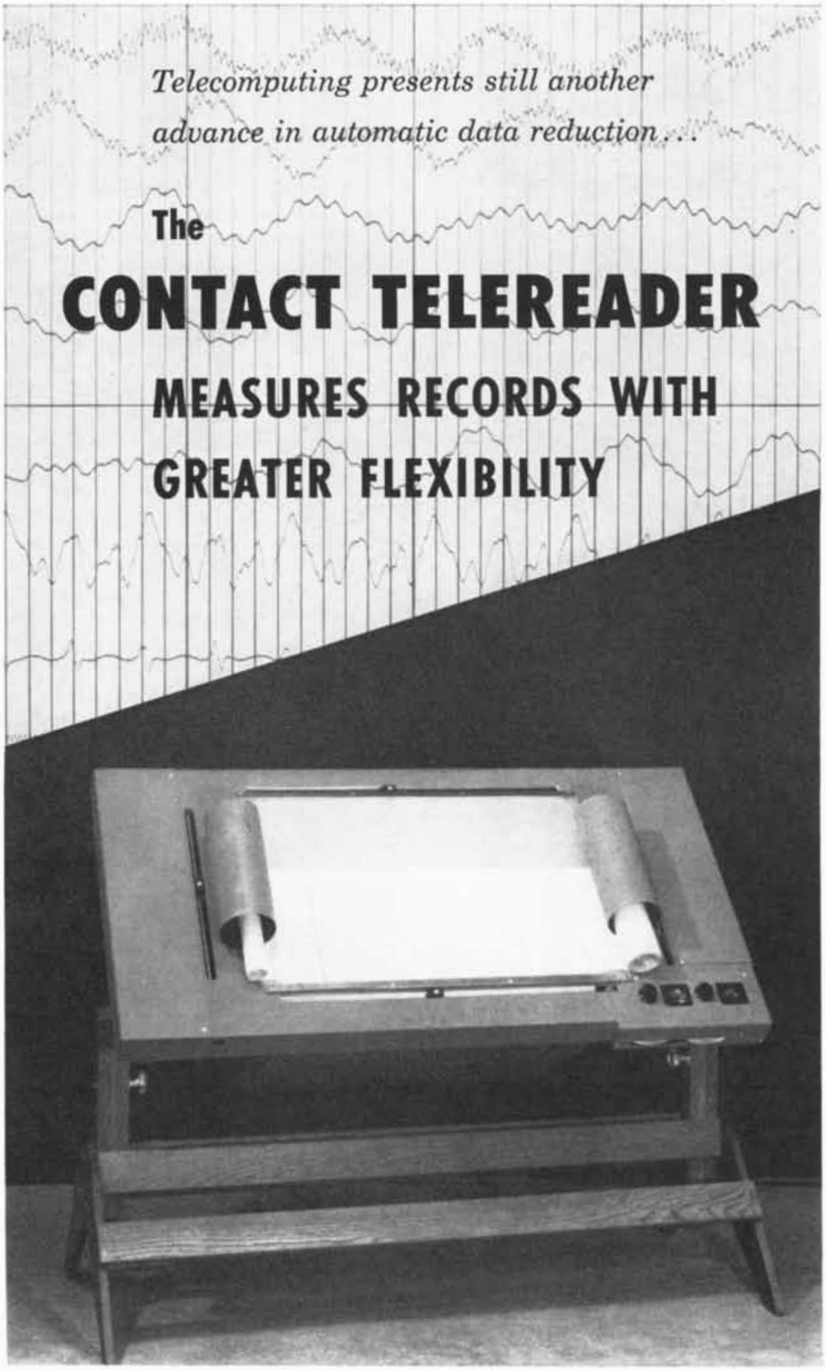
"Last month Professor Faraday delivered a lecture on electricity before the Royal Institution in London, in which he directed attention particularly to those conditions of electric force exhibited in the phenomena of conduction and insulation. He commenced by showing the difference between the conducting powers of metals—iron and copper—and the difference between the travel of heat and electricity through them. The charge of a Leyden jar was sent through a long wire suspended from the top of the theater to show that no perceptible interval occurs in the transmission of electricity through such a length of wire. As proved by Mr. Wheatstone, electricity travels at the rate of 300,000 miles a second."

THE AUTHORS

LAWRENCE P. LESSING ("High-Speed Chemistry") recently joined the Board of Editors of SCIENTIFIC AMERICAN. Born in Buffalo in 1908, he is a journalist who has specialized in technology. His formal education was wholly nonscientific, although he expressed an early interest in natural science by making an extensive collection of Erie County beetles. An equal interest in literature and writing led him to replace the beetles with a collection of French Symbolist poetry and then to take up journalism as a career. He comes to this magazine after 14 years on the staff and board of editors of *Fortune*.

GUNTHER S. STENT ("The Multiplication of Bacterial Viruses") is a biologist who holds degrees in chemistry and owes his choice of career to a physicist. Born in Berlin in 1924, Stent came to the U. S. in 1940, worked as a waiter, office boy and soda clerk, and entered the University of Illinois. Just before he received his Ph.D. a friend gave him a copy of Erwin Schrödinger's *What Is Life?* Stent was "so impressed by what I read that I decided to have a try sometime at becoming a biologist." The opportunity soon came in the form of a two-year Merck fellowship awarded by the National Research Council, which sent him to the California Institute of Technology in 1948 to study viruses under Max Delbrück. Another two-year fellowship from the American Cancer Society permitted him to continue his studies in Denmark and at the Pasteur Institute in Paris. Last year he joined the new Virus Laboratory of the University of California. In Denmark he developed another interest. "No different from most of the bachelor scientists who have come to spend a year in Copenhagen," he writes, "I did not leave Denmark a single man. . . . As the only variation to the normal pattern, I married an Icelandic rather than a Danish girl."

ERNEST D. COURANT ("A 100-Billion-Volt Accelerator") is a physicist at Brookhaven National Laboratory and one of the originators of the new principle his article describes. He was born in Göttingen, Germany, in 1920 of good scientific stock. His father is the noted mathematician Richard Courant, and his grandfather was Carl Runge, mathematician and physicist. The younger Courant came to the U. S. in 1934 and, after preparatory schooling, entered Swarthmore College. He was graduated in 1940 and went on to the University of Rochester to take his Ph.D. in theoretical physics in 1943. He then worked on nuclear reactor design for the Canadian



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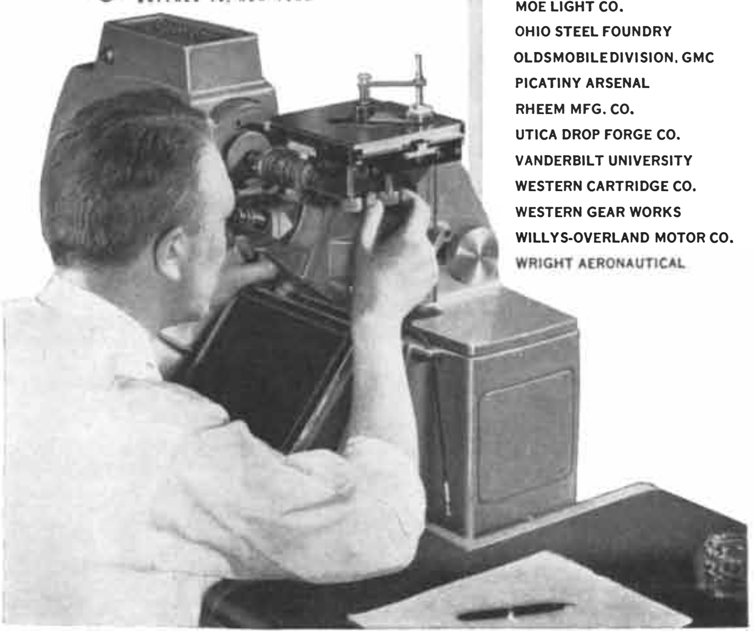
Street Address ____________ City and State ____________ atomic energy project and spent two years at Cornell University helping to design its synchrotron. He has been at Brookhaven since 1948.

ANGUS CAMPBELL, Warren E. Miller and Gerald Gurin ("Television and the Election") are staff members of the University of Michigan's Survey Research Center. Campbell, an experimental psychologist, received his Ph.D. from Stanford University in 1936. Before coming to Michigan he had taught at Northwestern University and worked for the U. S. Department of Agriculture, directing a nationwide survey of rural radio. Gurin and Miller are doing postgraduate work on the project, serving as study director and assistant study director respectively.

GERARD DE VAUCOULEURS ("Mars"), a French-born astronomer working at the Commonwealth Observatory in Australia, has been observing the heavens since 1932, when he was 14. He did most of his work on Mars in 1939 and 1941, sandwiching military service in between. From 1943 to 1949 he studied physics at the Sorbonne and at the University of Paris. He joined the staff of the Astrophysics Institute in Paris and started researches on extragalactic nebulae, his chief field of interest. He also taught and did research in scientific photography. De Vaucouleurs spent a year in England, working at the University of London Observatory and directing the science program in the French service of the British Broadcasting Company. In 1951 he went to Australia as a Research Fellow of the Australian National University to do a comprehensive study of the southern galaxies. He has written a number of popular books, including *The Planet Mars*, which has appeared in an English translation by P. A. Moore, and *Physique de la Planète Mars*, of which English and American editions are now in preparation.

MARTIN LÜSCHER ("The Termite and the Cell") teaches experimental zoology at the University of Basel in Switzerland, and is on the scientific staff of the Swiss Tropical Institute. He is in charge of the Institute's termite division, where materials and products for the tropics are tested for termite resistance. While preparing himself for this job, Lüscher, whose training as an embryologist made him especially aware of differentiation problems, became interested in the caste-differentiation phenomena about which he writes in this issue. He was born in Basel in 1917 and attended the University there, receiving his Ph.D. in 1944. After four years of postgraduate research in England and France he returned to Basel to take up his present position. Since then he has left Switzerland twice. In 1949 he went to East Africa to study tropical termites,



and last year he worked in the U. S. on a Rockefeller Foundation fellowship. While here he investigated termite taxonomy with A. E. Emerson at the University of Chicago and, with Carroll M. Williams at Harvard, studied the hormones involved in termite caste differentiation. The Swiss Tropical Institute, with which he is connected, is a state-supported private institution for research and teaching on tropical problems and for treatment of tropical diseases.

PAUL R. NEEDHAM ("The Mortality of Trout") is an ardent and fortunate fisherman who has been combining the business of studying fish with the pleasure of catching them since early boyhood. A graduate of Cornell University, he received his Ph.D. in 1928 in limnology—the scientific study of fresh waters, including their biological conditions. He has worked in the Bureau of Fisheries, the U. S. Fish and Wildlife Service and the Oregon Game Commission. Since 1948 he has been professor of zoology at the Berkeley campus of the University of California where he teaches fisheries courses. His interest in fisheries work dates from 1916, when he traveled around New York State in baggage cars delivering cans of fish.

HERBERT S. BAILEY, JR. ("The Voyage of the *Challenger*") has satisfied his amateur interest in science by serving first as science editor and now as editor of the Princeton University Press. In addition to publishing technical books, he has tried, he says, to build up Princeton's list in the history of science, believing that "the best way for humanists to approach science is through its history, and also that a knowledge of its own history humanizes science." Bailey took as many science courses at college as an English major could squeeze in. This training came in handy during the war, when he taught electronics at Navy schools. Bailey was co-author with Albert W. Tucker of the article "Topology" in the January, 1950, issue of SCIENTIFIC AMERICAN. One of his chief recreations is poetry, of which he wrote a considerable amount as a student.

WARREN S. McCULLOCH, who reviews W. Ross Ashby's *Design for a Brain* in this issue, is a neurophysiologist. Trained as a psychologist and physician (M.D. from Columbia in 1927), he is now working in the Research Laboratory of Electronics at the Massachusetts Institute of Technology on nerve impulse transmission. After practicing medicine for a few years, he turned to teaching and research. He was a Sterling Fellow at Yale from 1932 to 1936 and assistant professor of neurophysiology there from 1936 to 1940. He then went to the University of Illinois where for 11 years he was professor of psychiatry. His hobbies are surveying and building.

THE COVER

The pictures on the cover are from two monographs by the 19th-century German biologist Ernst Haeckel. At the top are four medusae, or jellyfish. At the bottom is the tentacle of another medusa. Most of these creatures were collected on the voyage of the *Challenger* (*see page 88*).

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DESIGNING WITH ALUMINUM

This is one of a series of information sheets which discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series will be supplied on request. Address: Advertising Department, Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

NO. 1

Light weight with strength

FAVORABLE WEIGHT-STRENGTH RATIO OF ALUMINUM ALLOYS OFTEN MAKES POSSIBLE PRODUCT IMPROVEMENT, MANUFACTURING ECONOMIES

One thing that almost everyone knows about aluminum is that it is a light metal. Its density of approximately 1/10 lb. per cu. in. makes it only about a third as heavy as steel or copper.

Less well recognized is the fact that various aluminum alloys possess great strength, though they are seen daily in strength-requiring applications like highway transportation equipment and aircraft. Some aluminum alloys compare favorably with high-strength low-alloy steels. For example, the typical ultimate tensile strength of 75S-T6 is 83,000 psi; its yield strength is 73,000 psi.

On a weight basis the performance of aluminum alloys is more striking. Even commercially pure aluminum is stronger pound for pound in the three-quarter-hard temper (H16) than structural steel. The relationship in weight, strength and stiffness between steel and a few of the aluminum alloys and tempers is shown in the chart immediately below.

This favorable ratio of strength to weight for many aluminum alloys applies also in relation to almost all other common metals. It is a characteristic that is especially useful in design and manufacture because it is combined with other valuable properties such as conductivity, reflectivity, workability and finishability along with economy and availability.

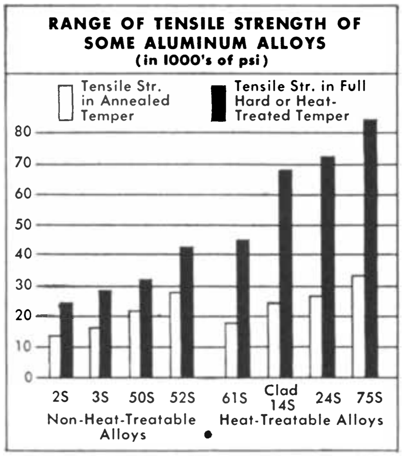
Strength and stiffness

A stressed aluminum alloy structural member can have equal stiffness with steel, and greater strength, and save up to 50 per cent in weight.

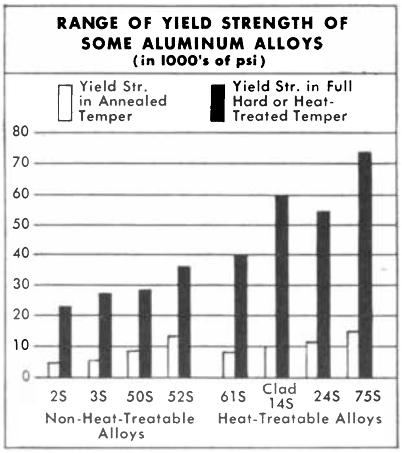
To achieve equal stiffness with steel aluminum sections require greater moment of inertia because the modulus of elasticity of aluminum is less than that of steel (roughly 10,300,000 as compared with 29,000,000). However, if an aluminum member is made 44 per cent thicker than a similar steel part, it will have the same stiffness and still weigh only half as much.

Wide range of strength in aluminum alloys

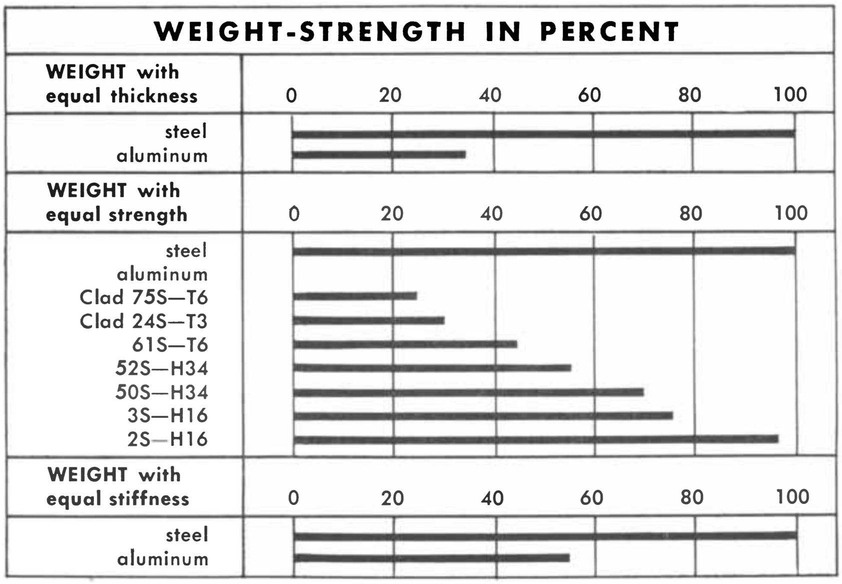
Alloys and tempers of aluminum are available to meet many strength requirements. The charts below illustrate in part the range of tensile and yield strengths available from 2S in its soft (0) temper to heat-treated 75S (T6 temper).



RANGE OF TENSILE STRENGTH OF SOME ALUMINUM ALLOYS (in 1000's of psi)



RANGE OF YIELD STRENGTH OF SOME ALUMINUM ALLOYS (in 1000's of psi)



The fact that wrought aluminum alloys fall into two classes, non-heat-treatable and heat-treatable alloys, helps adapt them to many different types of application. Non-heat-treatable alloys gain their maximum strength from cold work hardening.

PLEASE TURN TO NEXT PAGE ➡

The heat-treatable alloys, which include the strongest, attain maximum strength through heat treatment. Because they can be formed readily in the annealed condition, it is frequently possible to do severe forming easily and economically and then heat-treat the finished structure or part to obtain high strength. This procedure is regularly used in the aircraft industry.

Aluminum for dynamic, static applications

Weight is an important factor in acceleration and deceleration, as is shown by these typical formulas:

$$\text{FORCE to accelerate} = \frac{\text{WEIGHT}}{32.2} \times \text{acceleration}$$

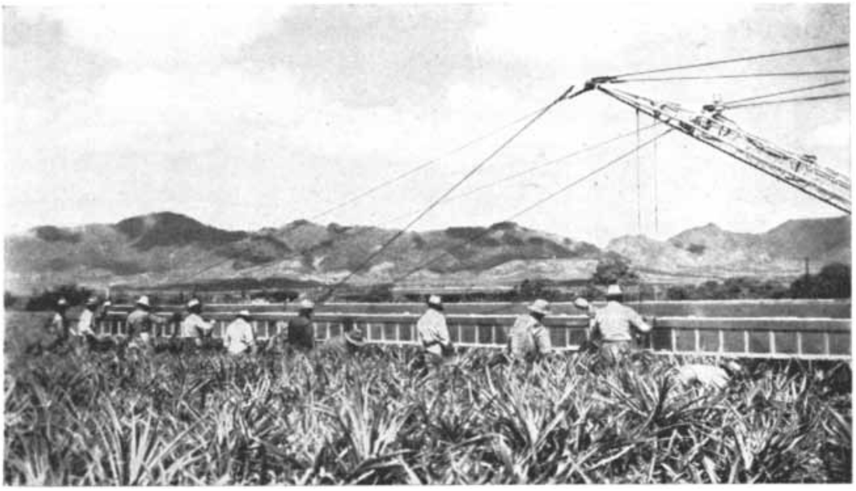
$$\text{WORK to accelerate} = \frac{\text{WEIGHT}}{32.2} \times \text{acceleration} \times \text{distance}$$

$$\text{POWER to accelerate} = \frac{\text{WEIGHT}}{32.2} \times \frac{\text{acceleration} \times \text{distance}}{\text{time}}$$

Therefore, the lightness and strength of aluminum offer a major advantage in dynamic applications. Use of aluminum in torque converters for automobiles offers an outstanding example. Aluminum's light weight with adequate strength improves efficiency under the severe acceleration and deceleration to which the converters are subjected. (It is worthwhile noting, also, that the high thermal conductivity of aluminum serves in this application to dissipate heat and thus helps maintain more uniform viscosity of the fluid.)

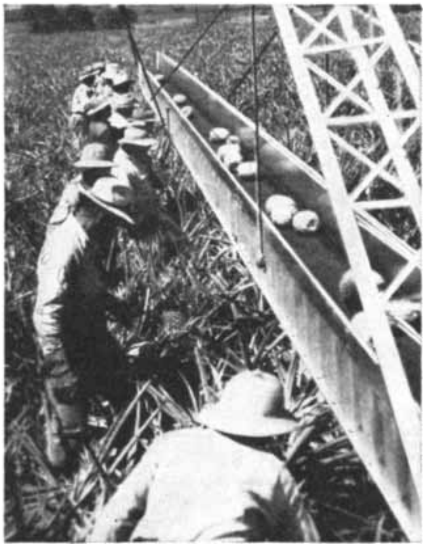
Successful dynamic applications range from engine pistons, fans, spindles, bobbins and other moving parts to aircraft and transportation equipment. The advantages from the use of aluminum often begin in the manufacturing stage—the light metal is easier and more economical to handle and machine.

In static structures the dead weight of a stressed member is usually calculated as a load factor. Here aluminum alloys may make important savings possible. Reduction in dead weight sometimes enables design changes to be made in the basic structure to improve its efficiency. Aluminum alloys, for instance, are being increasingly used in many architectural applications to effect substantial weight savings, besides providing improved appearance, better weathering resistance and maintenance economy.



Better harvester boom built of aluminum

Aluminum's light weight and strength solved a tough problem for Libby, McNeill & Libby in their pineapple operations in Hawaii. The 65-foot conveyor



boom of a field harvesting machine—made from welded high-alloy steel tubing—proved unsatisfactory in service because it was structurally weak in torsion and lacking in lateral stability.

With the assistance of Kaiser Aluminum engineers the boom was completely redesigned in aluminum, taking advantage of aluminum's properties. Specifications called for the boom to withstand wind velocities up to 50 miles an hour, take the lateral and vertical whip involved in movement through the pineapple fields and be readily rigged for highway travel.

The new boom is an extremely light semi-tension field beam, fabricated from heat-treated aluminum alloy sheet and extrusions, that has proved itself in rugged service. In use with the harvesting machine it reduces the back-straining work of carrying heavy loads of pineapples out of the field and loading them into a truck.

Improve your products with aluminum alloys

Wherever motion is involved or wherever a load must be supported, there is a place where the designer may well consider the use of aluminum alloys. The result will be a substantial saving in weight, plus one or more of the following additional benefits: savings in power and size of motive equipment—improved performance—savings in operating and maintenance costs—greater payload—improved corrosion resistance.

Why not get complete information on the light weight, strength and other properties of aluminum alloys as they apply to your design problems? At your request, Kaiser Aluminum engineers with long experience will gladly work with you to help you get the most from the many advantages of aluminum. Call or write any Kaiser Aluminum office in principal cities. Kaiser Aluminum & Chemical Sales, Inc., Oakland 12, Calif.

see our catalog in PRODUCT DESIGN FILE or write for copy

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SCIENTIFIC AMERICAN

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CONTENTS FOR MAY, 1953 VOL. 188, NO. 5

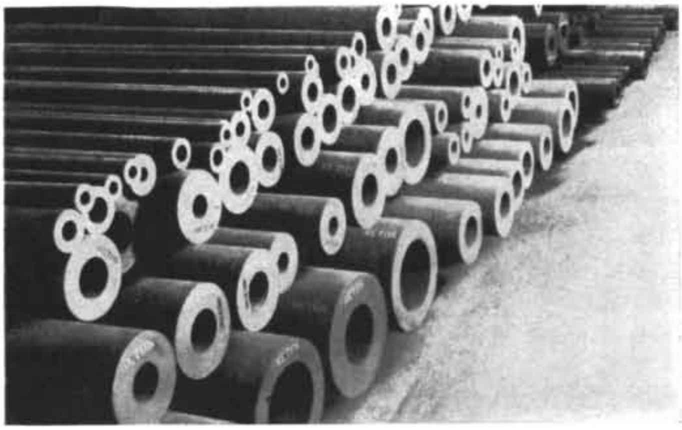
ARTICLES

DEPARTMENTS

What's Happening at CRUCIBLE

about hollow tool steel

Crucible is now making its high quality tool steel available in hollow form. Bars of Crucible Hollow Tool Steel can now be obtained with machine finished inside and outside diameters and faces — in three famous grades: KETOS, AIRDI 150 and SANDERSON. Already its use has effected substantial savings for makers of tool steel parts with cutout centers.



typical applications

The ring shaped tools that can be fabricated from hollow tool steel are virtually limitless — beading rolls, bearings and bushings, blanking and briquetting dies, cam dies and followers, chuck jaws, circular knives and shears, cutters, die holders and inserts, engraver and edging rolls, extrusion dies, feed and flue rollers, forming rolls, nozzles, saws, sleeves, slitters, stamping dies, wheels . . . and many others.

how it cuts costs

Crucible Hollow Tool Steel permits a toolmaker to bypass drilling, boring, cutting off and rough facing operations. Naturally, this results in less production time per unit, greater machine capacity, and a reduction in scrap losses. In some cases material costs alone are cut 20% by the use of Crucible Hollow Tool Steel instead of regular bar stock.

availability

All grades and sizes of Crucible Hollow Tool Steel are carried in stock in Crucible warehouses conveniently located throughout the country.

CRUCIBLE HOLLOW TOOL STEEL

Sizes (inches)	GRADES		
	Sanderson	Ketos	Airdi 150
2 O.D. x 1 I.D.	x	x	
2½ O.D. x 1½ I.D.		x	
3 O.D. x 1½ I.D.		x	
3¼ O.D. x 1¼ I.D.	x	x	x
3¼ O.D. x 1½ I.D.		x	
3½ O.D. x 1½ I.D.	x		
3½ O.D. x 2 I.D.	x	x	x
4 O.D. x 1½ I.D.			x
4 O.D. x 2 I.D.		x	x
4¼ O.D. x 1¾ I.D.			x
4½ O.D. x 2 I.D.	x		x
5 O.D. x 2 I.D.	x	x	x
5 O.D. x 2½ I.D.		x	x
5 O.D. x 3 I.D.	x	x	
5½ O.D. x 1¾ I.D.			x
5½ O.D. x 2 I.D.		x	
5½ O.D. x 2½ I.D.	x		x
6 O.D. x 1¾ I.D.			x
6 O.D. x 2 I.D.		x	
6 O.D. x 3 I.D.	x	x	x
6½ O.D. x 3¼ I.D.			x
6½ O.D. x 3½ I.D.		x	
6½ O.D. x 4 I.D.			x
7 O.D. x 2¼ I.D.			x
7 O.D. x 3 I.D.	x	x	
7 O.D. x 3½ I.D.			x
7 O.D. x 4 I.D.	x	x	
7½ O.D. x 3 I.D.	x	x	
7½ O.D. x 3½ I.D.	x	x	
7½ O.D. x 4 I.D.			x
8 O.D. x 3½ I.D.	x	x	
8 O.D. x 5 I.D.	x	x	x
8¼ O.D. x 3½ I.D.			x
8½ O.D. x 5¼ I.D.	x	x	x
9 O.D. x 4 I.D.	x	x	
9 O.D. x 5 I.D.		x	x
9 O.D. x 6 I.D.	x		
10 O.D. x 4 I.D.		x	
10 O.D. x 5 I.D.	x	x	
10 O.D. x 6 I.D.	x	x	x
11 O.D. x 4 I.D.	x	x	
11 O.D. x 6 O.D.	x	x	
11 O.D. x 7 I.D.		x	x
12 O.D. x 5 I.D.	x	x	x
12 O.D. x 6 I.D.	x	x	
12 O.D. x 7 I.D.	x	x	
12 O.D. x 8 I.D.		x	
13 O.D. x 6 I.D.		x	x
13 O.D. x 7 I.D.	x	x	
13 O.D. x 8 I.D.			x
13 O.D. x 9 I.D.		x	
14 O.D. x 7 I.D.	x	x	x
14 O.D. x 10 I.D.		x	
15 O.D. x 9 I.D.		x	x
15 O.D. x 10 I.D.		x	
16 O.D. x 10 I.D.	x	x	x
16 O.D. x 12 I.D.	x	x	

technical service

If you make tools with machined-out centers and wish additional information on Crucible Hollow Tool Steel, or technical assistance in solving an application problem, call in a Crucible representative. Our experienced staff of tool steel specialists is always available.

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National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

SCIENTIFIC AMERICAN

MAY, 1953 VOL. 188, NO. 5

High-Speed Chemistry

The study of extremely fast reactions in flame fronts and in other chemical combinations is opening an entirely new field of chemistry. It presages the chemical plant of the future

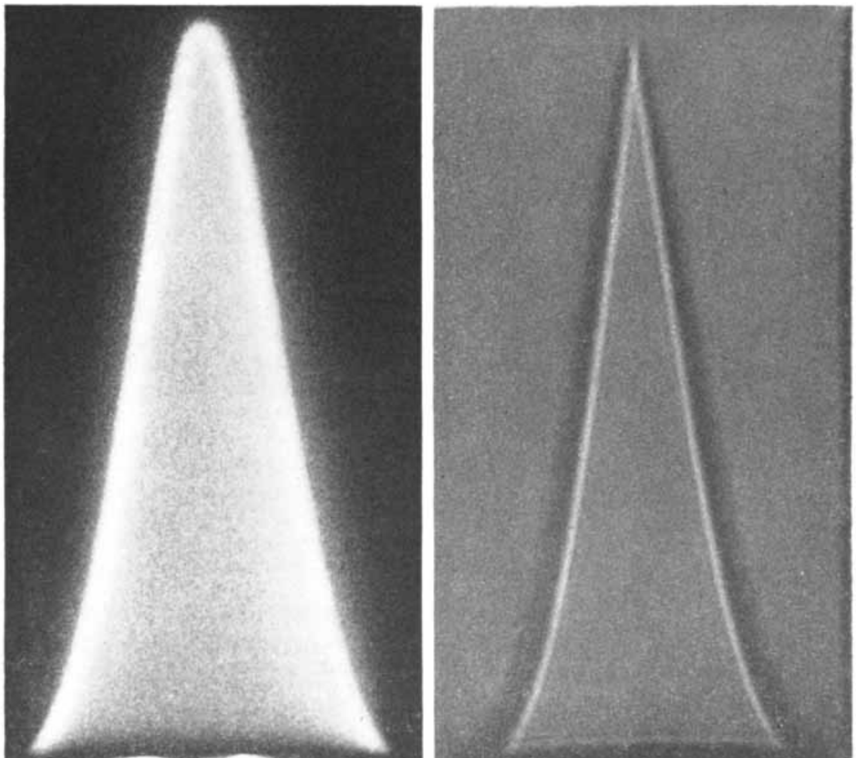
by Lawrence P. Lessing

WHEN you look into the flame hovering over a Bunsen burner, you are looking at some very fast chemical reactions. Today the close study of such reactions is a fast-growing field of research. It is probing basic mechanisms about which little was known less than a decade ago. These high-speed reactions have increasing significance in rocketry, biochemistry, upper-atmosphere researches, air pollution and an entirely new class of chemical processes from which may develop completely automatic, high-speed, continuous-flow chemical plants.

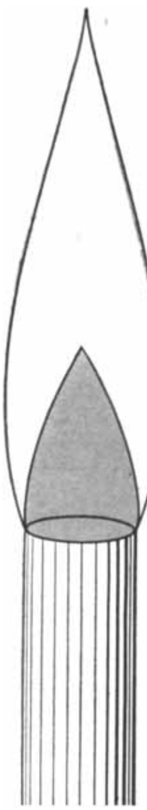
Robert Wilhelm Bunsen of Heidelberg, who invented the Bunsen burner in 1876, might have been startled and not a little mystified if he had attended a recent convocation at Princeton University and heard what modern specialists have learned from his humble appliance. The conference was held at Princeton's James Forrestal Research Center, a leading institution for fast-reaction research in the U. S. Some of its basic studies and measurements of high-speed chemical kinetics are made upon the flames of glorified Bunsen burners.

The Bunsen burner is simply a gas tube with an air valve in its base. When the valve is open and air is sucked into the gas stream, this premixture of fuel and oxygen produces a very hot flame. If the fuel is a simple gas such as ethylene, the flame is composed of two zones: (1) a bright blue-green inner cone, hollow and cool in the center in the uprush of as yet unignited gases; (2) an ethereal blue outer cone of combustion products streaming away in air. If the gas is a rich hydrocarbon mixture, the flame may have two or three perceptible zones beyond the bright inner cone. When the air valve in the burner is closed, the flame subsides into a lazy yellow blaze, burning like a candle in the supporting air.

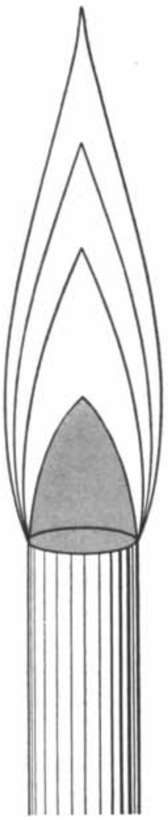
The significant area in a premixed Bunsen flame is the bright envelope of the inner cone. This thin shell, about a fiftieth of a millimeter thick, is the flame front in which all the initiating combustion reactions occur. The energy of a match sets off the reactions. It jolts the molecules of the gas-air mix from equilibrium and pushes them rapidly past the barrier of their resistance to change. After that the reaction goes of itself, giving off its own heat. The rush



PROPANE-AIR FLAME on a Bunsen burner is photographed by its natural luminosity (*left*) and by shadowgraph (*right*). Shadowgraph shows the inner cone rimmed by thin, luminous flame front where reactions occur.



ETHYLENE-AIR FLAME shows two-cone form of simple gas flames. Inner one is bright, outer pale blue.



HYDROCARBON FLAME of mixed content has four cones, cracking gases in stages to luminous hot carbon.

of chemical reactions going on in the flame front leaves simple chemistry far behind and bewilders kineticists.

IN A FLAME FRONT the widely spaced gas molecules, under increasing heat and pressure, become more and more energetically agitated, gain velocity and interact. Gas atoms and molecules have long been conceived as perfect elastic spheres, shooting about, ricocheting, colliding with one another and, wherever they collide squarely with enough velocity to break molecular bonds or merge into a bigger molecule, releasing more heat-energy. The chemist Henry Eyring, formerly at Princeton and now at the University of Utah, has refined the picture further by applying quantum mechanics to the analysis of the simplest reactions, such as those of elemental hydrogen. He calculated the actual energy levels, the reaction routes and the yields between specific interacting atoms and molecules at all stages of a reaction, plotting the results on a potential energy curve and on a kind of topographical map.

But in the flame of mixed hydrocarbon gases the reactions are vastly more complex than in a hydrogen flame. There are double and triple molecular collisions, straight-chain, branched and side reactions, with the products of one reaction becoming reactants in the next, all in variable concentrations. Some flashing indications of these intermediate products have been seen in the flame front. The ones seen have been mainly fragmentary free radicals of methane and ethane, plus some free hydrogen and carbon. But all the transitory molecules are being cracked, reformed and broken down again so fast that no one yet has been able to follow the exact order or mechanism of the reactions.

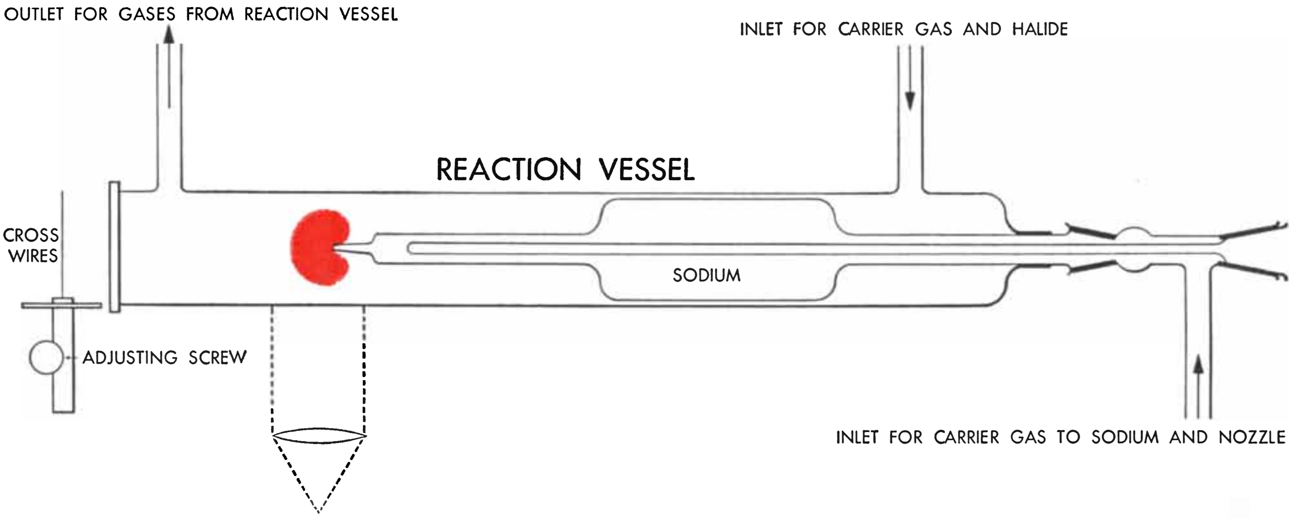
The British investigator A. G. Gaydon, whose major work is in the spectroscopy of flame reactions, calculates that the gases pass through the thin flame front and through all their reactions in something like one 100,000th of a second. Another way of saying this is that the gases, which may be coming up the Bunsen tube at 100 to 200 feet per second, are accelerated through the flame front to a speed of 3,000 feet per second or more.

There are other kinds of fast reactions. Oxygen flames have reaction times of less than a millionth of a second—which is about as fast as an explosion. True explosions are reactions of a microsecond or less, almost instantaneously reaching velocities of 6,000 to 8,000 feet per second. These form a special class of reactions about which even less is known than about other fast reactions, and they will not be considered here. Down the scale are certain reactions much used in rocketry, in which two chemicals react in thousandths of a second upon simple contact. In addition there is a big range of almost instantaneous, low-heat, ionic reactions in solution, forming metallic salts. And there are many catalytic reactions with extremely short reaction times at the surface of the catalyst, though passage through the catalyst bed is fairly slow. Most of the fast reactions considered here, however, are of the gaseous or vapor-phase type, more amenable to mathematical and statistical analysis than those in solids or solutions. They take place in something under half a second, but are not as fast as a detonation. The thin dividing line is much the same as that in an automobile engine, where one distinguishes between so-called smooth burning of compressed gases in the cylinder—producing useful work—and detonation or knock.

The great interest in such reactions starts from the fact that chemists want to know all they can about reaction rates and don't like the frustration of being told that some reactions are going too fast for them to measure. It is, moreover, useful to understand simple fast reactions in order to increase understanding of the general theory of chemical kinetics. Much of the recent push to research has also come from practical problems in jet and rocket engines, which are basically devices for getting power out of high-velocity gas streams. To make the engines longer-lived, jet engineers want to know how to control combustion reactions so that there will be a minimum of corrosive products such as nitric acid, which eats away tail cones and combustion chambers. To get more thrust, they want reactions that deliver a maximum of straight translational rather than rotational or vibrational energy to molecules.

A MAJOR PROBLEM in fast-reaction research, therefore, has been to devise instruments and techniques for starting millisecond chemical occurrences under controlled conditions, studying them while in progress, and then getting into the system to exercise, if possible, some control over it. For these purposes various investigators have improvised a number of ingenious kinds of attack and apparatus. Since most of the reactions under study give off intense heat and light, the equipment includes spectrographs for analyzing the light spectra of chemical products, photoelectric tubes for measuring light intensities, and the like.

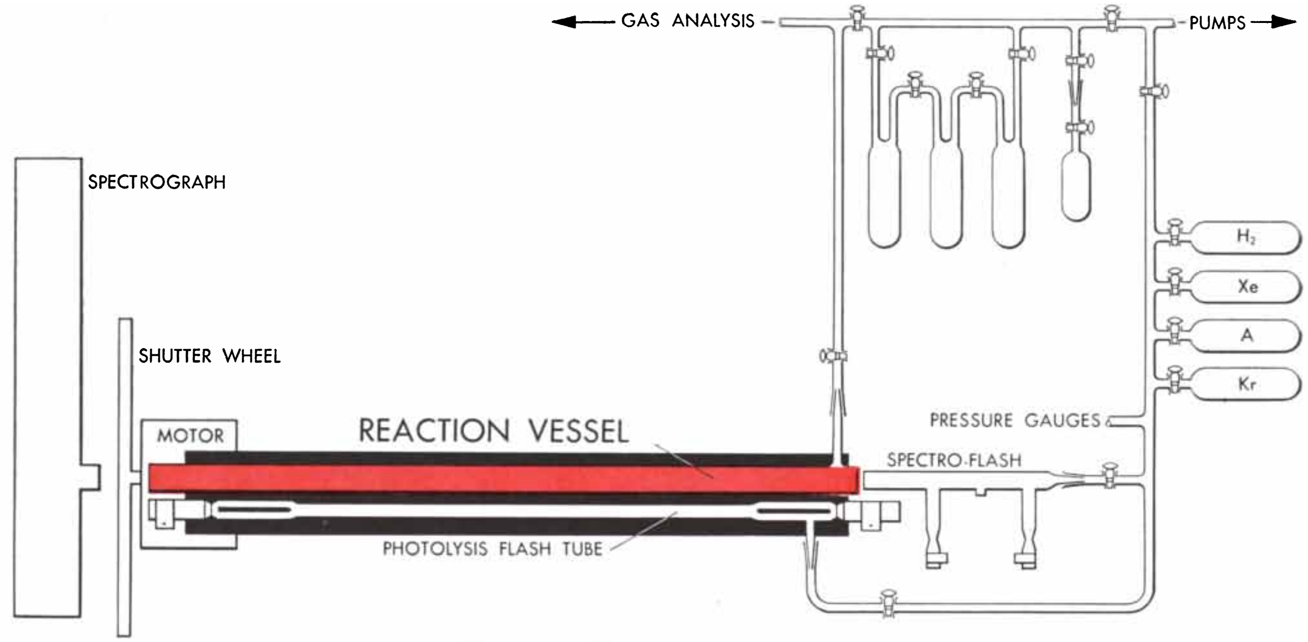
Among the earliest techniques was Michael Polanyi's sodium-flame apparatus for studying reactions in a flowing, diffusion-flame system. This was set up in Great Britain in the early 1930s for a series of experiments which are landmarks in the field. From an inner glass



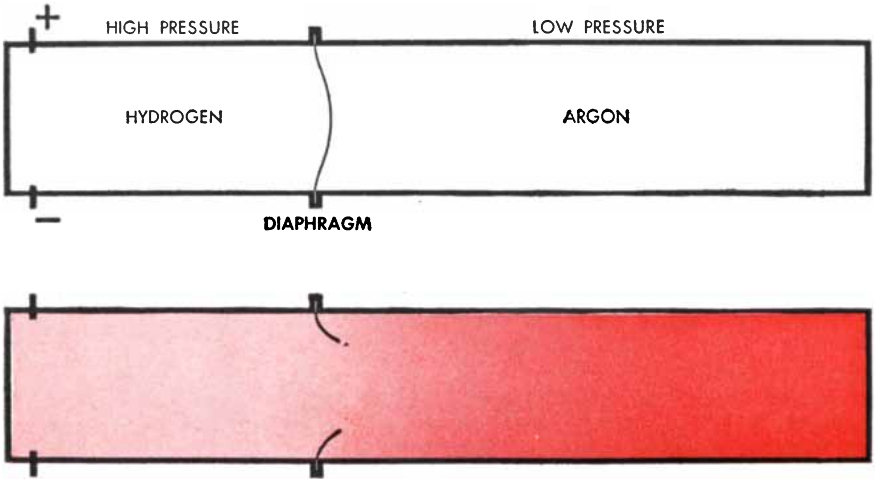
SODIUM-FLAME APPARATUS, designed by Michael Polanyi, was one of earliest techniques for studying fast reactions in a flowing system. Sodium vapor is released from inner chamber through nozzle into halide atmosphere for flame reaction. Depth of flame, measured by cross wires and resonance lamp, gives reaction rate.

tube within a larger low-pressure tube, sodium was allowed to vaporize through a thin nozzle into a halide atmosphere carried by an inert gas, thus producing a spontaneous flame reaction. The diffusion area was measured by eye and analyzed by spectrograph and phototube. By this means Polanyi established the transitional reaction products, until then unknown, and later produced a clearer theory of the mechanism of a very fast reaction than any theretofore. George B. Kistiakowsky and his associates at Harvard University, using an apparatus of the same type but with a thermocouple at the inner nozzle to measure heat levels in the flame, have similarly investigated fast reactions of boron trifluoride and methylamines.

Norman Davidson and his group at the California Institute of Technology, Arthur Kantrowitz and his associates at Cornell University and others have recently used another technique. They pass a strong shock wave through a gas in a tube. A shock tube is a heavy, two-chambered affair divided by a thin plastic or rubber diaphragm. In one chamber is a light "driver" gas (such as oxygen or hydrogen) under high pressure; in the other, a heavier gas under low pressure. When the driver gas is heated or ignited by an electric current or spark, the diaphragm explosively bursts and a shock wave hurtles through the heavy gas. Under this terrific jolt of energy the reaction takes place in between 10 and 1,000 microseconds, with pure aerodynamic characteristics. Velocities are measured electrically at points in the ionized gas behind the shock wave. This wave is in fact a luminous flame front. In it Kantrowitz, working with argon gas, has recorded temperatures up to 10,000 degrees centigrade or higher. Heat-luminosity data are obtained by photomultiplier tube and fast oscillograph or by photocell and



FLASH-TUBE APPARATUS, designed by England's R. G. W. Norrish, provides another method for studying fast reactions. A high-speed flash lamp, releasing up to 10,000 joules of light in a few microseconds, kicks off a reaction in chlorine or other light-sensitive chemical. The reaction is recorded by high-speed spectrograph.

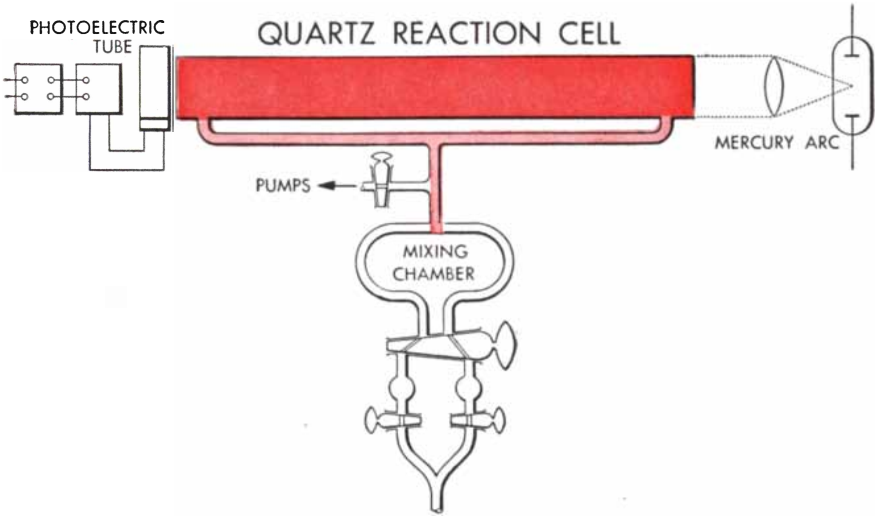


SHOCK-TUBE APPARATUS is also used to study fast reactions. A light gas (hydrogen) is heated by electric current in one end of tube, exploding diaphragm and sending a jolting, reaction-starting shock wave into a heavier gas (argon). Heat, velocity and luminosity are measured.

oscillograph. The latter is employed by Davidson, using a lower energy wave to get closer quantitative results in studying nitrogen oxide and other reactions.

Still another method of initiating and studying fast reactions is by high-energy flash photolysis, a technique devised in 1949 by R. G. W. Norrish of Cambridge University and used also by Davidson at Caltech. Here the reactants studied must be substances that react to light, *e.g.*, chlorine gas or iodine vapor. The light source is a high-speed flash-discharge lamp, delivering an intense bolt of light in less than one 2,500th of a second, which kicks off the gas reaction in a nearby quartz cell. The reaction is then followed and analyzed by the sweep of an oscilloscope and by flash spectrography. These reactions are slower than those initiated by shock wave, but they can be followed more selectively through all stages to produce more qualitative information. The flash lamp also is useful for examining liquid and solid reactions.

Harold S. Johnston of Stanford University and D. M. Yost of Caltech have developed an entirely different way to study fast reactions. This is a fast mixing method in which two reactants are rapidly flowed together down a Y tube, then quickly isolated in a quartz optical cell, where the course of the reaction is viewed by phototube and oscilloscope. The method is limited by the speed with which reactants can be mixed—no faster than a hundredth of a second or so—but unlike most other methods this allows reactions to take place under closely controlled conditions, constant temperature and fixed volume, so that the analytical results may be compared with those obtained by conventional slow methods. Johnston, for instance, has measured the rates of a number of interesting nitrogen oxide and ozone reactions. Some of these apply to rocket problems, and some to reactions in the atmosphere, including an unusually heavy formation and destruction of ozone in the Los Angeles smog area.



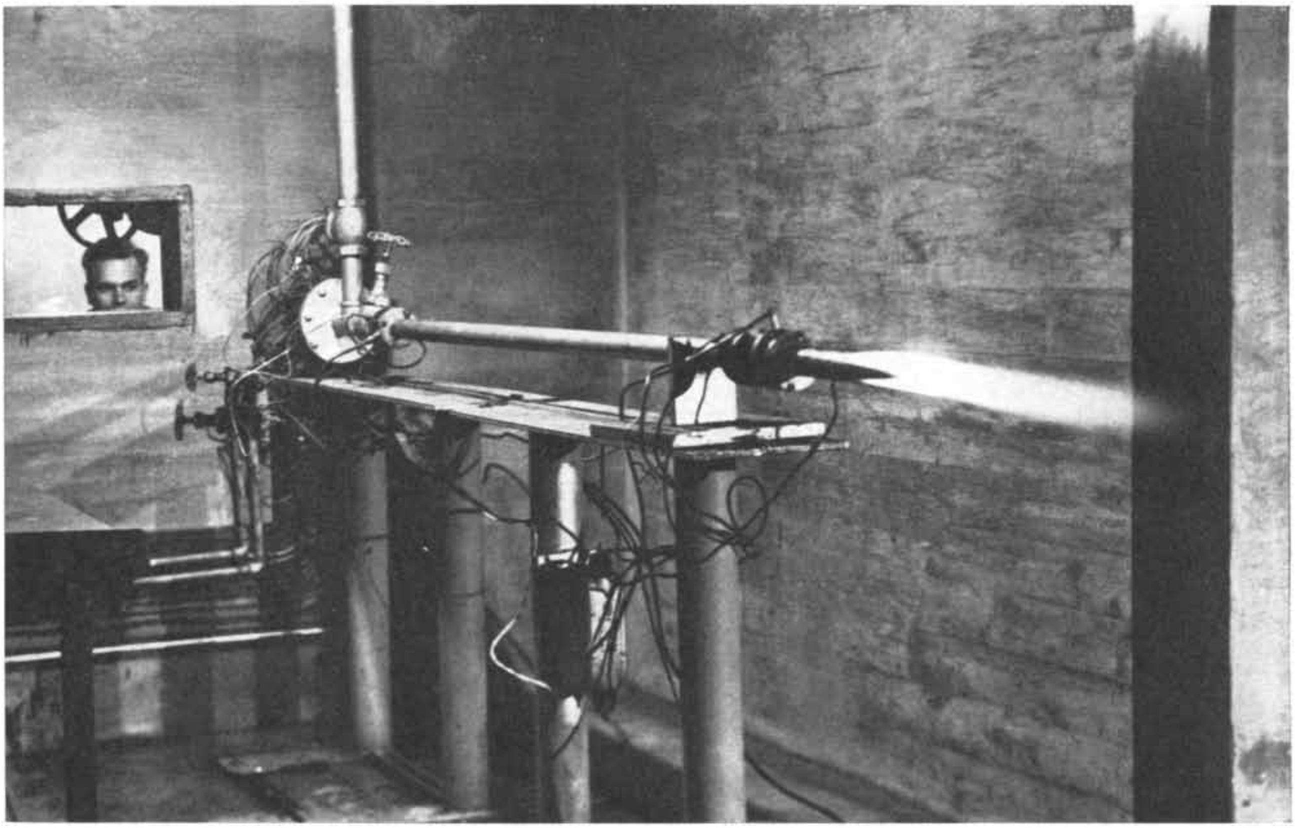
FAST-MIXING APPARATUS, devised by Harold S. Johnston and D. M. Yost of the U. S., is a novel new tool in fast-reaction research. Two reactants are rapidly shot into mixing chamber, then quickly isolated in the quartz cell and studied by photoelectric tube and fast oscilloscope.

These methods by no means exhaust the list of ingenious devices with which investigators are now tracking down high-speed reactions. Martin Kilpatrick's group at the Illinois Institute of Technology, and others, employ bomblike reactors equipped with pistons. In these, two reactants such as a sodium potassium alloy and water are brought together and reacted in two milliseconds by the swift plunge of the pistons, driven by pneumatic injectors. The variable pressures of the reactions are measured by fast electrical strain gauges, and the pistons' fall is timed by a photoelectric device.

IN MANY DIRECTIONS, therefore, men are now engaged in the patient gathering of data which always precedes any great step forward in a science as ramified as chemistry. Briefly recapitulated, the problem is that in fast, complex chemical reactions the starting materials are known, the end products are known, but the transitional compounds produced in the swift course of the reaction—compounds which may be more interesting and economically important than the end products—are largely unknown or uncontrolled.

This is not to say that the chemical industry does not already employ some fast reactions, for it has often boldly worked out processes empirically before clearly understanding their mechanisms. There are a number of industrially important fast reactions. One, for instance, is a process for making ethylene from propane gas by simply passing the gas through a hot tube—a process developed to high efficiency by the aliphatic or so-called petrochemical industry. In the red-hot tube much of the heavier propane is cracked into methane and ethylene, which is a basic starting material for a host of chemical products, beginning with ethylene glycol antifreezes.

Then there is a process of the Monsanto Chemical Company in which benzene is passed over molten lead to yield diphenyl, used in transformer oils. There is The Dow Chemical Company's red-hot dehydrogenation of ethyl benzene to produce styrene for polystyrene plastics and synthetic rubber. There are fast chlorinations of hydrocarbons, producing such items as vinyl chloride plastics and pentane. There is a new, cyclic regenerative process for fixing nitrogen from air as nitrogen oxide in a double, gas-heated furnace. It was developed by



THE RAM-JET ENGINE, here shown in a small laboratory setup at Experiment Incorporated in Richmond, Va., is both a problem in high-speed chemical kinetics and a means of studying it. Fuel and air are rammed into one end of the "stovepipe" tube, burned, and shot out as high-velocity exhaust gases developing thrust.

Farrington Daniels and Nathan Gilbert of the University of Wisconsin and incorporated in a new Western plant by Food Machinery & Chemical Corporation. This is the first process in over 30 years to compete with the famed Haber process for fixing nitrogen from air *via* ammonia into nitric acid, explosives and fertilizer.

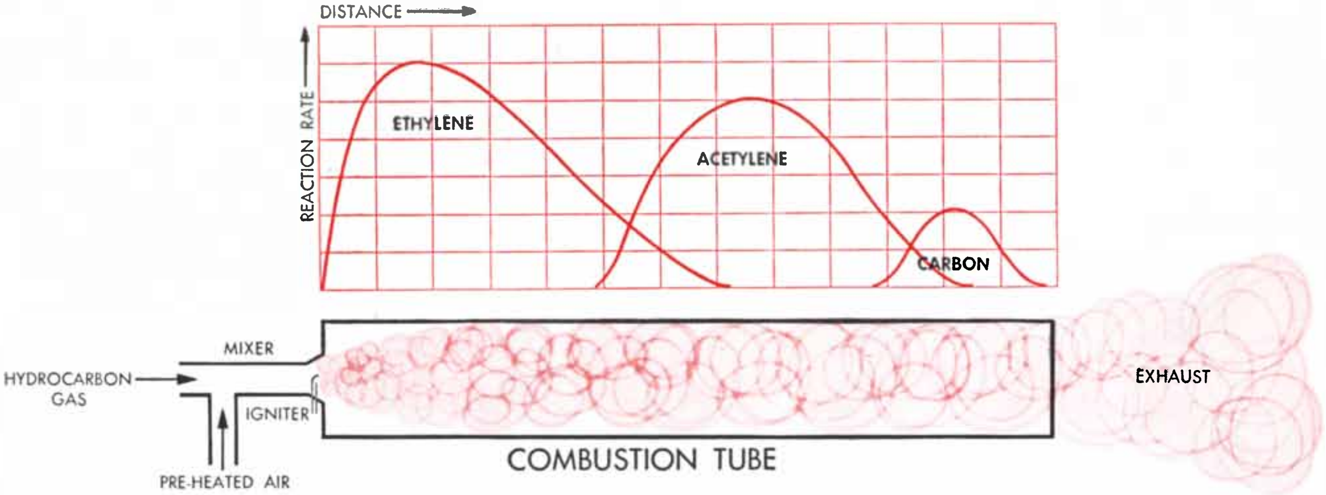
The number of really high-speed reactions in commercial use, however, is still small, though the trend is growing. As the chemical industry has learned to handle higher temperatures and pressures, reaction rates have been steadily climbing. The advantages of speed are that for a given capital investment more product can be run through a plant, or a smaller plant can be built to yield a given amount of product.

PERHAPS the most interesting development on the horizon, stemming directly from the study of extremely fast reactions, is a new type of thermochemical process conceived by a small company known as Experiment Incorporated in Richmond, Va. This company grew from the collaboration of a group of young chemists and physicists who had worked on military rockets during the war. Headed by James W. Mullen II, the company was organized to do contract research for the government and industry. Experiment Incorporated has so far worked mainly on rockets, ram jets and ballistics for the military, but in the ram jet it has found a new type of chemical plant. The process, first reported last year, is now in intensive development for the production of acetylene, under the direction of Experiment's E. Justin Wilson, Jr., with rights owned by Chemical Construction Corporation, an engineering and construction subsidiary of the American Cyanamid Company.

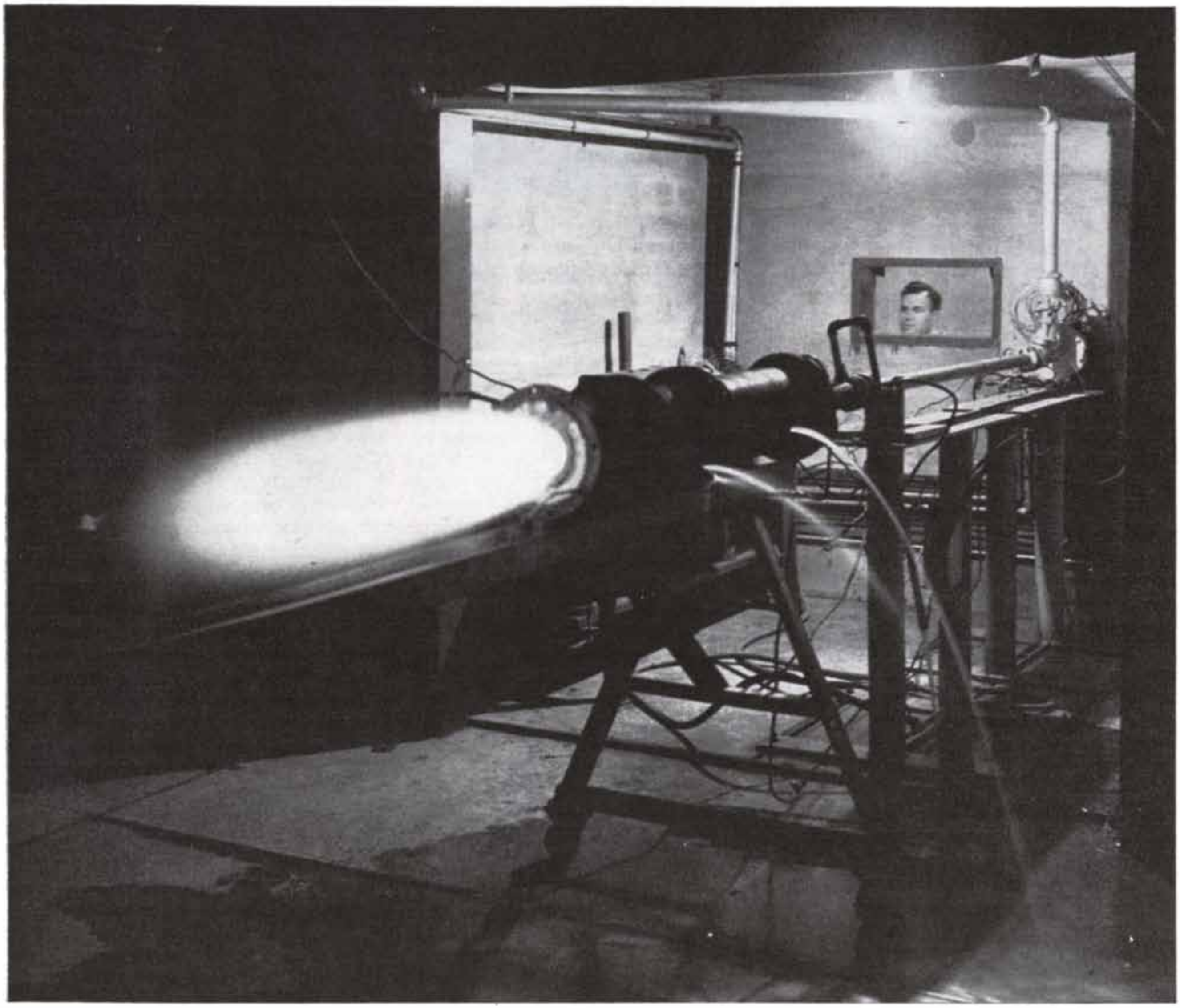
In the ram jet, which made its first appearance in a slightly different form in the German buzz-bomb, fuel is burned in a long, open-ended stovepipe combustion chamber. Air is rammed in at one end, and a heavy, turbulent flame of combustion gases is thrown out at the other. The air and fuel mixture enters the forward part at about 200 feet per second, and the hot exhaust gases are shot from the tail outlet at some 3,000 feet per second. The reaction thrust propels the pipe through the skies. Experimenters found that what they had in the stovepipe was an extremely fast gas-stream reaction something like an extended but confined Bunsen burner flame. As the work progressed, they found that this flame could be quite sharply controlled as to ingredients, size, shape and speed, and could be chopped off at any stage. Mullen, Wilson and J. B. Fenn thereupon conceived the idea that by drawing out millisecond reactions in space in a long tube and slowing the reactions slightly to about 1,000 feet a second, they could lengthen the flame's reaction zones sufficiently to allow them to tap the pipe at certain points and draw off homogeneous groups of intermediate reaction products.

For instance, when a mixture of hydrocarbon gases is burned in the tube, ethylene may form in quantity in the first zone, then fall off, break down and reform to acetylene in the second, which in turn, if the reaction is allowed to go its full length, drops off and decomposes to carbon in the tail zone. Acetylene forms in the high heat of the second zone by the collision reaction of two methane molecules. By quenching the tube wall with a water jacket at the proper point, which slows down or halts the reaction, the acetylene can be drawn off at a tremendous rate.

Acetylene, a highly reactive starting material for many organic compounds, has long been made by a laborious two-stage process, first producing calcium carbide in an electric furnace, then dropping the carbide into water to release acetylene gas. The new fast-reaction method promises to be cheaper, and the lower cost would open up large



A THERMOCHEMICAL PROCESS, being developed by Experiment Incorporated, employs the ram-jet principle for chemical production. As roughly diagrammed, hydrocarbon gas and preheated air are burned in tube to produce ethylene, then acetylene, then carbon. Chemicals are drawn off by quenching tube at proper point.



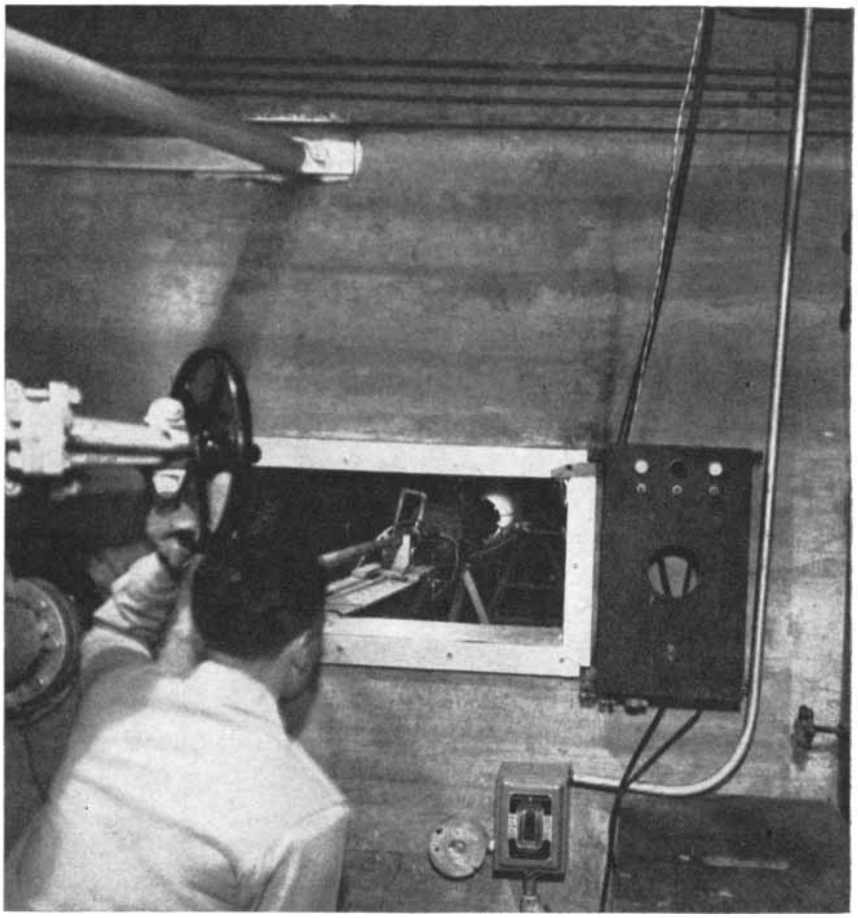
HIGH-SPEED CHEMICAL PLANT in test operation produces acetylene by the thermochemical process described above. Note water pouring out of quenching jackets. The roaring exhaust flame is economically used to preheat air going into the process, rights to which are held by Chemical Construction Corporation.

new fields of use for acetylene. But as is usual in chemistry, it will have stiff competition to meet in the shape of other developments in acetylene technology. Recently more advanced, semi-continuous calcium carbide processes have come into production in new plants built by the Union Carbide and Carbon Corporation, long the biggest producer, and by the Air Reduction Company. And there is also a new German process for obtaining acetylene directly from the partial combustion of methane. Faster and less costly than the old method, it is being used in a new plant by Monsanto and has been modified into a process of its own by Union Carbide's chemical division. It is also being built into a big new plant for American Cyanamid by Chemical Construction, which also has come to own U. S. rights to the German process. To compete with it, the investigators of the fast "jet chemical" method are currently striving for yields that will give their process a clear edge.

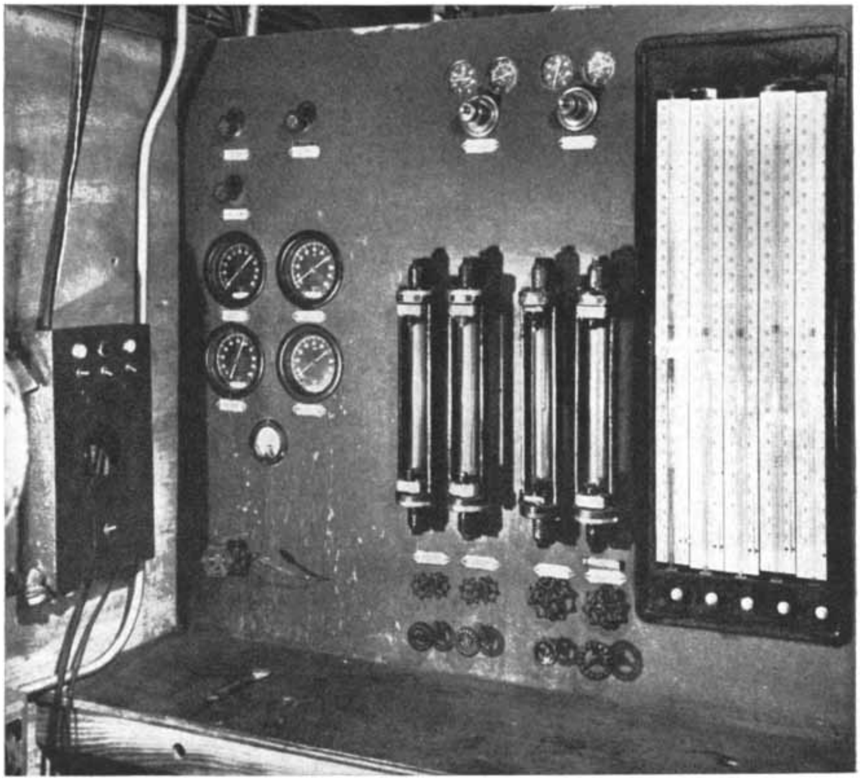
THE CONCEPT of a thermochemical process using high-velocity gas streams is only at the beginning of its development. It has wide significance for a large range of chemicals. Such a dynamic gas reaction economically supplying its own heat-energy should be an almost ideal system for the high-speed, continuous manufacture of not only acetylene but ethylene and almost any one of a large number of other chemical products requiring high heat. The process may also have application to the petroleum industry in the reforming of hydrocarbons. Moreover, by employing the same reaction as the new Daniels nitrogen-fixation process, using only enough fuel and preheated air to make it go above 2,100 degrees centigrade, the jet tube may offer still faster, continuous, straight-line production of nitrogen oxide, the base for the whole nitrogen industry.

The eventual operation of such fast processes must depend on extremely fast controls, probably monitored, if they are to be linked up in a complicated series, by an electronic digital computer. The pilot plant of Experiment Incorporated already contains a continuous infrared spectrometer—an advanced piece of apparatus which relatively few full-scale chemical plants have yet adopted.

Discoveries made in the studies of high-speed reactions in gases are likely to light the way for a more complete understanding of the mechanism of reactions in solids and liquids and to have a profoundly quickening effect on all chemistry. The futuristic concept of a chemical industry operating at lightning speed on nothing but a few simple raw materials such as marsh gas and carbon monoxide may still be a long distance off, but research, like the reactions, is moving fast.



TEST BAYS for high-velocity ram-jet, rocket and thermochemical experiments are heavy concrete structures equipped with thick glass portholes and a mass of control and recording instruments as shown below.



The Multiplication of Bacterial Viruses

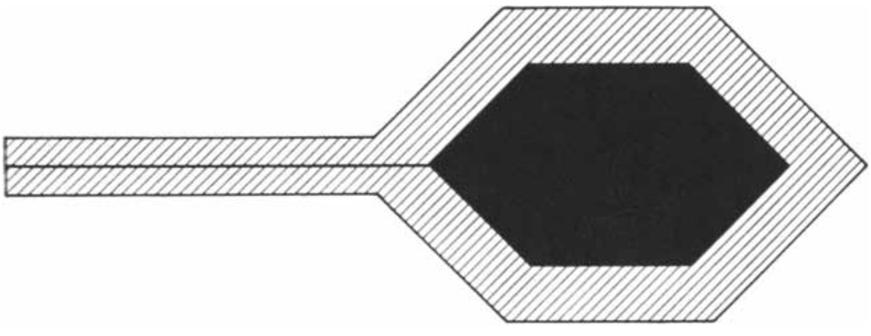
The organisms that infect bacteria provide a means of studying the mechanism of heredity. Some new tracer experiments reveal that their reproduction has several rather unexpected features

by Gunther S. Stent

THE PROCESS of heredity—how like begets like—is one of the most fascinating mysteries in biology, and all over the world biologists are investigating it with enthusiasm and ingenuity. Of the many angles from which they are attacking the problem, none is more exciting than the experiments on bacterial viruses. Here is an organism that reproduces its own kind in a simple and dramatic way. A virus attaches itself to a bacterium and quickly slips inside. Twenty-four minutes later the bacterium pops open like a burst balloon, and out come about 200 new viruses, each an exact copy of the original invader. What is the trick by which the virus manages to make all these living replicas of itself from the hodgepodge of materials at hand? What happens in the host cell in those critical 24 minutes?

Within the past few years studies with radioactive tracers have made it possible to begin to answer these questions. By labeling with radioactive atoms the substances of the virus or of the medium in which it multiplies, experimenters can follow these materials and trace the events that lead to the construction of a new virus. This article will tell about some of the experiments and the facts learned from them.

The bacterial virus, a tiny organism only seven millionths of an inch long, is a nucleoprotein: that is, a particle made up half of protein and half of nucleic acid. The latter is desoxyribonucleic acid—the well-known DNA which is a basic stuff of all cell nuclei [see "The Chemistry of Heredity," by A. E. Mirsky; SCIENTIFIC AMERICAN, February]. We are interested in the respective roles of the two parts of the virus molecule: the protein and the DNA. We are also interested in where the various materials come from when a virus synthesizes replicas of itself inside the bacteria growing in a culture medium.



BACTERIAL VIRUS of the T2 strain, which infects the bacterium *Escherichia coli*, has a hexagonal head and a tail and is approximately seven millionths of an inch long. In this schematic drawing the virus is divided into two parts. Its outer layer (*diagonal lines*) is composed of protein which has the ability to attach itself to the surface of a bacterium of the appropriate species and to react with antivirus serum. Its core (*black*) is made up of nucleic acid, which is protected by the layer of protein.

First let us consider the tracer technique. Suppose we wish to label the DNA part of the virus particles. Since an important constituent of DNA is its phosphate links, we shall label the element phosphorus with the radioactive isotope phosphorus 32. We begin with the medium in which we are growing bacteria that are to be infected by the virus. The culture contains inorganic phosphate as the source of phosphorus for the bacteria. To this medium we add a little radiophosphorus, so that there is one radioactive atom for every billion atoms of ordinary, non-radioactive phosphorus. The bacteria will take up the same proportion of radioactive and ordinary phosphorus. We can tell how much phosphate the bacteria contain simply by counting the radiophosphorus atoms with a Geiger counter: the total amount of phosphorus is a billion times that.

Now if we infect the culture of bacteria with viruses, the virus progeny also will have the same proportion of radiophosphorus. But to measure their phosphorus we must isolate them, for the culture contains a great deal of phosphorus not incorporated in them. We can separate the viruses in three ways: (1) by a series of centrifuging operations that remove the other materials through their differences in weight; (2) by adding non-radioactive bacteria, on which the viruses become fixed and which can then be removed by low-speed centrifugation; or (3) by adding a serum (developed in rabbits) which contains antibodies that combine with the viruses and precipitate them from the culture.

Two radioactive isotopes are used in

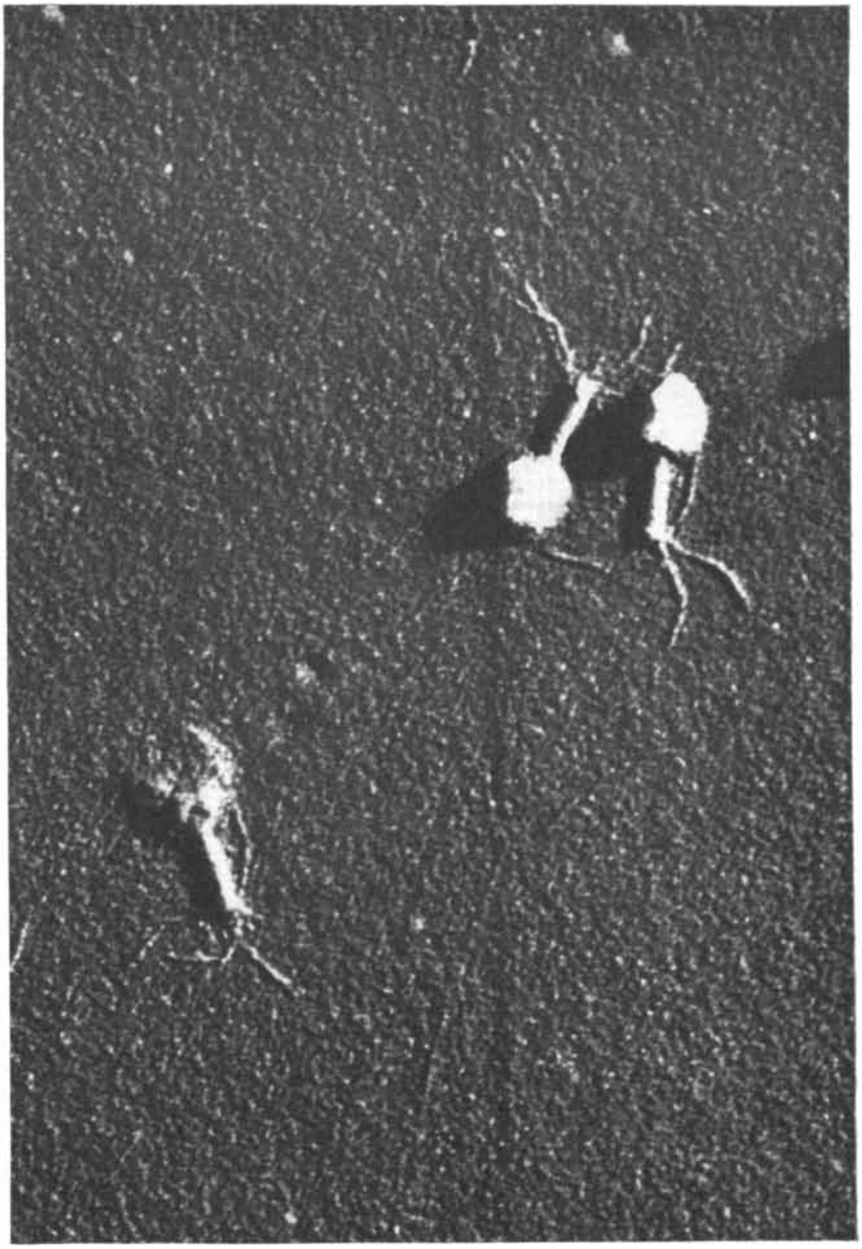
the bacterial virus work: phosphorus 32 to label phosphate and the DNA part of the virus, sulfur 35 to label the protein part of the virus. Now let us look at the experiments.

ALL OF THESE experiments were done on bacterial viruses of the strain called T2, which infects the common bacterium *Escherichia coli*. Some years ago two investigators—Thomas F. Anderson of the University of Pennsylvania and Roger M. Herriott of The Johns Hopkins University—observed that something curious happened to bacterial viruses when they were exposed to "osmotic shock," namely, a sudden change in osmotic pressure effected by adding distilled water to the liquid in which they were suspended. These viruses could still attack and kill bacteria. But they had lost their ability to reproduce. Under the electron microscope they looked like sacs that had been emptied of their contents, and a chemical analysis indicated that they had lost all their DNA.

Recently A. D. Hershey and M. W. Chase, working at the Carnegie Institution of Washington genetics laboratory in Cold Spring Harbor, N. Y., repeated and confirmed these experiments with the help of radioactive tracers. The DNA, labeled with radiophosphorus, was indeed removed from the virus by osmotic shock. It remained as DNA in the solution, but it was easily broken down by an enzyme—an indication that it had lost the protection of the protein "coat" of the virus. As for the protein shell of the virus, when separated from the solution and placed in a culture of bacteria it showed all its old power to seize upon and kill the bacteria. It also retained its ability to react with antivirus serum.

This looked very much as if the two parts of the virus had specialized functions. Apparently the virus' ability to attach itself to and kill a bacterium resided in its protein "coat." Did its power to reproduce and build hereditary images of itself reside in its DNA core? Other investigators had found that DNA did control hereditary continuity in bacteria. Hershey and Chase proceeded to investigate the question in their viruses.

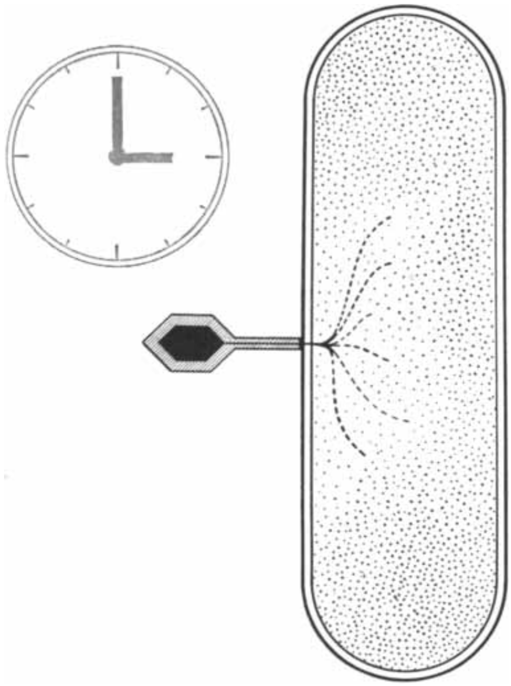
They first put viruses in cultures of bacteria that had been killed by heat. The viruses attached themselves to the dead bacteria and apparently poured out their DNA, for the DNA (labeled with radiophosphorus) was easily broken down by the enzyme desoxyribonuclease, just as when it was spilled out from viruses after osmotic shock. Similarly, when bacteria were killed by heat after viruses had infected them, the enzyme again broke down the DNA. The enzyme had no effect, however, on DNA discharged into *living* bacteria. It seems that the living membrane of a bacterium protects DNA from the enzyme, but when the bacterium is killed, its membrane becomes permeable and lets the enzyme through.

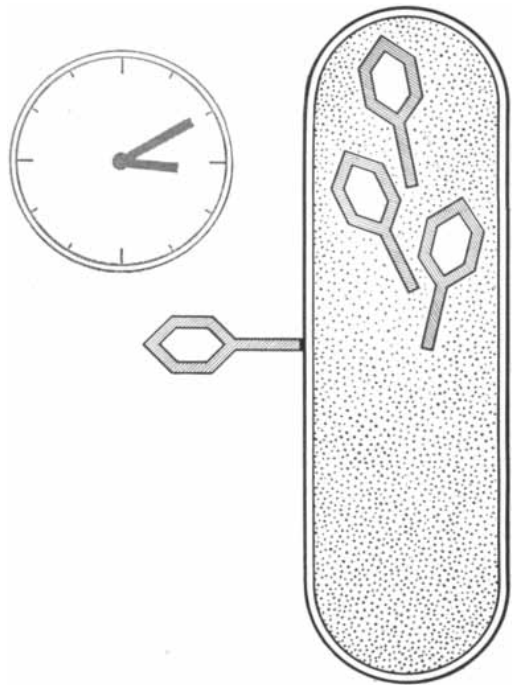


THREE BACTERIAL VIRUSES of the T2 strain are shown in this electron micrograph made by Robley C. Williams and Dean Fraser of the Virus Laboratory at the University of California. At the upper right are two intact viruses; their tails and hexagonal heads are clearly visible. At the lower left is a virus from which the nucleic acid has been removed; as a consequence the head of the virus has collapsed. This reproduction of the micrograph magnifies viruses approximately 100,000 diameters.

WHAT HAPPENS to the protein coat of the virus after it has emptied its DNA into the bacterium? Hershey and Chase infected living bacteria with virus, this time labeling the protein with radiosulfur. Then they shook up the suspension of infected bacteria in a Waring blender—the device used for stirring laboratory mixtures and for making milk shakes. The shearing force of the mixer stripped more than 80 per cent of the labeled protein off the bacteria. On the other hand, it did not remove any significant amount of DNA or interfere with the reproduction of viruses within the bacteria. The experiment showed that the virus protein stays outside the bacterium, and its job is finished as soon as it enables the DNA to gain entry into the cell. By the same token, it indicated strongly that the DNA is responsible for reproduction.

Once inside the host, the task of the nucleic acid is to reproduce itself 200-





REPRODUCTION of bacterial viruses is shown at four stages in the drawings on these two pages. The large stippled structure is the bacterium. Beside it is a clock which tells the time at which each stage is depicted. The first stage is infection. In it the virus particle attaches itself, probably by the tail, to the surface of the bacterium. The nucleic acid core of the virus empties into the bacterial cell; the protein coat of the virus remains outside. The second stage, called the "dark period," is shown about 10 minutes later. The virus nucleic acid has begun to multiply within the bacterial cell, and has induced the formation of

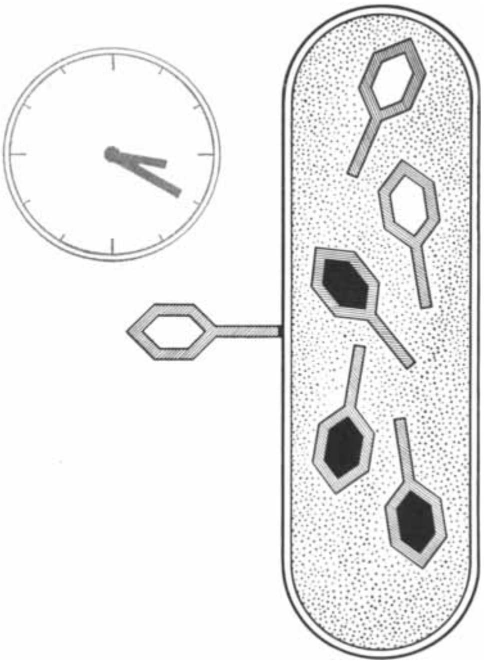
fold. It must also stimulate the production of 200 protein coats exactly like the one it has just shed. Where do the raw materials come from, and how are they put together?

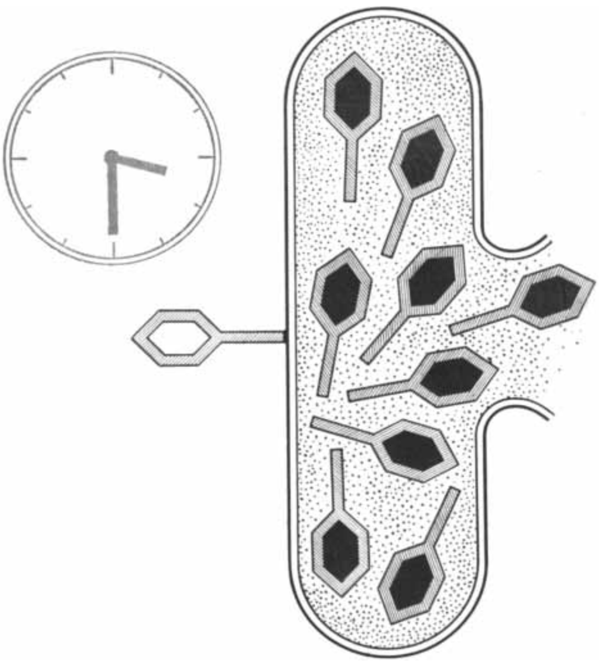
In 1946 Seymour S. Cohen of the University of Pennsylvania, the first investigator to study bacterial virus reproduction with radioactive tracers, conceived an experiment directed to this question. He wished to find out whether the needed raw materials, particularly the phosphorus, came from the bacterial cell itself or from the medium surrounding it. He grew two cultures of bacteria, one in a medium containing radiophosphorus, the other in a non-radioactive medium. Then he removed the bacterial cells from the liquid in the two test tubes and switched them, putting the non-radioactive bacteria in the radioactive medium and *vice versa*. Now he infected both cultures with viruses. When the bacteria burst and the new viruses emerged, he isolated the viruses and measured their radioactivity. The viruses that came out of the non-radioactive bacteria transferred to the radioactive medium were radioactive: they had two thirds as high a concentration of radiophosphorus as the medium in which the bacteria had been immersed. On the other hand, the viruses that came from the radioactive bacteria in the non-radioactive medium had only one third as much radiophosphorus as the bacteria. Cohen therefore concluded that the new generations of viruses had obtained two thirds of their phosphorus from the growth medium while they were being formed and only one third from their host bacteria. This was a great surprise to those bacteriologists who had long supposed that bacterial viruses were formed from ready-made structures already present in the host cell.

At the University of Chicago Frank W. Putnam and Lloyd M. Kozloff, making similar studies with nitrogen 15 as the tracer, have found that the protein of viruses, like their DNA, is derived mostly from substances assimilated from the growth medium.

COHEN'S EXPERIMENT had covered the state of the system at just one stage: the next step was to follow the whole history of the conversion of inorganic phosphorus into virus DNA, from the moment bacteria began to grow in the medium until the newborn viruses finally emerged. At the State Serum Institute of Denmark Ole Maaloe and I extended Cohen's experiment with radiophosphorus, making the switch of radioactive bacteria to a non-radioactive medium and *vice versa* at many different stages in the development of the culture, both before and after infection of the bacteria with virus. In this way we were able to determine just how much of the phosphorus that the bacteria eventually donated to the new viruses was assimilated by them from the medium during the various periods of development. Before they were infected with virus, the bacteria took up that phosphorus at the rate of their own growth, which means that they were using the phosphorus to make their own DNA. But after infection, their assimilation of phosphorus that they were to donate to the viruses increased sharply. Most of the phosphorus the bacteria were now taking up was going directly into the synthesis of new viruses.

We also observed that it takes at least 12 minutes to convert inorganic phosphorus into virus DNA. Hence any phosphorus that is to go into the making of the new viruses must have been assimilated by the bacteria by the end of the first 12 minutes of the 24-minute period during which the viruses are synthesized in the cell. As a matter of fact, A. H. Doermann has found that the 24-minute latent period divides into two 12-minute phases. In experiments at Cold Spring Harbor he opened infected bacteria at various stages. During the first half of the latent period there were no fully formed viruses with infective power within the bacterial cell; even the original invader had disappeared. Then, after 12 minutes, the first infective particle appeared, and more followed until there were 200 just before the cell burst. The explanation is clear. The original invading virus had shed its protein coat on entering the cell and therefore was no longer an infective unit. No virus could appear in the cell until at least one new protein coat had been manufactured and coupled with a unit of DNA. Apparently





new protein coats. The protein coats contain no nucleic acid; there are no infective particles, not even the particle that caused the infection. The third stage, called the "rise period," is shown about 20 minutes after infection. Now some of the protein coats contain nucleic acid; the first infective particles of the new generation have made their appearance within the bacterial cell. The final stage is shown about 30 minutes after the first. The infected bacterium bursts and releases the new generation of virus particles into the surrounding medium. In the final drawing only a few of the 200 particles in the new generation of bacterial viruses are depicted.

this proceeding takes some 12 minutes.

It seems that the manufacture of protein and of DNA goes on side by side within the cell. In experiments with radiosulfur as the label, Maaloe and Neville Symonds of the California Institute of Technology have recently shown that by the time the first new infective virus appears, there is already enough virus protein in the cell to form about 60 viruses. On the other hand, in similar experiments with radiophosphorus as the label we have found indications that completed units of DNA do not unite with protein units until the last moment; the particle then becomes infective.

THE DNA of the original invading virus is responsible, as we have seen, for reproduction within the cell, both of DNA itself and of protein. How does it go about its job? Putnam and Kozloff labeled viruses with radiophosphorus and followed the radioactivity to see what happened to the phosphorus after the viruses infected bacteria. They found that about 40 per cent of the labeled phosphorus showed up in the viruses' progeny, the rest being discarded in the debris. Experiments with radiocarbon have shown that the same is true of other constituents of the DNA. In other words, about 40 per cent of the DNA of the parent viruses is passed on to the descendants.

How is the old DNA passed on? Is the parent's DNA handed on intact to a single individual virus offspring in each bacterial cell in a random 40 per cent of the cases, or is it distributed generally among the descendants? At Washington University of St. Louis Hershey, Martin D. Kamen, Howard Gest and J. W. Kennedy examined this question. They infected bacteria in a highly radioactive medium (one in every 1,000 phosphorus atoms was radioactive) with non-radioactive viruses. The DNA of the parent viruses was stable; not containing any radiophosphorus, it would not decay by radioactivity. Hence if it was passed on intact, a recognizable number of the viruses' descendants also should have stable DNA. But this was not the case. The descendant population steadily lost its infectivity, due to radioactive decay of its phosphorus atoms, until fewer than one tenth of 1 per cent of the descendants were infective.

Is it possible that the hereditary continuity of the virus resides in a fraction consisting of 40 per cent of the DNA, and that the rest of the DNA does not participate in reproduction at all? To answer this question Maaloe and James D. Watson at the State Serum Institute of Denmark produced three generations of virus. The first had its DNA labeled with radiophosphorus. A single virus of this generation then produced generation II, and passed on to it 40 per cent of its radiophosphorus. Now if the radiophosphorus transmitted from generation I to generation II was carried in a special reproductive fraction of the DNA, all of it should have been passed on to generation III. Actually it was found that generation III received only the usual 40 per cent. One must therefore conclude that the parent DNA material is not handed on in intact fractions but rather is distributed in a general fashion over the structures of the descendants.

SUMMING UP, the tracer studies so far have given us the following picture of how bacterial viruses reproduce themselves. By means of some property residing in its protein coat, a virus is able to attach itself to the surface of a bacterial cell. The contact immediately uncorks the virus, and it pours its DNA into the cell. The emptied protein coat is left outside the cell and thereafter plays no further part. Inside the cell the virus DNA begins to make replicas of itself, using as raw materials the nucleic acids of the bacterium and fresh substances absorbed by the bacterium from the medium surrounding it. About 40 per cent of the parent virus DNA itself is conserved and will reappear in the descendants. The virus DNA also induces the synthesis of new protein in the cell. Finally units of the protein combine with the DNA replicas to form 200 exact copies of the parent virus.

The facts discovered so far give us only an outline of the process, but they seem a good start on the road to solving the mystery of how organisms build structural copies of themselves and pass on their heredity from generation to generation.

A 100-BILLION-VOLT ACCELERATOR

A year ago subatomic particles were for the first time accelerated to energies of more than a billion electron volts. Now a much more powerful machine is in prospect

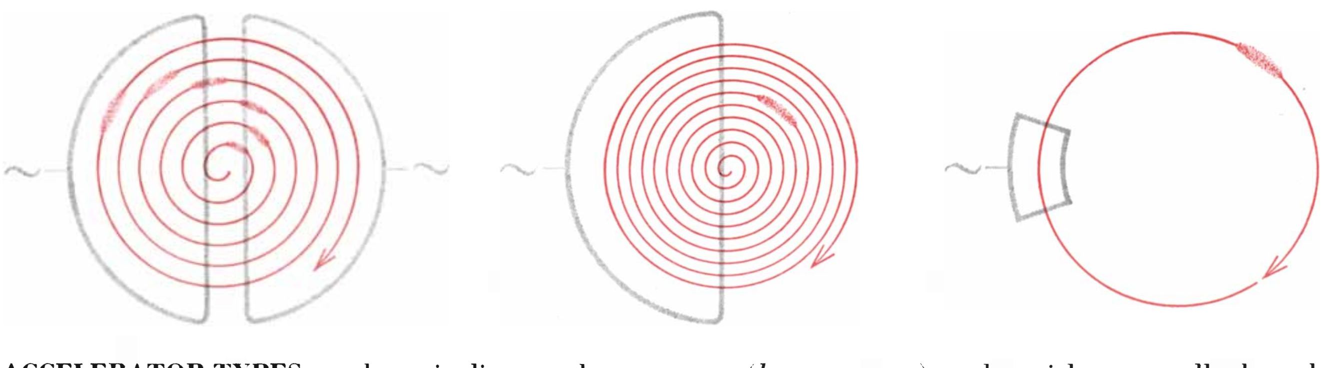
by Ernest D. Courant

THE HISTORY of atomic physics for the past 25 years in a sense is epitomized by the rise in energy of the machines built to attack the nucleus of the atom. In 1930 the most energetic accelerator bombarded the nucleus with 100,000 electron volts. Since then the energy of the machines has been increased roughly by a factor of 10 every six years [*see chart on the opposite page*]. And each jump in energy has opened a new field of exploration into the nucleus.

Today the most energetic machine we have is the Cosmotron at the Brookhaven National Laboratory, which accelerates bombarding particles to 2.3 billion electron volts (Bev). The University of California will soon put into operation a somewhat larger machine of the same type that will reach 6 Bev ["The Bevatron," by Lloyd Smith; SCIENTIFIC AMERICAN, February, 1951]. But to get to a higher order of energy, a new principle is needed, just as was required for each jump in the past. Such a principle has been worked out in the last few months by a group at Brookhaven. The design is called the "strong-focusing" synchrotron, and with it physicists hope to reach 100 Bev. A machine of 30 Bev along these lines already is being designed by the builders of the new central nuclear research laboratory projected by a group of European countries.

Before we discuss the new idea, let us review briefly the reasons for the scramble to produce higher energies. Essentially what we want is to get a better look at the extremely tiny nuclei of atoms. To see what something looks like we generally shine light on it. When the object is small, we may need a microscope. But for atoms or nuclei even a microscope will not do, because it cannot resolve objects smaller than the wavelength of light. An atomic nucleus is smaller than a wavelength of visible light by a factor of 50 million. Its diameter is only about one trillionth of a centimeter. To "see" it we must have wavelengths of something like that size. Only the atomic particles themselves can generate such wavelengths.

A BEAM of particles, like a beam of light, has the characteristics of waves. In accordance with quantum theory, the wavelength associated with a given particle decreases as the particle's energy (or speed) increases. When protons are accelerated to an energy of a few million electron volts



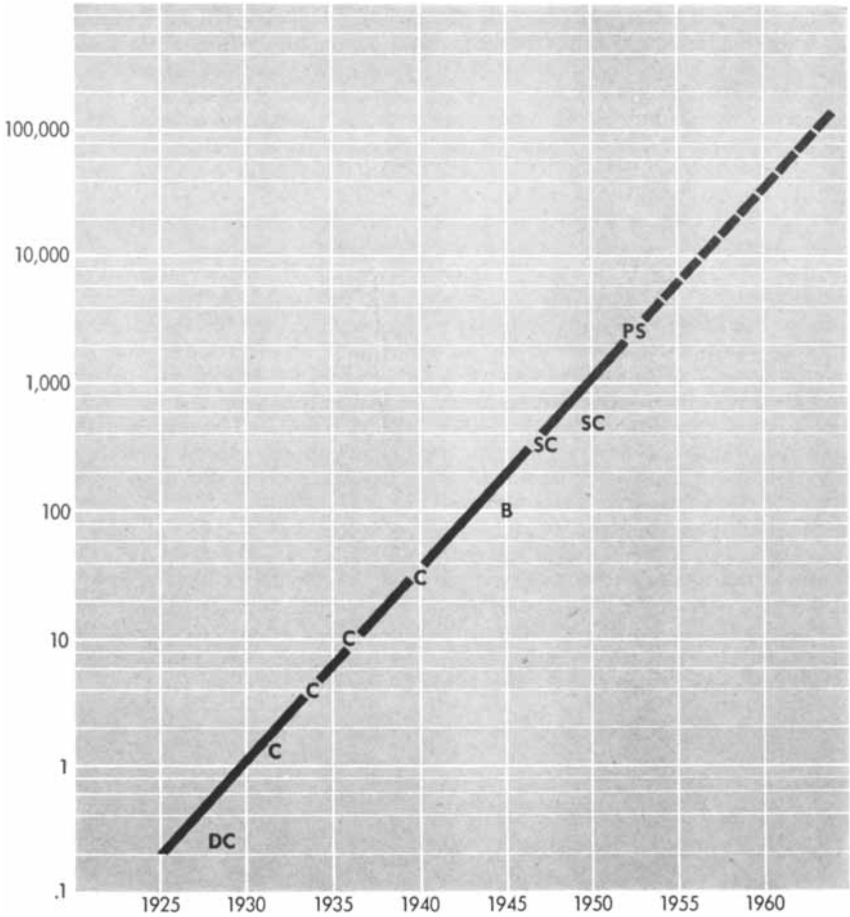
ACCELERATOR TYPES are shown in diagram above. In linear accelerator (*top*) bunches of particles cross each gap between drift tubes just when the oscillating charges on the tubes are such as to give an accelerating kick. Cyclotron (*bottom left*) and synchro-cyclotron (*bottom center*) send particles repeatedly through the same gap in larger and larger circles. Synchrotron (*bottom right*) keeps particles on same circular path for whole acceleration by changing the strength of the magnetic field that makes particles travel in circle.

(Mev), their wavelength is about a trillionth (10^{-12}) of a centimeter. Thus with a proton beam of this energy we can "see" an atomic nucleus. The accelerator that produces such a beam should really be called an "atomic microscope" rather than an atom-smasher.

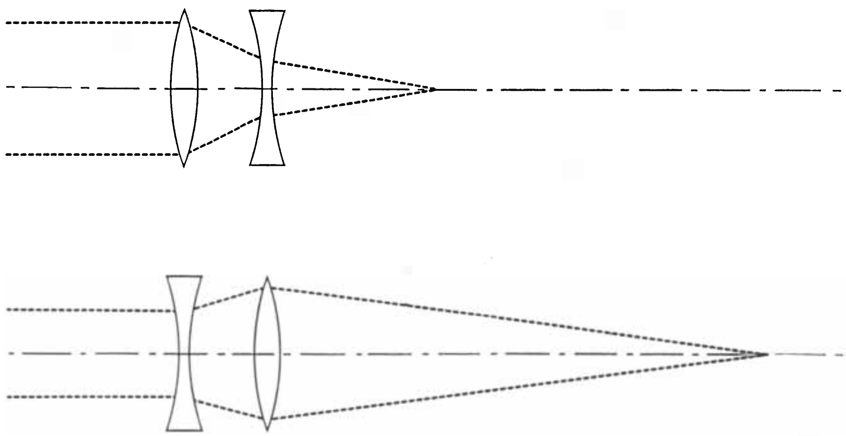
Now to examine the forces within the nucleus we need still shorter wavelengths, for those forces are exerted over distances of 10^{-13} cm. or less. We can obtain a wavelength of 10^{-13} by accelerating protons to several hundred Mev. When we bombard the nuclei of atoms with beams in the energy range of 200 to 450 Mev, we begin to produce mesons—the particles that are believed to have something to do with the binding forces of the nucleus. We know, furthermore, that other mysterious particles appear when the nucleus is attacked by the still shorter wavelengths of the extremely energetic cosmic rays. To investigate those particles we need to bombard nuclei with billions of electron volts under controlled conditions in the laboratory. The force fields around the proton operate over distances of 10^{-14} cm., and the investigation of these fields also will require several billion electron volts. With energies of 10 Bev or more we can reasonably expect to produce and detect the so-called negative proton, which so far is only theoretical. And this is not the end: the higher we go in energy, the more questions arise and the more energy we need to answer them.

So the main problem in designing accelerators is not where we want to stop but how far we can go. Every successive design has hit a ceiling beyond which it could not practicably go. All accelerators are based primarily on the same operation: electric potential (pressure) is applied to a charged particle and accelerates it across the electric field. The simplest way to accelerate the particle to the desired energy is to build up the pressure to the necessary voltage. But this method, exemplified by the Van de Graaff electrostatic generator, works only up to a few million volts; beyond that it becomes too difficult to build insulation to hold the high electric pressure in the machine.

THE CYCLOTRON solved this impasse by accelerating particles with a series of kicks across small electric fields, instead of in one big field. The particles travel in a circular path, being bent into such a path by a magnetic field. They get their boosts in energy at the gaps between the D-shaped halves of the circle [*drawing at left, bottom of opposite page*]. Across each gap an electric field is applied by an alternating current, so timed in frequency that it applies a kick to the particles in the direction of their travel just as they reach each gap during their revolution. The successive boosts raise the particles to higher and



ACCELERATOR ENERGY shows a steady rise since 1925. DC stands for direct-current machines; C, for cyclotrons; B, for betatrons; SC, for synchrocyclotrons; PS, for proton synchrotrons such as the Bevatron and Cosmotron.



FOCUSING ACTION of alternately converging and diverging lenses, which combine to give a net converging effect, demonstrates how the magnetic fields in a strong-focusing system would hold atomic particles on a path.

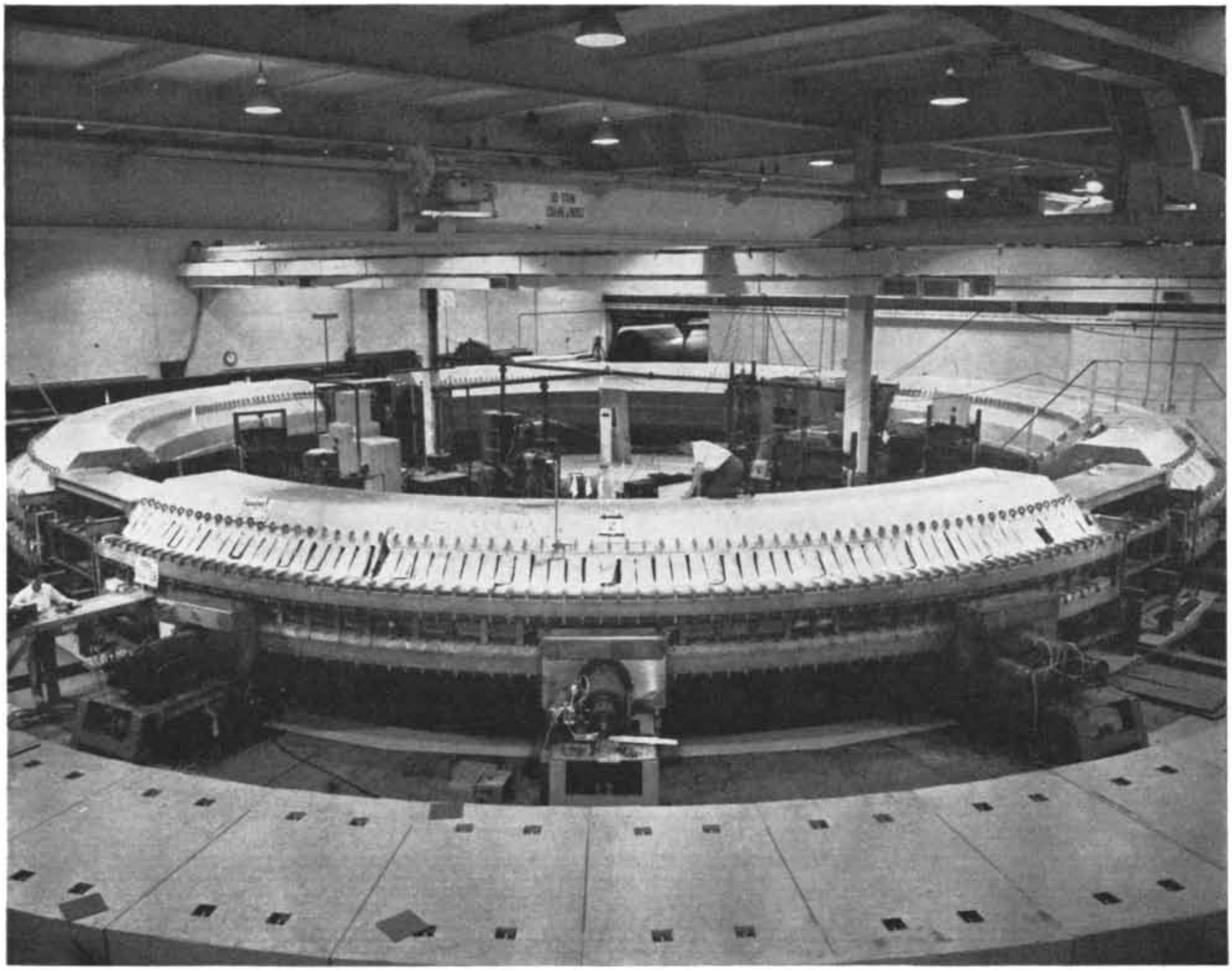
higher speeds. As their speed increases, they spiral out into larger and larger circles, so that they still reach the gaps after the same interval each time, in step with the oscillating field. Hence the prescription for stepping up the energy of cyclotrons is simple: build them bigger, so the accelerated particles can spiral out in larger circles. But again this works only up to a point. When the particles reach very high speeds, they begin to increase in mass, according to relativity principles, and now they take a longer time for each round trip and fail to reach the gaps in synchronization with the accelerating field. The energy limit of a cyclotron, for protons, is about 15 Mev.

The answer to the cyclotron's limitations was a change in design that compensated for the particles' increase in mass. The oscillator was made variable so that it adjusted its frequency to the increasing length of the particles' trip and synchronized its boost with their arrival at the gaps each time. This type of machine is called a synchro-cyclotron. A further refinement was to make the magnetic field, as well as the frequency of the electric field, adjustable. Now the path of the particles can be kept constant: The strength of the magnetic field is increased as the particles gain in energy, so that they always travel in the same circle. This type of machine, called the synchrotron, requires less magnet iron than the synchro-cyclotron, because it does not need a magnetic field everywhere inside it but only near the fixed orbit of the particles.

Brookhaven's Cosmotron and California's Bevatron are synchrotrons. They have raised the acceleration of particles to the billion-volt range, and in theory there is no limit to the energy they could achieve. But there is a practical limit: the size of the magnet. The Bevatron magnet already weighs 10,000 tons, and a 30-Bev synchrotron would require at least 100,000 tons of iron.

AFTER THE COSMOTRON went into operation last summer, a group of physicists at Brookhaven began to speculate on how the magnet size might be reduced to make practicable a much bigger machine than the Cosmotron. In the Cosmotron the particles travel through a doughnut-shaped tube. To reach the billion-volt energy range they must go round and round through the tube for the enormous distance of 150,000 miles. The slightest error in aiming the particles when they are shot into the tube will take them off the course long before they reach their goal. They may also be knocked off course by collisions with stray gas molecules in the evacuated tube or by fluctuations in the accelerating voltage or frequency. The Cosmotron's magnet keeps them in the necessary orbit by means of corrective forces that push the particles back on the course when they begin to stray. Even so, the particles must be given a fairly wide channel to travel in, and that is the main reason the magnets must be so large. In the Cosmotron the pipe through which the particles move is 7 by 36 inches in cross section, and the magnet is eight feet thick.

Suppose that the straying of the particles could be controlled so closely that they stayed almost exactly on a perfectly circular orbit. Then the channel could be



THE COSMOTRON at Brookhaven National Laboratory is the largest accelerator yet built. In it protons have attained an energy of 2.3 billion electron volts (Bev). In the foreground is heavy concrete shielding.

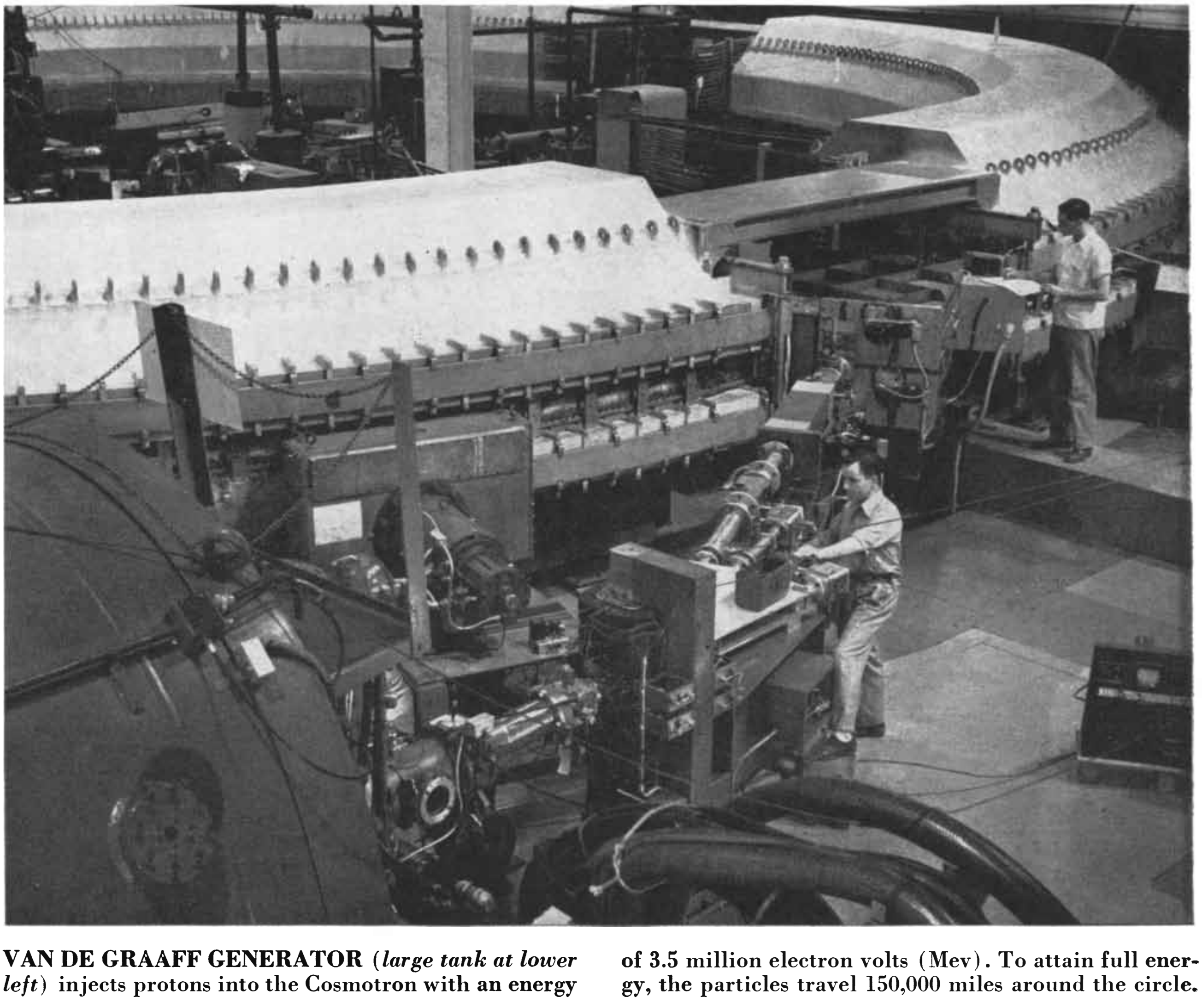
very narrow and we would need only a thin magnet around it. We could build a very much larger circle with the same weight of magnet metal, and thereby accelerate particles to far higher energies.

The problem is to find a way to apply stronger focusing forces, and this was the problem that our group at Brookhaven undertook to solve. Focusing is an appropriate word here, because the forces act on straying particles in much the same way as a lens focuses a diverging beam of light. In the Cosmotron the focusing force is applied by the same magnet that bends the particle path into a circle. It is a question of shaping the magnetic field. The poles of the magnet are so shaped that the strength of the field falls off gradually with increasing distance from the center of the circle. As a consequence the lines of force of the field are concave toward the center of the particle orbit [*see drawing at top of page 45*]. The effect is to provide a small upward force from below and downward force from above which controls the vertical straying of particles. The trouble is that the weakening of the field in the direction away from the center accentuates horizontal straying. Fortunately, some horizontal focusing is provided by the force that bends the particles in their circular path. But the balance is delicate, and neither the vertical nor the horizontal focusing force can be made strong.

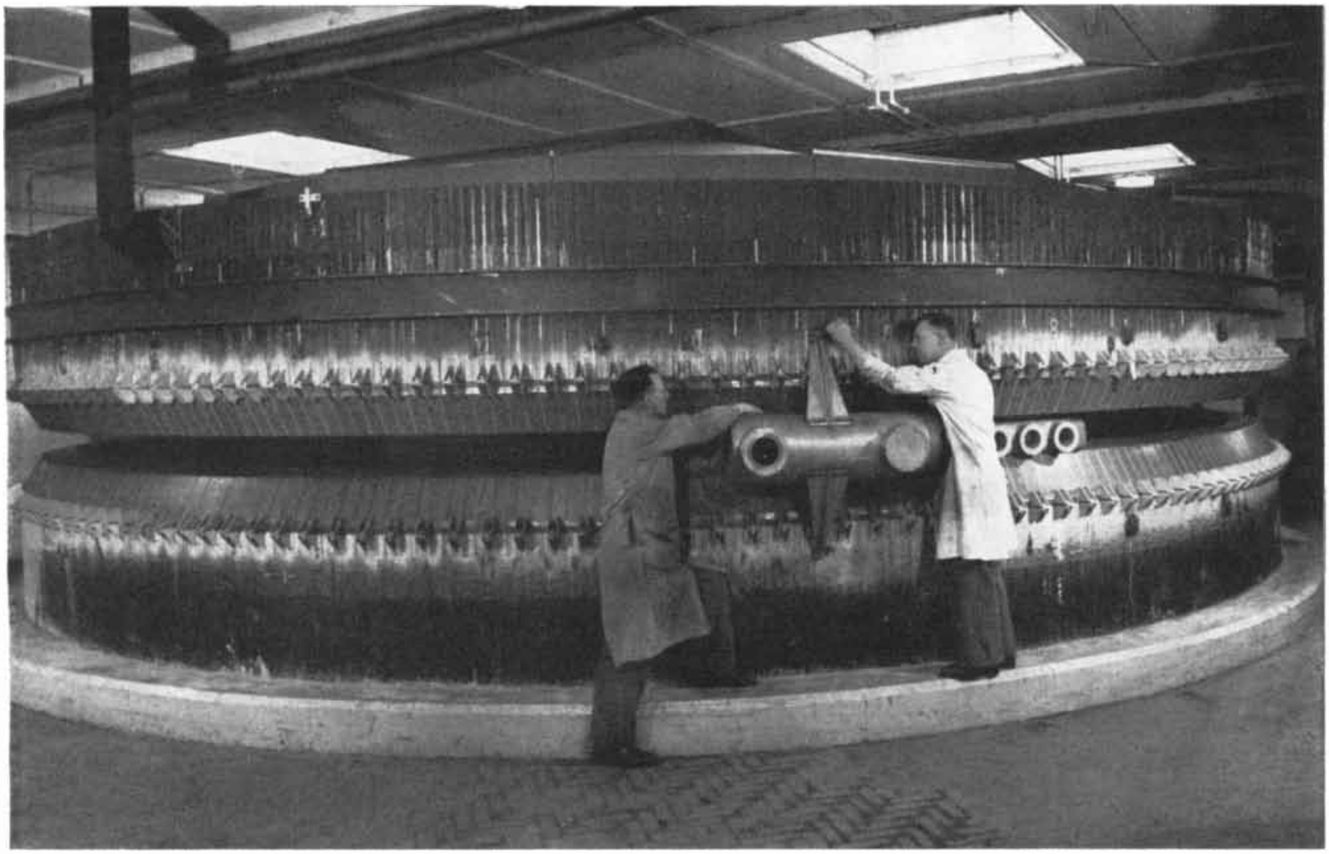
The Brookhaven group that pondered the question included myself, M. S. Livingston, H. S. Snyder, J. P. Blewett, W. H. Moore and others. Livingston made a suggestion that sounded interesting. Suppose, he said, that instead of a single magnet around the whole circle we had a series of C-shaped sections alternately facing in opposite directions—the back of one C toward the center of the circle and the back of the next toward the outside. We set up equations to see whether such an arrangement could keep the particles in a stable circular orbit, and found that it could. What was more, we calculated that it could provide very strong focusing forces. The poles of each magnet (the open ends of the C) could be shaped so that the magnetic field increased or decreased in strength very rapidly with distance from the center of the circle, which means that the lines of force would be strongly concave and strongly convex in the alternate sectors. One sector, with the poles sloping inward, would apply strong vertical focusing forces and horizontal defocusing (diverging) forces; the next would reverse the slope and the forces. To our surprise, we found that the net effect, if the sectors were properly spaced, would be to focus the beam strongly, just as a series of alternately converging and diverging lenses focus a beam of light [*see drawings at bottom of page 41*].

With such a setup we can use a very much smaller channel, and hence a much thinner magnet, than in the Cosmotron. Another important aspect of the design is that by breaking up the magnet ring into many sectors we can kick the particles again and again in their round through the ring, instead of only at one gap.

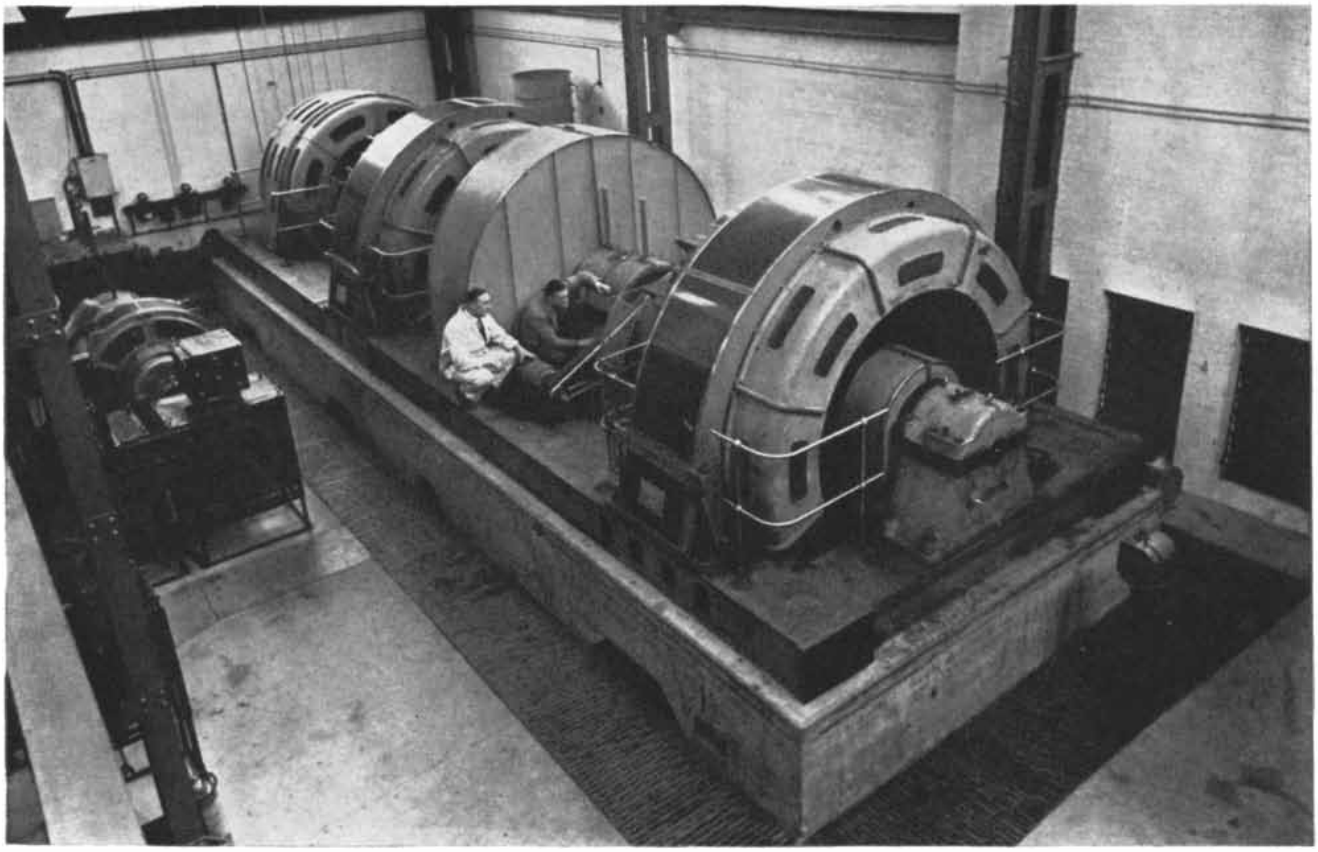
WE HAVE made a tentative design for a "strong-focusing" synchrotron that might accelerate particles to as



VAN DE GRAAFF GENERATOR (*large tank at lower left*) injects protons into the Cosmotron with an energy of 3.5 million electron volts (Mev). To attain full energy, the particles travel 150,000 miles around the circle.



MAGNET AND GAP of a proton synchrotron are seen in this photograph of the unfinished machine which is being built at the University of Birmingham in England. The magnet weighs 810 tons and is 32 feet in diameter.



POWER FOR MAGNET in British machine comes from the gigantic motor-generator set pictured above. The generator furnishes 12,500 amperes of current at 1,100 volts. Its flywheel (*behind men*) weighs 37 tons.

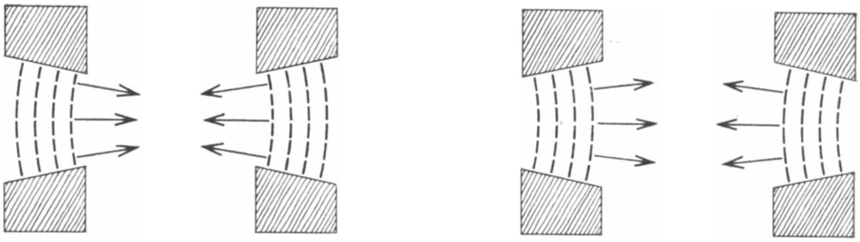
much as 100 Bev. It would have, say, 300 C-shaped magnets spaced around a circle 2,300 feet in diameter. (The Cosmotron's diameter is 75 feet.) Each magnet would be 20 feet long and 2 feet by 3 feet in cross section (instead of 8 feet by 8 feet). In the space between the pole tips of the magnets the particles would travel in a pipe only 3 inches by 4 inches in cross section (instead of 7 inches by 36 inches). The magnets would be separated by 4-foot gaps, and in every other gap a radio-frequency accelerating unit would give a 6,000-volt kick to the particles as they came through. (In the Cosmotron ring they get only one 1,000-volt boost on each round.) This 100-Bev machine would get by with a total magnet weight of some 6,000 tons—only twice that of the Cosmotron and a little more than half that of the Bevatron.

M. G. White of Princeton University has suggested an alternative design. The particles might be bent around the circle by magnets which had uniform fields and did essentially no focusing, while the focusing was performed by separate magnets placed between the bending magnets. The advantage of this design is that uniform fields could be made stronger than the inhomogeneous fields required for simultaneous bending and focusing; its disadvantage is that there would be large intervals without focusing forces. It may well be that the ultimate solution will be a compromise between the two designs.

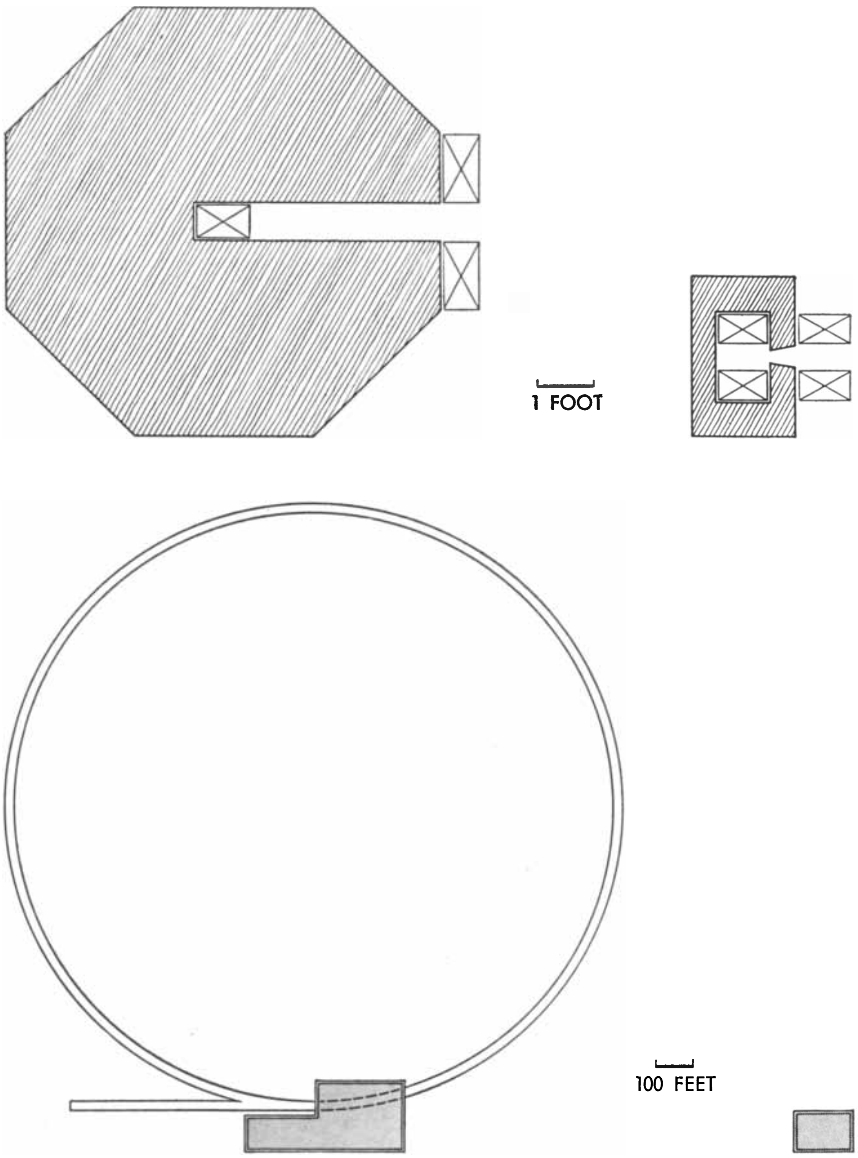
MANY PROBLEMS remain to be solved before such a machine is actually built. For example: We shall need to find ways of economizing on power if we are to have 150 accelerating units of 6,000 volts each. There is the problem of controlling the frequency and synchronizing all those units to keep them in step with the flying particles. There is the problem of correcting imperfections in the magnets and errors in their alignment. There is the question of ground movements and temperature variations around the fantastic 2,300-foot ring, bearing in mind that conditions at one side of the circle may well be different from those at the other side nearly half a mile away.

These problems are not insoluble; many people are now considering them and believe that they have, in principle, found methods for overcoming the difficulties. The job of working out a detailed design is still ahead; when it is done the machine may look very different from what has been outlined.

In any case these main features are likely to remain: A magnet cross section much smaller than that of existing high-energy machines, and a magnet and radio-frequency system composed of many comparatively small, identical components, which will lend themselves to mass production techniques.



MAGNETIC FIELDS in adjacent sections of a strong-focusing synchrotron are diagrammed above. The force (*arrows*) on a charged particle in a magnetic field acts at right angles to the direction of the field (*dotted lines*). Thus a field that is concave toward the center (*left*) would force particles that are above or below the midline toward this line. A field bending in the other direction (*right*) would force such particles farther from the line.



COMPARISON between Cosmotron and a proposed 100-Bev strong-focusing proton synchrotron shows relative sizes of components. At the top left is a cross section of the Cosmotron magnet; at right, the magnet of the proposed machine, drawn to the same scale. Rectangles with crosses indicate electric coils. At the bottom the building that houses the Cosmotron (*right*) is compared with the installation planned for the new machine.

TELEVISION AND THE ELECTION

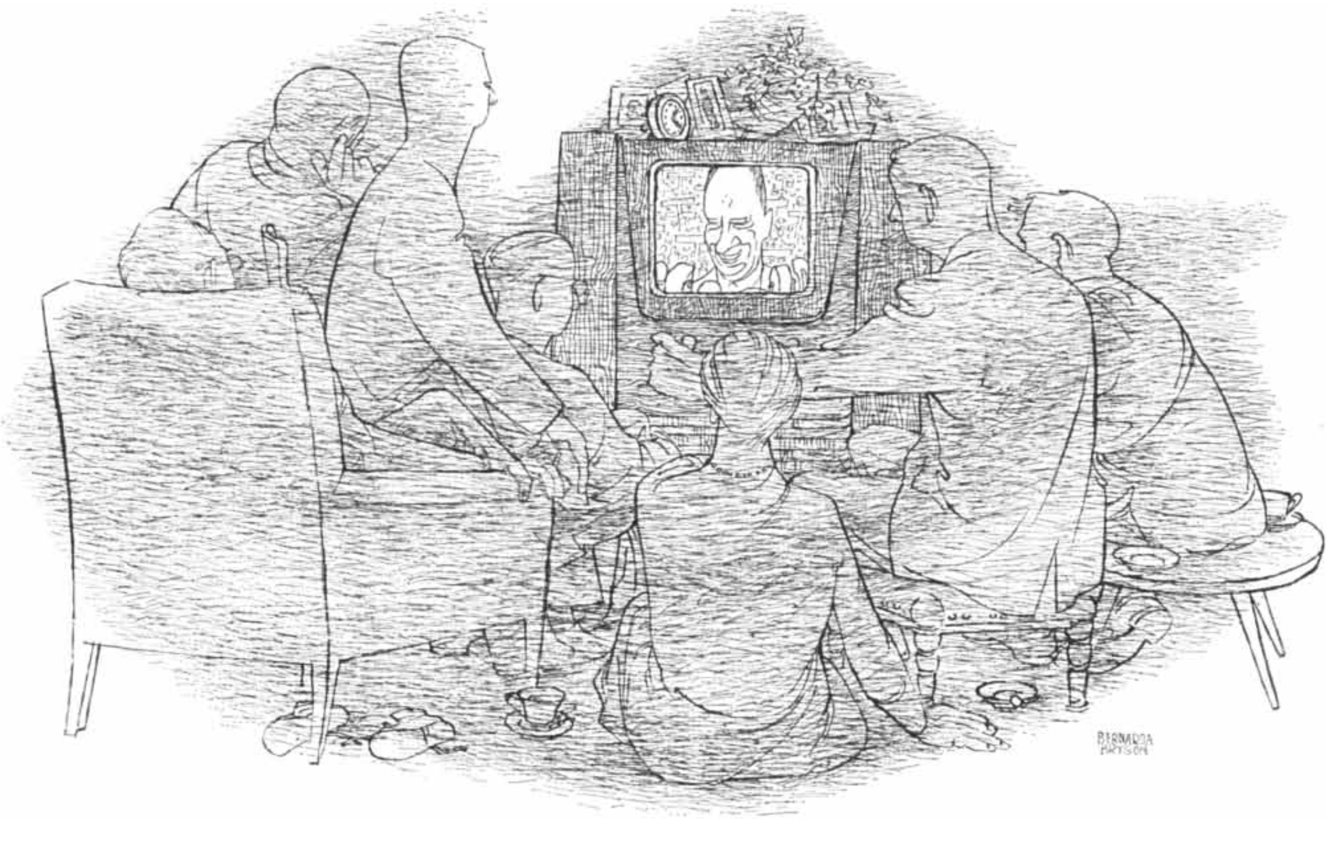
The new medium played an important part in the recent presidential campaign. How did it compare with radio, newspapers and magazines as a source of information?

by Angus Campbell, Gerald Gurin and Warren E. Miller

THE PRESIDENTIAL campaign of 1952 was the first in which television played a major part. How much did this new medium influence the election? No one really knows, because no specific studies were made to measure the impact of TV on the thinking of the electorate. But we do know something about how television compared with the other media of information in bringing the campaign to the public, and what groups in the population were most exposed to, or affected by, the television campaign.

As part of a two-year study of political behavior financed by the Carnegie Corporation, the Survey Research Center of the University of Michigan last fall made an intensive analysis of the factors affecting the decision of citizens to vote. In the course of this we asked a sample of the U. S. population in November a few questions about the media (newspapers, radio, television and magazines) through which they had "paid attention to the campaign," and requested them to say which they considered had been most important to them. Our sample, 1,714 citizens of voting age, was selected in such a way that there is only one chance in 20 that its representation of the country at large is in error by more than four percentage points. Its representation of specific regions of the country or of classes of the population is subject to a somewhat larger margin of error.

The first noteworthy fact is that the public went out of its way to watch the campaign on television. Only about 40 per cent of the homes in the U. S. have television sets, but some 53 per cent of



the population saw TV programs on the campaign—a reflection of "television visiting." On the other hand, the campaign news and material in newspapers, magazines and on the radio did not reach all of their respective audiences: more than 80 per cent of the population take daily newspapers and have radios and more than 60 per cent regularly read magazines, but in each case the number following the campaign in these media was smaller than the total audience [*see top table at the right*].

There are several points of interest in the geographical picture given by this table. The relatively poor showing of radio in the Northeast indicates that television is supplanting radio in that region. In the South radio leads all other media because that predominantly rural region has relatively few TV sets and a smaller proportion of newspaper readership than other parts of the country.

WHEN PEOPLE were asked which medium had given them the most information about the campaign, the impact of television became even more striking [*see middle table at right*]. In the nation as a whole television, though available to only a minority of the people, led the other media in the number of persons who rated it most informative. Of those who actually watched the campaign on TV (nearly all of whom were exposed to other media), 59 per cent considered television their most important information source. In contrast, among those who followed the campaign in newspapers, which takes in 79 per cent of the population, only 28 per cent rated newspapers as the medium from which they got most of their information. Again there were marked regional differences: the Northeast relied most heavily on television, the South on radio, and the Midwest and West were almost identical in pattern, with television in the lead.

To what sections of the population did television appeal most? The situation is summarized in the table at the top of the next page, which breaks down the responses into population categories. To begin with, the ability to buy a set obviously is an important selective factor: the proportion of people who followed the campaign on television was much smaller in the lowest income group (under $3,000) than in the higher-income groups. (We know that ownership of sets rises with income.) In general the attraction, or availability, of television was highest in metropolitan areas and among the better paid groups—professional and business men, white-collar workers and skilled workers. The rural, low-income and unskilled groups relied mainly on radio. But it seems certain that among these people also television will supplant radio as TV sets, and broadcasting stations, become available to them. Where income and facilities allow, people of all groups tend to turn from radio to television.

When it comes to newspaper and magazine reading, the differences among the occupational and income groups are not so wide. But there are substantial differences according to education: the better educated people were, the more they read about the campaign. And by the same token, the less they valued television as the source of information. The income factor masks this, as well-educated people are more likely to have high incomes and therefore to own television sets. When we separated education from income status, however, we found that people with college degrees or some college education rated television markedly lower than did those with less schooling. This is shown in the table at the bottom of the next page.

Among people in the higher-income groups, who can afford television sets, the campaign on TV seems to have made a significantly greater impact on those with only a grammar or high school education than on college people. It got its highest rating from people with an income of $5,000 or more who never went to high school. A third of the college group considered TV the most important single source of information on the campaign, but reading played a proportionately larger part in their information-getting than it did for those with less education. This simply bears out the truism that higher education tends to create active rather than passive habits of obtaining information.

Television as a campaign medium has made its main inroads into radio. On the whole the newspapers and magazines so far seem to have held their ground, for their importance was rated as high in the Northeast, where TV sets are most common, as in other regions. But as television expands its coverage and develops techniques for appealing to the various kinds of audiences, it will undoubtedly offer more and more competition for the attention of the voters.

AS TO HOW television affected the voting itself, we have no clear evidence. Those who rated television their most important source of information voted for Eisenhower in about the same proportion as those who relied mainly on radio or newspapers [*see bottom ta-*

	Northeast	Midwest	South	Far West	**Total**
Television	71	57	31	57	**53**
Radio	60	72	74	72	**69**
Newspapers	80	87	66	83	**79**
Magazines	35	43	36	52	**40**

PERCENTAGE OF PEOPLE in various parts of the U. S. who "paid attention to the campaign" through each medium is given in this chart.

	Northeast	Midwest	South	Far West	**Total**
Television	48	33	13	33	**31**
Radio	13	27	39	28	**27**
Newspapers	21	24	21	22	**22**
Magazines	4	6	5	5	**5**
More than one medium	9	7	10	8	**9**
None of the four	5	3	12	4	**6**

SOURCE OF MOST INFORMATION about the campaign is also given in per cent. Here the differences among the media are much more striking.

	Television	Radio	Newspapers	Magazines
Voted for Eisenhower	43	40	44	54
Voted for Stevenson	38	25	33	22
Did not vote	19	35	23	24

INFLUENCE OF MEDIA was difficult to assess. Percentages give behavior of each group which rated one medium their most important source.

	Television		Radio		Newspapers		Magazines	
	Watched Campaign	Most Important Source	Listened to Campaign	Most Important Source	Read about Campaign	Most Important Source	Read about Campaign	Most Important Source
Sex of Respondent								
Men	56	31	72	23	83	27	42	6
Women	51	31	68	31	76	18	39	4
Place of Residence								
Metropolitan	76	49	62	14	82	22	35	4
Towns or Cities	47	27	71	30	81	23	43	5
Open Country	36	16	76	41	67	19	38	7
Family Income in 1952								
Under $3000	34	17	73	38	66	20	27	4
$3000 to $4999	60	37	68	23	84	25	40	4
$5000 or above	70	42	67	19	91	22	58	7
Occupation of Head of Household								
Professional people	63	22	80	19	97	30	67	15
Businessmen, managers, officials	69	43	70	21	92	21	60	7
Clerical, sales, office workers	61	38	67	18	89	25	46	7
Skilled workers	61	43	63	20	79	22	32	2
Unskilled workers	36	22	68	39	63	17	22	3
Farmers	33	14	78	42	72	21	53	6
Education of Respondent								
Grammar School	40	25	67	33	65	21	23	2
High School	63	38	69	25	86	21	45	5
College	60	28	80	20	95	28	75	11

SECTIONS OF THE POPULATION who either "paid attention to the campaign" through one or more media, or rated one medium their most important source of information about the campaign, are given in per cent by this table. A selective factor emphasized by the breakdown is the ability to purchase a television set.

ble above]. Magazine readers were considerably more Republican. Stevenson did somewhat better among the television devotees than among those who preferred radio or newspapers, but these differences may not be very significant, as geographical and other factors also entered into the situation.

We cannot tell from our studies whether television had a distinctive impact on voters. It may be that television, radio and the newspapers were all equally partisan (or nonpartisan) in covering the campaign and thus had similar effects on their followers. On the other hand, it is also possible that television did have a more potent effect on the individuals who viewed the campaign, but that the degree of its influence is concealed by selective factors which were not controlled in our analysis. To measure the comparative effects of the various media it will be necessary to track down these other factors and make allowances for them.

In the 1956 election there will be an opportunity to analyze the effects specifically and precisely, and it is to be hoped that such studies will be undertaken. By then television probably will have expanded its coverage of the nation so greatly that the sociological pattern of its audience, and of the other media audiences, will be substantially different from what it was in the 1952 campaign. The direction of these changes will itself be revealing as to the nature of television's impact.

Another word of caution should be added. The 1952 data apply only to the audiences for political broadcasting and reporting. It cannot be assumed that the same pattern of media preferences would be found in other areas of information or entertainment.

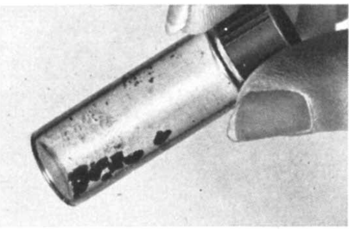
	Less than $3000			$3000 to $4999			$5000 or Over		
	Grammar School	High School	College	Grammar School	High School	College	Grammar School	High School	College
Television	13	27	10	37	40	29	49	45	33
Radio	40	37	27	26	22	20	14	20	19
Newspapers	20	15	43	25	25	28	18	20	25
Magazines	2	6	7	2	5	7	4	5	13
More than one medium	9	9	10	6	6	15	10	7	9
None of the four	16	6	3	4	2	1	5	3	1

LEVEL OF EDUCATION influenced the choice of the medium which was the most important source of information about the campaign. In general the better educated the respondent to the questionnaire, the more he relied on reading and the less he relied on television. The proportions are given in per cent.

Kodak reports to laboratories on:

super infrared sensitivity . . . a very minty ketone . . . solving the record storage problem . . . a photorecording paper for high temperature processing

Infrared sensitizer



The granules in the vial above represent a very significant advance in man's kit of tools for examining the nature of the physical universe. It is a new Kodak sensitizing dye for infrared-sensitive plates. We have no need to exaggerate its importance. For studies on, say, the main helium emission line at 1080 mμ, it gives the 200-inch Hale Telescope on Palomar Mountain as much space-penetrating power as a fantastic 900-incher would have had a year ago. (Thermonuclear reactions involving helium are, for better or worse, very interesting these days.)

We do not sell Kodak sensitizing dyes as such, but you get the new one now in Kodak Spectroscopic Plates and Films of Class Z sensitization, wherein photographic sensitivity goes out to 1200 mμ—farther than any other sensitizer commercially available. The spectral distribution of sensitivity remains the same as before, but it has been reported that where the previous Class Z sensitization required a 4-minute exposure, the new one requires only 12 seconds.

Kodak Spectroscopic Plates and Films of Class Z and other sensitizations—in many emulsion types and many sizes—are sold by the Kodak Industrial Dealer in your locality. It is advisable to get in touch with Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y., before placing an order.

Essence of an essence

Pulegone, a ketone isomeric with camphor, is now available from us to serve the needs of those delvers into the mysteries of olefaction who like to work with a pure chemical entity and don't like to bother laboriously separating it out of pennyroyal oil. Very minty in itself, it is readily converted into other minty materials. Under as little as 12 mm Hg pressure, its boiling range is way up at 95-98 C. Currently we are asking only $1.40 for 25 grams of it.

In addition to Pulegone (*Eastman 6739*) *we supply over 3500 other organic chemicals for science and industry. For a copy of our catalog, write to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y.*

New microfilmer

If you have not yet taken effective steps toward an orderly solution for the vexing problem of laboratory record preservation, we have a concrete suggestion—the Recordak Junior Microfilmer. A new model went on the market this year at $1550. This may seem like a stiff outlay for a device that will never point to new directions in scientific insight. But picture the peace enveloping the administrative mind secure in the knowledge that every notebook page, every table of data, every scrap of significant luncheon-table doodling, in a project involving many hands and many months, is safely captured in a small reel of 16mm film. The new microfilmer not only does the photography (36:1) but also projects the finished microfilm back (1:34). It takes documents up to 9½″ by 14″, and by a twin-lens system lays each successive pair of images side by side on the film. Reel length is 200 feet, but shorter lengths can be removed for processing at any time. Projected image quality is good enough for photocopies on Kodagraph Projection Paper.

The new Recordak Junior Microfilmer is demonstrated and sold by the Recordak Corporation, a subsidiary of Eastman Kodak Company, with offices at 444 Madison Avenue, New York 22, N. Y. If your microfilming requirements are not of a continuing nature, you may wish to rent one for $25 a month.

Hot-clime photorecording

Out in the world's lonely places roam the oil hunters, the field seismographic parties setting off their small explosions and recording the stratigraphically reflected or refracted vibrations on Kodak Linagraph 480 Paper. Some of the lonely places have climates such that a tank of processing solution can get scalding hot to the touch. Hot-clime seismographers could, if necessary, work out some refrigeration arrangement to achieve the recommended 68 F, but it would be a lot more convenient if their photographic paper could stand processing at temperatures as high as 120 F. On this point we have news: it can. Not only does

the new Kodak Linagraph 480 Paper take such treatment in stride, but it gives blacker traces on clean, white backgrounds and a surface with more "tooth" for pen or pencil notations. All this without a change in the speed range, which people count on as a constant in a Kodak sensitized material.

Seismographers and all others requiring a photorecording paper that can stand high-temperature processing should ask their Kodak dealers for Kodak Linagraph 480 Paper, Type 1272. (*Those last digits are important.*) *It comes in a great variety of sizes and spoolings, details of which are obtainable from Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.*

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

Kodak TRADE-MARK

WE FIXED A TEA WHOLE CHEMICAL

The little housewife with the leaky teakettle didn't know what she was starting. Nor did her dealer in Altoona, Pa., when he sent the kettle back to Alcoa. But they *did* know that a nearly new kettle shouldn't spring leaks.

Oddly enough, some users of aluminum heat exchanger tubes were having the same trouble. They, too, knew that aluminum tubes shouldn't be perforated in a few short months.

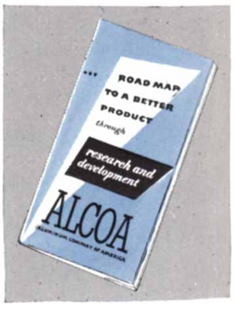
Engineers at Alcoa's Research Labs reasoned that something in the water was the cause. Painstakingly, they analyzed water from trouble spots all over the country (Fig. 1). In each case, they found traces of copper or tin or lead. This suggested that the aluminum was sacrificing itself to these heavy metals by electrolytic corrosion.

One Alcoa researcher thought he could protect kettles and tubes by coating them with a layer of pure aluminum. But how to apply it?

Months of trying and failing followed. Finally, they rolled a slab of pure aluminum with a slab of high-strength aluminum (Fig. 2). The working of the rolls bonded the two metallurgically and

Alcoa
Aluminum

ALUMINUM COMPANY OF AMERICA



KETTLE AND THE INDUSTRY BENEFITED

Alclad sheet was born—strong aluminum alloy with a layer of pure aluminum.

Test after test proved that this new kind of aluminum lasts far longer in contaminated waters (Fig. 3). Although the pure aluminum slowly etches away, it protects the strong underlayer for years and years.

Now how to make exchanger tubes of this "two-layer" aluminum? Alcoa metallurgists found a way to extrude "two-layer" billets—then draw them into tubes.

For heat exchanger builders, Alcoa's Process Development Labs developed ways to form and flare the tubes into tube-sheets. To test the tubes in actual service, they made miniature exchangers and convinced manufacturers to try them in parallel with their big exchangers (Fig. 4).

Out of all this has come the Alclad aluminum heat exchanger tube. Lowest cost of all metals—handling hundreds of touchy compounds —lasting years longer. And for housewives, like our heroine, 1,500,000 Alclad teakettles have been made in the past 17 years.

MORAL: We tell you this story, not because we think you are vitally interested in heat exchangers or even teakettles. But we do think you may see something interesting in the *way* these problems were solved. This same method may place your product head and shoulders above competition.

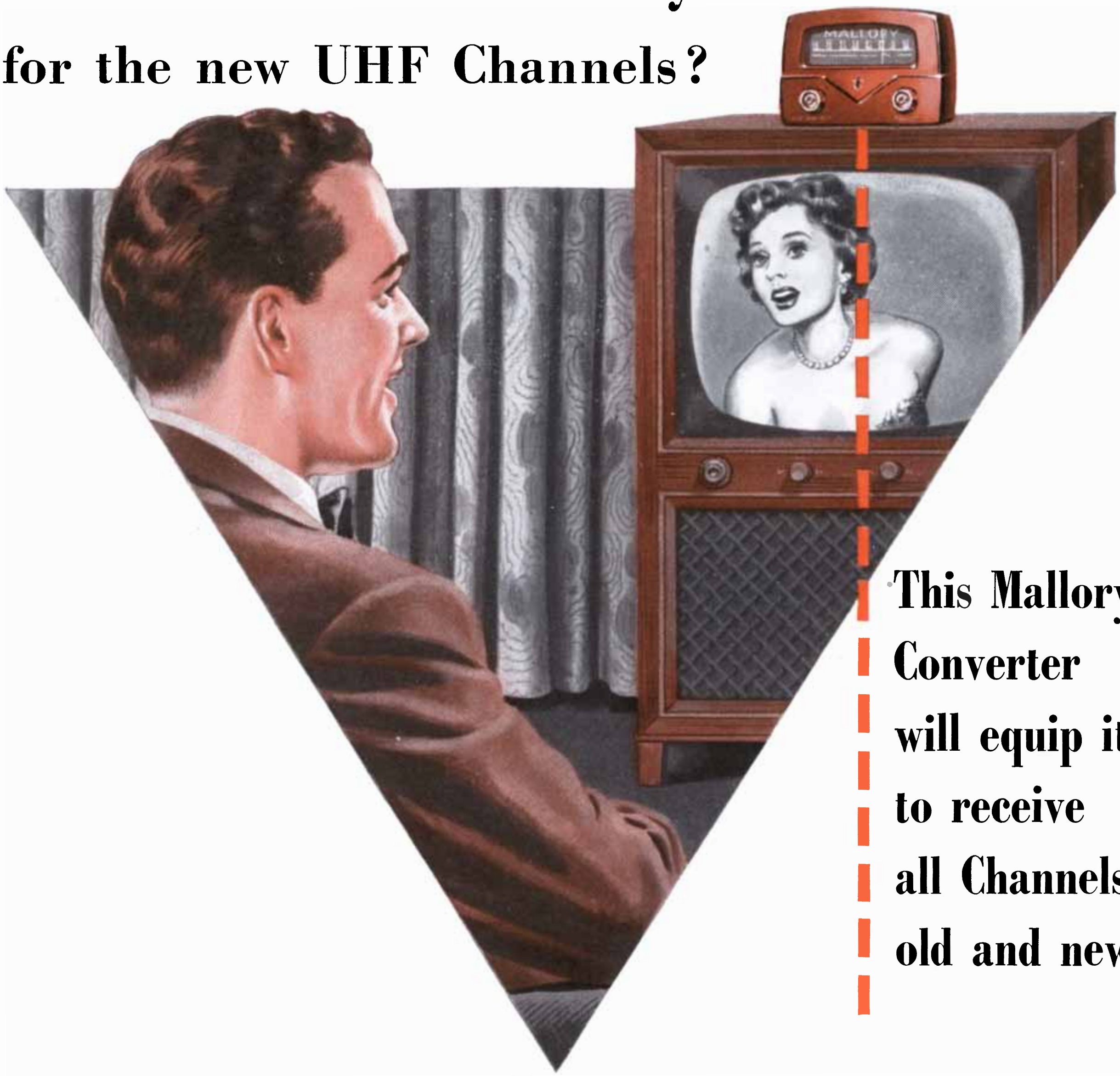
For example, there are *Alcoa Engineers* familiar with the problems of your industry. *Alcoa's Research Labs* are ready to dig deeply into your project. *Alcoa Test Facilities* will prove the theories of basic research. And *Alcoa's Process Development Labs* will work closely with you to help solve your production problems.

Now is the time to call your local Alcoa sales office, or write

ALUMINUM COMPANY OF AMERICA, 2182-E Alcoa Building, Pittsburgh 19, Pennsylvania.

Is Your TV Set Ready

for the new UHF Channels?



This Mallory Converter will equip it to receive all Channels . . . old and new

That's right! As new UHF channels go on the air in your area, you will receive them all . . . with no sacrifice of existing channels . . . with no internal changes in your set. The Mallory Converter can be connected to any set in a few minutes, right in your home.

The heart of the Mallory Converter is the Mallory UHF Tuner . . . an outgrowth of a tuning principle pioneered by Mallory in the early days of television. This Tuner provided a practical answer to the problems of UHF reception within weeks after the television "freeze" was lifted. It made possible the production of both Converters and new, all-channel receivers in time for the first commercial UHF telecasts.

The Mallory Converter is a visible demonstration of engineering accomplishment. Many other Mallory products work behind the scenes—for example, the vibrator power supply in your car radio . . . the timer control in your automatic washer . . . the contacts in your home thermostat. Common to all of them are Mallory engineering research and Mallory precision quality that mean better performance and lower costs for a host of products in the fields of electronics, electrochemistry and metallurgy.

P. R. MALLORY & CO. Inc.

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SERVING INDUSTRY WITH THESE PRODUCTS:

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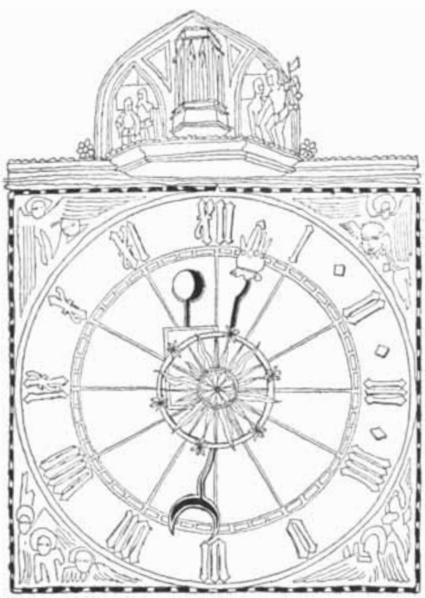
P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

SCIENCE AND THE CITIZEN



The Bureau of Standards Case

THE discharge of Allen V. Astin as director of the National Bureau of Standards by Secretary of Commerce Sinclair Weeks last month started a controversy over scientific policy in Washington. Weeks announced that "the functions and objectives of the Bureau of Standards" must be revaluated "in relation to the American business community and other agencies of Government."

The immediate cause of the firing was the Bureau's refusal to approve the claims of a manufacturer for a product said to prolong the life of storage batteries. At a hearing before the Senate Small Business Committee, Weeks and Assistant Secretary Craig Sheaffer accused the Bureau of not having been "sufficiently objective" in testing the product.

The battery additive, known as AD-X2, is manufactured by Pioneers, Inc. Composed of sodium sulfate and magnesium sulfate, it is claimed to dissolve the coating that sometimes covers a battery's plates and thus rejuvenate the battery. At the request of the Federal Trade Commission, the Bureau tested this product in 1950 and found it no more effective in restoring battery life than some 100 other additives the Bureau had tested in the past 25 years. In 1952, after the manufacturer had interested the Senate Small Business Committee in the case, the Bureau tested the product again and came to the same conclusion as before. Last February the Bureau issued a *Statement on Battery Additives* summarizing its tests and declaring that "there exist . . . no valid technical data for believing that battery additives have any beneficial action on normal storage battery operation." The U. S. Post Office issued a mail fraud order against the manufacturer of AD-X2.

Secretary Weeks persuaded the Postmaster General to suspend this order. Later the Department of Commerce halted distribution of the Bureau's *Statement* and of an older pamphlet on battery additives.

Explaining the discharge of Astin to the Senate Committee, Weeks said the Bureau had refused to follow the manufacturer's suggestions on how tests of the additive should be conducted and had discussed its report with "the very people who might not want to see the additive remain on the market" (*i.e.*, battery manufacturers). He also declared that many users had given testimonials to the value of the product, that tests made for the manufacturer by the U. S. Testing Company had "rendered credible the experience reported by the consumers," and that other tests made by a group of scientists at the Massachusetts Institute of Technology had yielded findings which "differed in some respects" from those of the Bureau.

The Bureau commented that the results of the M.I.T. tests could be reproduced "only under conditions which are not encountered in the normal use or operation of automobile storage batteries," and that the M.I.T. group had conceded that their results did not necessarily prove the additive had a beneficial effect on batteries in normal use.

Astin declared that he had proposed that the Bureau's findings be reviewed by its consulting committee of five leading U. S. scientists or by the National Academy of Sciences. But, he said, he was refused "the privilege of a conference" with Weeks before his discharge.

The first reaction to the case from a scientific organization came from the Federation of American Scientists. Its executive committee stated that "scientists both in and out of the Government have been shocked by the abrupt and ill-considered dismissal." Noting that the Bureau of Standards had traditionally been kept out of party politics, the Federation said that Astin's dismissal throws a "shadow . . . on the working relationship between science and government." The Federation declared that "the nation is entitled to know whether it can continue to rely on the objectivity of findings of governmental scientific agencies."

New Chairman

REPRESENTATIVE W. Sterling Cole, New York State Republican, was elected chairman of the Joint Congressional Committee on Atomic Energy last month. The choice broke a two-month deadlock in the committee over whether the post should go to a Senator or a Representative. Bourke B. Hickenlooper, Republican Senator from Iowa, was named vice-chairman.

In an interview after his election, Cole said that the Committee's first major job would be to consider changing the Atomic Energy Act to promote commercial production of atomic power.

Reactors

TWO important developments in nuclear power were announced last month. The reactor being built as a prototype for a submarine engine at Arco, Idaho, went into operation and began to produce power. And at the Oak Ridge National Laboratory an experimental reactor of the "homogeneous" type produced 150 kilowatts of electricity. "It could turn out to be the most important achievement at Oak Ridge since the war," said Alvin Weinberg, the laboratory's director of nuclear research.

The homogeneous reactor contains its uranium fuel and moderator in a single solution. This mixture is pumped through a heat exchanger, where the heat produced by the nuclear reaction generates steam to run a turbine-generator. The reactor produces new fissionable material as well as power.

Government Research in Colleges

IN an effort to resolve the growing conflict between the research needs of the Federal Government and work in basic science in the nation's colleges and universities, the American Council on Education has issued a report offering advice to both the Government and the institutions.

The report, prepared by a special Committee on Institutional Research Policy, notes that the Government is now spending $150 million a year to support academic research. Most of this money is allocated to "hardware" projects—those from which quick practical results are expected. They are frequently in fields where security considerations prevent the publication of results. The projects often pay salaries far higher than the normal academic scale. As a result, says the report, academic research is now leaning too heavily toward applied science, and there is reason to fear that students are not being trained along lines that will produce a new generation of creative scientists.

The Committee urged institutions to refuse all classified projects unless the emergency is compelling and no other agency can handle the work. It recommended that any Government research a college or university does accept should be closely related to the objectives of the institution and the interests of its staff. When Government work is accepted, the funds should be large enough to cover all expenses, both direct and indirect. No institution should accept so much Government work that it becomes financially dependent on this outside support.

The Committee advised the Government to support basic scientific study along with its immediate research projects. It suggested that all classified work be transferred as soon as possible from academic institutions to Government, private or industrial laboratories. Projects that must be continued under college or university auspices should be carried out in central laboratories set up at convenient points, so that several institutions could jointly contribute personnel to the research staff. The Committee added that some of the larger projects, which now occupy too much of one institution's resources, could be distributed by subcontract to several laboratories.

The chairman of the Committee was Virgil M. Hancher, president of the University of Iowa. Serving with him were Robert F. Bacher, professor of physics at the California Institute of Technology; James H. Corley, vice-president of the University of California at Berkeley; Carey Croneis, president of Beloit College; James R. Killian, Jr., president of M.I.T.; Laurence R. Lunden, comptroller of the University of Minnesota; James B. Macelwane, dean of the Institute of Technology at St. Louis University; Edward McCrady, president of the University of the South; J. C. Morris, vice-president of Tulane University; Franklin D. Murphy, chancellor of the University of Kansas, and T. P. Wright, vice-president of Cornell University.

Secretary of A.A.A.S. Resigns

HOWARD A. MEYERHOFF, administrative secretary of the American Association for the Advancement of Science, and Gladys M. Keener, executive editor of the Association's publications, *Science* and *The Scientific Monthly*, resigned last month. They said their resignations stemmed from their "desire not to hamper the two administrations to follow that of Detlev W. Bronk, retiring president."

The two administrations will be those of Edward U. Condon, incoming president, and Warren Weaver, president-elect. Weaver and Condon have been advocates of a broadening of the Association's functions. They have criticized the annual meetings as too specialized and have urged that the organization concentrate on public education and on integrating the sciences.

Before his resignation, Meyerhoff wrote an editorial in *Science* asserting that "there is no substance . . . to the unfounded impression that the Association's meetings are 'outmoded,' that its programs have grown 'thinner.' . . . It is not the Association that lags, but those who fail to comprehend the scope and the impact of its current program. Intellectual bankruptcy and deterioration will indeed set in if the A.A.A.S. turns from programming important science merely to ballyhooing the importance of science."

The resignation statement notes that Weaver had taken "vigorous exception" to this editorial and that he was "critical of A.A.A.S. journals and meetings." It also states that Condon had "repeatedly and severely criticized" the editors "both for the content of *Science* and its rigorous editorial standards."

Fields Unified?

ALBERT EINSTEIN has just published a revision of his generalized theory of gravitation which, he believes, may at last comprehend gravitational and electromagnetic phenomena in a single system. The new work appears as an appendix to the fourth edition of his book, *The Meaning of Relativity*, issued by the Princeton University Press.

Since his announcement three years ago of a unified field theory (see his article "On the Generalized Theory of Gravitation"; SCIENTIFIC AMERICAN, April, 1950) Einstein has been working to dispel certain doubts in his own mind about the choice of his field equations. He has now developed a new mathematical method to compare the "strength" of different systems of equations and thereby to indicate the correct choice.

Einstein continues in this paper his argument with quantum theorists, who are "convinced, as a result of the successes of the probability-based quantum mechanics, that one must abandon the goal of complete descriptions of real situations in a physical theory." He is still determined to achieve such a description and says that he sees "in the present situation no possible way other than a pure field theory, which then, however, has before it the gigantic task of deriving the atomic character of energy." He holds that it is "unjustified to assert, *a priori*, that such a theory is unable to arrive at the atomistic character of energy."

In a letter to a reporter of *The Christian Science Monitor* Einstein described his situation as "floating." He has succeeded "after many and lengthy attempts" in finding "the logically simplest laws compatible with prior knowledge." But because of "insurmountable mathematical difficulties," he has been unable to "draw conclusions from the laws thus found which can be tested by empirical facts." He compared himself with Newton who, after he had formulated the general laws of motion, had to invent the differential calculus to check his theory against Kepler's laws of planetary motion. Einstein has not yet found the calculus he needs.

Computers for All

BEFORE the end of 1953, giant digital computers will be on the way to becoming generally available, if rather expensive, articles of merchandise. International Business Machines Corporation and Remington Rand Inc. have announced plans to turn out the machines on what for this field is a mass production basis. I.B.M. expects to produce a dozen or more of its 10,000-ton electronic data processing machines this year. All of these are already earmarked for government agencies and defense industries. Thereafter it hopes to maintain an output of 15 to 20 per year. It will not sell the machines, but will rent them out for about $12,000 per month.

Remington Rand, already producing UNIVAC computers at the rate of one a month, is adding an equally big but faster computer to its line. Called "ERA 1103," the machine will be made by the Remington Rand subsidiary Engineering Research Associates and will sell for about $850,000 installed.

Heavy Artillery

PHYSICISTS at the Oak Ridge National Laboratory are opening new fields of nuclear research with a 63-inch cyclotron especially designed to accelerate heavy particles. Operating at the comparatively modest energy of 25 million electron volts their accelerator hurls triply charged nitrogen atoms at target nuclei to produce reactions never before observed under controlled conditions. It has fused the nitrogen nuclei with such elements as beryllium, carbon and oxygen to form nuclei of fluorine, sodium and aluminum.

That valuable information could be gained from using heavy projectiles was first suggested by Gregory Breit, Yale University physicist and consultant to Oak Ridge. He pointed out that, in addition to fusion reactions, there might be exchange reactions in which individual protons and neutrons passed from one nucleus to another, and that new transuranic elements might be made and studied by bombarding heavy atoms. The latter reaction will not be possible with the Oak Ridge machine, however, for about 70 Mev would be needed to penetrate the nucleus of uranium.

Another new particle accelerator, an electron synchrotron, has been announced by Cornell University. When completed it will be the most powerful such machine in existence, operating at energies of one billion electron volts. Originally designed for a conventional magnet, it may now incorporate the strong-focusing principle described in this issue (*page 40*).

Chemical Plating

A CHEMICAL method of nickel plating, which is said to use much smaller amounts of the scarce metal and to have other important advantages over conventional electroplating, has been announced by the General American Transportation Corporation of Chicago. The new technique is called Kanigen (short for catalytic nickel generation).

General American, a firm that builds tank cars, developed Kanigen as a substitute for the costly enamel linings that are customarily baked onto the interiors of cars designed to carry corrosive liquids. Electroplating had proved unsatisfactory for this purpose. Having perfected Kanigen for its own needs, the firm ran a series of general tests and discovered properties that may recommend chemical plating for a wide variety of uses. The most important properties, according to General American chemists, are the evenness of the coating deposited and the accuracy with which its thickness can be controlled. Kanigen does not appear to vary more than 5 per cent from specified thickness. The depth of plate can be controlled to within one 10,000th of an inch. Chemical plating will, they say, give complete coverage with half or perhaps even a third of the metal formerly used.

Gears, valves and other parts machined to a fine tolerance could be made of cast steel and protected from corrosion with a nickel surface. At present, they are made from Monel metal or other non-corrosive alloys. General American has applied the process successfully to a wide variety of surfaces, including ceramics.

Soviet Astronomy

THE International Astronomical Union is the only international scientific organization in which the Soviet Union is now participating. This, says American astronomer Otto Struve, "is a source of professional gratification to the astronomers of the U. S.; it is also the origin of a large number of thorny problems." Struve, who was elected president of the Union at its meeting in Rome last summer, discussed some of the problems and assessed the present state of U.S.S.R. astronomy in a recent issue of *Science*.

He reported that Soviet and Western astronomers disagree on a number of astronomical issues, especially in the field of stellar evolution. Few American or European astronomers keep abreast of the Soviet work, because the Russians no longer publish translations or abstracts of their papers, and Struve notes an increasing tendency of Soviet astro-

IDEAS HAVE ENABLED THE PETROLEUM INDUSTRY to power our nation on wheels with ever-increasing efficiency. Crude oil produced an abundance of gasoline in 1951. But if the oil had been refined by 1900 techniques, we would have been short 33 billion gallons! Today we are able to be the world's largest per capita consumers of petroleum, thanks to ideas evolved by the more than 30,000 businesses and 1,900,000 people in the oil industry.

IDEA-CHEMICALS
help oil clean as it lubricates
... increase oil's power to fight friction

Alone, oil *cannot* effectively clean away the dirt deposits which form in the working parts of machines. It *can* lubricate, cool, seal and cushion, but it *cannot* clean without a special chemical additive.

That's why the petroleum industry is so interested in a group of Idea-Chemicals from Du Pont—"Lorol"* fatty alcohols. These versatile straight-chain alcohols are used as intermediates in the preparation of lubricant detergent additives which help oil purge and dissolve lead salt, carbon, oil decomposition products and other deposits... keep them in suspension, where they can do no harm.

Du Pont "Lorol" fatty alcohols work for the petroleum industry in other ways, too. They're used in the manufacture of lubricant additives which serve as pour-point depressants and viscosity-index improvers. And they have been suggested as intermediates in the preparation of synthetic lubricants.

But "Lorol" fatty alcohols are only one example of the chemical products from the Du Pont Polychemicals Department helping the oil industry do a better job. The list includes Crystal Urea, Methanol, "Hexalin" cyclohexanol, Adipic Acid and Hydroxyacetic Acid—to name a few.

Write for our new booklet on Polychemicals products for industry

These products for the oil industry are typical. In all, there are over 100 Polychemicals products for industry—amides, alcohols, esters, organic acids, solvents, resins and plastics. For more information about products which may be useful in your industry, send for our new booklet "Products of the Polychemicals Department." You'll find descriptions, properties, uses, possible applications and other data. Write on your business letterhead for your copy. We will gladly cooperate with you on any applications for Polychemicals products you would like to investigate.

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nomers to disregard Western discoveries and theories.

On the basis of "thousands of hours spent in studying their publications," Struve concludes that the U.S.S.R. has more, and better-trained, research workers in astronomy than the U. S.; that their research output is enormous but inferior in quality to ours; that they tend to do better in theoretical studies than in observational and experimental work; that while they do not possess as powerful telescopes as the U. S., they are making rapid strides in the construction of novel auxiliary equipment.

Vaccines

SUBSTANTIAL progress in developing a vaccine for poliomyelitis was reported last month by the University of Pittsburgh School of Medicine. Writing in *The Journal of the American Medical Association*, Jonas E. Salk, of the University's Virus Research Laboratory, described how small quantities of virus can be made to produce a large antibody response when mixed with an emulsion of mineral oil and water and injected into muscle.

In trials of the polio vaccine Salk has inoculated 90 subjects with a mixture of the three polio virus types, inactivated by formaldehyde, and has found an increase in the level of the three corresponding antibodies. Four and a half months after the start of the experiment the antibody levels had shown no signs of declining. None of the subjects showed "any signs of illness that could be attributed to the inoculation." Salk emphasized that his results, while "encouraging," did not mean that a practical vaccine had been achieved. It still takes "considerable time" to prepare a batch of vaccine and check it for safety.

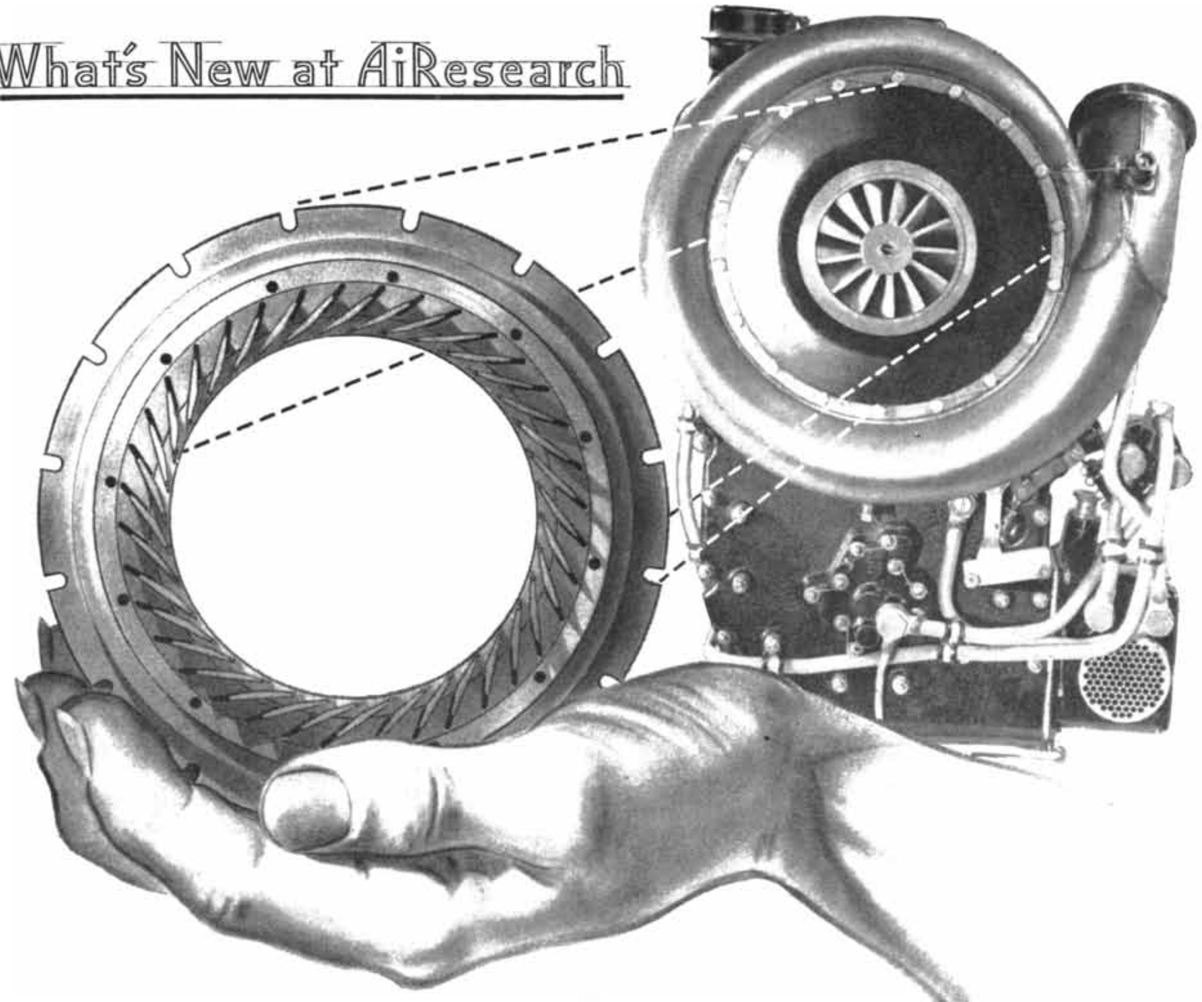
Salk has applied the same emulsion method to prepare a vaccine for influenza. Tests on 20,000 persons have shown that the virus and oil mixture produces immunity lasting up to two years against the known varieties of the flu virus.

Arthritis and Growth

A NEW understanding of the cause of arthritis has come unexpectedly from some cancer experiments at the University of California. William O. Reinhardt, professor of anatomy, and C. H. Li, professor of biochemistry, found that the growth hormone secreted by the pituitary gland is responsible for the diseased joints of arthritis. Cortisone, they believe, relieves the symptoms of arthritis by preventing the manufacture of the pituitary hormone or by counteracting its effects on the body's cells.

Evidence for this theory came from an experiment to determine the influence of the adrenal glands on cancer. Reinhardt and Li had removed these glands from a

What's New at AiResearch



Variable Area Nozzle only inches in diameter—applies principles formerly limited to giant steam and water turbines 12 feet in diameter. Another example of the ability of AiResearch to meet unusual power requirements with a small package.

First production air turbine motor with variable area nozzle!

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This motor incorporates a variable area nozzle, first developed by AiResearch.

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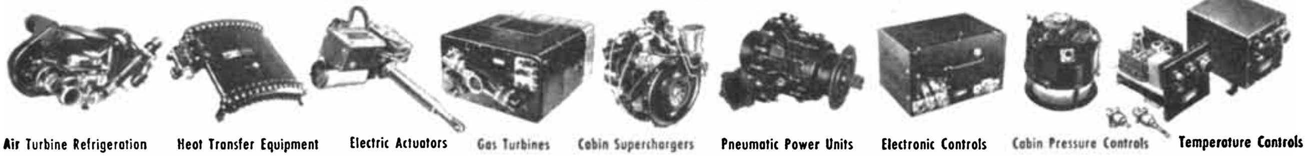


Air Turbine Refrigeration · Heat Transfer Equipment · Electric Actuators · Gas Turbines · Cabin Superchargers · Pneumatic Power Units · Electronic Controls · Cabin Pressure Controls · Temperature Controls number of female rats and were injecting the rats with growth hormone. The animals developed arthritis, while a group of normal rats that also got the growth hormone did not. The animals without adrenal glands of course had no cortisone. When the experimenters injected cortisone, the animals improved.

Reinhardt and Li suggest that as the activity of the adrenal glands in human beings declines with age, the pituitary's output of growth hormone, now inadequately inhibited, causes the joints to grow and produces arthritis.

The Navigation of Porpoises

PORPOISES and bats do not seem to have much in common, but some recent Navy research suggests that they may share one highly unusual gift. Bats, as everybody knows, navigate by means of a kind of radar—high-pitched sound waves which they emit to detect obstacles by the echo. Students of porpoises have been struck by the fact that they, like bats, can move fast through dark regions full of obstacles. The question arose: Are porpoises equipped with an underwater echo-locating mechanism—*i.e.*, sonar?

W. N. Kellogg, Robert Kohler and H. N. Morris, under a contract with the Office of Naval Research, went out to look into the matter in the waters off Florida and the British West Indies. They followed porpoises in a small boat in the open sea and also tested some captives, taking recordings with sensitive hydrophones. Sure enough, they discovered that the small cetaceans chattered constantly, giving out noises suitable for echo-ranging. When they played the tape recordings, they detected two kinds of porpoise sounds: a whistle and a clack. The whistle is not unlike a canary's cheep. It lasts for about half a second. The clacks, coming in rapid succession, have been compared to a creaking door, a woodpecker's tattoo or a Bronx cheer. They vary in frequency from five to 100 per second. By analogy with sonar, the warbling tone of the porpoise's whistle is appropriate to a frequency modulation system; the clacks would fit sounding equipment that was pulse-modulated.

When the clacks are played back slowly, distinct echoes can be heard. Although these sounds are in a low register, they carry many supersonic overtones. The short waves would be doubly convenient for the porpoise: they could readily be separated from the interference of normal marine sounds and they would give a more accurate report of the shape, size and location of the reflecting object than do the longer audible waves. But whether the porpoises actually use the echoes to steer themselves through the ocean traffic remains to be proved by further experiments.

It's VERSATILITY that sells SANBORN in the field of Industrial Recording

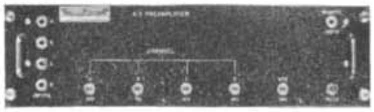
As indicated by references at the right, you may have a choice of five different instruments (A) for quick and convenient standard rack mounting in the system at A_1, PLUS a choice of up to four of any of the three different type amplifiers (B) or any combination of these amplifiers

with the

SANBORN
FOUR-CHANNEL
OSCILLOGRAPH RECORDING SYSTEM
(MODEL 67)

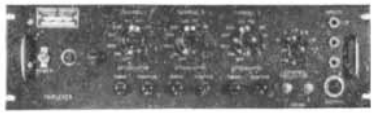
A

DC PREAMPLIFIER



AC PREAMPLIFIER

DC CONVERTER—for low level DC recording such as thermocouple output.



TRIPLEXER—when coupled to a DC amplifier permits the recording of three events in one channel.

THRESHOLD MONITOR provides means for the control of voltage levels or rate of change.

B

DC (General Purpose) AMPLIFIER

STRAIN GAGE (Carrier) AMPLIFIER

SERVO MONITOR AMPLIFIER—a phase discriminating AC amplifier used in servo design and testing.

As shown in the diagram, removing or interchanging any of the amplifiers or other instruments is simply a matter of sliding the unit in or out of the mounting rack where contact is made automatically by plug-in connectors. Screws at the four corners of the panel hold the instrument in place.

Other features of this system which add to Sanborn VERSATILITY are the choice of eight paper speeds — 50, 25, 10, 5, 2.5, 1.0, 0.5 and 0.25 mm/sec, and the use of either 4-, 2-, or 1-channel recording paper.

And, of course there are these popular Sanborn advantages: a high torque movement (200,000 dyne cms per cm deflection), direct *inkless* recording in *true rectangular coordinates,* and provision for code and time markings.

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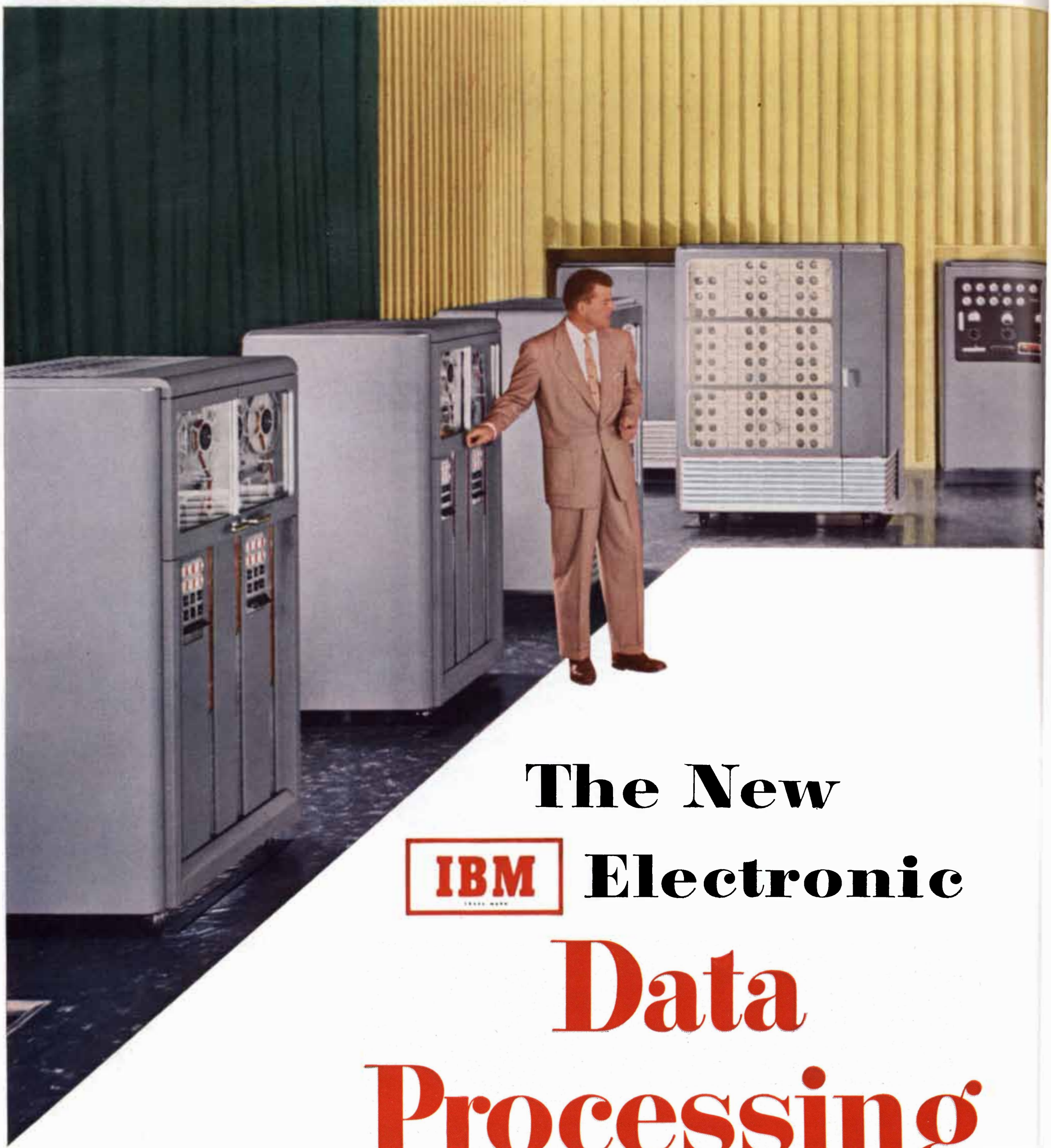
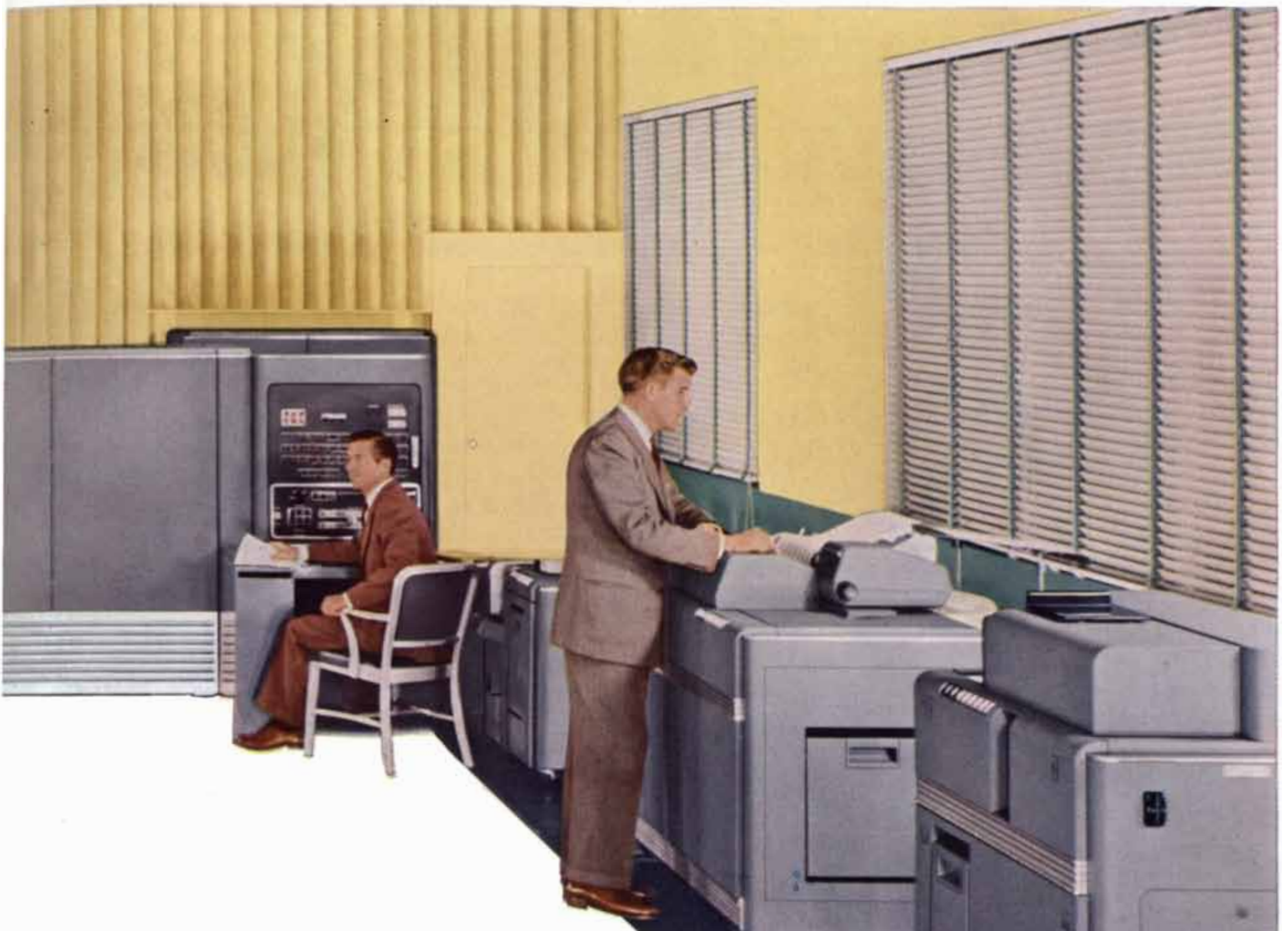
SANBORN 1-, AND 2-CHANNEL RECORDING SYSTEMS

One channel Model 128/141 above and two-channel Model 60 at right both incorporate Sanborn recording advantages which include interchangeability of amplifiers and (with Model 60) preamplifiers.





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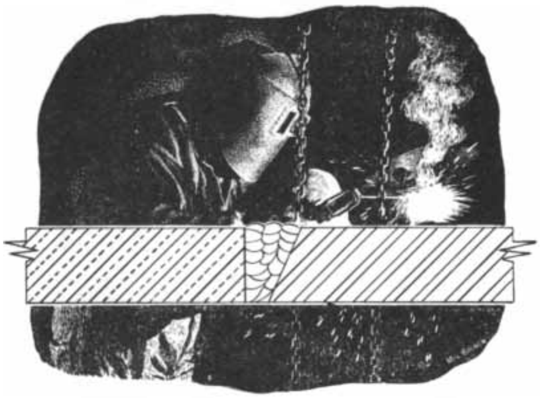
BUSINESS IN MOTION

To our Colleagues in American Business . . .

Late last year an important customer surprised us with an emergency call for help. It is a large company, and an unusually capable fabricator, so it is seldom indeed that it asks us for more than metals. Now it was not only having trouble, but was fast approaching a penalty period of $2,400 a day for failure to deliver. The difficulty arose in butt-welding aluminum bronze to steel, so two of the men from the Welding Section of the Revere Research Department assembled their equipment and left at once. They found that the test specification called for welding 1½ inch plates, and then making a side bend without damage. This had nothing to do with the stress conditions which the pressure vessel would experience in service, but there it was, and welders had to be qualified by that test. Nobody had been able to pass it, which was why we were asked for collaboration.



• Working closely with the customer, and with the inspectors assigned to approve the work, our welding engineers dug deep into this problem. On Saturday, Sunday and Monday five test plates were made, each showing a definite improvement, though extreme difficulty was experienced in getting a satisfactory joint at the root of the weld. This was due to the fact that the design called for a 25-degree bevel on the steel plate, and no bevel on the aluminum bronze. Good fusion was impossible at the root, as was proved when the bottom of a test piece was cut off; the upper three-quarters of the weld then made the side bend satisfactorily.

• After close mutual analysis of the problem, permission was obtained to open the joint to a 60-degree angle, to correspond with the joint of the actual vessel. The following day welds of the joint were made without difficulty, and passed the severe test without question. The remainder of the week was occupied in setting up the welding equipment we selected, and instructing the customer's welders in the necessary procedures. One of the methods recommended involved the placing of the beads of weld metal. Small beads were advised, and after each layer had been laid it was carefully power brushed to remove any oxides which otherwise might have caused planes of weakness.

• In all this work it was evident that our men were so obviously familiar with what they were doing, and with the practical limitations and opportunities of the job, that they were able to bring the customer and the inspectors together in a mutual meeting of minds, by showing how to make a weld which would withstand the test. Production began to meet schedules thereupon, just in time to avoid the $2,400 daily penalty.

• Revere finds that operating a welding service of this kind is good business. It increases our contributions to American industry, and is in line with the recommendations we have given in these pages for many years. Namely, that you take full advantage of the knowledge of your suppliers, as well as buy their materials. No matter what you purchase, nor from whom, there must be one or more firms by whose experience you can profit, if you will just ask for it.

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MARS

The red planet has been intensively studied by many gifted astronomers. The assembled observations have now given us a remarkably detailed picture of its surface and atmosphere

by Gérard de Vaucouleurs

For nearly a century the planet Mars has captivated the passionate interest of astronomers and the credulous imagination of the public—of which we had an example not long ago in the great "Martian" scare instigated by a radio program. Thanks to modern astrophysical research we now know a good bit about the physical and climatic conditions and the possibilities of life on Mars. The facts, although perhaps not quite as exciting as the former speculations, are interesting enough.

Mars is, next to the Moon, our closest neighbor in the solar system. It is a small planet, about half as big in diameter (4,200 miles) as the Earth, and with only one tenth of the Earth's mass. Its day is about the same as ours (a little more than 24½ hours), and its year—the period of revolution around the Sun—is 687 days. Its four seasons, unlike the Earth's, vary considerably in length [see *table on the next page*].

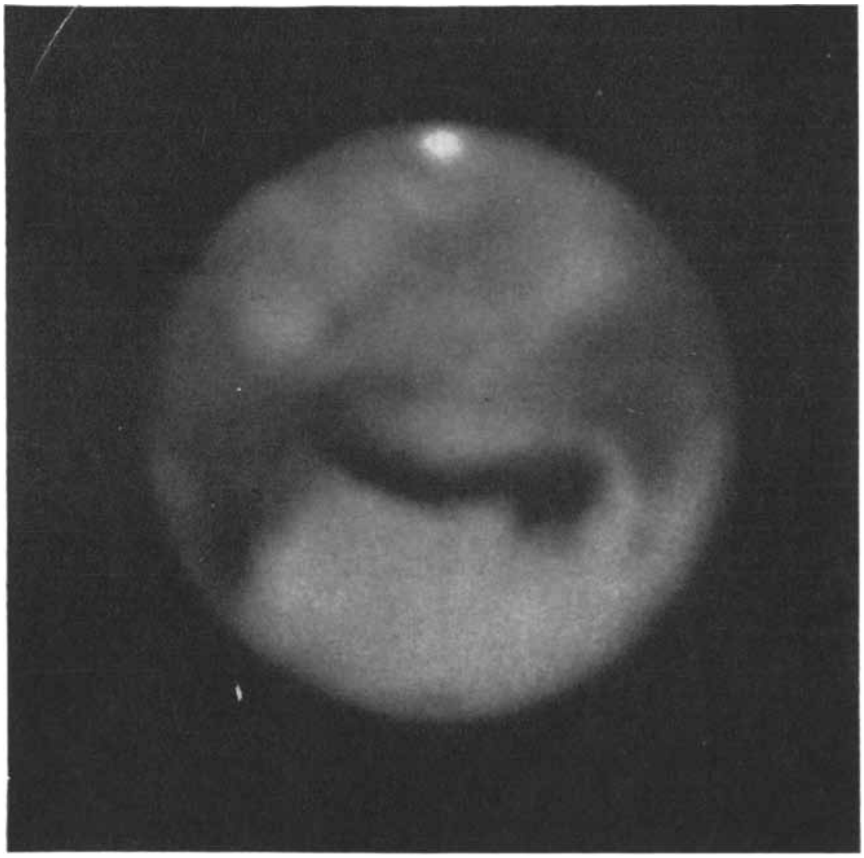
Mars has a decidedly eccentric orbit, and its nearest approach to us comes at intervals of about 15 years: the next one will occur in 1956. At its closest it is about 35 million miles from us—150 times farther away than the Moon. Even with our largest telescopes we can get no better view of Mars than we can of the Moon through low-power binoculars. Nevertheless, the long, patient visual examination of the planet by a few astronomers who took a special interest in Mars—notably the Italian Giovanni Schiaparelli, the American Percival Lowell and the Frenchman Eugène Antoniadi—and recent physical studies have given us a fairly detailed description of the main features of the planet's surface and atmosphere. Today the study of Mars has achieved the status of a full-fledged branch of astronomy.

The Polar Caps

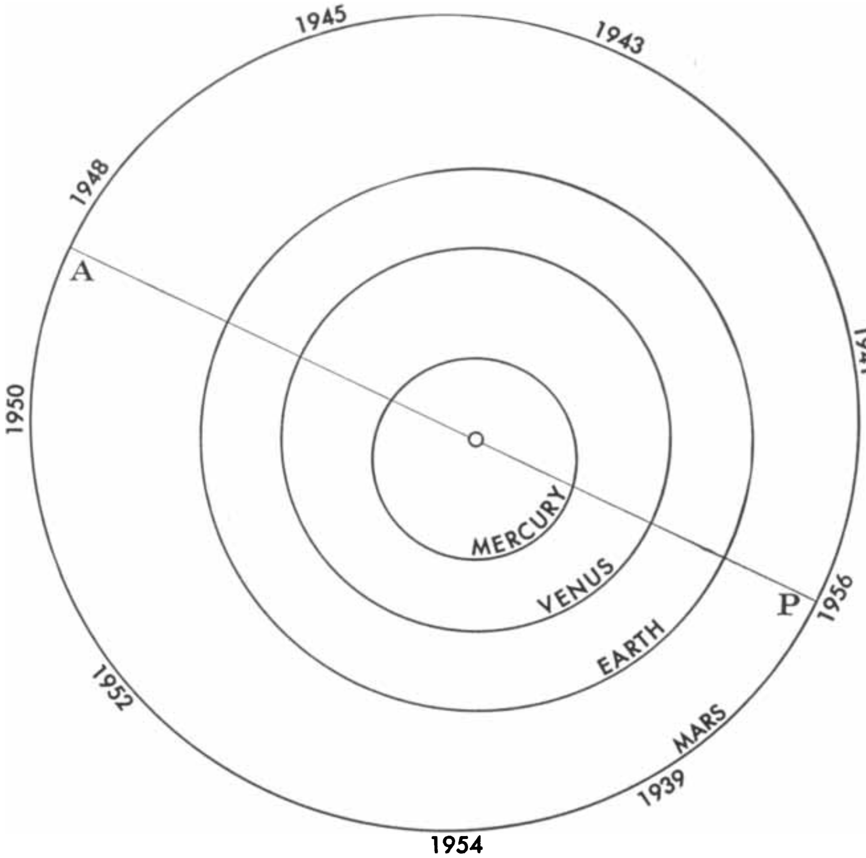
Easily the most conspicuous feature of the planet is the white caps that cover its polar regions. They display a fascinating rhythm of advance and retreat. At the end of winter in each hemisphere the polar cap covers some four million square miles. As spring comes, it begins to diminish—rather slowly at first, then at an increasing rate. Near the middle of spring dark rifts appear. They grow steadily and soon split the cap into several sections. Disintegration of the fragments then proceeds rapidly. But the cap never disappears completely: even in midsummer a tiny dazzling spot remains near the pole.

As summer draws to its end, diffuse patches of whitish cloud appear in the polar region. They spread quickly. With the arrival of fall they drop a curtain over the entire scene, covering not only the polar area but part of the "temperate" belt. The rather bright and unsteady veil persists throughout the fall and winter, concealing from our view the icecap re-forming beneath it. By the end of winter the cloud cover breaks up and the polar cap reappears, somewhat dim at first, then growing bright.

Year after year this cycle follows the same general pattern. But its regularity is far from perfect: the cap may vary slightly in size from year to year. Some astronomers have suggested that the ir-



PHOTOGRAPH OF MARS was made by E. C. Slipher of the Lowell Observatory in 1941. The small white spot at the top is the South polar cap.



ORBIT OF MARS is eccentric. The various oppositions of the planet are denoted by the years. The closest oppositions occur when Mars is at perihelion (P); the farthest oppositions occur when it is at aphelion (A).

DISTANCE FROM THE SUN	
AT APHELION	155 MILLION MILES
AT PERIHELION	129 MILLION MILES
DISTANCE FROM THE EARTH	
AT PERIHELIC OPPOSITION	35 MILLION MILES
AT APHELIC OPPOSITION	62 MILLION MILES
PERIOD OF REVOLUTION *(YEAR)*	687 *(TERRESTRIAL)* DAYS
PERIOD OF ROTATION *(DAY)*	24 H 37 M 22.6 S
DIAMETER *(EQUATORIAL)*	4,200 MILES
POLAR FLATTENING *(DYNAMICAL)*	1/192
INCLINATION OF EQUATOR	25 DEGREES
MASS *(EARTH = 1)*	.106
GRAVITY *(EARTH = 1)*	.38
MEAN DENSITY *(EARTH = 5.52)*	3.95
SOLAR INTENSITY *(EARTH = 1)*	
AT PERIHELION	.52
AT APHELION	.36
DURATION OF SEASONS	
SOUTHERN SUMMER (NORTHERN WINTER)	160 DAYS
SOUTHERN AUTUMN (NORTHERN SPRING)	199 DAYS
SOUTHERN WINTER (NORTHERN SUMMER)	182 DAYS
SOUTHERN SPRING (NORTHERN AUTUMN)	146 DAYS

CHARACTERISTICS OF ORBIT AND GLOBE are given in this table. The length of the Martian day is given in hours, minutes and seconds. The term "solar intensity" refers to the intensity of the sun's radiation.

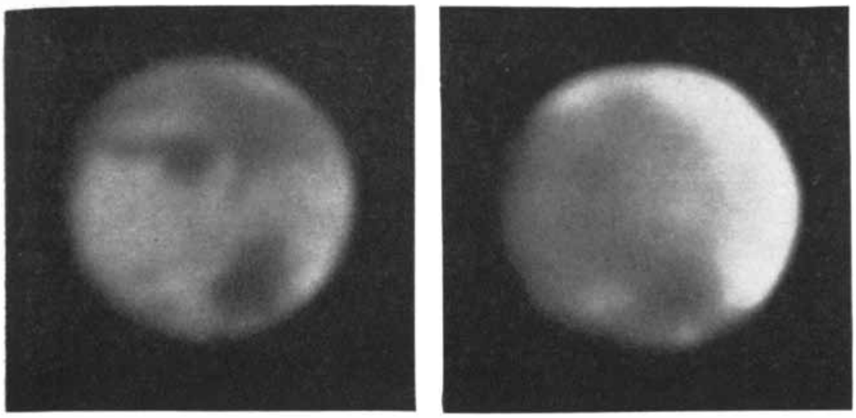
regularities may be correlated with the 11-year sunspot cycle, but we have no definite evidence of this.

The fragments into which the polar caps break up in the spring always appear in the same places on the surface of the planet. This suggests that those areas may be mountains or plateaus. Another notable phenomenon is that the receding polar cap is surrounded by a dark fringe, which closely follows its retreat. This is hard to explain, and at first the fringe was thought to be an optical illusion—an effect of the contrast between the white cap and the dark adjoining area. But its existence seems to be confirmed by several facts. The Frenchman Georges Fournier, working in the Jarry-Desloges Observatory at Sétif, North Africa, noticed in 1926 that the fringe often varies in intensity along the border of the cap, and it can be seen through red filters, which greatly reduce the contrast between the white cap and the dark fringe. Moreover, the fringe usually is not visible at the end of winter, when the polar cap has reached its limit, nor in summer, when it is at its minimum. In 1943 I found that the time of greatest visibility of the fringe coincides with the period when the polar "snows" are "melting" most rapidly.

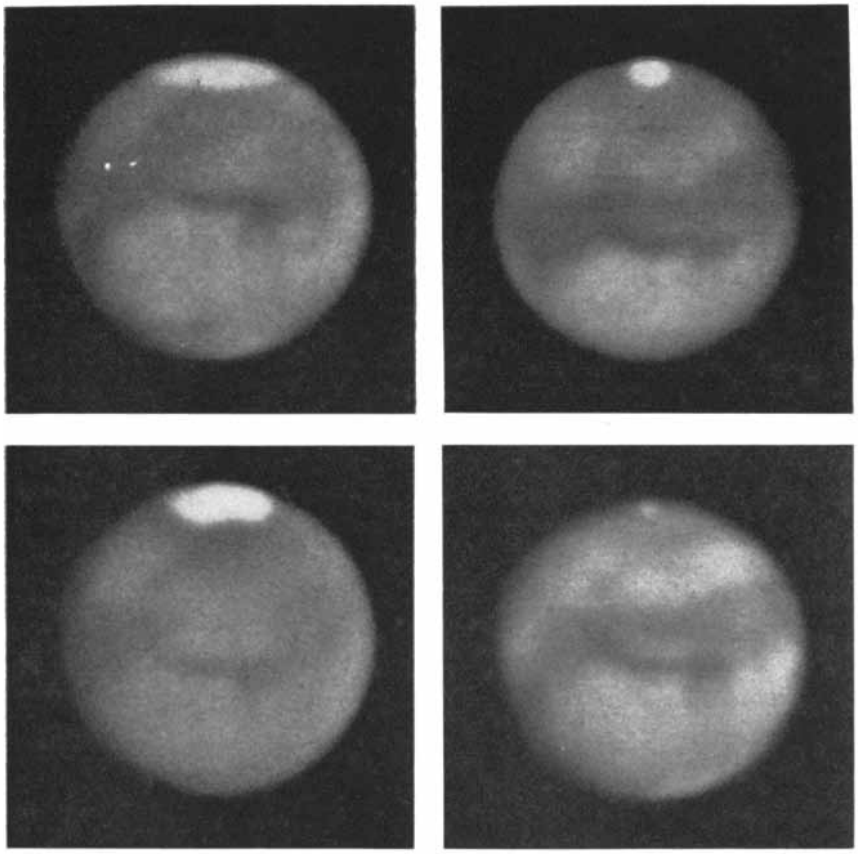
That the polar caps consist of ice crystals was definitely proved by the University of Chicago astronomer Gerard P. Kuiper. With a spectrophotometer attached to the 82-inch reflector of the McDonald Observatory in Texas, he obtained infrared spectra which showed that the material of the polar caps was frozen water. According to these spectra, the Mars caps are not thick snow and ice fields but probably thin coverings of frost on very cold ground. These thin deposits condense during the cold season under a cover of wintry mists and evaporate with the return of the Sun's spring warmth. Indeed, the "snows" of Mars must evaporate, or sublimate, rather than melt, because the atmospheric pressure on the planet is very low and the atmosphere extremely dry. The French astronomer A. Dollfus has actually reproduced the same amount of polarized light as comes from the Mars polar caps by evaporating a thin layer of white frost at low pressure and temperature under the strong light of an electric arc.

The Deserts

About three fourths of the surface of Mars is covered with bright reddish or yellowish areas. They have long been considered to be sandy deserts—bare tracts covered by a silicated dust colored red by iron oxide or some other metallic impurity. This hypothesis, originally based on their resemblance to the reddish sands and sandstones of our deserts, was first proposed late in the



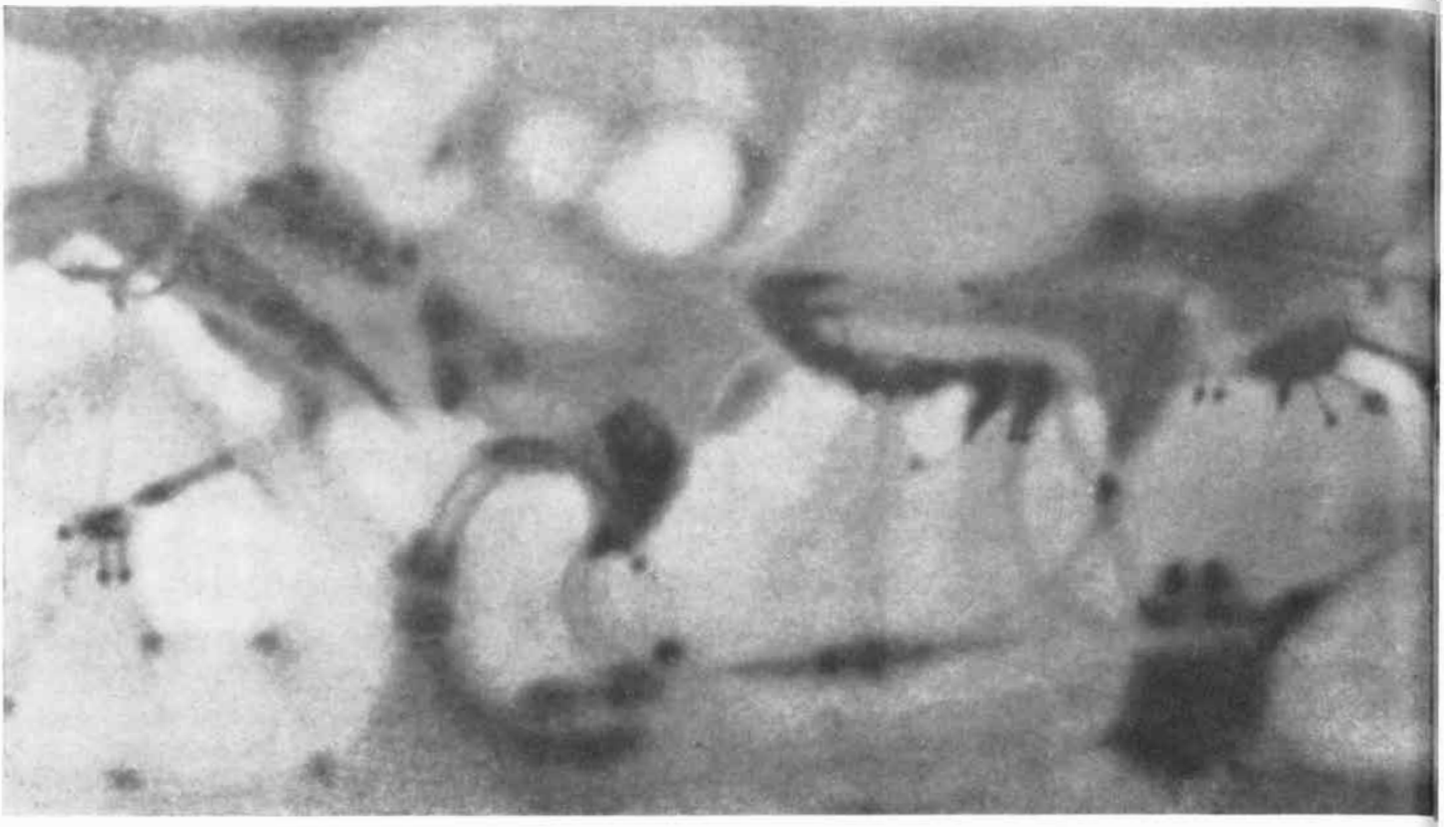
BLUE HAZE and clouds are demonstrated by these Slipher photographs. The photograph at left, made by yellow light, shows surface markings. In the photograph at right, made by blue light, these markings are obscured.



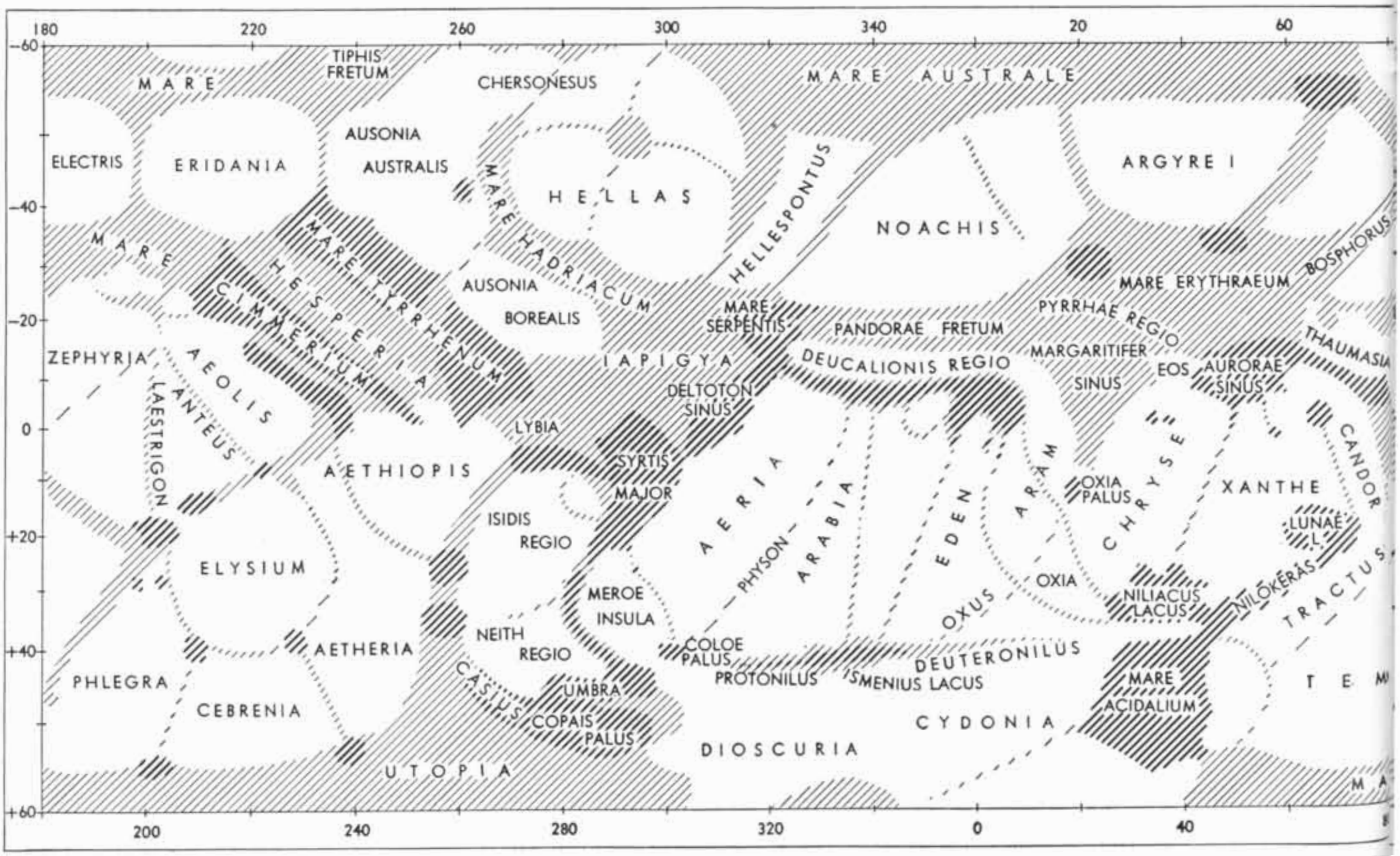
SEASONAL CHANGES appear in these photographs by Slipher. The two photographs at left were made in the springs of two different Martian years. The two photographs at right were made in the summers of the same years.

19th century by the great British astronomer Sir John Herschel and independently by the Frenchman Emmanuel Liais, astronomer to the Emperor of Brazil. It seems to be supported by the fact that yellowish veils, reminiscent of the dust and sandstorms of our deserts, spread over the areas from time to time —a phenomenon first noticed by the Irish astronomer C. E. Burton in 1880 and definitely established at the Lowell Observatory by A. E. Douglass in 1899.

During the last few years Dollfus, as the result of extensive experiments at the Pic du Midi and Meudon Observatories in France, has found that the polarized light reflected from the terrestrial mineral limonite, which is almost pure ferrous oxide, is exactly like that from the Mars sands. On the other hand, Kuiper, on the basis of his infrared spectrophotometric studies, finds that the Mars dusts resemble another mineral: felsite, an igneous rock consisting of a

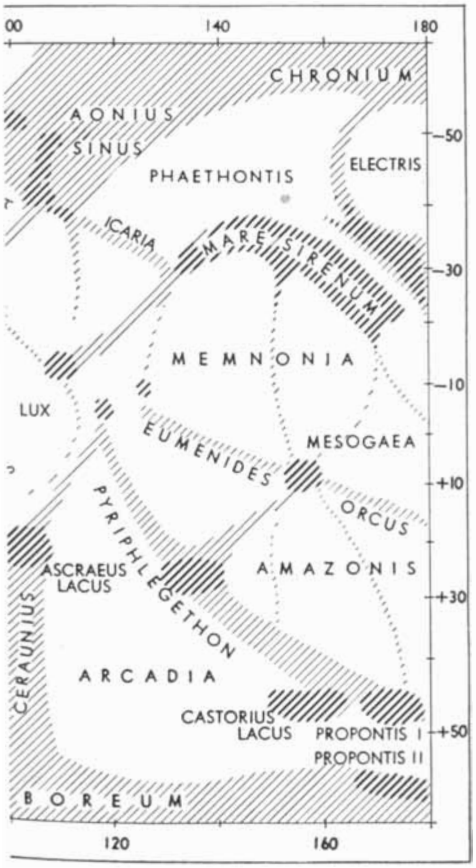


DRAWING projects the features of Mars on a flat surface. It is based upon observations by Slipher at the Bloemfontein Observatory in 1939, by B. Lyot, H. Camichel and M. Gentili at the Pic du Midi Observatory in



MAP gives the names of the principal features that appear in the drawing at the top of these two pages. Most of the names date back to a map made by Giovanni Schiaparelli in 1877. The map and the drawing show all

1941, by de Vaucouleurs at the Peridier Observatory in 1939 and 1941.



360 degrees of Mars' longitude and all but 60 degrees of its latitude.

silicate of aluminum and potassium with quartz and other inclusions. The National Bureau of Standards physicist W. W. Coblenz also has found evidence that the Mars minerals consist of silicates. At all events, whatever their mineralogical nature, there seems little doubt that the large yellowish areas on Mars are deserts.

The Atmosphere

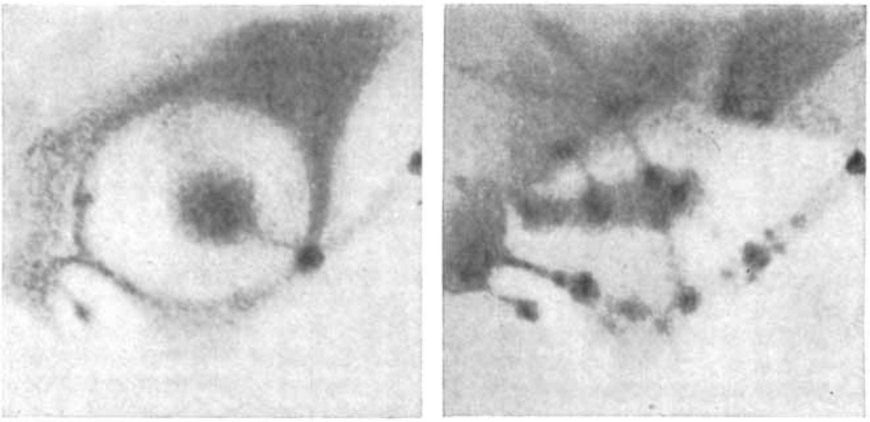
About the atmosphere of Mars we have more definite information. In the first place, we know that it cannot contain any hydrogen or helium. Mars is not massive enough to hold these light gases: in their random thermal movement they must long ago have escaped from the planet. Secondly, chemical considerations exclude the possibility of many other gases, including ozone, remaining free for long in the atmosphere of Mars. Thirdly, a long search for oxygen at the Mount Wilson Observatory has failed to detect any trace of that element in the Martian atmosphere. It cannot contain a hundredth, probably not even a thousandth, of the amount of oxygen in the atmosphere of the Earth. The Princeton University astrophysicist Henry Norris Russell suggested that the oxygen of Mars may have been exhausted by fixation in the soil.

The one gas that has definitely been identified in the Martian atmosphere is carbon dioxide. Kuiper established this by spectral analysis in 1947. He estimated the amount of carbon dioxide on Mars to be about twice that in the atmosphere of the Earth.

As far as water vapor is concerned, the results are less definite. Observers at Mount Wilson, who have been searching for it since 1937, believe that Mars probably has less than 1 per cent as much water vapor as the Earth. This conclusion has been disputed by some astronomers, who point particularly to the positive spectral evidence of water vapor on Mars obtained by V. M. Slipher of the Lowell Observatory in 1908. It is generally agreed, however, that most areas of Mars must be extremely dry, and the planet as a whole in an advanced stage of desiccation.

What gases, then, do make up the bulk of the Martian atmosphere? They must be gases that evade spectroscopic detection, are fairly heavy, are not too active chemically and are cosmically abundant. This narrows us down to one most likely choice—nitrogen. Nitrogen, which constitutes four fifths of our air, probably also accounts for the bulk of the atmosphere of Mars. To it, besides carbon dioxide, may be added a small amount of the rare gas argon, known to be a decay product of a radioactive isotope of potassium.

The physical structure of the atmosphere of Mars has been examined for



NON-SEASONAL CHANGES in Solis Lacus (*see map on preceding two pages*) are shown in these drawings. The first drawing is based on one made in

many years by means of photographs taken through color filters. In general, the Martian atmosphere is opaque to light of short wavelengths—blue, violet and ultraviolet. But occasionally the surface of the planet has been clearly visible in blue light. In 1937 the Lowell Observatory astronomer E. C. Slipher pointed out that this must mean there is an absorbing and scattering layer of finely divided matter floating in the Mars atmosphere: most of the time it blocks blue light, but on rare occasions it clears and lets the short wavelengths through. The nature of the particles constituting this "violet layer" is still something of a mystery. In 1948 the University of Florida meteorologist Seymour L. Hess, then working at the Lowell Observatory for the Air Force Project on Planetary Atmospheres, suggested that the layer may be made up of minute crystals of dry ice (carbon dioxide), which condense at a high level in the atmosphere. More recently Kuiper put forward the hypothesis that the crystals are simply of water, as in our ice clouds, condensing at a much lower level. This theory seems more likely and appears to agree with Dollfus' polarization measurements. The average size of the crystals, according to calculations based on the spectral transmission curve of the layer, is about half a micron.

The Clouds

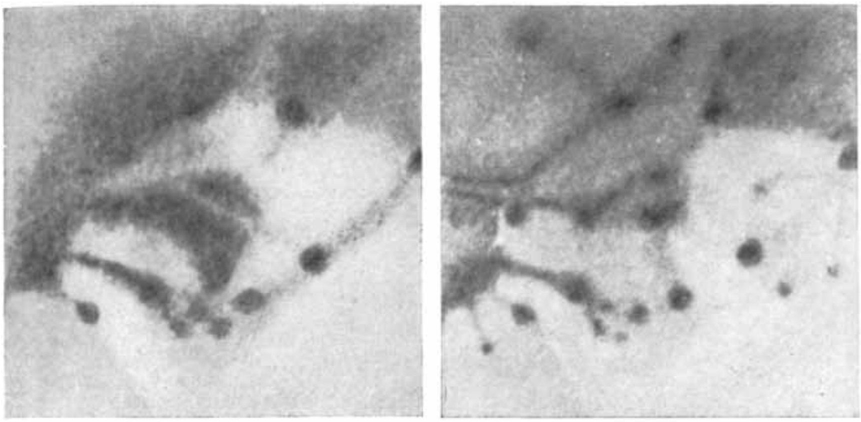
Mars has three main types of clouds: (1) "blue" clouds, recorded only in blue and violet light, which seem to be mere local condensations in the violet layer; (2) "yellow" clouds, visible only in yellow and red light, which probably are desert dust storms, and (3) "white" clouds, which could be made up of tiny ice crystals, like our cirrus clouds—an assumption supported by polarization measurements and by Schiaparelli's remark in 1886 that the white clouds are more numerous when Mars is farthest from the Sun, as though their condensation is favored by the lower temperature. In 1941 the French geophysicist P. Bernard made the interesting suggestion that solar phenomena also might play some role in controlling the occurrence of the white clouds.

From the movements of the clouds on Mars, we can judge that the planet has winds ranging up to 60 miles per hour. Rudimentary weather maps of Mars have been constructed, and they look something like those of our own planet.

How dense is the atmosphere of Mars? As early as 1907 Lowell guessed that the planet's atmospheric pressure was 60 millimeters of mercury—and his guess has turned out to be surprisingly accurate. Fairly precise determinations of the atmospheric pressure have been obtained during the last 10 years or so by several French and Russian astronomers. These are based on an analysis of the photometric and polarimetric properties of the light reflected by Mars, part of which is due to molecular scattering in its atmosphere. The measurements agree that the atmospheric pressure at ground level on Mars is about 65 millimeters of mercury. This is rather less than one tenth of the sea-level pressure on the Earth. The atmospheric pressure at Mars's surface is about the same as that some 11 miles up in our atmosphere. But owing to Mars's smaller force of gravity, at altitudes above about 17 miles its atmospheric pressure must be greater than ours. This may help to explain the very high levels reached by the Martian clouds: they go up to 20 miles or more.

The Climate

A quarter of a century ago W. W. Coblentz, C. O. Lampland and Donald H. Menzel at the Lowell Observatory and Edison Pettit and Seth B. Nicholson at Mount Wilson made astronomical history when they succeeded in measuring with a thermocouple the temperatures of the planets. Their measurements were especially detailed in the case of



1877; the second, on one made in 1924; the third, on one made in 1926; the fourth, on one made in 1941. The scale is about 1,600 miles to the inch.

Mars and gave a fair idea of its climatic conditions.

The mean temperature of Mars seems to be somewhere between 30 and 40 degrees below zero Fahrenheit—far colder than the Earth's mean of 60 degrees F. But at noon in summer when Mars is nearest the Sun the temperatures in its tropics are definitely above freezing. The recorded temperatures then go up to about 70 degrees F. in the bright areas and 80 degrees F. in the dark areas, which absorb the Sun's radiation more efficiently. These are the highest temperatures ever reached on Mars. At aphelion, when it is farthest from the Sun, the daytime temperature rarely rises above freezing. Although no direct measurements of the dark side of Mars are available, there is little doubt that the nights must be intensely cold—perhaps as low as 70 degrees below zero F. The extreme thinness and dryness of the atmosphere of course is responsible for its poor heat-retaining capacity. During the long polar night the Martian temperature may well fall as low as 150 degrees below zero F.

All in all, the climates of Mars may be likened to what one would find in a hypothetical polar and stratospheric desert on the Earth—a not too encouraging prospect for future explorers of the planet.

The Dark Areas

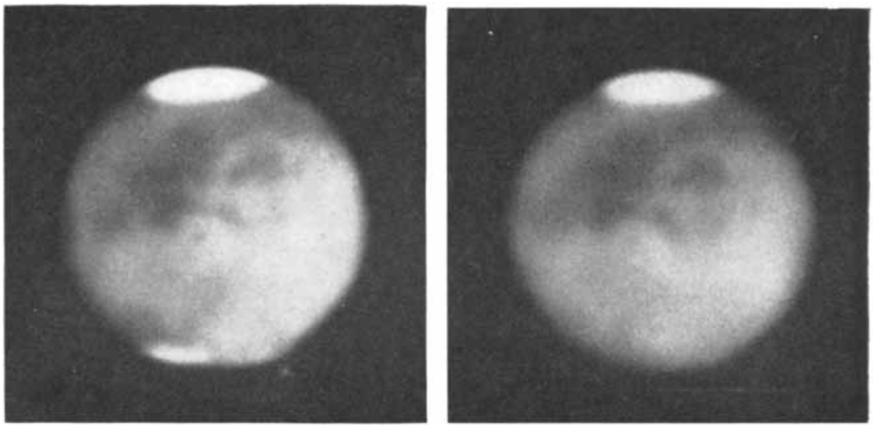
The polar caps and "deserts" cover four fifths of Mars's surface. The remaining fifth consists of dark areas of various shapes, each known by a Latin name. The most conspicuous is Syrtis Major, a dark triangular spot first observed by the Dutch astronomer Christian Huygens with his crude telescope in 1659. The dark areas are permanent features of the landscape on the whole, but the details of many change. For example, from time to time a bright area, usually near the edge of a dark spot, will darken and remain dark for months or years. Why this happens is still a mystery; one theory is that these areas become temporarily fertile and are invaded by vegetation from the nearby dark area.

That some kind of plant life grows on Mars was first suggested in 1896 when Lowell and Douglass detected seasonal color changes in the dark areas. This wash of new color over the landscape, studied in great detail by Antoniadi in 1924, is strikingly related to the seasonal variations of the polar caps. In winter the dark areas are grayish, bluish or greenish. During spring a brownish band starts from the edge of the polar cap and spreads rapidly toward the equator. By summer all but a few spots of the dark areas have turned brown, chocolate or even violet or crimson.

The degree of darkness of the spots also varies with the seasons. Fournier, who patiently followed these variations for more than 30 years, reported that during winter the dark areas appear faint and rather ill-defined; as spring advances and the polar cap regresses, they turn very dark, and the darkening spreads over the temperate and equatorial zones and eventually spills over into the other hemisphere. When summer arrives, the polar areas turn pale again, "as though they were emptied of their dark content."

The dark wave seems to flow along large arteries, apparently extensions of the rifts in the polar cap. This was once thought to indicate that water from the "melting" polar cap flows through natural or artificial ditches irrigating a sensitive vegetation. But such a hypothesis is difficult to reconcile with our present knowledge regarding the low temperatures, low pressure and extreme dryness of Mars, which would make liquid water freeze or evaporate almost immediately.

In 1939 I made some observations at the Peridier Observatory in southern France which suggest that a spreading of water vapor through the atmosphere may account better for the observed phenomena. Besides the dark flows



RAPID CHANGES at the Martian North Pole (*bottom*) were photographed by Slipher during the Martian autumn in 1939. The first photograph was

along the arteries, which move at a rate of 11 miles per day, there is a general wave of darkening, traveling 28 miles per day, which does not seem affected by local topographical features. It can be calculated theoretically that just this rate of circulation in the Mars atmosphere would transfer the water from one polar cap to the other every six Martian months.

Plant Life?

To decide whether such movement of water vapor is responsible for the seasonal variations in the dark areas of Mars, we must first determine the nature of the dark areas themselves. They cannot be oceans or seas, for if they were, they should reflect the Sun's image, and no such reflection has ever been observed. Nor does it seem likely that they are covered with green, chlorophyll-bearing plants. Our green landscapes on the Earth have a very high reflecting power in infrared light. The dark areas on Mars are just the opposite: in infrared pictures they show up as almost black—a good proof that the characteristic reflection spectrum of chlorophyll is absent.

Still this does not exclude the possibility that lower forms of plant life, *e.g.*, lichens, mosses or algae, may exist on Mars. Kuiper observed in 1948 that such plants on the Earth have a reflection spectrum which seems to agree with that of the dark areas of Mars. And Coblentz long ago pointed out that of all the forms of plant life we know, lichens and mosses seem the best adapted to resist the rigors of the Martian climate.

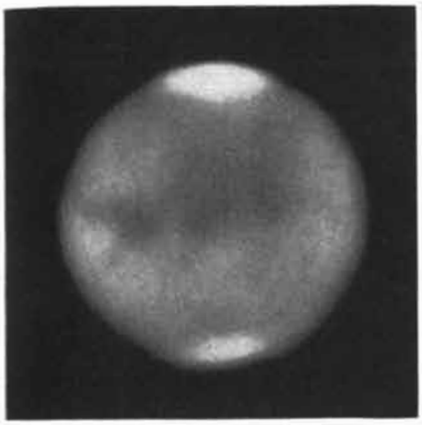
Nevertheless, the climatic conditions on Mars are so severe that some doubt even mosses could survive there. Another explanation of the seasonal color changes has been proposed. The great Swedish physical chemist Svante Arrhenius and, more recently, the French geophysicist A. Dauvillier have suggested that the dark areas of Mars may be covered with water-absorbing substances containing metallic salts whose color is sensitive to humidity. Yet this is an artificial and unattractive theory. Moreover, the Esthonian astronomer E. Öpik, of Armagh Observatory in Northern Ireland, has pointed out that "sandstorms" on Mars would have covered the dark areas with a thick layer of yellow dust within a few million years if these were lifeless mineral surfaces. All in all the plant-life hypothesis so far seems to provide the most likely explanation of the Martian dark regions.

The Canals

Arguments over the question of the "canals" on Mars have raged for more than half a century. It was Schiaparelli who in 1877 discovered across the bright areas of the planet the delicate, more or less straight lines which he called "canali." Lowell and his co-workers found an amazing number of these exceedingly narrow lines, connecting the dark areas with one another. Many of them appeared to have at their intersections small round spots, which Lowell called "lakes" or "oases."

Because of the network's geometrical regularity, its seasonal variations and its remarkable pairing of the canals and oases, Lowell and some other astronomers firmly believed that all this was the work of intelligent beings to irrigate a drought-stricken planet. But investigators soon pointed out that the canals drawn by Lowell and his collaborators were suspiciously narrow and sharp—so narrow that they must be beyond the resolving power of the telescopes used. Many came to consider the canals as illusions put together by the eye from faint markings on the threshold of visibility—either the jagged edges of faint shadings, or lined-up spots or even wholly random features.

After 20 years of observations with the 32-inch refractor of the Meudon Observatory, Antoniadi came to the conclusion that there were no canals. He



made on July 23; the second, on July 25; the third, on July 30.

said in 1929: "The details of Mars display everywhere an infinitely irregular and natural-looking structure." This conclusion was fairly widely endorsed and accepted. Nevertheless the opposite school retains its supporters, foremost among them the present director of the Lowell Observatory, E. C. Slipher. He has repeatedly asserted that "the extensive visual observations made at the Lowell Observatory have been confirmed in toto, and corroborated in detail, by the photographs."

Indeed, as Fournier pointed out in 1939, the linear markings—whether continuous or not—discovered by Schiaparelli three quarters of a century ago are still to be seen in the same positions and seem to share in the general seasonal cycle of the more prominent dark areas. Most significantly, dark bands sometimes develop precisely along the courses of the linear markings and last for years. This inescapable fact, with other observations, proves that the canal phenomenon is specifically Martian.

As to the fine structure of the "canals" much uncertainty remains. Because of our atmosphere's interference with clear "seeing," until recently the photographs of Mars have been much too small and blurred. In 1941, however, the late Bernard Lyot and his co-workers obtained some good pictures and visual observations with the 24-inch refractor at the Pic du Midi Observatory, where superior seeing conditions prevail at times. The observers have since seen and recorded on photographs a number of straight lines, both single and double. But with the large aperture of the telescope, and under perfect seeing conditions, they have resolved some of these into jagged and irregular spots.

More definite results will perhaps be obtained in 1956, when Mars will approach us again and the 100-inch reflector of the Mount Wilson Observatory will be trained on it in an endeavor to photograph the "canals" under the most favorable conditions.

THE TERMITE AND THE CELL

Like the cells of an embryo, the nymphs of a termite colony differentiate into various forms. The analogy has suggested experiments with termites as a way to study both phenomena

by Martin Lüscher

TERMITES, closely related to the roaches, are relatively primitive insects which have nevertheless developed extremely elaborate social habits. There are no solitary termites. Of about 2,000 known species, all have at least three structurally different forms, which live together as castes with different functions in the colony. Some have as many as six or seven easily distinguishable castes.

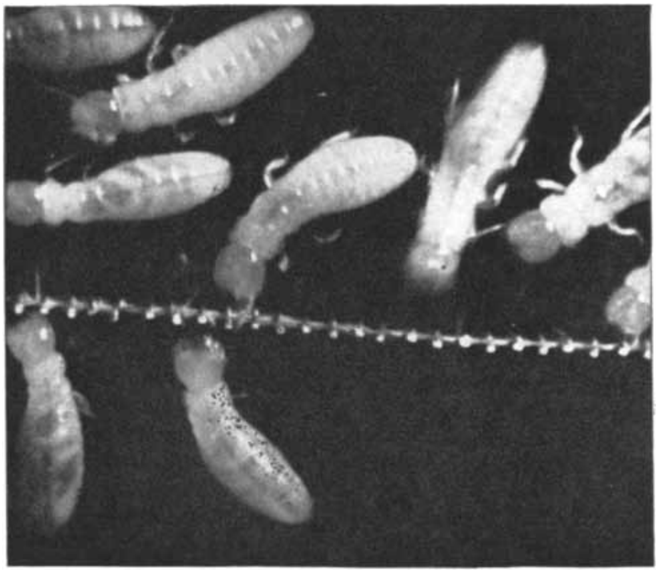
Each caste generally possesses its own special instincts. The king and queen, which develop from winged forms that lose their wings after the nuptial flight, start the colony. They are extremely well adapted to their single occupation of reproduction: some tropical queens lay as many as 20,000 eggs a day. When they die, nymphs in the colony develop into a special caste to take over their procreative function. These nymphs grow reproductive organs, molt and become fertile. They are called supplementary reproductives.

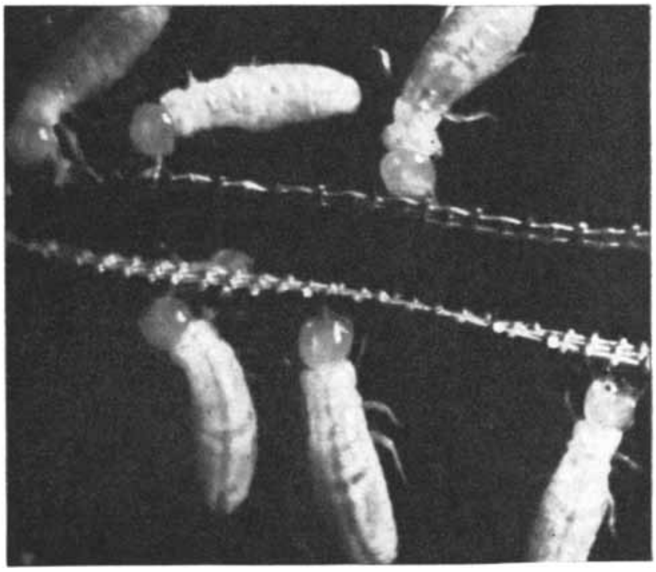
All other castes in the colony are sterile, though they contain both sexes. There are soldier castes equipped with enormous jaws to defend the colony against predators. Many species also have worker castes, which build the nests and runways, collect food to feed the colony, and take care of the eggs. Termite species of the temperate regions usually have no true worker caste; their growing nymphs do the work.

The caste arrangement among the termites has attracted investigators for a long time. Early authorities thought that the differences among the castes were hereditary, but it is now known that they develop according to the needs of the colony, just as the embryonic cells of a single animal differentiate into blood cells, bone cells, muscle cells and so on. Thus a colony of termites is a kind of superorganism in which we can study differentiation in a nice, convenient way.

It was the late S. F. Light and his colleagues at the University of California who demonstrated that the caste of a termite is not fixed by its genes. They discovered that any nymph in a colony of termites could develop into either a soldier or a king or queen of the supplementary type, depending on what the situation demanded. For example, in the species of damp-wood termites they studied, a new colony always has one soldier, and only one, in the first brood. When they removed the soldier, another always developed, from a nymph which would not normally have become a soldier. This occurred up to as many as six times; each time a soldier developed to replace the one removed. Likewise the elimination of reproductive termites caused replacements to develop.

Light's group concluded that the soldier and reproductive termites already present in a colony inhibited the development of additional ones, and that they exercised this inhibition by means of some kind of "social hormone." To test this theory the experimenters fed extracts from reproductive termites to developing nymphs. There was a slight inhibition in the production of new kings and queens and a delay in egg-laying, but the effect was not sufficiently clear-cut to prove the social hormone theory.





TWO TERMITE COLONIES at the left are separated by wire mesh. When the king and queen are removed from one, they are regenerated but then killed. At the right the colonies are separated by a double screen, which keeps the antennae of their members from touching. These colonies behave as though they were isolated.

Recent experiments, however, have given the theory more definite support.

IF A TERMITE colony is considered as a superorganism, then caste differentiation may be looked upon as an embryological problem. The differentiation of cells in an embryo is always initiated at a certain critical stage in their development; in other words, a given group of cells cannot change until it is ready. One may assume that a nymph in a termite colony similarly can be induced to differentiate only at a critical stage of readiness.

We have studied the critical period in the European dry-wood termite. We marked the nymphs individually with colored spots and kept them under observation daily for two years in flat nests. They went through several molts. As individuals molted they were measured and marked again, since they lost the spots with the castoff skin. From time to time the king and queen were removed so that new reproductive termites would develop from the nymphs.

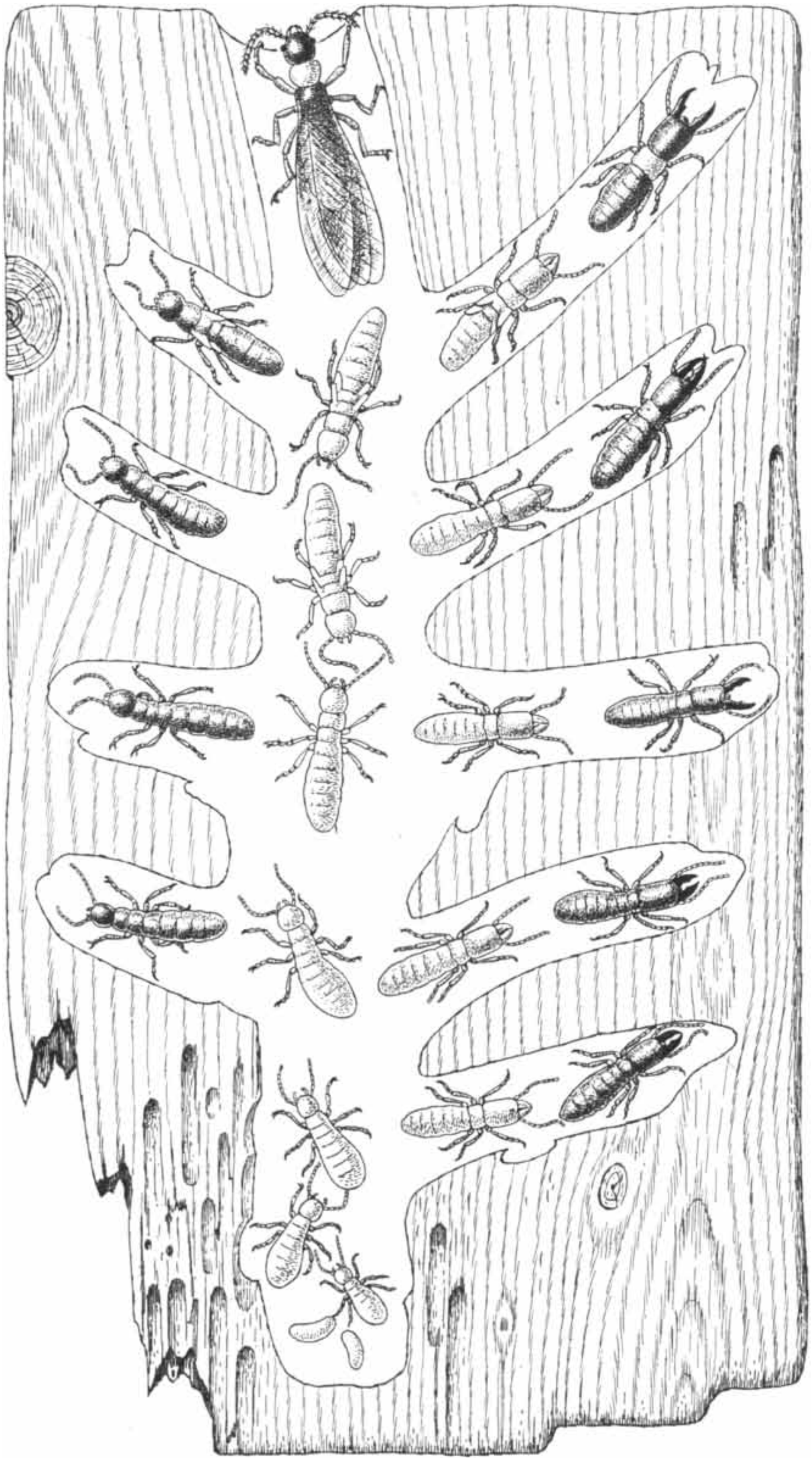
This investigation showed that there is a certain critical period during the molting interval when a nymph has the capacity to differentiate into a special adult caste. But whether it will do so depends on the make-up of the colony's population. Most of the nymphs never differentiate, though they may go on molting at regular intervals. These arrested nymphs function as workers in this species, which has no true worker caste. We call them "pseudo-workers." A pseudo-worker may develop wing pads and become a winged adult.

The pseudo-workers are the undifferentiated elements of a colony, like the undifferentiated cells of an organism. What makes them convenient for study of differentiation is that they can be followed individually, unlike the cells in an organism.

It is easy to produce new adults of the reproductive caste experimentally. All one has to do is to remove the king or queen or both from the colony. Within 10 to 20 days several supplementary reproductive adults of both sexes appear. But the colony will tolerate only one king and one queen; it promptly kills and eats the excess.

So long as the reproductive pair is present, no others are produced. Yet if the pair is removed for only 24 hours, new candidates at once begin to develop as their replacements. In that 24-hour period the differentiation of the candidate nymphs is irreversibly determined. Even though the original king and queen are returned to the colony, the nymphs that have started to differentiate will go on developing and become reproductive adults in 8 to 14 days.

THE CAPACITY of a given nymph to change into a reproductive adult depends on the stage of its molting cy-



DEVELOPMENTAL POSSIBILITIES of a nymph of the termite *Kalotermes flavicollis* are shown in this drawing. From the eggs at the bottom of the drawing hatch the young nymphs. They molt five to seven times until they reach the pseudergate stage, represented by the termite in the middle of the drawing. At this stage the termite can molt many times without growing, and under environmental influences can change into a supplementary reproductive (*left side of drawing*) or, by way of a soldier nymph stage, into a soldier (*right*). At the pseudergate stage the nymph can also change, by way of two wing-padded nymphs, into a winged form (*top*). Reproductives and soldiers may also arise from younger or wing-padded nymphs.

cle. Any nymph that has just molted when the king and queen are taken away is certain to change. This capacity decreases exponentially with time after the molt: 19 days after the molt it has dropped to 50 per cent (*i.e.*, only half of the nymphs at this stage will change), and 38 days after the molt it is only 25 per cent. The curve showing the decline in the capacity to change resembles a radioactive decay curve—the half-life period in this case being 19 days (at a temperature of 80 degrees Fahrenheit). That is, after 19 days half of the originally capable termites have lost their competence to change. As in the disintegration of radioactive atoms, we cannot predict just which individuals will lose the capacity in 19 days; all we can say is that each has a 50 per cent chance of losing it by that time.

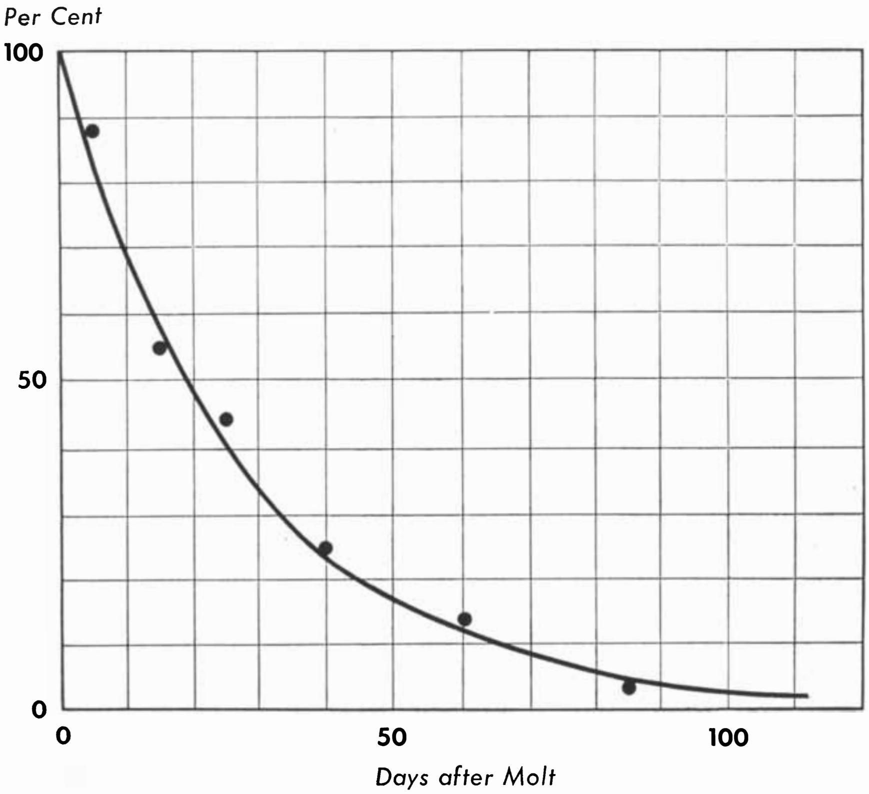
From the fact that the loss of competence is an exponential function we may conclude that it is due in each individual to a single biochemical event, possibly the disintegration or synthesis of a specific molecule.

All this bears a striking resemblance to an embryo cell's loss of competence to change. The University of Rochester embryologist Johannes Holtfreter has made a series of transplantations of ectoderm (outer) tissue from a young amphibian embryo into the site where nerve tissue develops in another embryo. He found that the tissue he took from the donor gradually lost its competence to change into nerve tissue as he kept it in artificial culture longer and longer before implanting it. For the tissue as a whole the decline in ability to differentiate was not exponential, but for the individual cells in the tissue it very likely is, as a single cell must change or not change: there are no gradations in between. The changes in the transplanted tissue ranged from complete alteration to a spinal cord to development of only a few neural cells.

We must of course be cautious about applying the conclusions about the termite "superorganism" to an actual organism, but it seems reasonable to assume, as a working hypothesis, that the loss of ability to differentiate in cells, as in individual insects in a termite colony, is effected by a single event, possibly a change in a single molecule in each cell.

IN A TERMITE COLONY, as we have seen, differentiation depends on two things: (1) the nymph's competence to change, and (2) inhibition, or lack of inhibition, by the colony. How is this inhibition exerted: by some active substance, a social hormone as Light suggested, or merely by a scent or other sensory warning given off by the king and queen?

To test these possibilities we observed two colonies of termites separated by a fine metal screen through which the colonies could maintain contact by rubbing antennae. One colony had a king



PROBABILITY OF CHANGE in a nymph decreases with time after molt. With the proper stimuli all nymphs that have just molted will change. Of the nymphs that molted 19 days earlier, only 50 per cent will change.

What General Electric people are saying . . .

J. H. HAGENGUTH

Mr. Hagenguth is Manager of the Company's High Voltage Engineering Laboratory.

". . . Thanks to the lightning hunters, among them such illustrious names as Steinmetz, Peek, McEachron, Foust, and Lewis of the General Electric Company, Gross of the American Gas & Electric Company, Schonland in South Africa, and others, we now have a fairly complete story on the lightning stroke formation and the currents involved. We have learned that a lightning stroke generally starts at the cloud in the form of a short streamer of about 150-foot length. This streamer hesitates for about 50 millionths of a second or 50 microseconds and then advances another 150 feet. This process is continued more or less regularly until the streamer reaches the earth after about 1/100 of a second from the start. Here charges of opposite polarity have meanwhile accumulated and as the streamer makes contact, there occurs an interchange of charges at a rate about 100 times as great as the streamer advance. A so-called current peak is produced which may have as much as 200,000 amperes of crest current traveling upward toward the cloud. This is the lightning component that shatters trees and houses.

Probably no two strokes are ever alike. However, we now know quite well the range of the important characteristics of lightning stroke current peaks, such as the time it takes to reach its crest, how slow or how fast it decays, the range of its current amplitudes. All these factors are of importance in the equipment protective field.

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Station WGY, Schenectady

E. S. LEE

Mr. Lee, a past president of the AIEE, is editor of the General Electric "Review."

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For the phenomena of Nature are beautiful, and it is to the honor of the scientist and the engineer to search them out and make them available to mankind in the products of industry. These are the prize possessions of the engineering student; and industry provides him with the opportunity to make use of them. This is not new. It has always been that way.

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General Electric Review

J. W. BELANGER

Mr. Belanger is Vice President, Defense Products Group.

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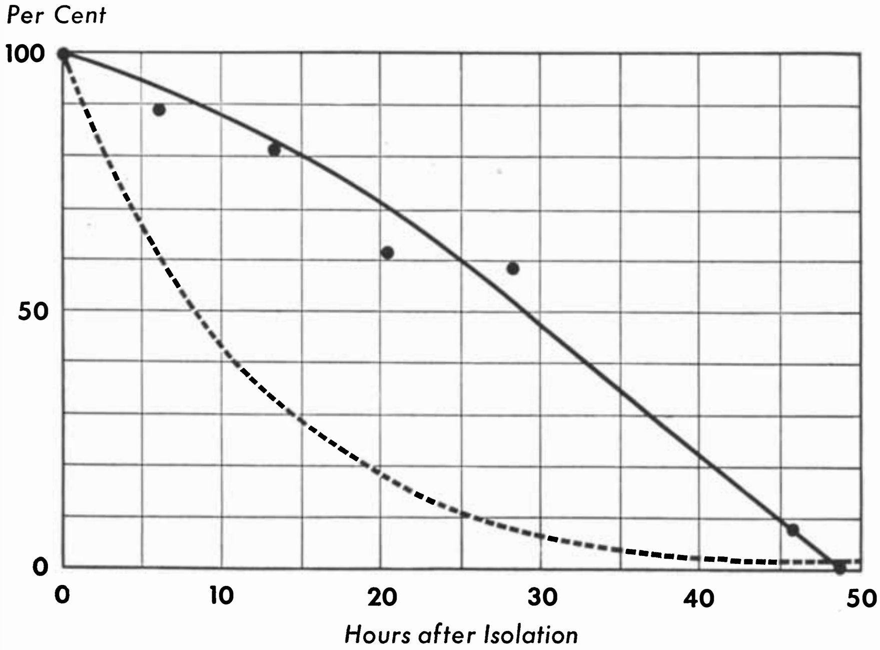


EMBRYONIC TISSUE also loses its capacity for change with time after its isolation. The solid line shows the percentage of transplants that changed; the dotted line, the theoretical decrease in this capacity for single cells.

and queen, the other was orphaned. The termites showed a strong tendency to touch antennae through the screen. Now the experiment had a curiously mixed result. The contact through the screen did not prevent the groups from behaving, in one sense, like two separate colonies: the orphaned colony always proceeded to produce its own king and queen. But in many instances it promptly killed them, as if it perceived the king and queen on the other side of the screen and considered its own surplus. This confusion progressed so far that the colony went on producing and killing kings and queens until it had almost annihilated itself.

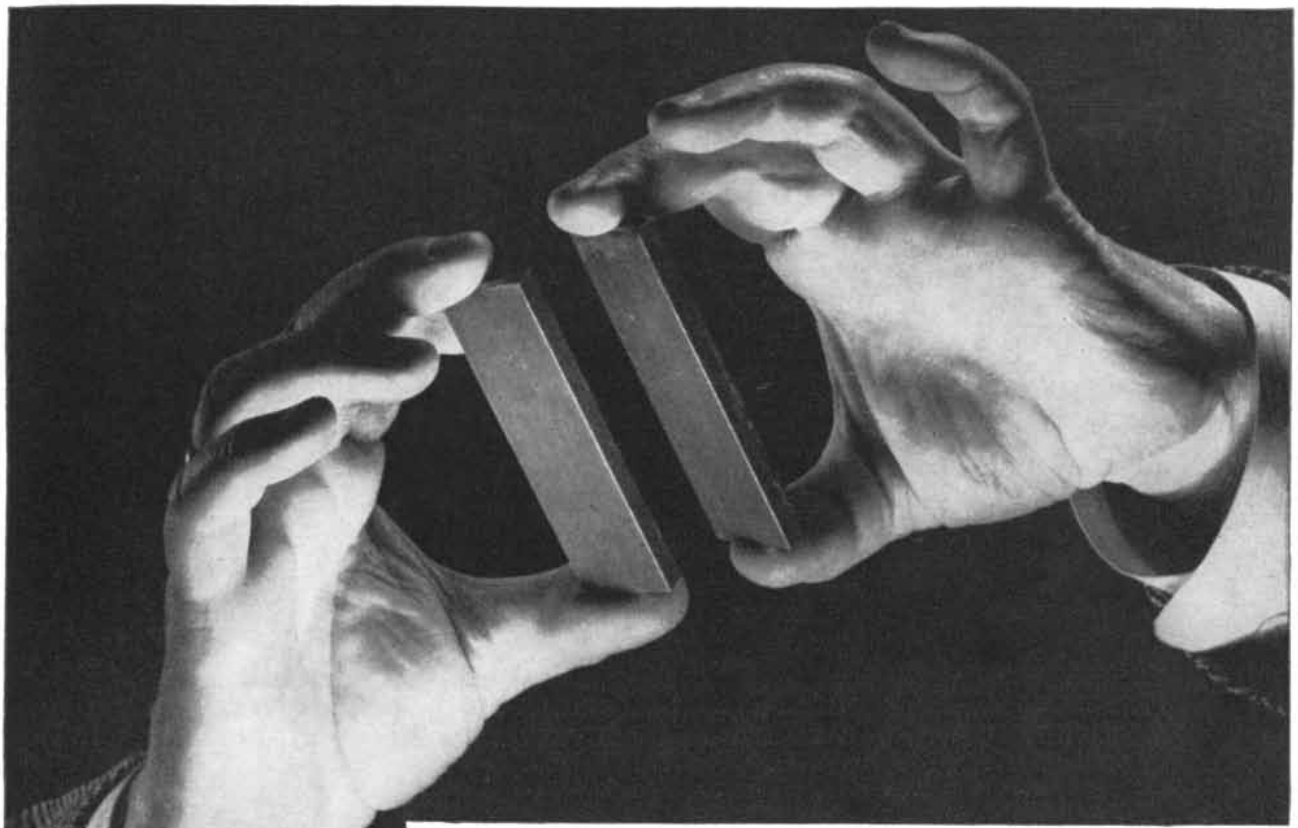
When the colonies were separated by a screen which prevented any contact, the orphaned colony produced and supported its own king and queen in the normal way. On the whole the experiment upheld the idea that an active principle transmitted by contact, that is, a social hormone, is responsible for the suppression of differentiation.

It seems likely that production of the soldier caste also is regulated by an inhibitory substance. But Frances Weesner of the University of California has recently discovered that in at least one species of termite the production of soldiers is controlled by a promoting factor as well as an inhibitory one.

The upshot of all this work on termites is that the balance of castes in a termite society seems to be maintained by means of certain special hormones, produced by the differentiated adults and acting upon the undifferentiated nymphs. A similar theory would explain many facts in cell differentiation. In an organism the various kinds of differentiated cells are always kept in constant proportions. By analogy with the termite colony, we might assume that each type of cell produces a specific hormone which inhibits the production of an excessive number of cells of the same type. Some evidence for this was recently gained by S. Meryl Rose of the University of Illinois, who showed that in the presence of an amphibian animal's adult tissues the differentiation of an embryo's cells into the same tissues is inhibited.

There is another striking parallel between a termite society and an embryonic organism. Among the termites winged adults develop only in colonies with a population of at least 100. When nymphs with incipient wings are transferred from such a large colony to a small one before a critical stage of their molting cycle, they lose their wing pads at the next molt. Similarly, at one stage in the development of an embryo, differentiation occurs only if the embryo contains a certain minimum number of undifferentiated cells. The same is true in some tissue cultures: differentiation can take place only when the culture has grown to a certain size.

THE STUDY of differentiation in termite societies has discovered so many analogies to cell differentiation that it is reasonable to expect more. The superorganism idea promises to be immensely helpful, for we can isolate and experiment on individual termites as we cannot on single cells in an embryo. We must always keep in mind, however, that an analogy can do no more than suggest a working hypothesis, which is not to be taken too seriously until it is experimentally confirmed.



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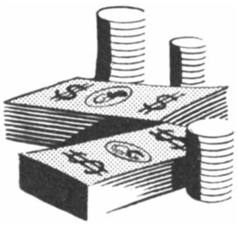

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The Mortality of Trout

The handsome and succulent inhabitants of our purest inland waters suffer grievous losses to their rigorous environment. In this attrition the angler plays a surprisingly small role

by Paul R. Needham

TROUT are the aristocrats of our inland waters. They require the purest waters in which to dwell—the cold, unpolluted "little waters" of upland streams and lakes in forested regions. Even there life is rigorous for these sensitive fish, and he who catches a trout should, like the compassionate crocodile that found a man sleeping by the waterside, weep over it before he swallows it.

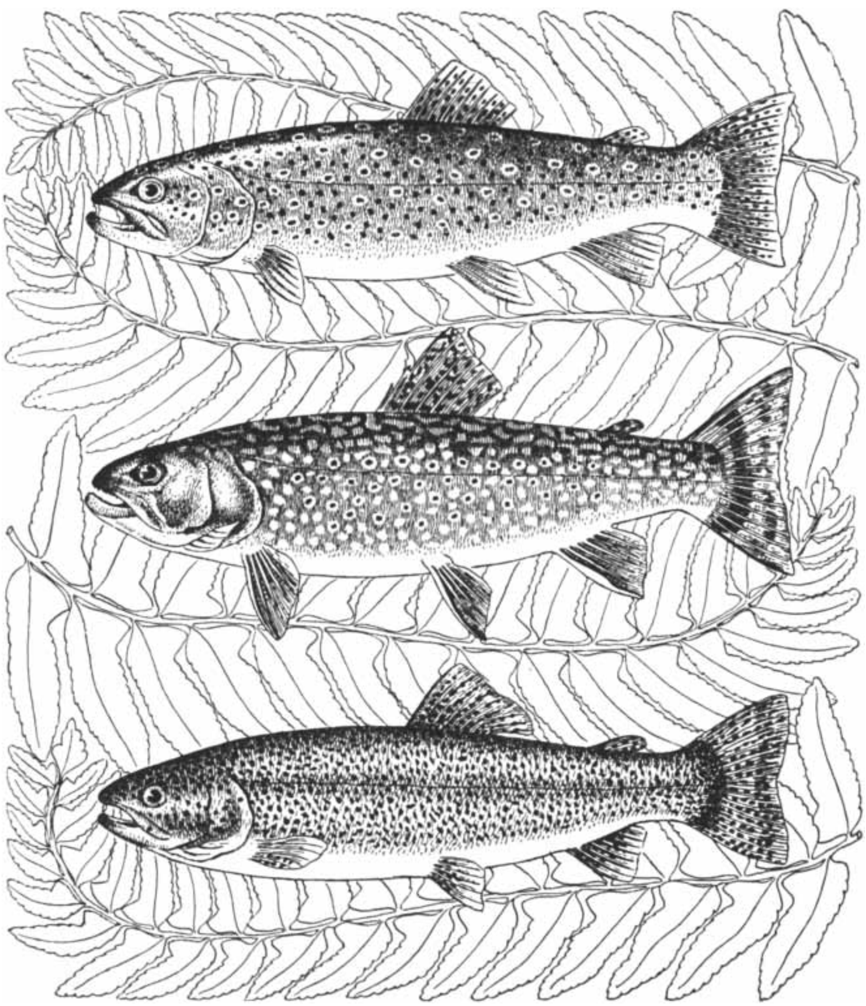
It takes a long time to produce a full-grown trout. Females usually reach sexual maturity in their third or fourth year, males at the end of their second year. Unfortunately the trout mortality rate is very high—and not primarily because they tempt fishermen. Only a small minority of the game little fish survive infancy and youth.

Since 1935 much study has been given in this country and abroad to the breeding habits and life history of the trout. There are, as every fisherman knows, three main varieties of these fish—brook, rainbow and brown trout. Of these the brown trout is by far the most abundant. In the West it is often called Loch Leven, after the Scottish lake from which some of its ancestors were brought to the U. S.; actually the Scottish variety by now has been so interbred with the German brown trout that we do not have a pure strain of either fish. Trout live on insects. They are a reasonably fertile fish: a female will lay about 1,000 eggs per pound of her weight each season. The chief aim of research on them is to find out why their mortality rates are so high.

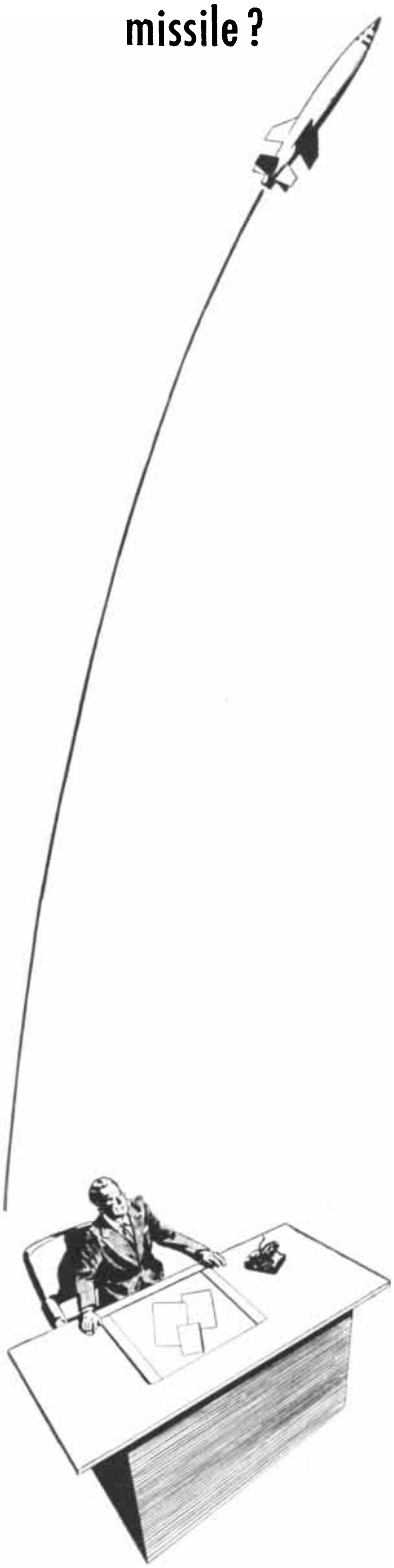
This is done in experimental streams where the baby fish are marked (by clipping their fins) and annual censuses are taken. The most accurate way of taking a census is to block off a sample section of the stream, divert the flow of water from above and pump the pools in the sample section dry. The trout taken from the dried beds are kept alive in screened boxes in water. After being weighed, measured and examined, they are returned to the pool from which they were taken, the stream in the meantime having been rerouted to its usual channel. The handlers of the fish wear cotton gloves to avoid injuring them, and every effort is made to care for them properly and return them to pools in the stream as soon as possible.

Of course not all of the fish trapped in the pools are trout. The record take from a single pool to date has been 684 fish. (The pool was 119 feet long.) Of this population only 46 were trout: 34 brown, 9 rainbow and 3 eastern brook. The rest were minnows (403), cottids or sculpins (138), suckers (88) and whitefish (9).

WE ARE LEARNING much from these censuses. From 1939 to 1944 the fishery biologists James W. Moffett, Daniel Slater and I took such counts at



THREE PRINCIPAL VARIETIES of trout in the U. S. are the brown trout (*top*), the brook trout (*middle*) and the rainbow trout (*bottom*).



WATER IS PUMPED from a section of Sagehen Creek by building two dams and routing the stream around them. One dam is in the background.

the Convict Creek Experimental Station of the U. S. Fish and Wildlife Service in the mountains (7,200-foot elevation) north of the town of Bishop in California. During our five years' work there we traced the fate of each new brood of brown trout. We found that 85 per cent of the young were lost before they had reached the age of 18 months; in other words, out of every 1,000 fingerlings produced in a given year, only 150 lived longer than a year and a half. And Convict Creek offered no more hazards to fish life, so far as we could see, than any other typical stream in that region.

The fish's reproduction varied greatly from year to year—from a low of 1,714 young brown trout per mile of stream in 1939 to a high of 4,905 in 1940. But the size of the population depended much more on mortality than on the number of young produced. We soon saw that the chief cause of death was severe winter conditions. On the average, 60 per cent of all trout, young and old, died each winter. The death rate varied with the severity of the winter's climate. In one instance we found several hundred dead trout underneath a snowbank. Anchor ice sometimes almost completely dams a stream and strands fish. A flood that washes sand, gravel and debris along the stream bottom will grind up whole faunas, killing fish and their food

IN WINTER Sagehen Creek is flanked by snowbanks and is sometimes even dammed by anchor ice. These conditions cause the death of many trout.

FISH ARE COLLECTED from the bed of the drained section. The man at the right wears cotton gloves to protect the trout from injury.

alike. A stream is a rough-and-tumble environment, and the trout that survives in it must be both quick and lucky.

We were able to explode some myths. One is that streams have little food in winter. We found that Convict Creek actually teemed with more trout food in winter than in summer: its winter content of bottom-dwelling insects (May flies, stone flies, midges, caddis flies and the like) averaged 134 pounds per acre, against only 109 pounds in summer. Probably the reason is that in winter most of the insects are in the immature nymph, larva or pupa forms and few leave the water as adults.

Another myth we disproved is that trout do not feed in icy water. The aquatic biologist John Maciolek took more than 100 healthy specimens of trout from Convict Creek one winter, and all but four had substantial amounts of food in their stomachs. Maciolek frequently saw trout feeding in winter, and on several occasions he took trout on bait in rapidly flowing water full of ice.

It may surprise some people to learn that fishing is not the most important factor in the depopulation of streams of trout. We compared the trout population in fished sections of Convict Creek with that in a half-mile section of the river closed to fishermen and to grazing by animals. The closed section had 297

TROUT ARE NETTED between the high snowbanks of Sagehen Creek. The stomachs of the trout are then studied to determine their winter diet.

OBSERVATION TANK is sunk in Sagehen Creek so the behavior of trout may be observed. Here the windows of the tank are visible at low water.

pounds of trout per acre, while the other sections averaged only about 68 pounds. Doubtless part of the difference was due to the activities of the anglers. But the fencing of the closed section against grazing animals may well have been much more important. The luxurious vegetation that grew on the ungrazed stream banks supported hosts of insects and other food material that fell or was blown into the stream. In the mountain-meadow areas of the Western states overgrazing by livestock definitely is a major cause of reduced productivity of trout.

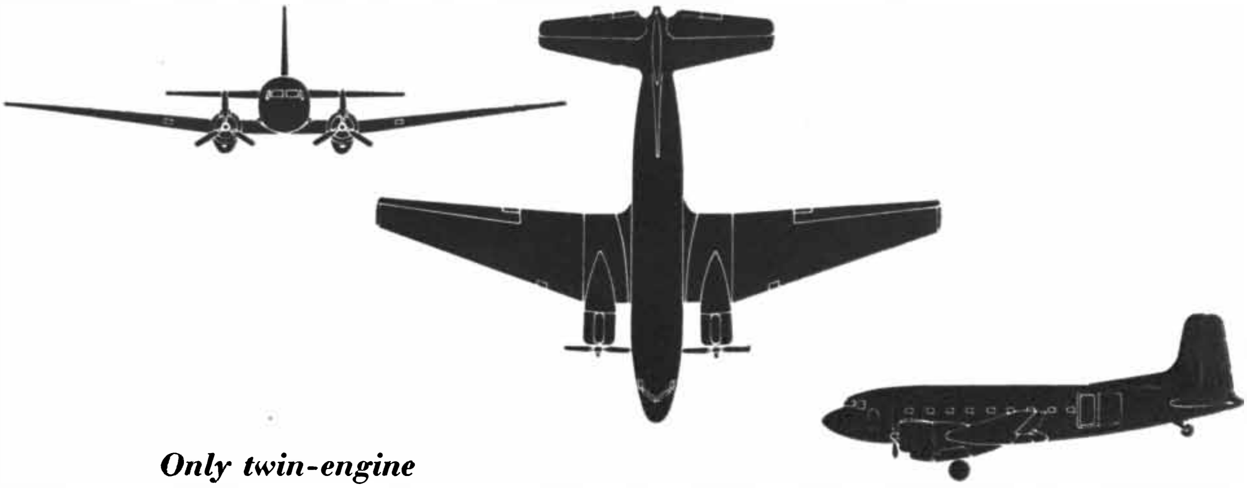
Trout fishermen often lay their lack of success at the door of the state conservation department, complaining that it has allowed streams to be fished out. This is seldom true. Even Convict Creek, which is intensively fished, had an average of 43 brown trout over six inches long per mile of stream near the close of the angling season each year. No, the fish are usually there; all that is needed to catch them is a bit more skill.

Last summer at the Sagehen Creek Experimental Fisheries Station we sampled 10 sections of the creek, scattered over a 10-mile length. Our sampling indicated that the stream then contained more than 24,000 trout, totaling more than 647 pounds. Each mile of the stream averaged roughly 176 trout over six inches long, and this was after considerable numbers had been caught by fishermen. Yet anglers complained about the poor fishing. The trout were simply hard to catch.

A LONG-TERM research program on mountain-stream fish has recently been set up by the University of California and the U. S. Forest Service at Sagehen Creek, which is at 6,600 feet elevation in the Sierra Nevadas near Lake Tahoe, Calif. The station has about 112 acres of land bordering the stream. It is equipped for year-round studies of the survival and migrations of fishes and of the effects on them of each major factor in the aquatic environment.

To obtain an idea of the numbers moving and the distance traveled by trout, both upstream and downstream, two-way fish traps are placed to catch fish moving in either direction. Each fish is marked and placed back in the stream beyond the trap to continue on its way in the same direction as when caught. During the fall spawning season of eastern brook and brown trout, large numbers are taken while moving upstream seeking suitable gravel beds in which to spawn.

One of our findings thus far is that even intensive angling cannot strip a stream of its breeding populations. Along some stretches the trout take shelter in undercut banks, logs, stumps and vegetation lining the stream banks, and there they cannot be reached with a rod. From late October to late November one can go out along the stream with a flashlight at night and see many pairs of trout over their nests in shallow water at the lower ends of pools, going through their courtship behavior, digging and laying their eggs in gravel beds. The low water temperatures in the late fall and winter prevent the eggs from hatching until the following spring. This is a most convenient arrangement, for the eggs remain practically dormant and buried in gravel largely protected from the decimating factors of ice and snow. But we know that the over-winter losses of trout are heavy, and we must find out in



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more detail what takes place in the stream bed in winter.

To do this we have installed an underwater tank from which we can watch what is going on. Made of sheet metal, it is just large enough for an observer to sit in and has four plate-glass windows. The graduate students who sit watch in it have aptly termed the box "the deep freeze." Eventually the tank will be provided with heat, a dictaphone and radio communication to the main laboratory. A lead-covered cable will be run 400 feet from the tank to a potentiometer and other instruments in the laboratory. Accurate micromeasurements of air and water temperatures, stream flows and other ecological factors will be recorded simultaneously.

IT IS a strange experience to get down in the tank and watch the underwater world. During a one-hour observation of a three-inch eastern brook trout that was feeding at a certain spot I saw it leave its "feeding position" 90 times to inspect or to eat materials drifting downstream, and six times it rose to catch food at the stream surface. The popular belief is that trout are not bottom feeders, but we have often seen an eastern brook trout suck up a mouthful of bottom sand, blow it out in the current and catch midges and other insect larvae thus dredged up before they sank back to the stream bed. The larger trout feed much less actively than small ones, especially in daylight. As evening approaches, however, their interest in feeding picks up noticeably. We have frequently seen a large trout at non-feeding time stretch its jaws wide in what seems to be a typically vertebrate yawn.

In addition to observations on the day-to-day behavior of fish, it will be possible to make accurate and detailed observations of their spawning habits. Last but not least, we shall be able to follow in detail the formation of stream ice in winter. We have found that even with a heavy layer of ice on the stream, an observer in the tank can see clearly for five or six feet. Lights will be installed for night observations. Special attention will be given, of course, to investigating the reasons for the high winter mortality rates among trout. To get all the facts we need, it will be necessary literally to "sleep" with the trout, winter and summer, in fair weather and foul. So far, at least, there seems to be no substitute for getting down under the water with the fish.

Sagehen Creek is a lovely stream and offers a wonderful opportunity to "get our feet wet" in digging up new facts useful to stream management. We hope it may contribute to better angling. The first requirement for improving the usefulness of animals to man is a detailed knowledge of their life history and habits. At Sagehen Creek we now have a fine opportunity to study the life of the trout.

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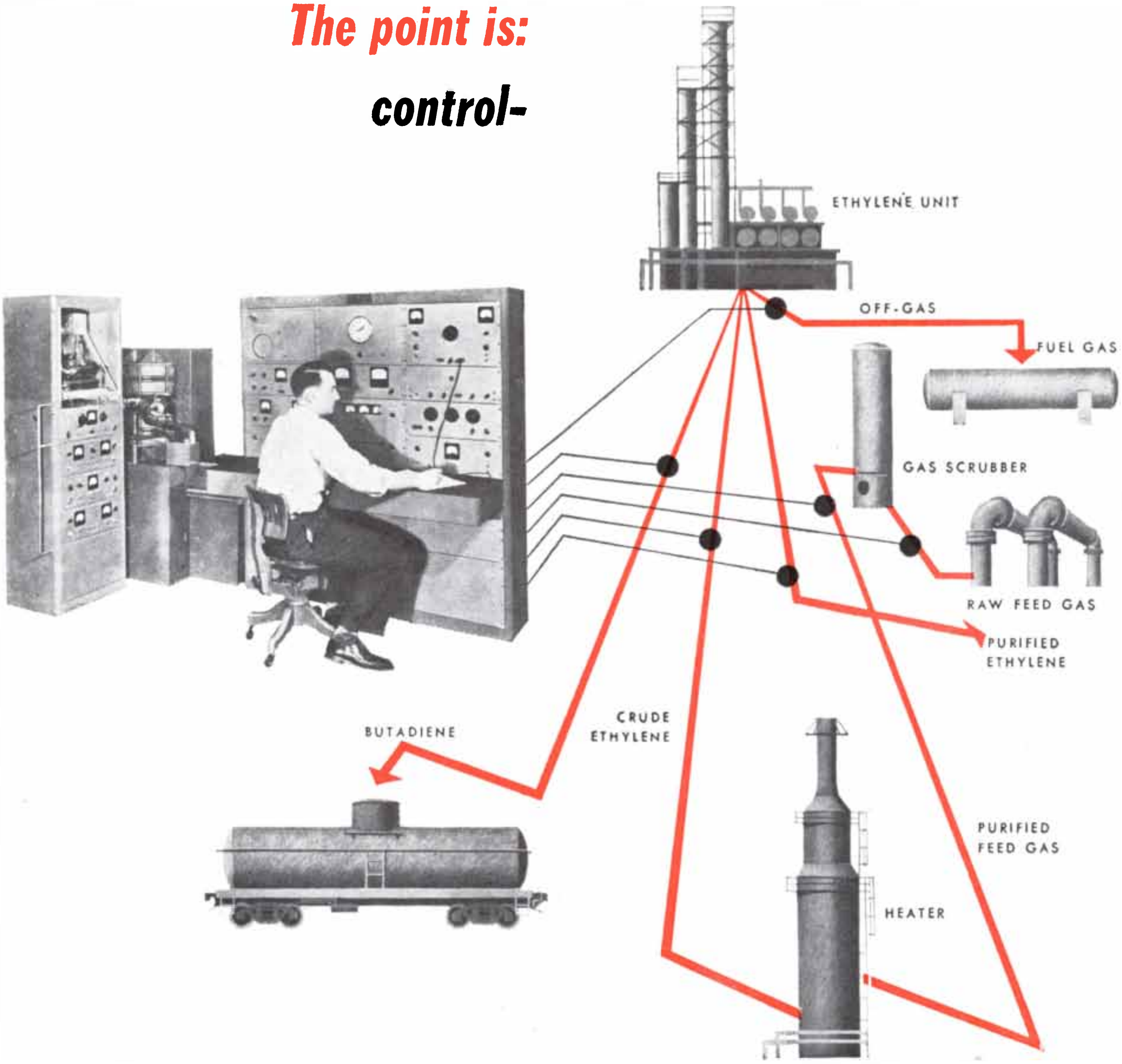

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The Voyage of the "Challenger"

From 1872 to 1876 a doughty little ship sailed the seven seas and gathered an unprecedented amount of information about them, thereby founding the science of oceanography

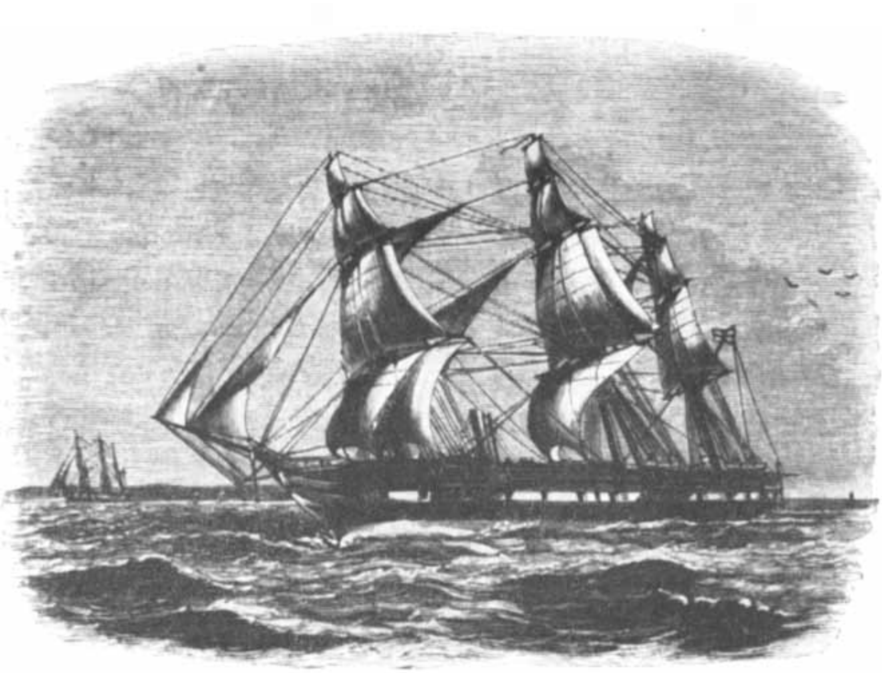
by Herbert S. Bailey, Jr.

JUST 77 years ago this month a spar-decked little ship of 2,300 tons sailed into the harbor of Spithead, England. She was home from a voyage of three and a half years and 68,890 miles over the seven seas. Her expedition had been a bold attack upon the unknown in the tradition of the great sea explorations of the 15th and 16th centuries. The unknown she had explored was the sea bottom. When she had left England, the ocean deeps were an almost unfathomed mystery. When she returned, she had sounded the depths of every ocean except the Arctic and laid the foundation for the modern science of oceanography.

The ship was called the *Challenger*. Her name and voyage are already covered with the dust of time, but her story is worth reviving today, when far more handsomely outfitted expeditions are once more exploring the sea deeps. They are filling in details and retouching parts of a picture which in its broad outlines has remained essentially unchanged since that pioneering voyage. It was the *Challenger*, rigged with crude but ingenious sounding equipment, that charted what is still our basic map of the world under the oceans.

Before the *Challenger*, only a few isolated soundings had been taken in the deep seas. Magellan is believed to have made the first. During his voyage around the globe in 1521 he lowered hand lines to a depth of perhaps 200 fathoms (1,200 feet) in the Pacific; failing to reach bottom, he concluded that he was over the deepest part of the ocean. (Actually the water where he took his soundings is 12,000 feet deep, far from the deepest bottom in the Pacific.) After Magellan no deep-sea soundings were taken for about 300 years. In the 19th century a few sea captains and layers of telegraph cables began to plumb deep waters, some of them getting their lines down as deep as two miles or more.

One of the first men to take a scientific interest in the ocean depths was Edward Forbes, professor of natural philosophy at the University of Edinburgh. He did some dredging in the Aegean Sea, studying the distribution of flora and fauna and their relation to depths, temperatures and other factors. Forbes never dredged deeper than about 1,200 feet, and he acquired some curious notions, including a belief that nothing lived in the sea below 1,500 feet. But his pioneering work led the way for the *Challenger* expedition.

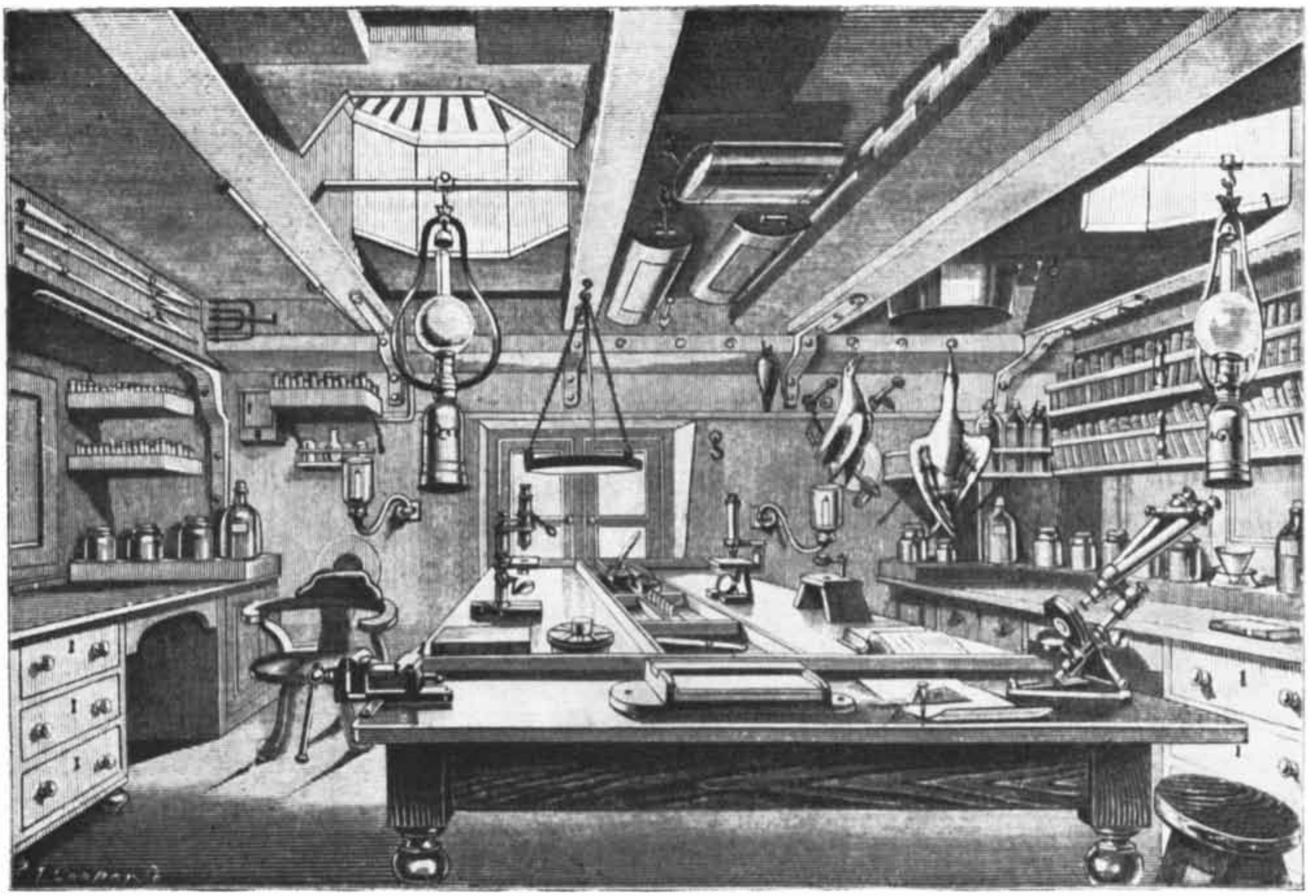


H.M.S. Challenger, *as depicted in the official* Challenger *report*

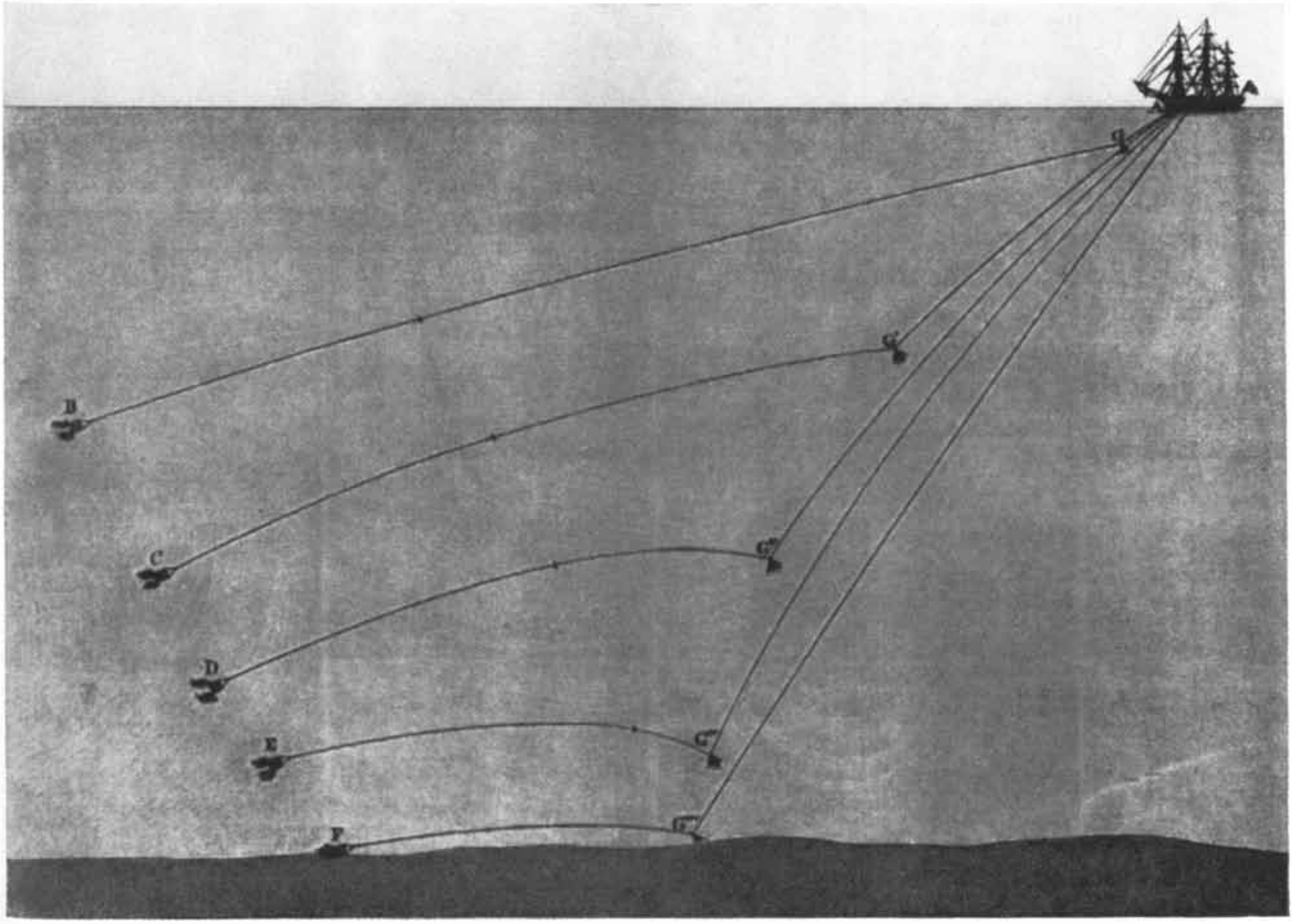
THE MAN WHO organized the expedition was Charles Wyville Thomson, Forbes's successor as professor of natural philosophy at Edinburgh. Thomson first made some summer dredging cruises in ships borrowed from the British Admiralty, and the results were so interesting that they prompted Thomson and the Royal Society to approach the Admiralty with a much more ambitious project. They asked for a vessel that could carry out an investigation of the "conditions of the Deep Sea throughout all the Great Oceanic Basins." The naval authorities, now fully awake to the importance of oceanic research, provided H.M.S. *Challenger*, a corvette fitted with auxiliary steam power in addition to her sails. A naval crew under Captain George S. Nares was assigned to the mission, and Thomson selected a staff of scientists and other civilians to assist him.

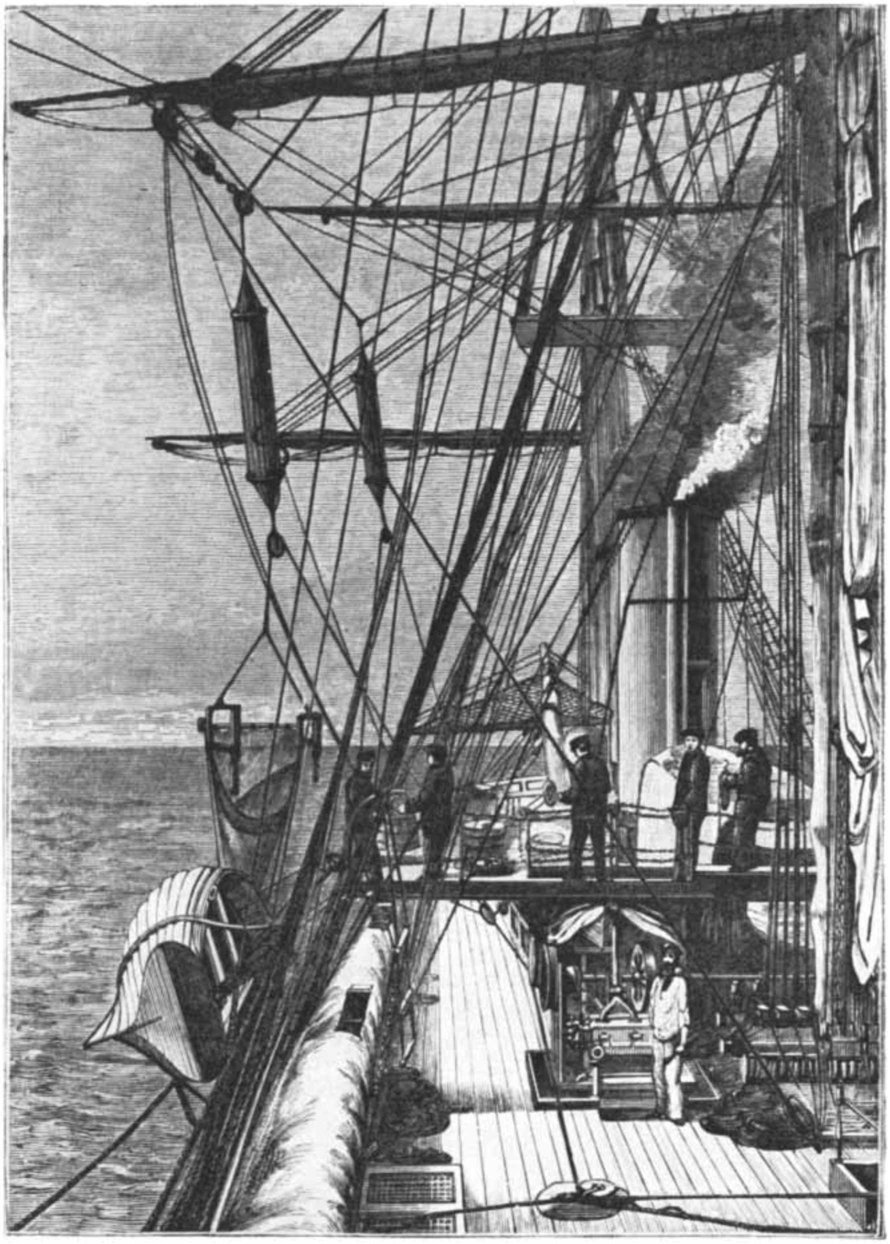
They proceeded to adapt or improvise the necessary scientific equipment and to fit out laboratories on the ship. To make room for their gear they removed all but two of the warship's 18 guns. Their equipment included instruments for taking soundings, bottom samples and undersea temperatures; winches and a donkey engine; 144 miles of sounding rope and 12.5 miles of sounding wire; sinkers, nets, dredges, a small library, hundreds of miscellaneous scientific instruments and "spirits of wine" for preserving specimens.

The expedition, coming after Charles Darwin's famous voyage in the *Beagle* and in the midst of the great uproar over his new theory of evolution, naturally attracted public attention. Even



The zoological laboratory of the Challenger (above), *and the principle of its deep-sea dredges* (below)





Dredging and sounding apparatus on the deck of the Challenger

Punch gave the *Challenger* a send-off:

Her task's to sound Ocean, smooth
humours or rough in,
To examine old Nep's deep-sea
bed. . . .
In a word, all her secrets from Na-
ture to wheedle,
And the great freight of facts
homeward bear.

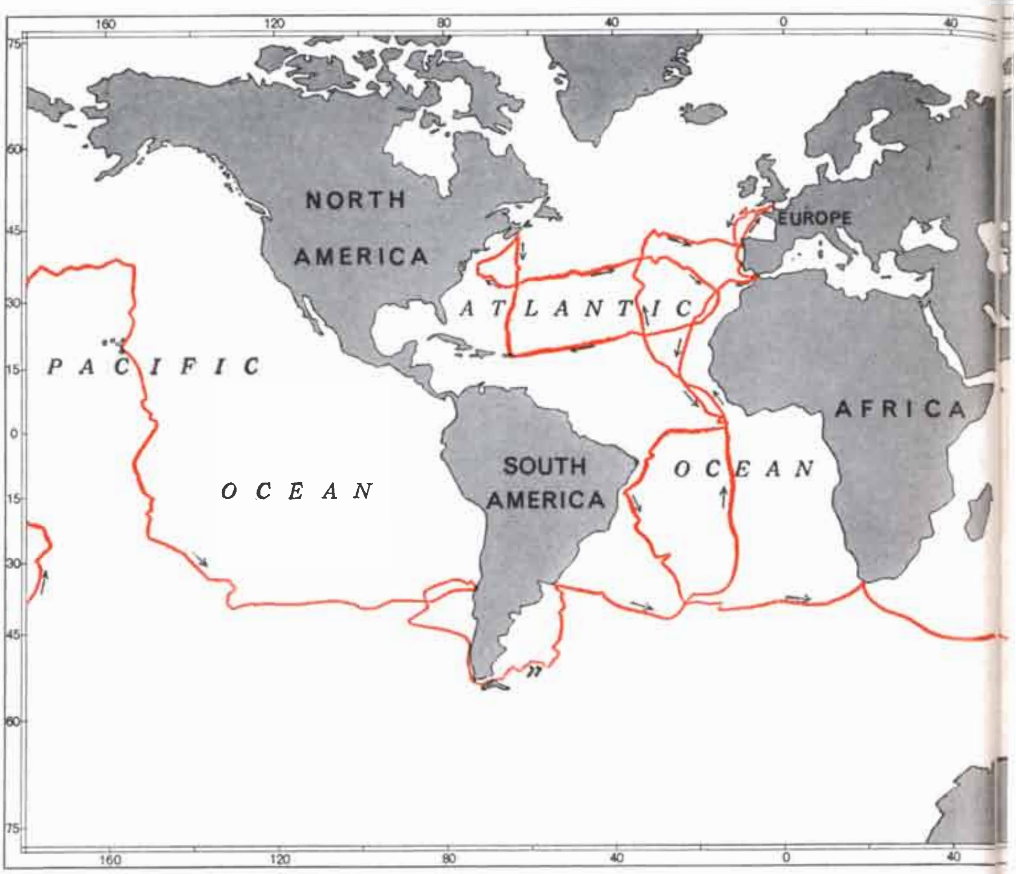
The *Challenger* sailed from Portsmouth on December 21, 1872. She immediately ran into a howling storm at sea. Thomson found this no evil omen, pointing out that the gale "brought all our weak points to light" and increased confidence in the arrangements. His staff spent the first leg of the voyage, as far as Bermuda, in training and practice on their work: sounding, dredging, trawling and making measurements. Holding the ship steady with her steam engines, the civil and naval crews each time took a standard series of observations: the total depth of water, the temperatures at various depths, the atmospheric and meteorological conditions, the direction and rate of the current on the ocean surface and occasionally of the currents at different depths. They also dredged up samples of the bottom, including its plant and animal life, and dipped up samples of the water and of the sea life at various levels. They found they had to make their soundings with the hemp rope, because the wire tended to kink and break. Attached to the line were sinkers, thermometers and water bottles; when the sinkers hit the bottom they were automatically detached. By the time they had finished their voyage, they had made such observations at 360 stations scattered over the 140 million square miles of the ocean floor.

The routine was long and laborious. In really deep water it took more than an hour and a half to reach bottom—and much longer to haul the line back. "Dredging," wrote one of the naval officers, "was our *bête noire*. The romance of deep-water trawling or dredging in the *Challenger*, when repeated several hundred times, was regarded from two points of view: the one was the naval officer's, who had to stand for 10 or 12 hours at a stretch carrying on the work . . . the other was the naturalist's . . . to whom some new worm, coral, or echinoderm is a joy forever, who retires to a comfortable cabin to describe with enthusiasm this new animal, which we, without much enthusiasm, and with much weariness of spirit, to the rumbling tune of the donkey engine only, had dragged up for him from the bottom of the sea."

THE TRIP was not, however, all drudgery. There was romance and adventure enough to inspire the officers and scientists, almost to a man, to produce memoirs, logs and other accounts for an eagerly waiting public at the end of the voyage. One of the first diversions occurred in the South Atlantic. Putting in at the tiny colony of Tristan Island, the *Challenger's* crew learned from the inhabitants that two brothers named Stoltenhoff, seeking their fortune at seal-hunting, had marooned themselves nearly two years earlier on aptly named Inaccessible Island. The ship diverted its course to rescue the brothers. They had kept themselves alive on a diet of penguins' eggs and wild pigs, but had had no luck catching seals. The ship also stopped at nearby Nightingale Island, a rookery for hundreds of thousands of penguins, and found it so covered with eggs that the shore party could hardly walk without stepping on them. The penguins defended their nests furiously and pecked one of the ship's dogs to death.

Beyond Cape Horn, on Marion Island, they saw multitudes of white albatross, but, heeding the warning of the Ancient Mariner, they killed none. This was a rare exception, for it was their practice to collect specimens of indigenous flora and fauna wherever they touched land.

Exploring in the southernmost Indian Ocean, the *Challenger* became the first steamship to cross the Antarctic Circle. The scientists were tremendously interested in the icebergs and even fired a cannon at one to break off a chunk. In an unsuccessful attempt to find the "Termination Land" reported by the U. S. explorer Charles Wilkes, the *Challenger* ran into a sudden antarctic storm while traversing a pack of icebergs. With the wind at 42 miles per hour and night coming on, the ship took refuge in the lee of a large berg, holding position close beside it with the steam engine. During an unexpected lull in the wind,



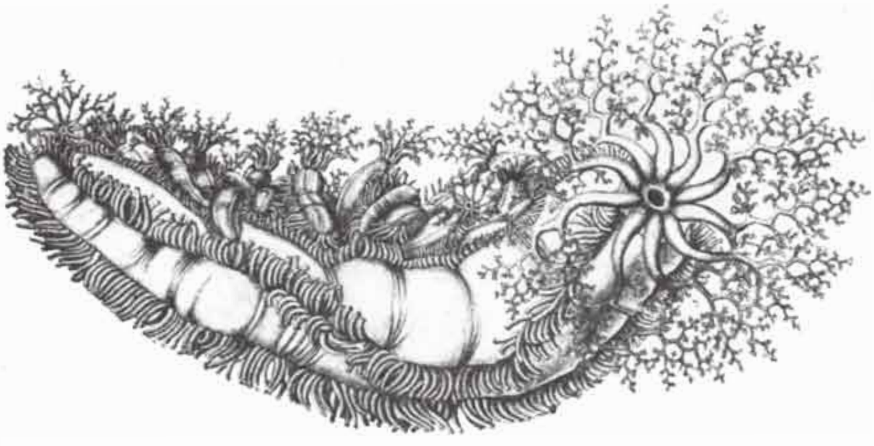
A general outline of the voyage of the

the ship rammed the berg before the engine could be reversed and lost its jib boom and other rigging. The damage was not serious and the rigging was recovered, but the company spent an anxious night steaming back and forth in a dense snowstorm between two large icebergs.

The ship next went on to Australia, New Zealand and the Pacific islands. In the Fijis they interviewed King Thackombau, a converted Christian, who had earlier cut out a prisoner's tongue and eaten it in his sight—before eating the prisoner himself. The ship called at the Philippines, Japan, China and the Admiralties. On March 23, 1875, off the Marianas Islands, the explorers hit their deepest sounding—26,850 feet. This was not very far from the deepest of all time: the record to date is a sounding of 34,440 feet, made in the Mindanao Trench off the Philippines by a U. S. Navy vessel in 1950.

The *Challenger* zigzagged across the Pacific, stopping at the Hawaiian Islands and Tahiti, and then rounded South America through the Strait of Magellan. It swung north through the South and North Atlantic and finally arrived home in England on May 24, 1876.

Of the *Challenger's* crew of some 240 men, seven died during the trip: two by



Cladodactyla crocea, *taken in the Falkland Islands*

lenger

drowning, one of yellow fever, the others of accidents and miscellaneous causes. Several of the crew jumped ship in Australia. The remainder returned to a joyful welcome—and to the long, hard task of organizing the vast amount of data accumulated on the voyage.

A COMMISSION was set up in Edinburgh to assess the results of the voyage, which were eventually published in an official report of 50 volumes. Two volumes contain a "summary of scientific results"; two a "narrative of the voyage." The other 46 are monographs written by some of the leading scientists of the day, among them T. H. Huxley,

Japetella prismatica

Alexander Agassiz, H. N. Moseley and the great German biologist Ernst Haeckel. Most famous of the official reports are Haeckel's monographs on certain sea organisms that had previously been relatively little known. One of the most interesting is on the radiolaria, of which the expedition collected 3,508 new species to add to the 600 then known.

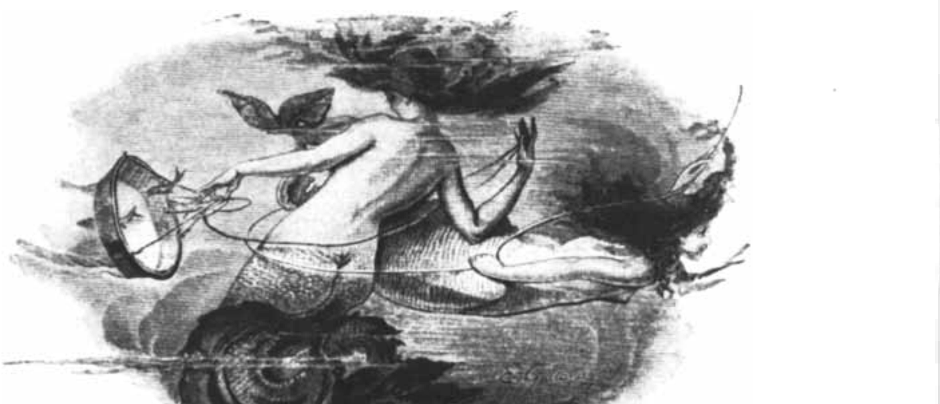
To see the *Challenger*'s scientific results in proper perspective one must remember that the voyage took place at a time when every new discovery was an exciting prize to be fitted into the evolutionary table. The *Challenger* discovered 715 new genera and 4,417 species of living things, thus demonstrating that the oceans were teeming with unknown life waiting to be classified. It proved beyond question that life existed at great depths in the sea. The voyage opened the great descriptive era of oceanography, which was followed by the analytic oceanography of our own century.

The summary volumes were written by Sir John Murray, who became head of the commission after Thomson, exhausted by the voyage, died in 1882. Murray's comments and theories have had an important influence on oceanography. He strongly put forward the view, for example, that at equivalent latitudes both the Arctic and the Antarctic have similar marine organisms, and that these are not to be found in the more temperate zones. This "bipolarity" theory has now been discarded, but for a time it stimulated much investigation. Murray also asserted that, contrary to what had been hoped and expected, the deep sea did not yield a widespread fauna of great antiquity, though some very ancient species were found. He believed that under about 600 feet below sea level the bottom deposits and fauna become more uniform with increasing depth until a point is reached at which conditions are almost the same in all parts of the world. He added, "When once animals have accommodated themselves to deep-sea conditions there are few barriers to further vertical or horizontal migration." Such suggestions, based on the *Challenger*'s observations, gave direction to further investigation.

The expedition washed out of existence a form of living matter that had been "observed" by Huxley and described by Haeckel. On the basis of preserved specimens dredged during earlier expeditions, Haeckel had decided that the entire ocean floor, or at least a major part of it, was covered with a thin layer of almost structureless living slime which he named "Bathybius." At a time when Darwin's theories were still under severe debate, "Bathybius" had been hailed as a living example of the primordial protoplasm. The scientists of the *Challenger* looked for it in vain, and finally discovered the answer to the puzzle. The alcohol and sea water in which the sea-bottom specimens were preserved had combined to form an amorphous precipitate of sulfate of lime. This was Haeckel's "Bathybius."

THE *Challenger* expedition made thousands of other contributions to various sciences—meteorology, hydrography, the physics and chemistry of sea water, geology, petrology, botany, zoology, geography. Murray's map of the world-wide sampling of oozes and other bottom deposits collected by the expedition has not been changed much by the many subsequent explorations. The *Challenger*'s crew perfected the method of "swinging the compass" to get accurate magnetic readings. The voyage established the main contour lines of the ocean basins and disproved the myth of the lost continent Atlantis. It yielded the first systematic plot of currents and temperatures in the oceans, and showed that the temperature in each zone was fairly constant in all seasons.

The achievement of the *Challenger* was tremendous: a barrier had been broken and the world of the depths explored. In a sense the *Challenger* had answered the question that had echoed down the ages in the words of Ecclesiastes: "That which is far off and exceeding deep, who can find it out?"



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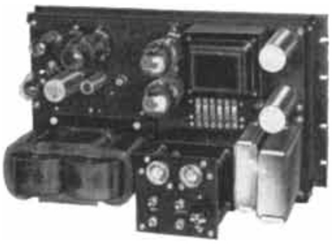

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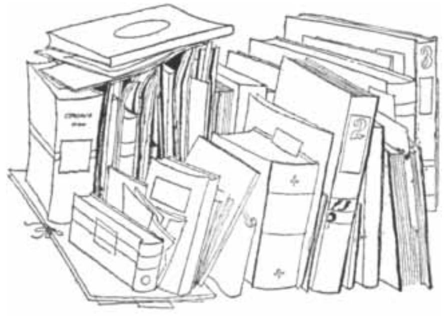


BOOKS

An original work about adaptability in machines and in the human brain

by Warren S. McCulloch

Design for a Brain, by W. Ross Ashby. John Wiley & Sons, Inc. ($6.00).

THIS BOOK deals with the general problem of adaptation—by human brains or by machines. The author, a physician who for years has been responsible for the care of the insane, in whom the adaptation process has broken down, became dissatisfied with any philosophy that places a gulf between mind and body. He was convinced that when something was wrong with thinking, something was wrong with the organ of thought—the brain. He wishes to relate the physical brain to its productions.

The actions of the brain are physical processes. You may call it a machine. But can you invent a machine that adapts in the same sense that a living thing adapts? Ashby's answer is yes. He begins by pointing out that many of the detailed connections among the 10 billion neurons in a human head are made by chance and by learning. The chance influence here, unlike that of subatomic physics, is determinate in the sense in which causality applies to the macroscopic world. It is to causal relations that Ashby gives his attention, ignoring all questions of consciousness and of other mentalistic notions because he finds them unnecessary. His problem is to identify the nature of the changes in a machine that would account for its learning, and to find out why these changes tend to cause better adaptation for the whole organism.

Specifically Ashby hopes to show that a mechanistic system can produce adaptive behavior, that the essential difference between brains and other existing machines is that brains make more extensive use of a principle which he calls "ultrastability." By applying this principle, he insists, we can make a machine as adaptive as we please. He has actually made a machine embodying this principle. He calls it a homeostat. It does not look like a living system. It is composed of batteries and electromagnetic coils which either operate stepping switches or move an electrode in a trough of salt water through which a current is flowing. These components are typical of ordinary machines. The laws relating the currents, the magnetic fields and the motions of the parts are the classical laws of the physics of such systems, and in describing his machine and its behavior, Ashby sticks closely to these laws.

Biologists are notoriously deficient in mathematics, perhaps because they were scared away from it in high school. With due consideration for their feelings, Ashby has removed his equations from his text to an appendix. If you are interested in the rigor of his proofs or in the scope of his generalizations, you will find that part of the appendix cross-referenced in the text. Actually Ashby wants his mathematics only to be sure that his general conclusions follow strictly from his premises. The argument of the bulk of the book is qualitative, for he is interested in a matter of principle, not in precise quantities. In fact, Ashby knows that the mathematics that fits well the machine he describes is not that which is most appropriate for computing the detailed behavior of the actions of the cells that compose our brains. The very dissimilarity of his machine from any biological system strengthens his argument.

A "system," as he defines it, is an arbitrarily selected set of measurable quantities, which he calls "variables"; that is, the quantities change with time. The primary operation of a scientist is to bring these variables to arbitrary values and then release the system to operate as it will. The state of the system is always defined as the numerical values of the variables at some instant. Imagine a Euclidean space in which the value of each variable is represented by a distance along one axis of the coordinate system. The state of the system is then represented by a point somewhere in that space. According to this symbolism, in any ordinary experiment the scientist brings the representative point to a particular place and lets go of it. The behavior of the system thereafter is described by a line drawn through the successive positions in the space that the representative point occupies at successive instants of time. Ashby defines as the "field" of the system the space which contains all the possible lines of behavior that the system would trace out if it were released at all possible points. Any system in which all the lines of behavior from a single initial state are the same is called "absolute"; another way of saying this is that the field of an absolute system does not change with time. Without some such notion it is impossible to define the repetitive properties of nature, on which all the laws of science are based.

Up to this point in Ashby's argument there is no distinction between the organism and its environment. In his homeostat you may regard any part of it as the organism and the rest as the environment. But because Ashby is interested in biology, not merely in physics, he now finds it necessary to make such a distinction. The central notion of biology is that there is an end, or aim, in every operation; in other words, it has a "function." Men have devised machines which may truly be said to have purposes or ends of their own. The cyberneticists Norbert Wiener, Arturo Rosenblueth and Julian Bigelow some years ago pointed out that this property merely requires that the mechanism be related to its environment by inverse feedback, a familiar phenomenon in physiology. The fundamental notion of cybernetics is that the output of a device decreases the input to the device. It is clear that such a notion can be applied only when we distinguish the device from its environment.

In the case of living things, it is immediately apparent that if a mechanism is to survive, the lines of behavior of the system of which it is a part may not take it beyond certain limits of its most significant variables. You cannot raise kittens in a furnace. Biologists usually call these "physiological limits." The same principle applies to machines.

Biologists, following the lead of physicists, used to think that energy was the most significant variable in living systems. But within the last few years, as the result of developments in thermodynamics and in information theory, particularly as it is applied to servomechanisms, they have come to realize that the crucial thing to be quantified is not energy but order, that is, the degree of organization of the system—what we may call negative entropy. This is because the behavior of the system is determined by the difference between its actual state and the state toward which it is being guided by the inverse feedback of information. In short, such devices are error-operated, and that makes them purposive, in the one sense in which this word has an objectively verifiable significance.

Obviously a system is adapted to an environment (*i.e.*, a system is "stable") if the lines of behavior of the system never take it beyond its "physiological limits." But we are here confronted with a new difficulty. The variables in our system are all those aspects of the organism and its environment which are important in determining stability. Some of them, however, may be constant all or part of the time. Hence each variable in our system may be represented by a function that belongs to one of four kinds: (1) "null," if the "variable" never changes, (2) "step," if at certain instants it jumps from one value to another, (3) "part," if it is constant for certain stretches of time but varies continuously during others, and (4) "full," if it is always varying. Of course, the variations must not take the organism or device beyond its "physiological limits" if it is to remain alive.

The space inside these limits is in several ways dependent upon how the variables change with time. If any variable is a null function, it effectively reduces the number of dimensions of the space by one, so that the space is of n-1 dimensions. If it is a step function, it breaks the space into subsets of possible points, *i.e.*, subspaces separated by gaps. Ashby calls any such subspace a "field." Now a change in a variable of the system, if sufficiently drastic in kind or amount, may threaten the system's stability. When such a change occurs in the environment, the organism or device must itself change or die. If the organism can change by step function, it may jump from one field to another. The possibilities of such a jump are limited by the number of step functions of which it is capable. It is easy to show, as Ashby does, that if an organism has about 35 such step functions at its disposal, it can jump from one step to another every tenth of a second throughout a man's lifetime without exhausting all possible fields available to it. In the case of evolution a threatened species jumps from one field to another, by variation, until it finds one in which it can survive, that is, a field to which it is adapted. So the laws are essentially the same for evolution as for adaptation of an individual organism. The field to which an organism finds itself adapted is called its "terminal field."

Ashby calls such a system "ultrastable." It is simply a system which by repeated step functions can find a terminal field wherein it survives, that is to say, a region defined by its physiological limits. To be self-regulating, a system must exhibit ultrastability. The device that prevents an airplane from rolling unduly is an automaton which, taking information from an instrument that determines which way is up, controls the ailerons of the plane. A reversal of the connections to the ailerons would cause the device to make the plane roll worse and worse until it crashed. But one might embody in such a device the principle of ultrastability, so that it would alter its internal connections, as Ashby's homeostat does, until it again counteracted all tendencies to roll.

Ashby believes, as already mentioned, that living systems differ from man-made devices in making more extensive use of ultrastability, which they have been forced to do by evolution or learning in order to survive. He presupposes that negative feedback underlies the survival of the fittest or learning by reward and punishment.

We have next to consider the crucial question as to the rapidity with which an organism or a manufactured device can adapt. Ashby postulates for his argument a system no more complicated than a human brain, except that it is fully connected to 20 "environments." The system is capable of jumping by steps at the rate of 10 per second. The universe is not old enough for such a system to have got to a terminal field. But as Ashby points out, the components of an actual system, such as an organism, are not fully or permanently interconnected. If changes in the separate components can take place independently or in sequence, the system may adapt in much less time. For example, at the hypothetical rate of change he suggests, a system of 1,000 variables would require 2^{1000} seconds to adapt if the components were fully connected to one another, but if they were separate, the adaptation could be accomplished in half a second.

The next main step in his argument considers the relations among variables within the system. He comes to the conclusion that there are systems composed of ultrastable subsystems whose main variables are linked together by functions which are constant for stretches of time. This permits an ultrastable subsystem to retain what it has learned in one environment over a long period of time while the other subsystems are adapting to one another. The total system is called "multistable." When a multistable system can adapt by parts, which speeds up its adaptation, it will do so. It will behave as a set of separate systems except when the environment requires more complex behavior. Under the latter circumstances the separate subsystems, if allowed sufficient time, will adapt themselves to one another in step-wise fashion so that the total system exhibits the required behavior.

This leads to a theory that a given item of memory, or learning, cannot be located uniformly in the same place, or even in any single place. If it is to be found at all, we must look for it in all those parts of the nervous system that have had time to adjust their behavior to the part initially affected. But that is not all. The kind of change we must seek, and the place where we must seek it, are determined by the order in which the organism adapted to its environment. This theory of memory avoids fallacies which have pervaded the thinking of many modern neurologists. No other author has suggested a theory as potent as Ashby's.

Thus, starting with a model which is far removed from the facts of biology, Ashby shows that it is possible to build a machine which, operating under the laws of classical physics, can produce adaptive behavior; that for this it requires a more extensive use of the principles of ultrastability than has been built into modern robots; and that separate ultrastable systems can be combined to produce a multistable system whose adaptations to the vicissitudes of life have no upper limit except those of our imagination. To a biologist Ashby's conclusions concerning memory are illuminating. They have the same flavor as his suggestions on the design of a chess player which can learn to play a better game than its inventor. Those who are interested in the progress of science will certainly profit by reading his book more than once.

Like Galileo, whose conclusions and proofs for the propositions that laid the foundation for our science of mechanics were occasionally defective, Ashby may have made errors. If so, it is up to the critic to detect them and to set him right. But even if he has failed to be as rigorous as he intended, he has laid the foundation for a mechanistic theory of how biological systems adapt which for many years to come will command the respect and guide the imagination of his most formidable critics.

Short Reviews

EUGENICS: GALTON AND AFTER, by C. P. Blacker. Harvard University Press ($5.00). The life and work of Sir Francis Galton, who was not merely an eminent Victorian but a thoroughly good and attractive man, is agreeably recalled in the first part of Blacker's book. Galton was a child prodigy, but he managed to overcome this handicap as well as the effects of a higgledy-piggledy education. As a young man he traveled in Europe and Africa and enjoyed, in moderation, the pleasures of sporting life. He then turned to scientific pursuits, becoming an amateur in many fields but never a mere dabbler. His discovery of the idea of correlation changed the course of modern social studies. He made measurements of man's anatomy, life span and mental states and processes. (One of his maxims was: "Whenever you can, count.") He is remembered also for his researches in fingerprinting and his writings on heredity and eugenics. It is less widely known that he contributed to meteorology (one contribution was the word anti-cyclone) and that he performed valuable experiments in blood transfusion. Galton's curiosity led him to study the peculiarities of identical twins, the sterility of heiresses, the proportion of pretty girls in different British towns, hypnosis and autosuggestion. He also built a number of mechanical and electrical gadgets, some of which were as useful as they were ingenious. Galton was an enthusiastic sponsor of new causes, but he was equally hospitable to new evidence by which these causes might be overturned. In his studies of heredity and genius he placed on biological factors, as determinants of personality and achievement, an importance which today seems somewhat extreme. Yet the nature-nurture controversy is far from settled, and no one would deny the significance of Galton's work or the soundness of many of his principles of eugenics. Blacker devotes the second part of his book to a survey of post-Galton developments in eugenics. His treatment of these is somewhat uneven, partly because so much material is squeezed into a limited space, but the book as a whole is intelligent, moderate and enlightening. To anyone who has not the time to read Karl Pearson's monumental four-volume life of Galton it offers a very readable substitute.

EX-PRODIGY, by Norbert Wiener. Simon & Schuster ($3.95). Norbert Wiener, the noted mathematician and founder of cybernetics, was a precocious child. He graduated from college at 14 and got a Ph.D. at 19. It was his misfortune to have a father—Harvard's first professor of Slavonic languages—who was fanatically bent on turning his son into a Lilliputian savant. Wiener's book is a record of this ordeal, and of his life up to his 31st year, when he finally married, broke away from his parents and joined the staff of the Massachusetts Institute of Technology, where he has served with distinction ever since. It is an interesting story, written in a fluent, occasionally self-conscious idiom. It describes Wiener's early training at home; his tragi-comic experiences in high school and at Tufts College; his years at Cornell and Harvard (where he got his Ph.D. in philosophy); his graduate studies at Cambridge (under Bertrand Russell) and at Göttingen; his adventures traveling in Europe and as a ballistics analyst during the First World War; his trial stints as a journalist, hack writer for an encyclopedia, engineer and instructor at the University of Maine; his untiring struggle to accommodate himself to society, emancipate himself from his father and mother and accept the fact that he is a Jew. This is a sensitive book by an honest man who has to a large extent overcome the handicap of precocity and who possesses an admirably human outlook on the problems of society. As an account of the tribulations of precocity itself the book is not very revealing: Wiener fails to recapture convincingly the thoughts and emotions of his childhood or to convey the conflict and misery of a prodigy as the central figure in a ridiculous tragedy.

SIR JAMES JEANS, by E. A. Milne. Cambridge University Press ($4.00). Jeans's writings were much admired by scientists and by Tallulah Bankhead; she described the best known of his works, *The Mysterious Universe*, as a book every girl should read. His career was divided into two periods. Until he was 52 he practiced as a mathematical physicist, gaining an international reputation for his achievements. In 1928 he gave up pure science, because he felt his mathematical powers were waning, and turned to popularization. Here he made an enormous success, though his later writings in the nontechnical vein were vehemently criticized for their emotional approach and philosophical naïveté. By the time Jeans died in 1946 it had become popular to belittle the Jeans-Eddington style of popular exposition, but the criticism, though partly justified, overlooked the fact that these writers had introduced to a wide audience the excitement, beauty and integrity of scientific research. In this book by the late E. A. Milne, who was himself a distinguished physicist, we have an honest, artless account of Jeans's life and work. It is not a very revealing portrayal of the man. Jeans was reserved, lonely and abrupt. Milne failed to pierce those defenses, or, if he did pierce them, fails to show the reader what inner traits they concealed. His analysis of Jeans's scientific labors is succinct, clear and interesting, but much of it is over the head of a person without special knowledge. Jeans merits a more vivid and rounded biography.

THE NEW FORCE, by Ralph E. Lapp. Harper & Brothers ($3.00). Lapp's book is an everybody's-what's-what of atomic energy: a history of nuclear research, weapons, domestic legislation and international negotiations, and an analysis of future prospects. Lapp is a physicist with broad experience in various phases of atomic energy affairs, scientific and administrative. His numerous popular articles have emphasized the importance of educating men to distinguish in nuclear matters between facts and mischievous fictions, and he has sharply criticized the Atomic Energy Commission, Congress and the military for their information policies. *The New Force* performs the great service of assembling examples of official folly and examining the consequences. Lapp is not especially gifted as a scientific expositor, and his general style of writing resembles that of Erle Stanley Gardner. But he is a consistently honest reporter, with a good grasp of a large and often confusing subject, and he is not afraid to express opinions which are bound to displease powerful men. He exposes the shocking irresponsibility of the armed services in competition for atomic weapons and in making reckless claims in order to attract publicity. He finds that Congress is irrational in its attitude toward atomic "secrets" and that the AEC has timidly framed its information program not on the basis of real security needs but in anticipation of outcries from Congressmen and generals against any atomic energy disclosures—other than their own. "The AEC," he says, "is scared to death of the military and of Congress."

INTRODUCTION TO THE FOUNDATIONS OF MATHEMATICS, by Raymond L. Wilder. John Wiley & Sons, Inc. ($5.75). This textbook on the nature of mathematical concepts, modern foundation theories, the axiomatic method, the theory of sets, symbolic logic and kindred topics is a work of exceptional clarity. Beyond that it is distinguished by a broad, enlightened outlook that recalls J. W. Young's classic *Fundamental Concepts of Algebra and Geometry*. Wilder is concerned not only with the rigorous, astringent aspects of mathematical thought but also with its cultural setting; he relates mathematical change and growth to other sociological and cultural developments. His book can be recommended to readers of philosophical inclination or to anyone interested in discovering where mathematics stands in the intellectual scheme.

THE SCALPEL, THE SWORD, by Ted Allan and Sydney Gordon. Little, Brown & Co. ($5.00). Norman Bethune, the noted Canadian surgeon, was an immensely successful practitioner, respected in his profession for his contributions to thoracic surgery. He was also a man of burning social conviction who served as a physician with the Loyalist army in Spain, joined the Communist party on returning to Canada and in 1938 abandoned his lucrative practice to go to China. He died there of septicemia a year later while acting as head of a guerilla medical service. As one might expect, Dr. Bethune was a center of vehement controversy, both in his own country and abroad. This devoted but poorly written biography records a tragic, conflict-ridden, often noble life.

CANCER IN MAN, by Sigismund Peller. International Universities Press, Inc. ($12.00). Dr. Peller, a specialist in medical statistics and cancer epidemiology, argues the following cause: "Cancer of one organ shields other organs to a considerable extent. A cured cancer leaves an increased resistance to the development of another primary tumor in some other part of the body. Although the nature of this resistance is unknown, its utilization for cancer control is possible. Forestalling the development of a highly malignant primary tumor by provoking in early life a skin epithelioma, curable in close to 100 per cent [of all cases], would cut cancer sickness and death by about 90 per cent of the present rates, and prolong present life expectancy. This is a policy of cancer control based on the principle of *taming and disarming rather than of eradicating cancer.*" Peller claims that his inoculation theory is based upon a statistical analysis of thousands of case histories in Vienna and at The Johns Hopkins University, where he worked for a time as a fellow in the department headed by the late Raymond Pearl. He supports his provocative recommendation with careful studies, but only experts are qualified to comment upon it. Peller admits that he has attracted few followers.

THE WORKS AND CORRESPONDENCE OF DAVID RICARDO, edited by Piero Sraffa with the collaboration of M. H. Dobb. Cambridge University Press (Volumes I to IX, $4.75 each). David Ricardo, a man of little formal education, retired from his brokerage business in England with a large fortune at the age of 25, was elected to Parliament and devoted most of his life to economic studies and to formulating laws and theories (rent, wages, value) which had a profound effect on his own and succeeding generations. This superbly edited book contains all the writings of that extraordinary man. It includes his famous treatise *On the Principles of Political Economy and Taxation*, his *Notes on Malthus*, his numerous pamphlets, papers and speeches, his extensive correspondence with Malthus, James Mill, John Ramsay McCulloch, Jeremy Bentham and other leading figures of his time. A biographical volume, yet to come, will complete this splendid contribution to economic learning.

INSECTS: THE YEARBOOK OF AGRICULTURE FOR 1952, compiled by the U. S. Department of Agriculture. Government Printing Office ($2.50). This most recent volume in the admirable series of Agriculture Department manuals contains 110 articles discussing almost every conceivable aspect of insect life: the good and the harm insects do to man and plants; the nature, uses and efficacy of insecticides; insect controls, economic entomology and similar topics. More than 800 insects are treated, and there are hundreds of illustrations, including 75 color plates.

INSECT PHYSIOLOGY, edited by Kenneth D. Roeder. John Wiley & Sons, Inc. ($15.00). Fifteen experts contributed to this 1,100-page survey of the "major trends in experimental research on insects." It is a book primarily for students and specialists, with an extraordinary richness and diversity of material. Numerous illustrations and excellent bibliographies.

THE AMERICAN THESAURUS OF SLANG, by Lester V. Berrey and Melvin Van den Bark. Thomas Y. Crowell Company ($6.95). This is the thoroughly reworked second edition of a book first published in 1942. It is as complete and up to date as two devoted editors and a posse of amateur slang hunters could make it. The volume contains 400 pages of general slang, 450 pages of special slang (underworld, sports, military, regional, and so on) and 50 pages of derivations. For word collectors it is as tempting a dissipation as Fowler's *Modern English Usage* or Mencken's *The American Language*. As a working tool, however, the book is dangerous. A writer unfamiliar with the vocabulary of slang and with no ear for its quality could cut himself to ribbons on the pages of this thesaurus. Slang is so ephemeral that trying to codify it is like trying to collect snowflakes. The editors say that they eliminated thousands of terms that died between 1942 and 1952, but they are still carrying thousands more that look as quaint as sideburns. Moreover, slang has style, and not every rude or fanciful expression deserves the term. A man who calls his wife "the fetter half" is making a wisecrack (not a very good one), but he is not talking slang. And it would be interesting to know how often ball players refer to first basemen as "guardians of the initial portal." Use this volume with extreme caution.

THE SCIENTIFIC WORK OF RENÉ DESCARTES, by J. F. Scott. Taylor & Francis, Limited ($4.40). An account of the principal mathematical and physical discoveries of the great 17th-century Frenchman, who is regarded as the founder of modern philosophy. Descartes' work on analytical geometry was his most celebrated contribution to science, but he made many others of importance, including researches which "prepared the way for the optical discoveries of Hooke, Grimaldi and Newton." Scott's scholarly and attractively written book is a valuable addition to the literature of the history and philosophy of science.

Notes

FROM LODESTONE TO GYRO-COMPASS, by H. L. Hitchins and W. E. May. Philosophical Library ($4.75). A brief, illustrated history of the compass, from the small revolving figures said to have been used on Chinese chariots in 2600 B.C. to the impressive pointing devices now used on aerial chariots. Useful bibliographies.

PHILOSOPHIC PROBLEMS OF NUCLEAR SCIENCE, by Werner Heisenberg. Pantheon ($2.75). A collection of Heisenberg's lectures and articles on miscellaneous subjects, including the history of the physical interpretation of nature, Goethe and Newton on color, problems of atomic physics, science and international understanding.

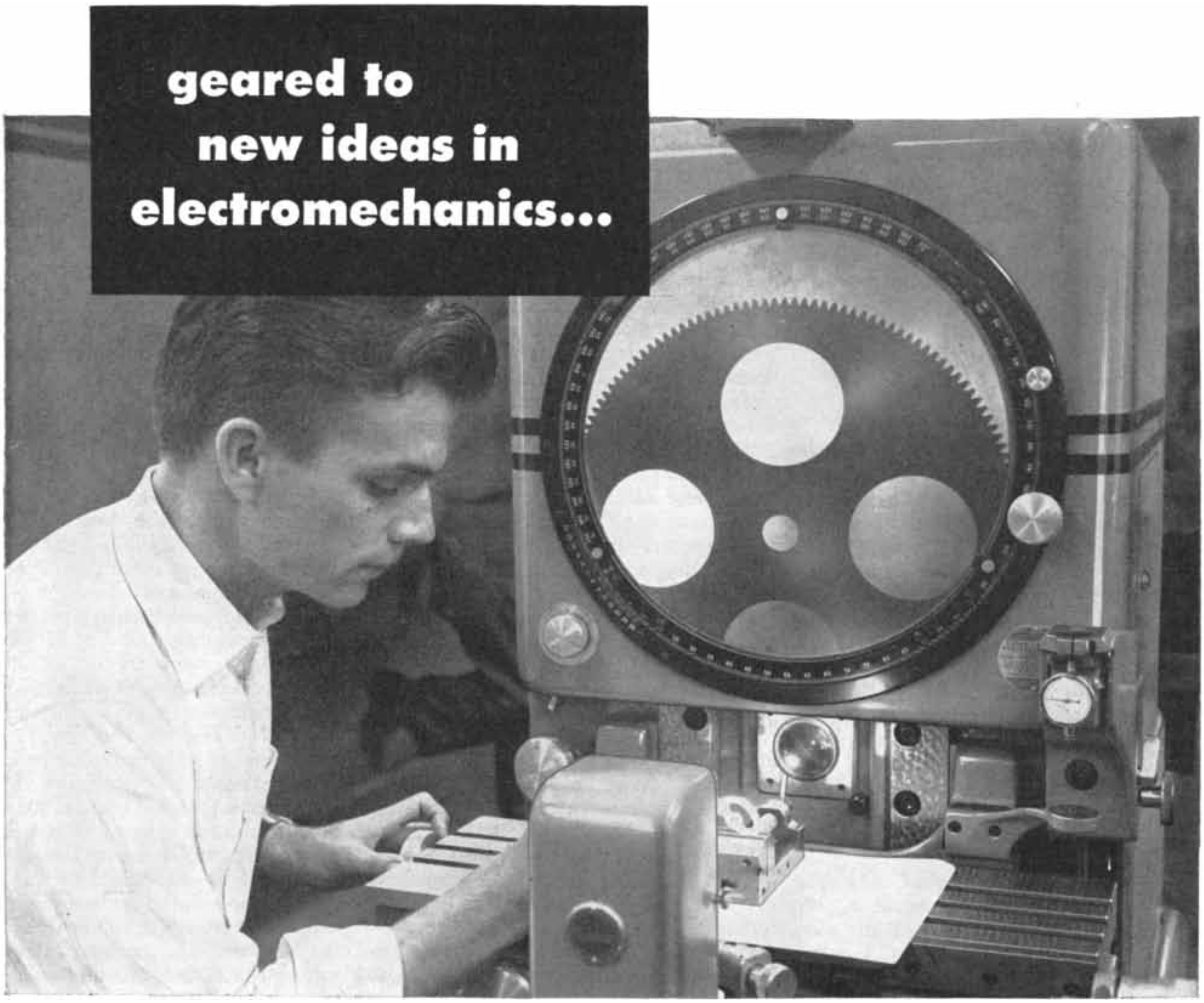
A CONTRIBUTION TO THE THEORY OF THE LIVING ORGANISM, by W. E. Agar. Melbourne University Press, distributed by Cambridge University Press ($3.75). Second edition of a philosophical essay on biology which interprets living organisms as "perceiving and therefore feeling and purposive agents."

OXFORD JUNIOR ENCYCLOPAEDIA, edited by Laura E. Salt and Robert Sinclair. Oxford University Press (Volumes VI and X, $8.50 each). Two more volumes—eight have been published thus far—of this ably written and attractively illustrated work. Volume VI covers "farming and fisheries"; Volume X, "law and order," which is to say world affairs, government, public services and the like.

NUMERICAL ANALYSIS, by D. R. Hartree. Oxford University Press ($6.00). A manual for workers in the fields of pure or applied science who have to carry out, with or without the help of machines, numerical calculations such as "approximations to some of the limiting processes of analysis, in particular integration." Even if you are lucky enough to have a high-speed computer handy, you must still know how to instruct it to work for you. Hartree has therefore included a chapter on the programming of these fussy creatures.

INTRODUCTION TO METAMATHEMATICS, by Stephen C. Kleene. D. Van Nostrand Company, Inc. ($8.75). A comprehensive reference manual for advanced students. It deals with foundation problems, the theory of sets, paradoxes, mathematical logic, recursive functions, the arithmetization of metamathematics, Gödel's theorem and related topics.

ARISTOTLE'S METEOROLOGICA, with an English translation by H. D. P. Lee. Harvard University Press ($3.00). A new translation of the four books of the Meteorologica (shooting stars, rain, clouds, snow, hail, earthquakes, hurricanes, thunder, rainbows, etc.) in the famous Loeb Classical Series. The main interest of the work, says Lee, lies in the fact that Aristotle was "so far wrong in nearly all his conclusions." This is a considerable achievement even for a philosopher.



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THE AMATEUR SCIENTIST

About the making of simple mathematical machines and the observation of Jupiter

Conducted by Albert G. Ingalls

IF YOU ARE in the habit of rummaging through electronic gear in war-surplus stores, you may have wondered why the piles of relays have begun to go down lately. They are still stacked high, of course, but the top layer has disappeared and the price has inched up a few pennies. You may also have wondered who is buying these bits of junk and for what purpose. This department learned the answer about a month ago. We were just leaving a surplus store in downtown New York when we noticed a husky fellow buying about a dozen relays. We walked right over and asked him what he intended doing with them. "Why," he said, "I'm going to use them in my homemade thinking machine." We forgot about our plans for a busy afternoon and wound up having dinner in the suburbs with Paul Bezold, purchasing agent for a large construction firm, and one of a growing number of amateurs who are having fun with relays.

"A lot of people will tell you that machines can't think," Bezold said, "and perhaps they are correct. But it seems to me it is largely a matter of what you mean by the word 'thinking.' Some of the purists say that if a machine can do it, you can't call it thinking. Whether it is thinking or not, I have made several machines which do a number of things that human beings do with their brains, and so have many other amateurs. My little machines take in information, remember it, pass judgment, make decisions, reach conclusions and take action. If the gadget I'm working on now pans out, it will play a game with you that is similar to the old match game of 'nim.' As it goes along, this machine will learn from experience to become a better player. It may make a mistake when it begins to play, but it will remember every error and will never pull the same boner again. I'll admit that all of the 'intelligence' exhibited by these devices must be designed into them, and that the little ones I have built are pretty stupid. But in certain ways a mouse can be smarter than a man—and this is so with some of these gadgets."

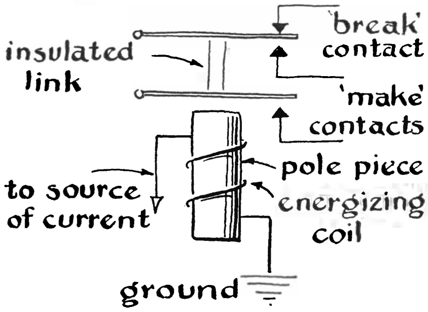
Bezold's nim-playing machine consists of a metal box three feet tall, two feet wide and about a foot thick, housing some 50 relays and accessory apparatus. The front holds three groups of signal lamps with associated push buttons. When the machine is turned on, all lamps light. The player can extinguish lamps by pressing the push buttons. A switch starts the game and tells the machine who gets the first play—itself or the human player. According to the rule, each player in turn may put out as many lights as he wishes in any *one* of the three groups. The one who puts out the last light wins.

As the machine is now constructed, the human player can win if, and only if, he makes the first move and plays a perfect game. Bezold hopes to endow the machine with a touch of human frailty by combining some new relays and associated circuits with those already in the gadget. After this modification the machine will forget all the strategy it knows each time the main switch is turned off. It will then begin competition on an equal footing with inexperienced human players. But the human beginner will have to keep his wits about him and remember perfectly everything he learns, for the machine will catch on quickly and never fall victim twice to the same line of opposing play.

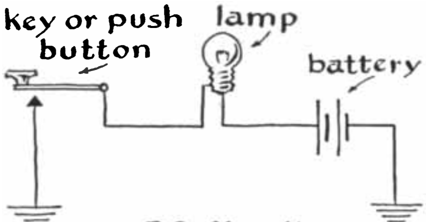
As Bezold points out, you do not have to be an electrical wizard to build these machines, nor do you need any mathematics beyond arithmetic. It helps a lot if you enjoy puzzles, and a knowledge of circuit symbols is handy. You can memorize the symbols in a few minutes. Perhaps the most novel idea the beginner will encounter is the use of switches, relays, lamps and other circuit elements to express words and logical relationships.

The two positions of a simple switch, for example, can mean more than "on" and "off." They can also symbolize yes or no, true or false, or the digits 1 or 0. A relay is not much more than a glorified switch, operated electrically. One part consists of a bar of soft iron surrounded by a coil of insulated wire [*see diagram at the left below*]. When current flows through the coil, the bar becomes a magnet which attracts a similar bar called the armature. The motion of the armature is transmitted through insulators to one or more flat springs that carry contact points. These serve as switches. Current flows through the relay's coil; the contact springs are flexed by the armature, and so the switch is operated. When the current stops, everything snaps back to normal.

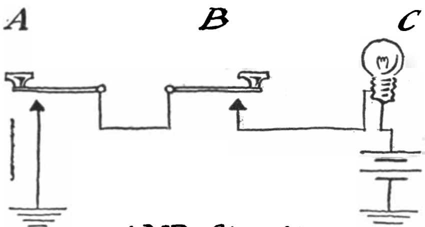
Offhand it may seem that putting a relay in a circuit is the hard way to go about flipping a switch. But in thinking machines most of the switches must flip automatically, usually by current flowing through other switches also operating automatically. Thus one or more input pulses can proceed through complex networks of relays as a spreading chain reaction, modified or conditioned



RELAY



DO Circuit
Operation of the key 'does' something, in this case lights the lamp.



AND Circuit
A 'and' *B* must both be operated to light *C*.

en route according to the requirements of the designer. This, incidentally, is the way the human brain works, with the neurons acting much like relays. In thinking machines the end of the reaction is always the same: an output circuit closes or opens, thus lighting a lamp or putting it out, starting or stopping a motor, or causing some other registering device to work. Essentially the reaction consists in the manipulation of logical relationships.

Thus far Bezold has used only five basic circuits in variations and combinations. With these five, he says, an amateur can build automatic devices to solve any puzzle that can be stated precisely in words. In addition to the simple "yes-no" circuit, the designer will need one expressing an "and" relationship. Such a circuit consists of two switches connected in series so that current must flow through first one, then the other to effect closure. The circuit is completed when both switch A *and* switch B are operated [*see diagram at the right on the opposite page*]. Equally useful is the "or" circuit. This has two switches connected in parallel so that operation of either one permits current to flow. Closing switch A *or* switch B makes the connection [*see top diagram at the right*].

The fourth basic circuit expresses the logical relationship of "if, then" [*second diagram at right*]. It requires a two-way or transfer switch in which the switch blade operates between two contacts, connecting with one in the "on" position and with the other in the "off" position. The first of these is called the "make" contact and closes when the switch is operated. The second is called the "break" or "back" contact, and it passes current until the switch operates, when it opens or breaks the circuit. Relays can be equipped with several sets of contact springs of both kinds. By connecting the make and break contacts of one relay to the switch arms of following relays, the designer can build up a branching pyramid of transfer circuits. With only five relays, for example, such a "transfer tree" can switch the input circuit to any one of 32 output circuits. Every relay added to these five will double the number of output choices available.

If the machine is to do any sort of advanced thinking, it must have a memory. This is easily contrived by wiring a make contact so that it will connect the coil of its relay to a source of current whenever the relay is operated. When operated by an incoming pulse, the relay will then remain "locked down" by its own internal circuit. To make the relay forget, it is only necessary to insert a break contact in series with the locking circuit. Usually the break contact is actuated by a part of the machine which calls on the memory for information. After the stored information has been delivered, the break contact operates. The relay returns to normal and thus "forgets" in preparation for the next incoming signal [*third diagram at right*].

Bezold has put all five of these basic circuits to work in a machine which can solve the old puzzle of the farmer faced with the problem of moving a fox, a goose and a bag of corn across a river in a boat large enough to hold only the farmer and one of the three objects. The fox cannot be left alone with the goose or the goose with the corn, for obvious reasons.

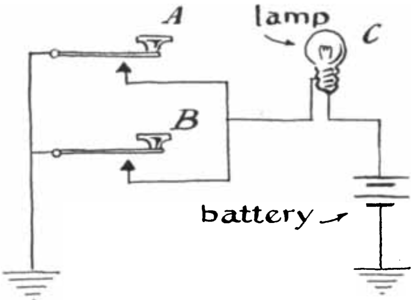
The problem is to design a combination of circuits which expresses the logical relationships posed by the farmer's dilemma and which will raise an alarm when the person working the puzzle makes an error. Each of the four principals—farmer, fox, goose, corn—is represented by a pair of switch keys, one on each side of the river [*see diagram on the next page*]. When you press the key on the right next to one of the principals, a signal lamp on that side lights, showing that the member has moved across to the right side of the river, and so on. A relay is tentatively assigned to each of the four, starting on the near side of the river.

An analysis of the logical propositions discloses what form the switching circuit shall take. First, it is seen that a safe situation exists whenever the farmer is where the goose is. Things are equally safe when the goose is alone. But trouble threatens whenever the goose is with the fox, with the corn or with both. Obviously the goose needs the most watching. The farmer and goose play opposite roles, the presence of one making for safety, the other for trouble. They act like a pair of switches or relays, one of which is the negative of the other, *i.e.*, one is a make contact and the other a break.

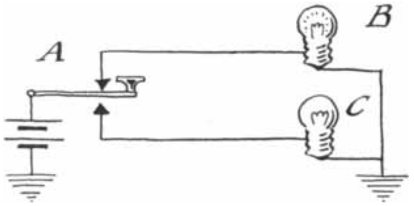
The fox and the corn also spell trouble. Relays representing them should, therefore, be of the same type as that for the goose.

Suppose, now, that a relay with a make contact is assigned to the farmer. In terms of logic it stands for "not farmer." Its contacts close whenever the farmer crosses the river in the boat, so that the farmer symbol may be contained in the boat. Hence break contacts are assigned to the other three characters.

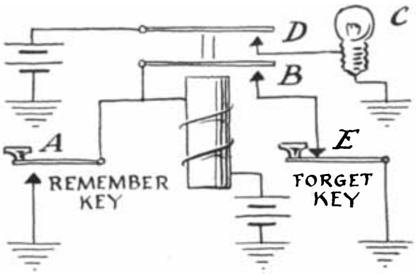
How shall the four relays be interconnected? The situation is always safe when the farmer is present; it is unsafe when he is absent *and* the goose is present *and* the fox *or* the corn is present. Hence the farmer's relay should be connected in series ("and" circuit) with that of the goose. The goose's relay in turn is connected in series with one side of a parallel connection ("or" circuit) between the fox and corn relays. If a lamp and battery are now connected across this circuit, nothing will happen



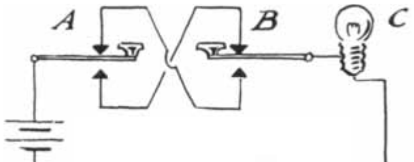
EITHER-OR Circuit
'Either' *A* 'or' *B* will light *C*.



IF, THEN Circuit
'If' *A* is depressed 'then' *C* lights, 'if' not 'then' *B* lights.



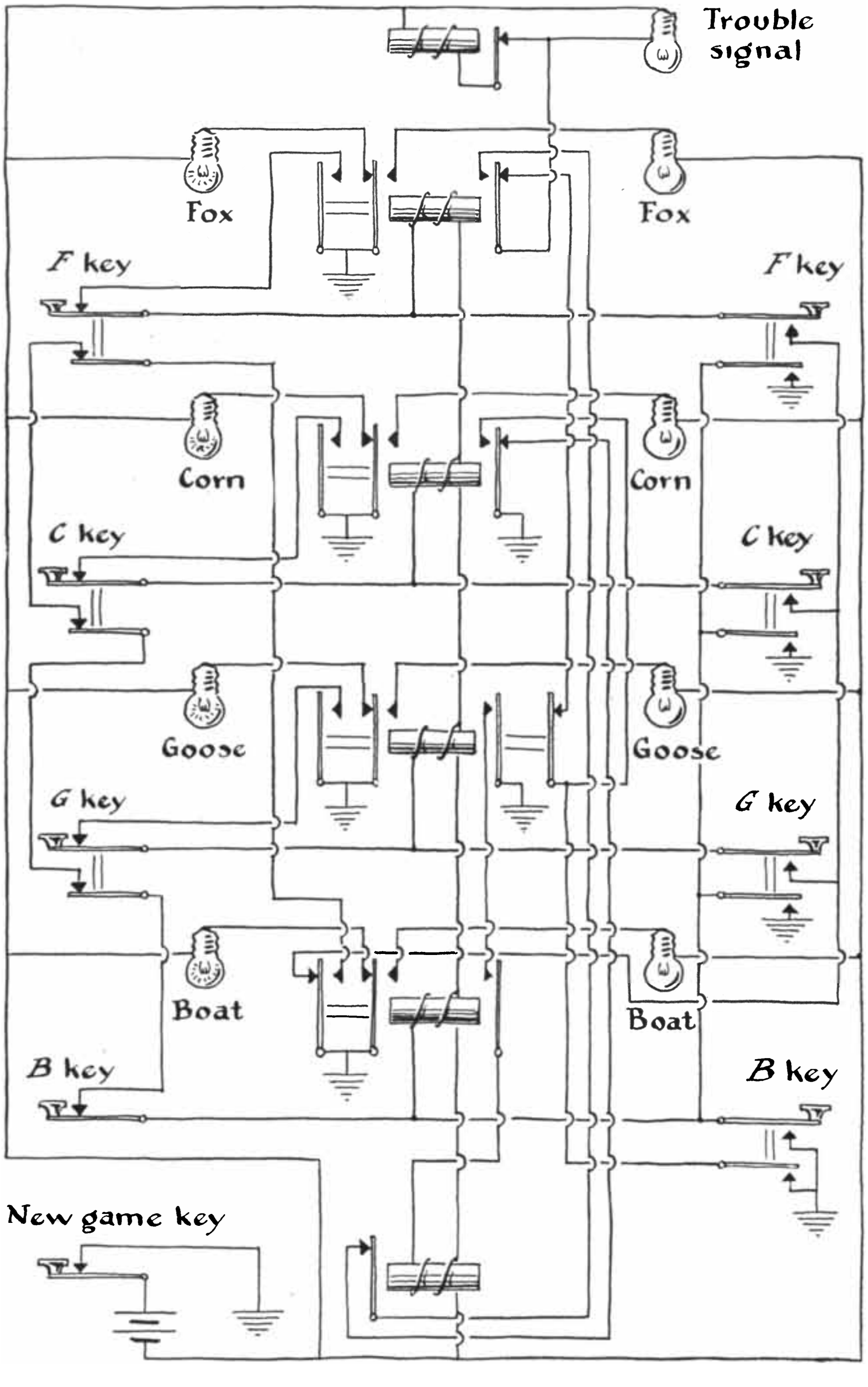
REMEMBER-FORGET Circuit
A closes relay, *B* locks it and *D* lights *C*.
E restores circuit to normal.



EITHER BUT NOT BOTH Circuit
'Either' *A* or *B* 'but-not-both' *A* and *B* will light *C*.

unless the farmer-boat relay is operated, indicating that he has crossed the river. But when he crosses, the contacts of his relay close and the circuit is completed through the break contacts of the unoperated relays symbolizing the goose, fox and corn. The circuit then signals trouble.

This takes care of the situation on



The circuit of a machine which solves a classical puzzle

the near side of the river, but a second circuit must be constructed to represent events on the other side. There the situation will be the negative of that on the near side; for example, the presence of the farmer on one side means that he is absent on the other. Hence, to give a complete picture of both sides we need a second circuit, the reverse of the first. In the second circuit a *break* contact is assigned to the farmer, while *make* contacts go to the goose, fox and corn. As long as the farmer is with them, his break contacts are open and there is no alarm signal. Suppose now that the farmer leaves the goose and the fox across the river and returns to the near side for the corn. As soon as he does, the break contacts close and the lamp lights. An investigation of the twin circuits will disclose that their operation in unison conforms to every logical requirement of the puzzle and that they accurately respond to every combination of events within the logical limits of the situation.

This portion of Bezold's machine could be constructed with four simple toggle switches and corresponding sets of make-break contacts. But such a machine would not be very convenient as a parlor game, because the player would have to throw the farmer's switch and one of the other three at precisely the same instant or the alarm would flash. Hence Bezold made a fancy affair in which each relay also functions as a memory element. This enabled him to simplify the logic circuit somewhat, although, as he confesses, the gadget's extravagant use of contacts would make a switching engineer very unhappy. "The extra contacts were on the keys and relays," he said, "so I just wired them in for the fun of it."

Noel Elliott of Kellogg, Idaho, who is preparing for a career in electronics at Washington State College, is another amateur who likes to build thinking machines. In 1950 his ticktacktoe machine won for him a Westinghouse Annual Science Talent Search Award.

"The design of this machine," Elliott writes, "closely resembles that of all electrical calculating devices, although on a much simpler scale than most. It can remember, calculate and transfer information from one circuit to another. The calculation and transfer, however, occur as soon as the information is received rather than in a timed sequence, such as takes place in a big calculator like ENIAC. This is possible because of the simple nature of the information. The operator informs the machine of his move by throwing a switch, and the machine, after carrying out its calculation, makes its reply move by lighting a pilot lamp in the appropriate space on the playing field.

"The machine has two basic functions: to prevent its human opponent from occupying three spaces in a row, and to prevent him from establishing a fork—the threat of making three-in-a-row along either of two lines. The work of design began with the classification of all possible moves.

"Since there are nine spaces on a ticktacktoe playing field, there are nine possible first moves. The moves are of three types: center, corner and side. Statistics show that the best move against a center opening is a corner, and against any outside opening, the center. The circuits that carry out this strategy consist of 'or' switches in all outside positions and a direct connection between the center switch and a lamp in one of the corners.

"After the opening move and the reply, the human player has a choice of seven remaining spaces. This means that for his first two moves he has a total of 63 possible combinations. The machine's replies to these are handled by an 'and' circuit, with current from the battery flowing through the first-move switch and the second-move switch to the lamp. Circuits that respond to subsequent moves are designed in the same way, although in some of them provision must be made against setting up duplicate paths and thus causing more than one lamp to light. Conflicts of this type are avoided by equipping the circuit with memory relays interconnected so that operation of one switch automatically opens the circuit of another which would otherwise interfere."

Neither Bezold nor Elliott has constructed a digital computing machine so far. These require too much apparatus for the average amateur's pocketbook if their capacity for numbers goes beyond a couple of digits. But Bezold has set up small circuits for the basic operations of arithmetic. A set of relays equipped with transfer and lockdown contacts, for example, can easily be interconnected to count pulses. Two relays are needed for each digit. A pulse (in the form of a momentary ground connection) enters the transfer contact of the first relay and energizes the coil of the second relay. The second relay locks down and simultaneously applies energy to a lead connecting with the coil of the first relay. But since the transfer contact of the first relay also is connected to this lead, thus grounding it during the pulse, no current can enter the coil of the first relay. When the ground connection is removed at the end of the pulse, the first relay operates, locks down and thereby transfers the input connection to the next pair of relays, where the second incoming pulse causes the cycle of operation to be repeated. The train of relay pairs may be extended indefinitely to count as many pulses as desired. One or more break contacts can be inserted along the line, of course, to unlock previously operated pairs.

Two relays may also be interconnected in such a way that each responds to alternate pulses, the incoming pulses causing one relay to lock down and the other to release in seesaw fashion. Such a pair in effect divides incoming pulses by two. Like the counting relays, these can be cascaded, each succeeding pair dividing the output of its predecessor. Such "flip-flop" circuits find extensive application in computing machines that work with binary numbers—in which all quantities are expressed by combinations of 1 and 0. In the binary system 1 plus 1 equals 0 with 1 to carry. The first relay of the flip-flop pair symbolizes the binary digit. If it is holding a digit when the pulse arrives, the circuit flip-flops, thus restoring the first relay to 0. The second relay then sends a pulse to the next succeeding pair, the first relay of which operates and thus stores the digit 1. The two sets of relays then stand at 10—which in binary notation means 2. The machine has, in short, performed an addition. Its capacity to add is limited only by the number of relays built into it.

UNLIKE MARS [*see page 65*] the planet Jupiter has never been seen. What we see of Jupiter is not the planet itself but an unbroken canopy of banded clouds hiding some wholly unknown entity beneath. The spectrograph tells us that these clouds consist of ammonia and probably methane, and the thermocouple reports that their temperature is more than 200 degrees below zero Fahrenheit.

A six-inch telescope magnifies this cloud-enveloped body to the apparent size of our moon as seen with the naked eye. A 12-inch telescope used visually reveals an appearance similar to that in the photograph on the preceding page. In it the two most prominent dark bands, a number of fainter dark bands and certain markings near the bottom and around the polar regions are red-brown clouds. The bright bands in between are white or yellowish-green clouds. The cause of the colors is unknown. The nature of the eye-shaped object called the Great Red Spot, which has been observed closely since 1878, also is still unknown. The dark spot above it is the shadow of Jupiter's satellite Ganymede, which is visible in space to the right of the planet. Ganymede, about 40 per cent as large as the Earth in diameter, is now being mapped by amateur astronomers.

None of the visible features of Jupiter

A photograph of Jupiter made by the 200-inch Hale telescope is fixed. The cloud bands vary from year to year—in number, in width and in latitude. Most of them last only a few weeks or months. Each rotates at a different rate. The broad bright equatorial band rotates most rapidly: its period is 9 hours and 50 minutes. The periods of the others are five or six minutes shorter; each rotates at a different rate without system or relation to latitude. Their edges are sharply bounded. Each drifts slowly past its neighbor.

Within the bands there are many minor markings, and these continually change. Watching the changes provides such variety that the observation of Jupiter is a lively business, especially since the planet rotates so rapidly. However, the observation would soon lose interest were it not for the intriguing riddle beneath, to which the puzzling visible performances seem in some mysterious way related. From the known mass and volume of Jupiter it is easy to calculate that the density of the planet averages but one and one third times that of water, and from this and the gradual shifting of the clouds it has been conjectured that the planet is partly fluid.

Almost the only systematic observers of Jupiter's ever-changing clouds have been serious amateurs, working mainly in organizations. Such work was begun several decades ago in Great Britain and has been taken up in the last few years in the U. S. and Canada. The observers have accumulated detailed records of the dark belts, the intervening bright zones and the many markings within each. These have been published as occasional reports in the memoirs of the British Astronomical Association. In the U. S., observers' reports and drawings of changes are collected by the Jupiter Recorder for publication in *The Strolling Astronomer*, the periodical of the Association of Lunar and Planetary Observers, which any amateur may join (1203 N. Alameda St., Las Cruces, N. M.).

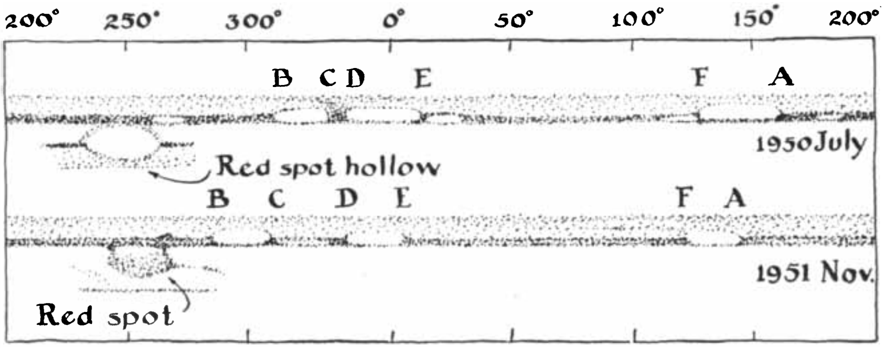
One A.L.P.O. member who has done outstanding work in observing Jupiter and in using observational data accumulated by others is Elmer J. Reese of Uniontown, Pa. Reese selected two of Jupiter's bands in which changes recorded since 1940 had persisted uncommonly long, and minutely observed them himself between 1940 and 1951 with his homemade six-inch reflector. A brief analysis of his findings has been published in *The Strolling Astronomer*, and a longer article on them has been written by Walter H. Haas, A.L.P.O. director and editor, for *The Griffith Observer*, publication of the Griffith Observatory in Los Angeles.

Reese's chosen bands are the ones in the photograph between the shadow of Ganymede and the Great Red Spot. In the standard nomenclature these are respectively the South Temperate Zone and the South Temperate Belt (south because astronomical telescopes invert). Like all other zones and belts on Jupiter, these encircle the planet.

The drawing below shows the bands unrolled. The dusky lower section in each band is the South Temperate Belt. The brighter upper part is the South Temperate Zone. The elongated white markings BC, DE, and FA show eruptive disturbances from beneath. They have persisted for several years longer than any disturbance recorded on Jupiter except the Red Spot and a nearby eruption which lasted for several decades.

Reese watched these white sections diminish in length as the dusky sections CD, EF and AB gradually encroached on them during the period indicated. He also saw them drift to the left at differing distances from the Red Spot. This spot lies in a third band called the South Tropical Zone. As the lower drawing shows, the Red Spot is in a depression called the Red Spot Hollow. At times the spot itself disappears.

Reese next plotted drift curves, shown on the next page, for six longitudinal sections—three dusky, three bright. The slope of these curves indicates duration and shows the rate at which the feature is moving. To make measurements he needed a way to time the markings as the planet rotated. While this can be done with a filar micrometer or by measuring photographs, the amateur uses a primitive method which may be equally precise. As a feature approaches the central meridian of rapidly rotating Jupiter,



Changes during an eruption on Jupiter

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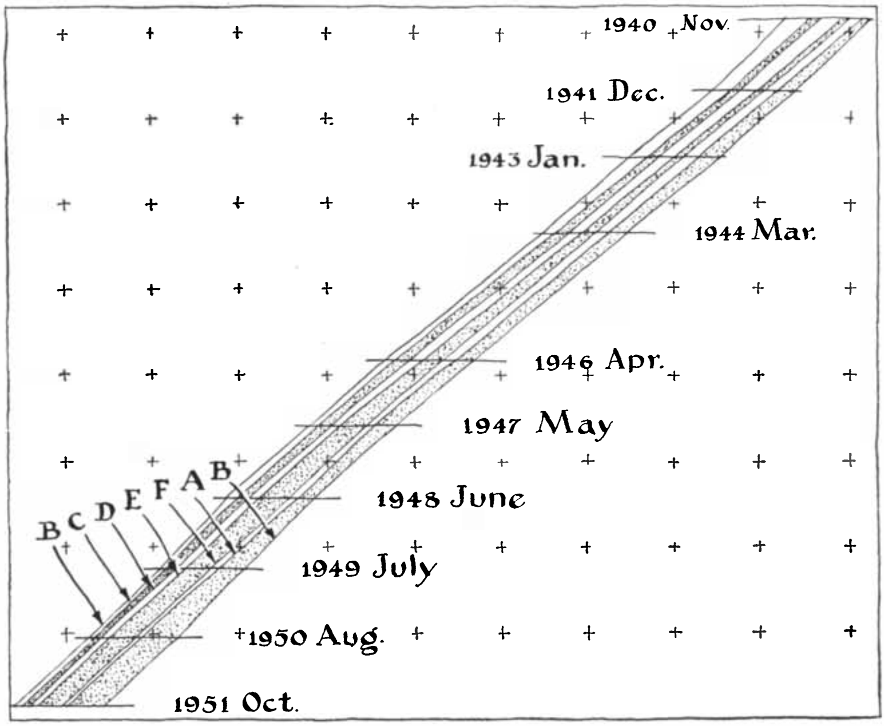

Drift curves for a belt on Jupiter

he decides to the nearest minute when it is centered on the disk and records the time. It is no more difficult to estimate accurately when a marking is centered on a planetary disk than to center a picture accurately in a frame with the eye alone. When the same marking is observed for a number of days, any error is reduced proportionately; in a month the error is reduced from minutes to seconds. On the drift curves drawn by Reese the shaded strips represent the three longitudinal dusky sections of the South Temperate Belt and the white strips the bright sections. (The strips should not be confused with the actual bands.) It is easy to see that in 1940 the white sections were wider, longitudinally, than the dusky sections. By 1950 the dusky sections had encroached so far on the bright that the bright eruption had almost ceased to exist.

In 1948 the motion of the six sections, which had been uniform, suddenly decelerated, as shown by the knee in the curve. At that date their rotation period lengthened by four seconds to 9 hours, 55 minutes, 10 seconds. Some unknown influence had also applied a brake to the entire band from the beginning in 1940: in that 11-year period it fell back nine laps (note nine spaces) in the race with adjacent bands.

It is not nearly as easy to keep track of a protean marking on Jupiter at the telescope eyepiece as it is to examine crisp drawings in an armchair. Another source of perplexity is the annual conjunction of Jupiter with the Sun, which makes it invisible for several months. When it comes into view again, the marking under observation may have changed so much that it must be identified by projecting its drift line on the chart. Nor is the seeing always good. Haas points out that a telescope of the very best optical quality and 10 or 12 inches in diameter gives the best results in the search for long-enduring markings on Jupiter. He asks, however, whether the scarcity on Jupiter of long-lasting features, such as the eruptions observed by Reese, is real or only apparent: "The ability of the telescopist to fail to see what he is not looking for is at times most remarkable!"

Haas calls Reese's work "an outstanding piece of Jupiter research done by an outstanding amateur astronomer." What have his 11 years of observations proved? Are the eager amateurs who sit up all night and hastily record 100 transits of markings on Jupiter accomplishing anything or merely accumulating useless statistical data on some clouds of gas? The basic data of science have often looked useless until the key to a riddle has turned up. Then the statistical data suddenly become valuable.

As this account was being completed, a news circular arrived from the British Astronomical Association. It says: "Observations by members of the Jupiter Section indicate the dark material from the South Equatorial Belt overflowed into the South Tropical Zone just preceding the Red Spot round which it passed to form a dark narrow belt on the following side." This means that the gaseous cohorts from a dark belt, which is dimly visible in the photograph on page 107, have crossed the border into the zone containing the Red Spot, and a conflict may result.

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Photograph by Barton Murray

Servants' Entrance, 1953

Your electrician calls this electric power connection to your home a "service entrance," but it might well be called a "servants' entrance." For if you are an average user of electricity you have the equivalent of 6½ full-time servants to help with the work around the house.

Much of the credit for this efficient answer to the servant problem belongs to America's vast network of electric light and power companies—a basic industry which serves, and is served by, American Cyanamid Company.

For it is with the help of electricity that Cyanamid produces thousands of chemicals and related products, many of which find their way, in turn, into materials for more efficient production of electric power, equipment and appliances.

Here is a typical example of how American industries work together to add to your well-being in the modern work-a-day world.

AMERICAN *Cyanamid* COMPANY

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