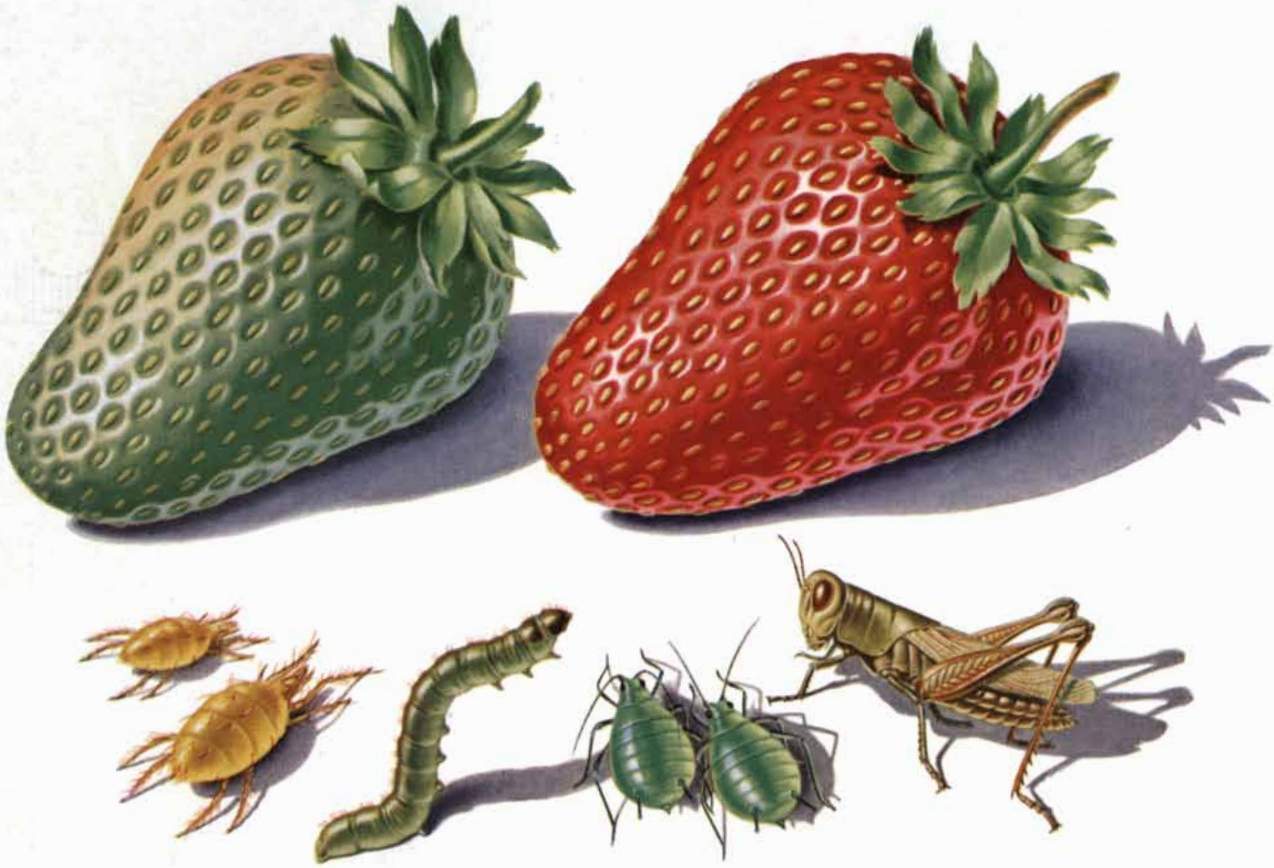
SCIENTIFIC AMERICAN

CATTLE

FIFTY CENTS

June 1958



Established 1845 SCIENTIFIC AMERICAN June, 1958 Volume 198 Number 6

ARTICLES

DEPARTMENTS

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THE COVER

The painting on the cover shows a bull of the Kankrej breed, one of the principal varieties of Indian zebu cattle (*see page 51*). The animal is depicted standing in front of a board of the sort often used in cattle-judging to get a quick estimate of size. Zebus are one of the two main species of cattle in the world. Unlike the European species, which includes all the breeds most familiar to Americans, zebus thrive under tropical conditions and have therefore been introduced into several tropical and semitropical regions. The Kankrej, a working breed of central India, is also the main genetic component of the "Brahman" cattle now bred in the Gulf States.

THE ILLUSTRATIONS

Cover painting
by John Langley Howard

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Tough to fabricate? Not today. With Mallory-Sharon's strict quality control and continuous research, titanium becomes a metal of uniform quality and predictable characteristics. It's being successfully machined, welded, formed to exacting specifications . . . in both aircraft and commercial applications.

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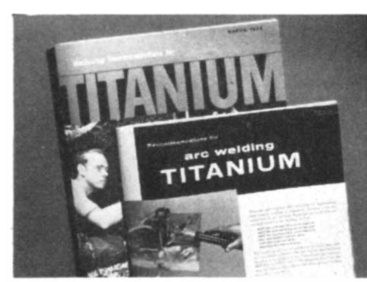

For Technical Data—*Technical brochures are available through Mallory-Sharon on machining, welding and forming of titanium. Write us for literature on the process in which you are interested. Our strong Service Engineering group is available to assist you on specific applications.*

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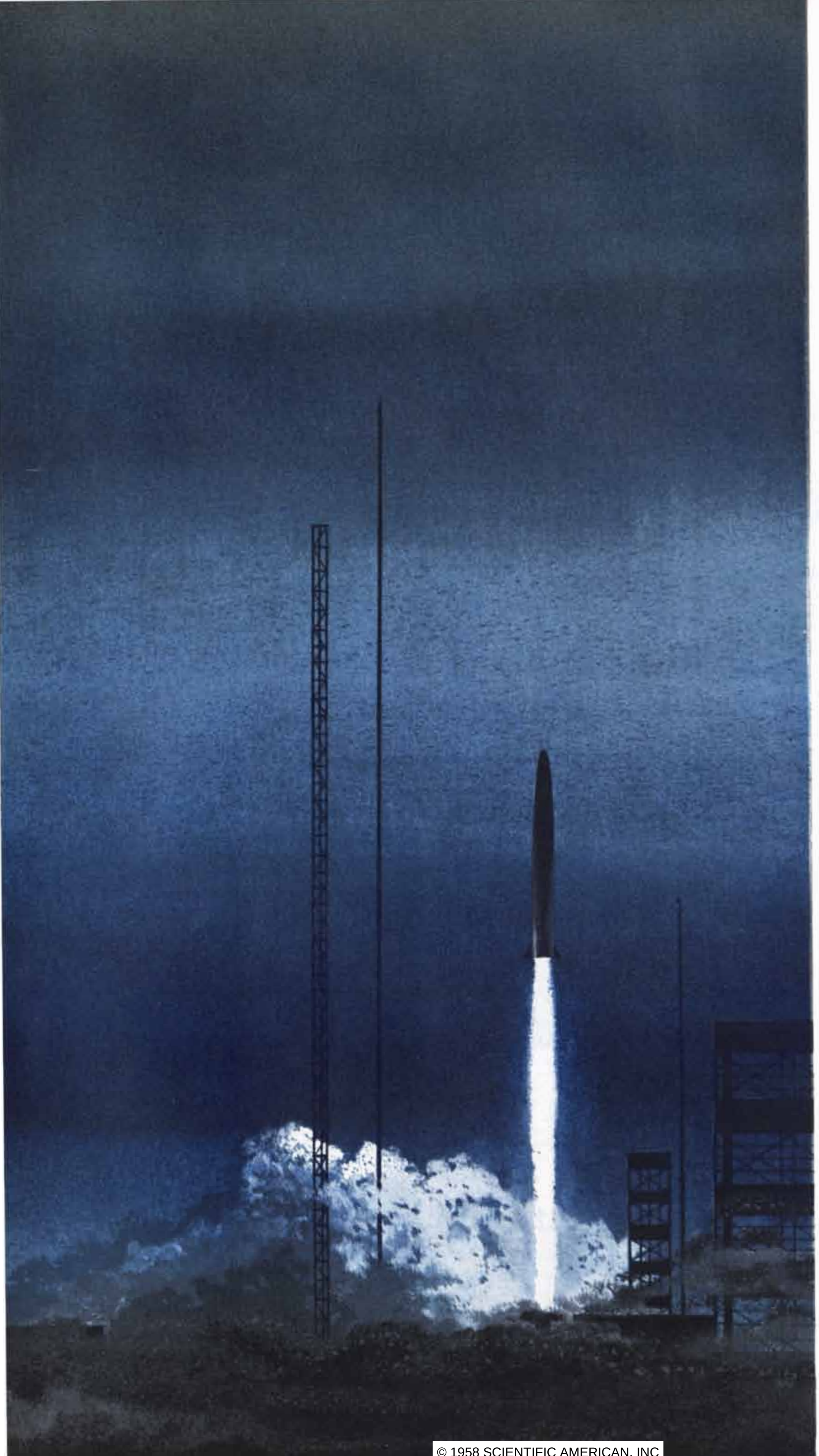

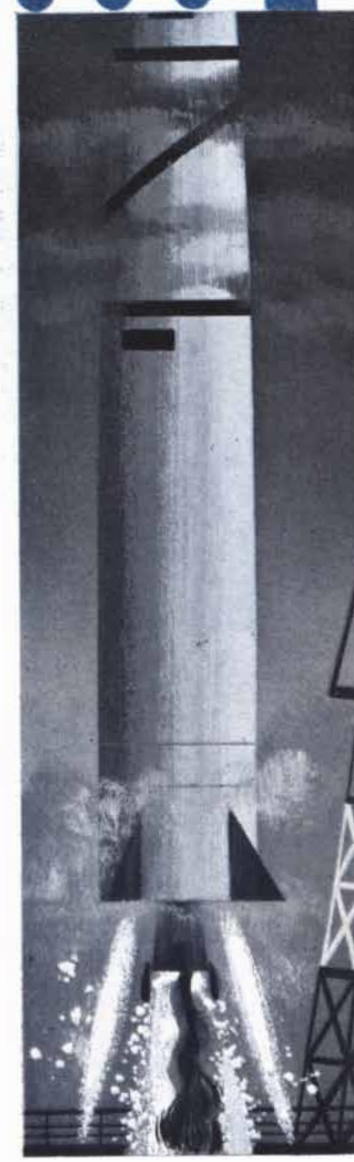

. . . and where

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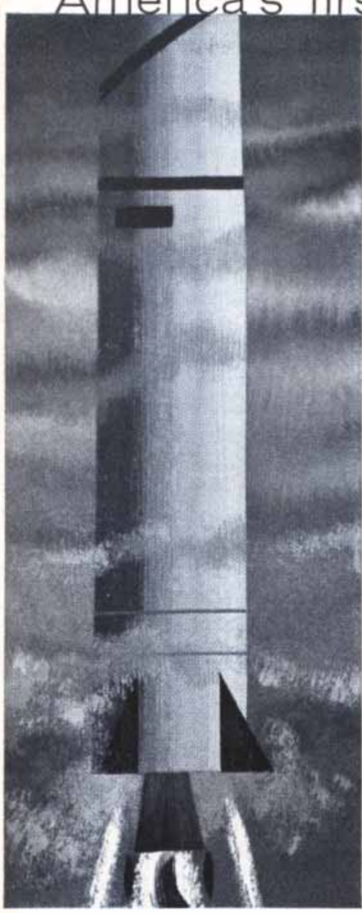

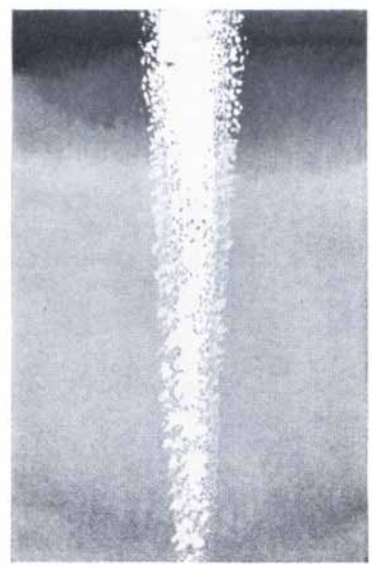

LETTERS

Sirs:

In the March issue of your magazine you have the unusual combination of an apparent technical error in one article, "Helmholtz," and in an entirely independent article, "Imprinting," a possible explanation of this error.

In the excellent biographical sketch on Helmholtz by A. C. Crombie, the author states: "For example, this page would look green if it was illuminated either by pure green light or by a mixture of blue and yellow light."

Application of the Young-Helmholtz theory, together with data from a table of tristimulus coefficients, indicates that the addition of a proper blue light to a "white" surface already illuminated by only spectral yellow, or simultaneously by spectral red and green, will produce the visual sensation of whiteness.

A correct and more dramatic illustration of the point which Crombie was making would be: If the upper half of this page were illuminated only by spectral yellow light, and the lower half illuminated simultaneously by only properly balanced spectral red and green light, the two halves of the page would appear identically yellow to the standard observer.

Your brief editorial sketch of Crombie states that he "lectures on the history and philosophy of science." Could it be that he (like so many persons associated with color reproduction in the graphic arts) has been so deeply "imprinted" by early experience with little cakes of "red," "yellow," and "blue" water colors (and not sufficiently de-imprinted by subsequent exposure to the psychophysics of color), that forever after, yellow mixed with blue, whether as pigment viewed in white light or as blended radiation impinging on a white surface, makes green?

CLYDE A. HUNTING

Research Department
R. R. Donnelley & Sons Co.
Chicago, Ill.

Sirs:

I am grateful to Mr. Hunting for drawing attention to the mistake in my article on Helmholtz in the March issue. I am of course well acquainted with the difference between the laws of the mixing of lights and the laws of the mixing of pigments. The passage in question should read: "For example, this page would look white if it were illuminated either by sunlight or by a suitable mixture of monochromatic blue and monochromatic yellow light." The example given by Mr. Hunting is an even more dramatic illustration of the same phenomenon.

A. C. CROMBIE

Oxford, England

Sirs:

In your March issue appeared a note that the platinum-iridium meter bar at Sèvres, which is the standard of length for the civilized world, may be melted down into wedding rings. My colleague, Dr. I. C. Gardner, who attended the last meeting of the Consultative Committee for the Definition of the Meter, assures me that no such recommendation was made by the Committee.

In fact the Committee, operating in an advisory capacity under the treaty on the meter signed in 1875, has not even recommended the adoption of the wavelength of light to replace the Sèvres meter bar. Had it so recommended, the adoption could not occur before the next meeting of the General Conference on Weights and Measures which is scheduled for 1960.

The Consultative Committee, however, was favorably disposed toward defining the meter in terms of the wavelength of a single spectral line, thus bringing nearer to realization a proposal made as long ago as 1827 by Jacques Babinet, a French physicist. The questions which have to be decided upon are which is the best spectral line for the purpose and what is the best value for that line in terms of our present international meter bar. The National Bureau of Standards and other standardizing laboratories of the world are at present developing the data on which these decisions can be made.

The desire to define the meter in terms of the wavelength of light is part of a general trend to define all of our standards in terms of natural constants which are indestructible and immutable. If this is done all laboratories of the world can have direct access to such standards. This does not mean that meter bars will have no further place in the science of measurement, but that the master meter bars will be calibrated directly in terms of wavelengths rather than by comparison with the Sèvres meter bar. The graven bars will still be used for the measurements for which they are suited.

One often hears unwarranted derogations of the platinum-iridium meter bars as standards—that they cannot be measured accurately and that they are subject to change. Those in use at the National Bureau of Standards are checked against each other with a probable error of only 3 parts in 10^8—1/20 of a wavelength of light. Since our national standard meter bar was first compared with the Sèvres meter 69 years ago there is evidence that no deviation in it as great as 1 part in 10^7 has occurred.

A. G. MCNISH

National Bureau of Standards
Washington, D.C.

Sirs:

In reading the fascinating story on the bathyscaph in the April issue of *Scientific American*, I was particularly interested in the details of the buoyancy controls. The use of gasoline as a buoyant liquid, the provision for water flow into the gasoline-filled buoyancy compartment, and the added effect of compression of the gasoline by sea water represent an ingenious solution to the old problem of marine submersion.

The authors also presented some ideas for improvements in future designs of the bathyscaph itself. They suggested, for example, that the light metal lithium would afford greater buoyancy than gasoline.

Naturally we always welcome sugges-

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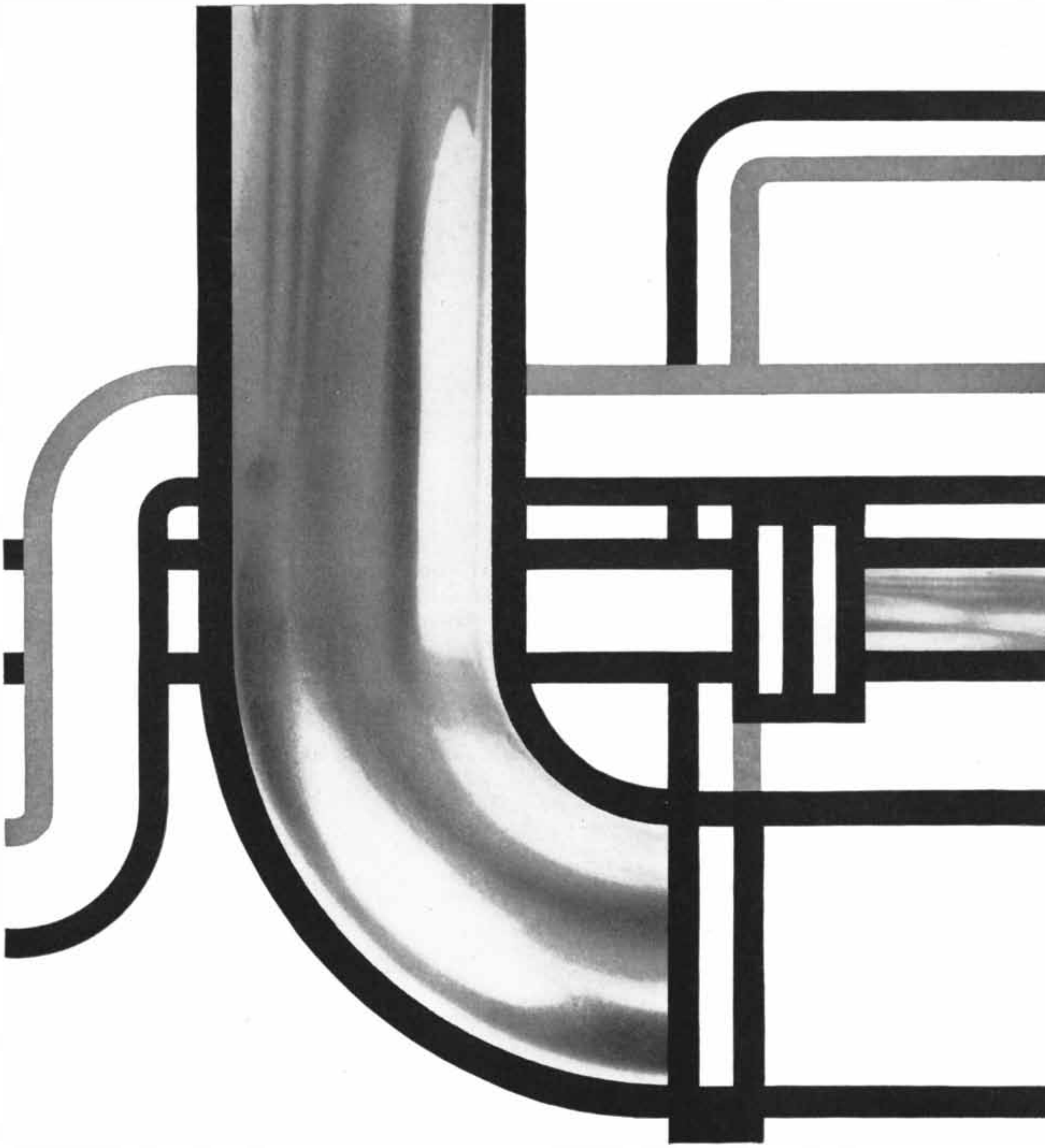


tions for new applications of our favorite element. In considering this possibility, therefore, we would like to make some observations that bear on the subject.

As for buoyancy, it is indeed true that lithium has a specific gravity (.534) that is approximately 30 per cent less than that of gasoline (.66 to .69). This property was discovered more than a century ago. Robert Wilhelm Bunsen in a paper on lithium published in 1855 stated that "lithium, which swims upon petroleum, has the least specific gravity of all the solid bodies."

The compressibility of lithium is several orders of magnitude less than that of gasoline. This would be an advantage in that it would obviate the necessity for jettisoning the pelletized iron ballast because of the much higher compressibility and consequent increase in density of the gasoline.

However, one distressing complication exists. Lithium metal is reactive with water, although not to the same extent as sodium and the other alkali metals. The reaction can be described by a simple chemical equation:

$$Li + H_2O \rightarrow \tfrac{1}{2} H_2 + LiOH$$

Although unskilled in the art of bathyscaph engineering, we will nevertheless assume that the buoyancy and the compressibility factors of lithium offer attractive advantages. The disadvantage—the reactivity of lithium in contact with sea water—could perhaps be eliminated by encasing the lithium metal in plastic bags or light-metal containers of suitable size and shape.

E. M. KIPP

Research and Development
Foote Mineral Company
Berwyn, Pa.

Sirs:

I was pleased to hear that E. M. Kipp, apparently an authority on lithium, agrees that metallic lithium may be a useful buoyancy substance for bathyscaphs. The high reactivity of lithium is indeed a distressing complication, but I am sure that watertight packaging is not beyond solution by modern know-how. There is now a considerable amount of experience, which would be partially applicable, in the handling of metallic sodium as a heat-exchanging substance in atomic reactors. To date there has been insufficient financial support of bathyscaphs to develop engineers skilled in their design or able to contemplate the use of lithium. We realize that the bathyscaph is still a primitive craft unworthy of contemporary levels of technology.

A bathyscaph floated with lithium to provide the fixed buoyancy would, of course, still require some gasoline (which, by the way, also involves dangerous but well-understood methods of handling) for variable buoyancy. Gasoline can be jettisoned, when a decrease of buoyancy is needed, but lithium cannot. Eventually it may prove feasible to construct manned deep-sea vehicles based on a buoyant (or almost buoyant) sphere by replacing the present steel cabin with one of some lighter alloy. This would entirely eliminate (or greatly reduce) the need for a fixed buoyancy mass.

An additional difficulty which Kipp does not mention is the high cost of metallic lithium: about $9 a pound. Thus the cost of each pound of buoyancy is also about $9. The five tons needed for a two-man bathyscaph would cost about $90,000.

ROBERT S. DIETZ

Office of Naval Research
London, England

Sirs:

I have noted the fine article by Sir Christopher Hinton in your March issue and wish to commend *Scientific American* for publishing such a comprehensive description of the United Kingdom's atomic power program.

There is one matter of fact, however, which I should like to call to your attention. Sir Christopher stated that the operation of the Calder Hall nuclear power station on October 17, 1956, "was the first time anywhere in the world that nuclear power had been used to generate electricity used in factories and homes." For the record, on July 17, 1955, electricity produced from nuclear energy was used to light and power the town of Arco, Idaho. The electricity was produced in the Boiling Reactor Experiment (BORAX) operated by the Argonne National Laboratory at the Atomic Energy Commission's National Reactor Testing Station, 20 miles from Arco.

I trust that you will wish to call this information to the attention of your readers.

MORSE SALISBURY

Atomic Energy Commission
Washington, D.C.

A REVOLUTION IN RARE EARTHS

Costs down sharply... large quantities available

a report by LINDSAY

Today you can buy at $50 per pound Samarium Oxide of 99% purity which in 1955 cost $1825—a price reduction of 97%, almost unprecedented in the chemical industry.

All high purity rare earths are priced substantially below the 1955 levels. Price ranges for four oxides, over a three-year period, are shown in the graphs.

During 1954, there was a rapidly developing industrial interest in high purity rare earths which were available then only in small, laboratory-production quantities and at very high prices.

In 1955, Lindsay pioneered the first commercially installed ion exchange pilot plant with 40 six-inch columns for the production of rare earth oxides in purities up to 99.99%. As these materials became available, the response from industry demonstrated that much larger production facilities were urgently needed.

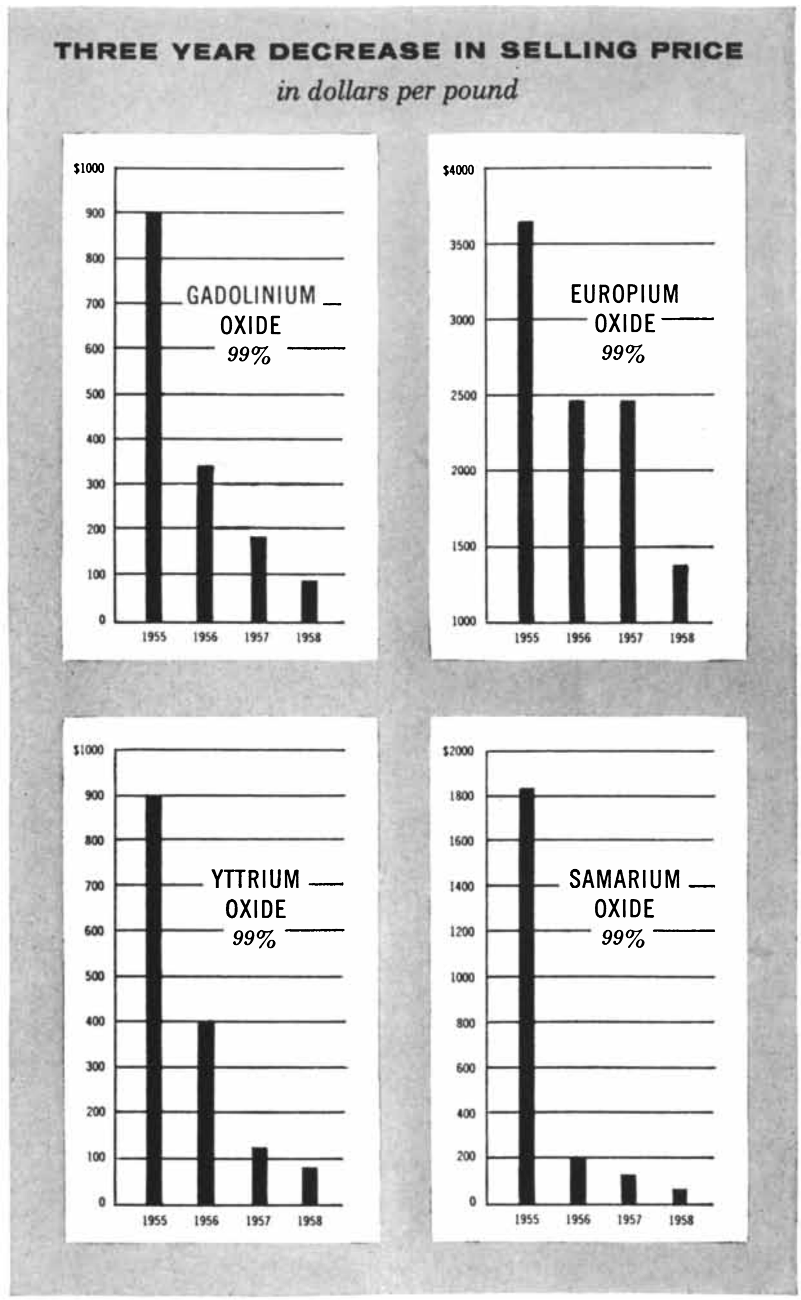
LINDSAY EXPANDED PRODUCTION

Consequently Lindsay immediately expanded its ion exchange plant and is now operating continuously more than 100 columns with large production units of eighteen-inch and sixty-inch diameters.

With large volume production, we can now make prompt shipments of high purity materials in quantities from a gram to hundreds of pounds.

Current prices make high purity rare earths extremely attractive and economically sound for a wide variety of chemical and industrial purposes.

We will be happy to supply technical data and information about availabilities, prices and industrial applications.



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264 ANN STREET • WEST CHICAGO, ILLINOIS

phenomena

The wave-form reflected in this engineer's eye is a "transient"—elusive burglar of corporate profits.

Wave-forms like this are electronic tracings of fleeting physical phenomena, made visible on an oscilloscope. Invaluable to modern industry, they can be used to gather data on missiles in supersonic flight; or a tire blowing out at high speed; how to synchronize camera shutters; or improve the efficiency of electrical circuits—literally thousands of fact-finding jobs to improve the products of American industry.

Lengthening the life expectancy of the widely used, much abused milk bottle by studying shatter-test transients, is typical of the ways in which the HUGHES *Memo-Scope oscilloscope will save American industry millions of dollars.*

But with ordinary oscilloscopes, the wave-form disappears in a matter of seconds—far too fast for study. This makes the pursuit and capture of elusive transients a costly, time-consuming job that exasperates the most patient researcher. Engineering man-hours accumulate so rapidly that testing and research costs can become a substantial drain on profits.

It was this problem that led HUGHES to develop the Memo-Scope® oscilloscope—a portable unit on which transients can be instantly "frozen" at the touch of a button. Thus captured, they can be retained indefinitely for study, or one-exposure photography.

The Memo-Scope oscilloscope is just one of the many advanced electronic systems and components designed and manufactured by HUGHES to provide American businessmen with the technology to continue their constant improvement in the production of useful products

Recently a HUGHES *Memo-Scope sales engineer solved in 15 minutes a vexing research problem that had stymied a group of 4 senior engineers for 3 days. This actual case is typical of hundreds in our files at* HUGHES.

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JUNE, 1908: "The airship designed and built by John A. Morrell came to a sudden and disastrous end during its first test, which was held Saturday, May 23, at Berkeley, Calif. It consisted of a large pointed balloon 485 feet long and 34 feet in diameter. It was, therefore, quite the largest airship that has ever been built in America, and was even larger than the German dirigible of Count von Zeppelin. On account of the nose of the balloon being tardily released, the envelope was given an upward inclination toward the rear of as much as 45 deg., the result being that the gas rushed to this end with great impetus and struck against the top at that point with a pressure of about 30 pounds per square foot, or 30 times more than would be considered safe with a well-constructed balloon. The oiled cloth, of which the envelope was constructed, could not withstand the pressure, and it burst, whereupon the machine fell rapidly to the ground, carrying with it its 19 passengers, who were tangled in a mass of broken machinery, flapping cloth, and network. The passengers on board the ill-fated craft consisted of the inventor, eight engineers, five valve tenders, two photographers and their assistants, and an aeronaut. Strangely enough, none was killed, six escaping uninjured and several others with slight injuries."

" 'According to the theory which best accounts for the phenomenon of radioactivity, a certain proportion of the atoms of a radioactive body is transformed in a given time, with the production of atoms of less atomic weight, and in some cases with the expulsion of electrons. This theory of the transmutation of elements differs only from the dreams of the alchemists in that we declare ourselves, for the present at least, unable to induce or influence the transmutation. Certain facts go to show that radioactivity appertains in a slight degree to all kinds of matter. It may be, therefore, that matter is far from being as unchangeable or inert as it was formerly thought; and is, on the contrary, in continual transformation, although this transformation escapes our notice by its relative slowness.'—*Mme. Curie*"

"On the 9th of March, a number of aeronauts were assembled in Ghent, Belgium, and Santos Dumont, Farman and Archdeacon advanced the idea that an aeroplane would soon be able to cover a kilometer when mounted by two persons. M. Charron held the contrary opinion, and laid a wager of $2,400 against $1,200 with the three aeronauts that an aeroplane with two persons on board, one of whom weighed at least 132 pounds, would not cover the kilometer distance before the 10th of March, 1909. It is only three months since that time, and this performance has now been easily accomplished. Subsequent to this flight, Farman flew a short distance with Mlle. P. van Pottelsberghe de la Potérie, a young Belgian woman, as passenger. This young lady is therefore the first woman to fly in a motor-driven aeroplane."

"It is not stretching the limits of praise too far to say that the most brilliant success achieved at Panama is to be credited to the work done by the Army Medical Corps, under Col. W. C. Gorgas, in the extermination of yellow fever and malaria and the betterment of the general sanitary conditions. When the Medical Corps took charge, the Panama Canal had become synonymous with disease and death; but today, thanks to the system introduced by the Medical Corps, the zone of operations is as healthful as the average city in the United States."

"Within a short time a Marconi wireless station will be established on the roof of the Bellevue-Stratford Hotel in Philadelphia, so that guests may communicate with their friends at sea. If the plant works successfully, a similar one may be put into operation on the roof of the Waldorf-Astoria in New York."

SCIENTIFIC AMERICAN

JUNE, 1858: "Four years ago, F. Grace Calvert, an eminent English chemist, made the extraordinary statement before the Society of Arts that 'ere long, some valuable dyeing substances will be prepared from coal.' A few weeks ago he stood up before the same society

1948—*Early "point contact" transistor.*

The remarkable transistor observes its 10th birthday

In 1948, Bell Telephone Laboratories announced the invention of the transistor. In 1958, the transistor provided the radio voice for the first United States satellite.

To advance the transistor to its high level of usefulness, Bell Labs had solved problems which, in themselves, approached the invention of the transistor itself in scientific achievement.

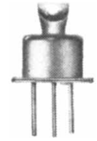
First, there had to be germanium of flawless structure and unprecedented purity. This was obtained by growing large single crystals—and creating the "zone refining" technique to purify them to one harmful part in *ten billion.*

The "junction" transistor, another radical advance, spurred transistor use. Easier to design, lower in noise, higher in gain and efficiency, it became the heart of the new electronics.

An ingenious technique for diffusing a microscopically thin layer on semiconductors was created. The resulting "diffused base" transistor, a versatile broadband amplifier, made possible the wide use of transistorized circuits in telephony, FM, TV, computers and missiles.

In telephony the transistor began its career in the Direct Distance Dialing system which sends called telephone numbers from one exchange to another.

For Bell System communications, the transistor has made possible advances which would have been impossible or impractical a brief decade ago.



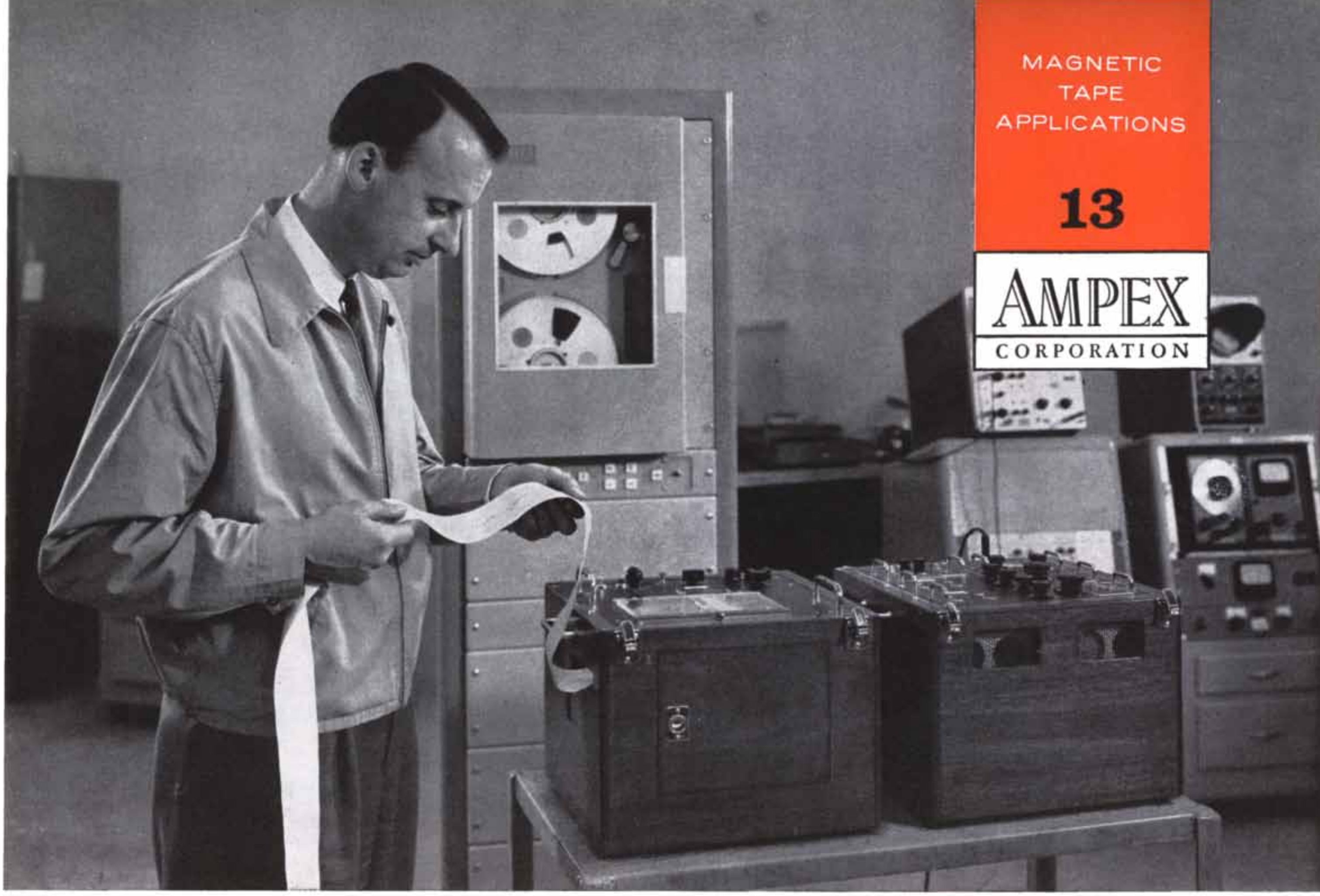
1958—*Satellite transistor, incorporating 10 years of Bell Labs research and development.*

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT in London to demonstrate the truth of the above expression by showing them a beautiful purplish blue color, rivaling that of orchil. These colors, for there are many of them, have been prepared from the alkalies of coal tar by Messrs. W. Perkin and A. H. Church, two rising discoverers, and have been called nitroso-phenyline and nitroso-naphthyline, &c. The colors have been tried on silk, and found perfectly fast. Mr. Perkin's process is as follows:—He dissolves in water the sulphates of aniline, of cumidine, and of toluidine, and adds sufficient bichromate of potash to neutralize the sulphuric acid in these sulphates. The whole is left to stand for twelve hours, when a brown substance is precipitated, which is washed with coal tar naphtha and then dissolved in methylated spirits. This solution, with the addition of a little tartaric oxalic acid, forms the dyeing liquor of Mr. Perkin."

"A great tubular iron bridge is now being constructed at Newcastle, England, and will be completed in about two years, for the Egyptian Railroad, which crosses the Nile about midway between Cairo and Alexandria. The river there is 1,100 feet wide, and a steam ferryboat is now employed to do the business. It does not suit the go-ahead spirit of the Pasha. He was once detained for four hours by an accident to the boat, and he then gave Robert Stephenson orders to build this bridge."

"A few years ago, some members of the Royal Institution of Great Britain suggested that could a telescope be placed at a great elevation, say 10,000 feet above the level of the sea, the observer would be able to scan a greater distance than had ever been seen before. In accordance with this suggestion, Professor C. Piazzi Smyth, Astronomer Royal for Scotland, amply provided with instruments, went to the Peak of Teneriffe, and the history of his observations he has just made known. Professor Smyth was accompanied by his wife, and a better assistant no astronomer ever had. They bivouacked on the top of Mount Guajara, 8,900 feet high, where the air was always calm, the temperature averaging 65 degrees, far above all clouds, and under a sky gloriously resplendent with stars. We have no doubt but that an observatory will be established on Teneriffe by some people or nation. We should like such a place to be cosmopolitan—open to the astronomers of the world; for the stars shine alike on all men, and know no distinctions of flags or nationalities."



How to write 10,000-cycle data on a pen recorder

A tape tie-in banishes frequency-response limitations and saves paper

We will cancel the laws of physics, throw out inertia, and behold here is a pen recorder writing out 10,000 cycles per second ready to read. Don't scoff. There is a way. Assuming visual data is really what you want, keep your eye on the oscillograph or pen recorder, and think of the tape recorder as an ingenious "frequency-response extender" or "data stretcher."

A SLOW-MOTION LOOK AT TRANSIENTS

When an aircraft manufacturer was having shock problems from the firing of an experimental plane's armament, nothing could be seen in real-time data. For a better look, shock waves were recorded on tape, slowed down, recopied and then written out in visual traces. A thousandth of a second was stretched out to a full second. The exact extent and nature of the shock pattern and its manner of transmittal through the plane's structure became clearly evident – and with it the design solution.

100-TO-1 DATA STRETCHOUT (and more)

Compared to any visual-trace recorder, an Ampex instrumentation tape recorder has virtually unlimited response. Frequency components as high as 10,000 cycles per second (and much more) are easily recorded. And tape has decided advantages too at 1000 or 2000 cycles. A tape speed of 60 inches per second captures any of these higher frequencies and has tremendous room for slowdown on playback. Reproducing the tape at 0.6 in/sec. reduces 10,000 cps. to a mere 100. Connect a direct-writing recorder to the tape recorder and 100 cycles response is all that you need.

Actually Ampex has a wide range of tape speeds and tape slowdown ratios available. Tapes can be recopied once or even twice multiplying these ratios accordingly.

TYPICAL TAPE SLOWDOWN (OR SPEEDUP) RATIOS

AMPEX MODEL	Basic speed ratio	First recopy	Second recopy
FR-1100	8 to 1	64 to 1	512 to 1
FR-100	32 to 1	1024 to 1	32,768 to 1
FR-1100 multirange (many versions available)	100 to 1	10,000 to 1	1,000,000 to 1

24 TIMES AS MUCH RECORDING TIME

On 5000-cycle data, an ordinary 10½" reel of 1-mil magnetic tape will record 24 minutes. On a visual-trace recorder writing 100 cycles per inch, a 250-foot magazine of expensive paper would last just one minute! When you record data first on tape, you will seldom recopy the whole test onto paper. With an oscilloscope or other scanning device, you find the important parts of the tape and copy as little as a few seconds onto the visual medium. The tape can be stored for future reference, cut into loops for analysis or can be erased and reused. It saves hundreds of feet of paper.

Because magnetic-tape data is an "electrical analog", it can also be used for automatic frequency analysis, computer input, simulation of phenomena and scanning, counting and correlating techniques. We have told the whole magnetic-tape story in a well illustrated and diagrammed 16-page brochure. For your copy, write Dept. S-13.

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A MESSAGE TO USERS OF

for COMPUTERS,

When the science of magnetic data recording was first being developed, we realized that the quality requirements for this application were far more exacting than for the normal reproduction of sound. To meet these requirements, we developed and perfected type EP Audiotape — the *extra precision* instrumentation tape for all specialized magnetic data recording applications. Right from the start, each year has seen a substantial increase in our sales volume.

In part, these gains may be attributed to the general expansion of the market. But only "in part." Purchases of this kind are not casually made. Engineers set up specifications carefully. They test and study product samples. And they continue to check quality constantly, even after they have made their selected purchases.

Therefore, we feel this business growth was won on merit — by providing something extra. That "something extra" is a superior product, plus thorough and efficient customer service.

We make mistakes, of course. There have been misunderstandings on specifications, and other minor set-backs. But these have been temporary. Over the twenty years we have been in business, we have managed to build an organization that has a keen interest in quality and a real sense of urgency in making deliveries on schedule.

The cases described here, typical of our experiences in this field, illustrate specifically what we mean.

CASE NO. 1 — A major aircraft manufacturer was having great difficulty with a huge new tape-controlled milling machine. The problems were traced to tape defects — oxide rub-off and excessive drop-outs. The tape failures persisted. Our local distributor and factory representative learned about the situation and we immediately air-expressed four reels of type EP Audiotape. They worked perfectly. Ten more reels were ordered. Again perfection. We sent our regional sales manager and a factory engineer to talk to their production men. It was agreed that some changes in reel specifications would be beneficial. Forty more reels of tape and 75 of the new empty reels were delivered within 20 days. Soon came another much larger order with scheduled delivery dates. All shipments made *on time!* The customer's engineer told us, "Actually, we were going down for the third time when you people stepped in and saved us."

CASE NO. 2 — For more than four years we have been supplying tape to one of the largest manufacturers of electronic computers. We got the original order after the computer maker asked all manufacturers of magnetic recording tape to submit samples for testing. After months of tests, they chose type EP Audiotape. The first production order was for many thousands of reels to be delivered over a few months' period. Again, deliveries are being made on schedule, and all specifications are being met or exceeded.

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Here's how others have already solved the same problems of tape quality and service that you may be faced with right now

CASE NO. 3—Another electronic computer manufacturer came to us with a special problem. After analyzing the machine, our engineers recommended a different base material and oxide formulation than his previous tape supplier had been using. We supplied sample reels of EP Audiotape to these specifications. The customer tested the tape and found that his problem was solved. He placed three orders for a large number of reels. The third order was extremely rush. We met the challenge by putting the shipment on a through night bus. The next morning our sleepy-eyed local salesman met the bus and made prompt delivery in his car.

CASE NO. 4 — One of our most important customers since 1950 has been a key missile launching and testing base. They selected type EP Audiotape only after very critical tests of all available instrumentation tapes. So they were well satisfied with *quality*. Our test on *service* was provided quite unexpectedly one morning when we got a frantic phone call. New tests were being started. Would the order they had previously placed arrive there on time? We took no chances. Even though the order was en route by truck, we immediately sent extra reels by air express. They got there in plenty of time to meet the shooting schedule.

CASE NO. 5 — When the chief engineer of a large insurance company installed an electronic computer section, he wanted to be sure that he protected his new investment with the best magnetic tape. He asked salesmen from all major tape manufacturers to submit samples for testing. All sample tapes were used on the transports for at least a month. The results of the test were clear: type EP Audiotape was chosen. The chief engineer wrote us: "To obtain the optimum reliability and performance from our computing system we need the oxide dust-free coating, uniform signal output level correct in both directions of travel, and high precision reels which you supply. Keep up the good work!" He later reported these findings in a paper presented to a regional computer users group.

* * *

Whether your tape requirements are unique or standard, whether your needs are large or small, we'll be happy to work with you and to see that you get the best possible magnetic recording tape for your specific application.

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THE AUTHORS

H. H. REMMERS and D. H. RADLER ("Teenage Attitudes") both work at Purdue University, where Remmers is professor of psychology and education and Radler is a science writer and editor. Remmers was born in Germany and came to the U. S. when he was eight years old. He attended the University of Iowa as an undergraduate and graduate student, receiving his Ph.D. in 1927. The next year he was made director of Purdue's Division of Educational Reference, the University's counseling and testing arm. He has held this post ever since. Lying awake one night in 1941, Remmers had the idea of divining the public opinion of the future by measuring the attitudes of today's teenagers. This knowledge, he decided, could furnish a yardstick with which to measure the actual effect of teaching on the outlook of future leaders. Remmers's idea led to the founding of the Purdue Opinion Panel, the first scientific study actually to ask teenagers what they thought. Radler studied humanities at Kenyon College, psychology at the University of Chicago and Japanese in the U. S. Army. He has edited a weekly and a daily, and written widely for magazines.

EUGENE M. LIFSHITZ ("Superfluidity") is one of the leading theoretical physicists of the U.S.S.R. This year he won the Lomonosov Prize of the Soviet Academy of Sciences for his theory of molecular attraction in solids. Now 43, Lifshitz graduated from the Kharkov Polytechnic Institute, then did research for several years at the Ukrainian Physical-Technical Institute before joining the staff of the Academy of Sciences in 1939. He is noted for his work in solid-state and low-temperature physics, and for his long collaboration with Lev D. Landau. One result of this collaboration is their seven volume work *Quantum Mechanics: Course in Theoretical Physics*, which is now being published in English.

J. HERBERT TAYLOR ("The Duplication of Chromosomes") will be a Guggenheim Fellow next year at the California Institute of Technology, where he will continue his work on the duplication of chromosomes. Now professor of cell biology at Columbia University, he has been using isotopes in biological research ever since high-resolution autoradiography was first developed in 1950. At that time he was teaching at the University of Tennessee and working as a consultant to the Oak Ridge National Laboratory. Taylor comes from Corsicana, Texas, was graduated from Southeastern State College in Oklahoma and acquired a Ph.D. in biology from the University of Virginia.

RALPH W. PHILLIPS ("Cattle") has studied livestock in Europe, the Near and Far East and the Americas. After completing 10 years in Rome with the Food and Agriculture Organization of the United Nations, where he was deputy director of the Agriculture Division, he was recently appointed director of international organization affairs in the U. S. Department of Agriculture. A West Virginian, Phillips graduated from Berea College, then took a Ph.D. in physiology at the University of Missouri. After several years of teaching and government work he was put in charge of the animal genetics studies conducted by the Department of Agriculture. During World War II the Department of State sent him to China as an adviser on livestock problems.

THOMAS S. BARTHEL ("The 'Talking Boards' of Easter Island") was born in Berlin in 1923. As a consequence of his work as a cryptographer during World War II, he became interested in the decipherment of primitive writing systems. He helped to decipher the writing of the Mayas, then turned to the even thornier linguistic problem of the inscriptions on Easter Island's "talking boards." Barthel now teaches anthropology at the University of Hamburg. With the problem of the "talking boards" behind him, he recently undertook an expedition to Easter Island to study the island's other and more celebrated enigma—the question of how and why its people erected those great stone heads.

ERNST J. ÖPIK ("Climate and the Changing Sun") is an astronomer at the Armagh Observatory in Northern Ireland. An Estonian by birth, one of 10 children of a civil servant, he worked his way through high school and the Imperial University of Moscow by tutoring Latin and mathematics. Later he taught astronomy at Moscow University, the University of Turkestan, and the University of Tartu in Estonia, where he earned a Ph.D. and held the post of astronomer until 1944. When Russian troops entered Estonia, Öpik emigrated to West Germany, where he helped to found the Baltic University under the auspices of the British Military Government. He was Estonian Rector of this

university until his appointment to Armagh in 1948. "My interest in astronomy was aroused at the age of 10," he says, "inspired by the enthusiasm of my elder sister and brother and by Camille Flammarion's writings. The problems of climatic change have also interested me from the beginning; as long as 40 years ago I felt that there must be a connection between terrestrial climate and the evolution of the sun." The latter interest was passed on to his younger brother, Armin Öpik, now Government Paleontologist of Australia.

DeWITT STETTEN, Jr. ("Gout and Metabolism") is on the staff of the National Institute of Arthritis and Metabolic Diseases in Bethesda, Md. He is a graduate of Harvard College and received his M.D. from Columbia University in 1934. After an internship at Bellevue Hospital in New York, he returned to Columbia to earn a Ph.D. in biochemistry, then taught biochemistry at Columbia's College of Physicians and Surgeons and at the Harvard Medical School. Stetten has been at the National Institutes of Health since 1954, conducting research on muscular dystrophy, gout and other metabolic disorders.

ALEX BERNSTEIN and MICHAEL deV. ROBERTS ("Computer v. Chess-Player") are respectively a mathematician and computer programming expert in the International Business Machines Corporation. Bernstein was born in Italy, graduated from the College of the City of New York, and studied medieval literature and industrial engineering at Columbia University. Roberts was born in England, graduated from the University of Manchester and acquired a doctorate in chemistry from the University of Cambridge. While he was at C.C.N.Y. Bernstein was U. S. intercollegiate chess champion.

S. ULAM, who reviews John von Neumann's *The Computer and the Brain* in this issue, is research adviser to the Los Alamos Scientific Laboratory. He was born in 1909 in Lwów, Poland, and received his D.Sc. from the Polytechnic Institute there. After his arrival in the U. S. in 1936 he lectured in mathematics at the Institute for Advanced Study in Princeton, N.J., at Harvard University, at the University of Wisconsin and at the Massachusetts Institute of Technology. His mathematical work has been concerned with set theory, topology and functional analysis. In 1943 he went to Los Alamos, where he has done important work on thermonuclear reactions.

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Teenage Attitudes

What are the beliefs, desires and problems of Americans of high-school age? The answer is sought through polls of 3,000 high-school students in all parts of the U. S.

by H. H. Remmers and D. H. Radler

What is today's younger generation really like? What is its prevailing attitude; what is it thinking; how is it likely to handle its own and the world's problems when it grows up? These are perennial questions to which past ages have never had any dependable answer. Nowadays, thanks to the development of public-opinion polling, we can look into the matter in a systematic way and arrive at rather reliable conclusions. Of course generalizations are always open to question. The teenagers of the U. S. are a heterogeneous group, with all sorts of opinions and attitudes. Paraphrasing Edmund Burke, we must grant that we do not know a method of drawing up a description of a whole generation. Nevertheless on a statistical basis we can paint something like a portrait of "the typical teenager." Scientific surveys of the nation's young people have made clear that their problems, beliefs and desires follow a characteristic pattern.

One of the authors (Remmers) started this study of adolescents in 1941. During the past 17 years his group at Purdue University has carried out more than 50 polls of samples of the U. S. teenage population. Last year we published a summary and interpretation of the results of the first 45 polls in the book *The American Teenager*. This article not only brings the polling results up to date but also gives us an opportunity to reexamine our conclusions and to clarify the interpretations set forth in the book.

Our samples of the younger generation have been drawn from the nation's high schools, which since the early 1940s have enrolled virtually all of the country's teenagers. Each sample consists of about 3,000 students, chosen to represent accurately all the high-school grades, the various sections of the country, rural and city dwellers and roughly the various family backgrounds. Aside from giving the correct statistical representation to these groupings, the samples are completely random. The poll questions are tested beforehand to make sure that they really ask what we want them to ask and that they will elicit uninfluenced answers; that is, the questions are made as semantically "clean" as possible. The subjects' responses are recorded anonymously. They are put on punch cards and tabulated and analyzed by computers.

The most significant place to start our examination of the results of these polls is to look at what U. S. teenagers list as their most common problems [*see chart on page 29*]. At the head of the list is the wistful plea: "Want people to like me more." And most of the things that 25 per cent or more of the teenagers list as problems express, in one form or another, the same sentiment. A majority of teenagers want to gain or lose weight or otherwise improve their appearance; they want more dates, more friends, more popularity; they get stage fright before a group, worry about their lack of self-confidence. Their overriding concern emerges again when they are asked direct questions about their feelings with respect to approval by others. More than half admit that they try very hard to do everything that will please their friends; 38 per cent declare that the worst of all calamities is to be considered an "oddball."

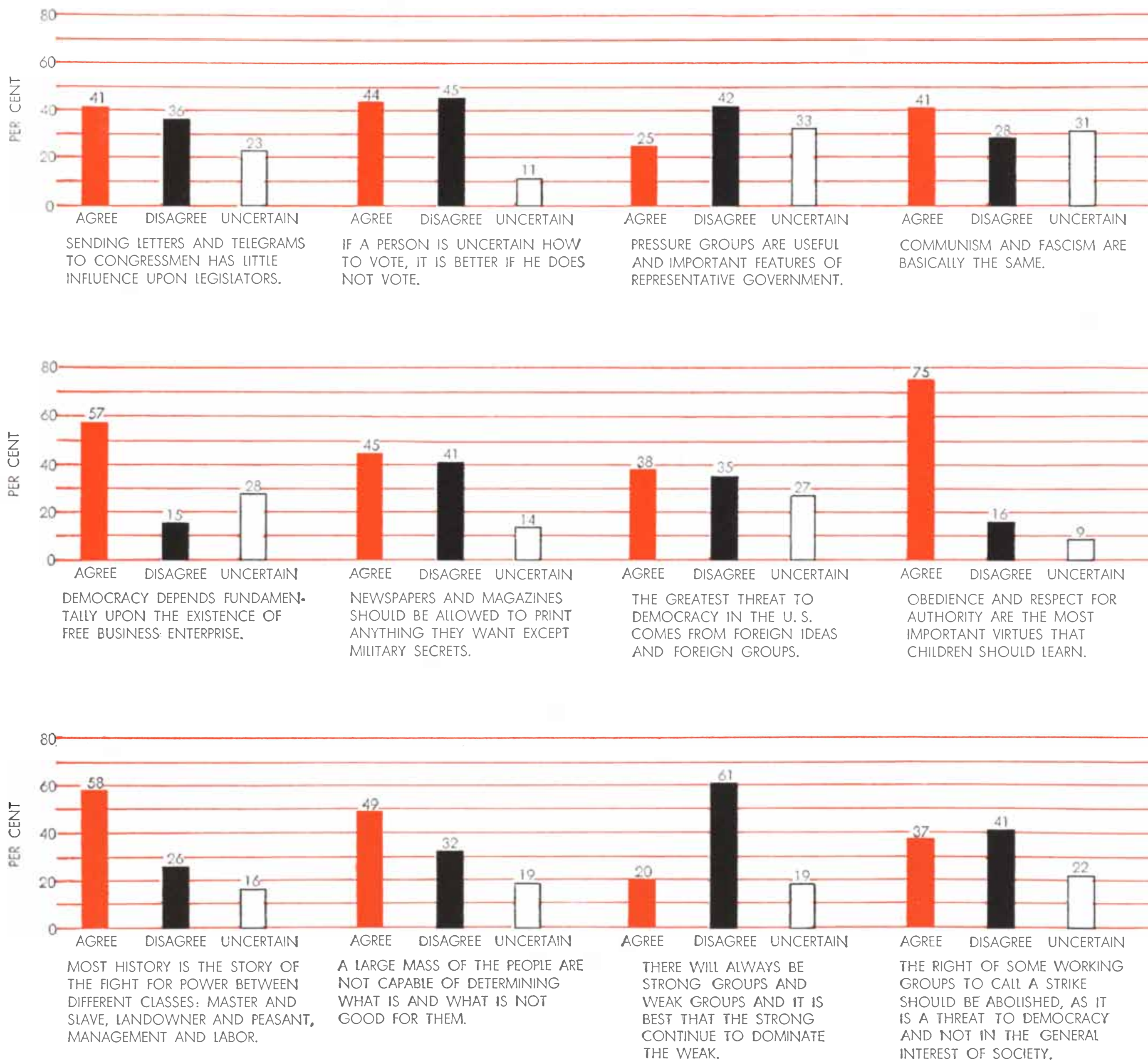
Naturally these feelings carry over into behavior. Nearly all the teenagers say they disapprove of high-school students drinking—but a quarter of them admit that they drink. More than three quarters disapprove of smoking—but 38 per cent smoke. The whole matter is summed up in the comment of a teenage girl: "It's hard for a teenager to say 'I don't care to' when all the rest of the gang are saying, 'Ah, come on.' "

It is hardly necessary to point out that all this has a bearing on the problem of juvenile delinquency. In the high-delinquency slums of our big cities the *average* child is delinquent, according to police reports. Probably one of the most important factors making for delinquency is the need to be accepted as one of the gang: the "bad boy" may become that way because he wants to be "a good guy" in the eyes of his peers, particularly of the leader who sets the standards of acceptance as the head of the neighborhood gang.

But what should concern us much more is how the passion for popularity translates itself into an almost universal tendency to conformity among our younger generation. It runs through all social classes. American teenagers show substantial class differences in many aspects of their behavior, problems and aspirations, but in their desire for popularity and their conformist attitude they are as one: low-income or high-income, their highest concern is to be liked.

This is the most striking and most consistent fact that has emerged from our polls through the 17 years. Poll after poll among our youngsters has given statistical confirmation of the phenomenon of American life which David Riesman, in his book *The Lonely Crowd*, named "other-direction"—extreme sensitivity to the opinions of others, with a concomitant conformity. As a nation we seem to have a syndrome characterized by atrophy of the will, hypertrophy of the ego and dystrophy of the intellectual musculature.

This rather unpleasant portrait is an inescapable conclusion from the mass of data on the attitudes of the younger generation. More than half of our teenagers believe that censorship of books, magazines, newspapers, radio and television is all right. More than half believe that the Federal Bureau of Investigation and local police should be allowed to use wiretapping at will, that the police should be permitted to use the "third degree," that people who refuse to testify against themselves should be forced to do so. About half of our teenagers assert that most people aren't capable of deciding what's best for themselves; fully 75 per cent declare that obedience and respect for authority are the most important habits for children to learn. On practically all questions of social policy the youngsters lean strongly to stereotyped views [*see below*].



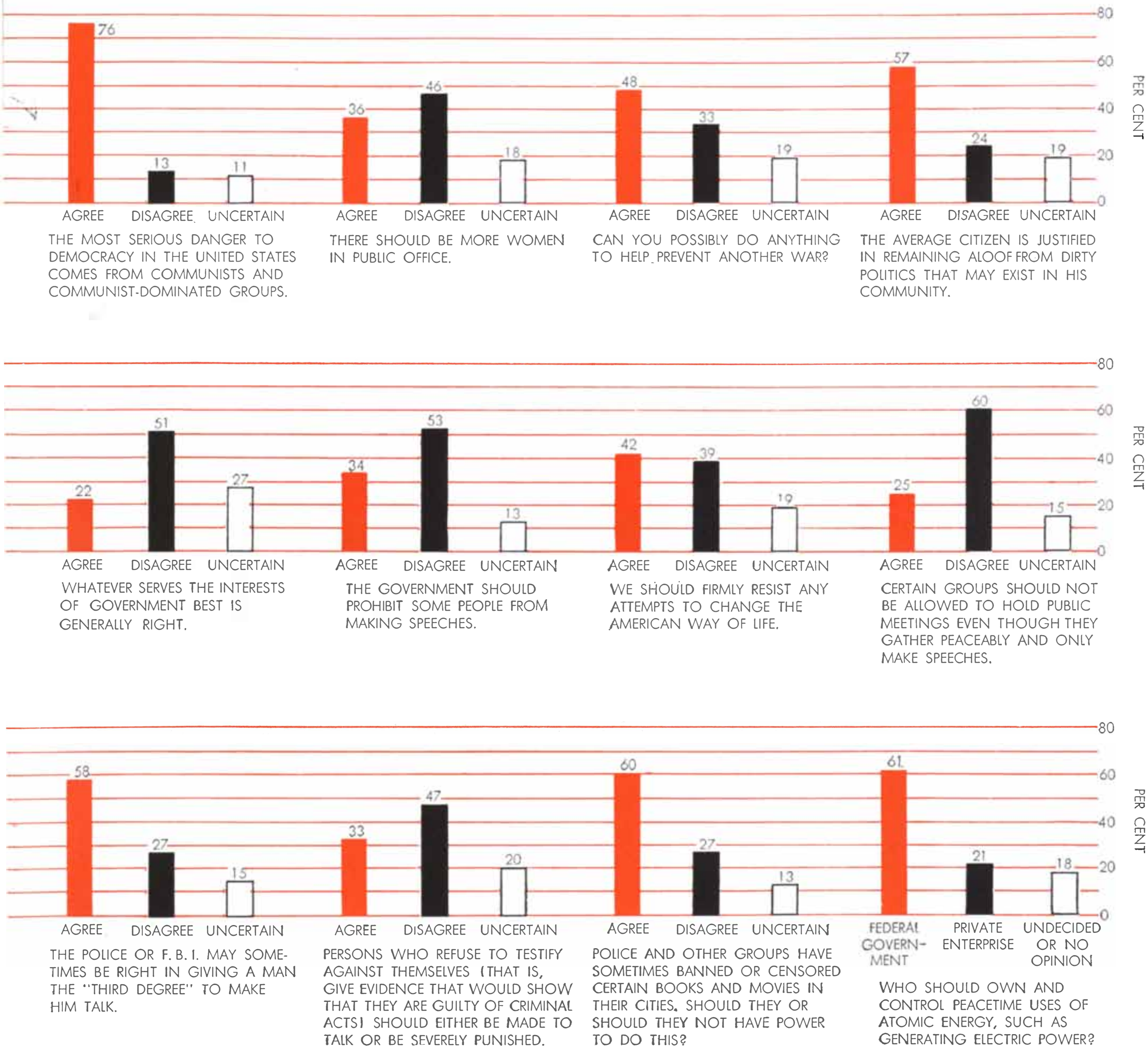
SOCIAL ATTITUDES of teenagers are reflected by the bars in these charts. Below each set of three bars is a statement framed by Remmers and his associates at Purdue University. Each bar represents the percentage of the teenagers polled who indicated that

Such answers may represent either unthinking responses or convinced and deliberate acceptance of an authoritarian point of view. In either case the picture is equally unhappy. The road to totalitarianism is the same length whether we walk down it consciously or merely drift down it. Unthinking conformity provides a setting which makes it possible for a demagogue to lead a nation into slavery.

As individuals our nation's young people consistently value others' opinions above their own. Fewer than half claim that they think things out for themselves and act on their own decisions. Only one fourth report that they often disagree with the group's opinion. No more than 18 per cent are willing to say that their tastes are quite different from those of their friends. Yet in spite of these admissions most teenagers declare that their freedom is not too limited.

Such soundings of the younger generation's attitudes uncover some of the roots of anti-intellectualism in the U. S. Almost three quarters of the high-school students believe that the most important thing they can learn in school is "how to get along with people." Only 14 per cent place academic learning first. In a recent poll of a representative sample of college students we found that the same attitude prevails at the university level: 60 per cent would rather be popular than brilliant; 51 per cent believe that students with low grades are more likely to be popular than those who get good marks; 72 per cent believe that development of a well-rounded personality is the main purpose of education; 71 per cent feel that personality counts more than grades when it comes to looking for a job.

The disdain for learning shows up



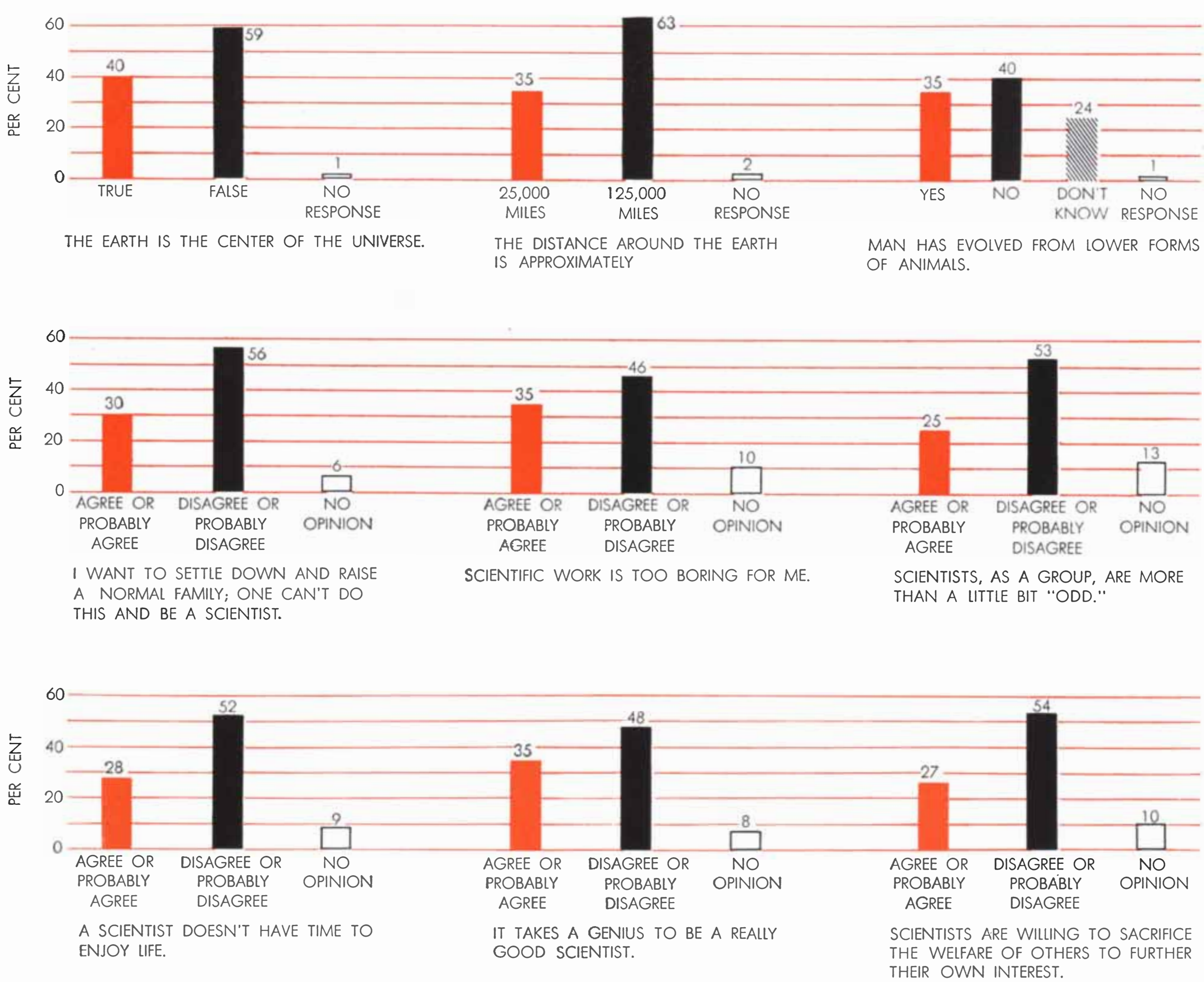
response to the statement. The 3,000 teenagers polled were chosen to represent all high-school grades, various sections of the country, cities *v.* rural areas, and family backgrounds. Only a few of the many statements tested in the poll are shown in the charts.

most sharply and most dismayingly in the attitude of teenagers toward science and scientists [*see charts below*]. Forty per cent of high-school students think that the earth is the center of the universe, and 63 per cent believe the earth's circumference is 125,000 miles! More than a third find scientific work boring; 25 per cent think scientists as a group are "more than a little bit odd"; about 30 per cent believe that a scientist cannot enjoy life or raise a normal family. In a poll in October, 1957—the month of Sputnik I—68 per cent of the teenagers said they would not like to be scientists. A majority asserted that scientists are likely to be radical, that they take no thought of the consequences of their work, that science should be restricted to physics and chemistry, that it is impossible to formulate scientific laws of human behavior. Most disquieting is the fact that views of this kind are just as common among students of high scientific aptitude as among those who have no interest in science. The climate of popular opinion among the nation's youth undoubtedly is keeping many able boys and girls out of science.

The current attempts to sell science on the basis of the benefits that flow from it seem to have sold the benefits but not the science from which they stem. Fully 90 per cent of the high-school youngsters agree that science has produced great practical fruits for mankind, but to most of them science has no appeal as an intellectual adventure. This attitude may well stem from the fact that the presentation of science by our schools and our press constantly plays "the one-note siren song of utility."

A need and craving to be liked, drifting with the crowd, conformity, a kind of passive anti-intellectualism—these seem to be outstanding characteristics of the present-day younger generation as it has expressed itself in our polls. Many of the youngsters themselves make this comment. One teenager observed: "High-school children think too much about what the crowd does or thinks rather than what they actually feel inside themselves. They seem to feel that if they go along with the crowd, they will be more popular. . . . We need to worry more about the person we live with all the time, our own self, rather than to worry so much about others."

The present conformist spirit—demonstrably not confined to the younger generation—seems to us something new in American life. It reverses our history and the American ideal, which has been, above all, individualistic. The American tradition suggests that we have not been in the past a people who passively accepted dictation by the crowd or sur-



ATTITUDES TOWARD SCIENCE are suggested by the statements in these charts. Another response not indicated in the charts: When asked in October of last year whether they would like to be scientists, 68 per cent of the teenagers polled said that they would not.

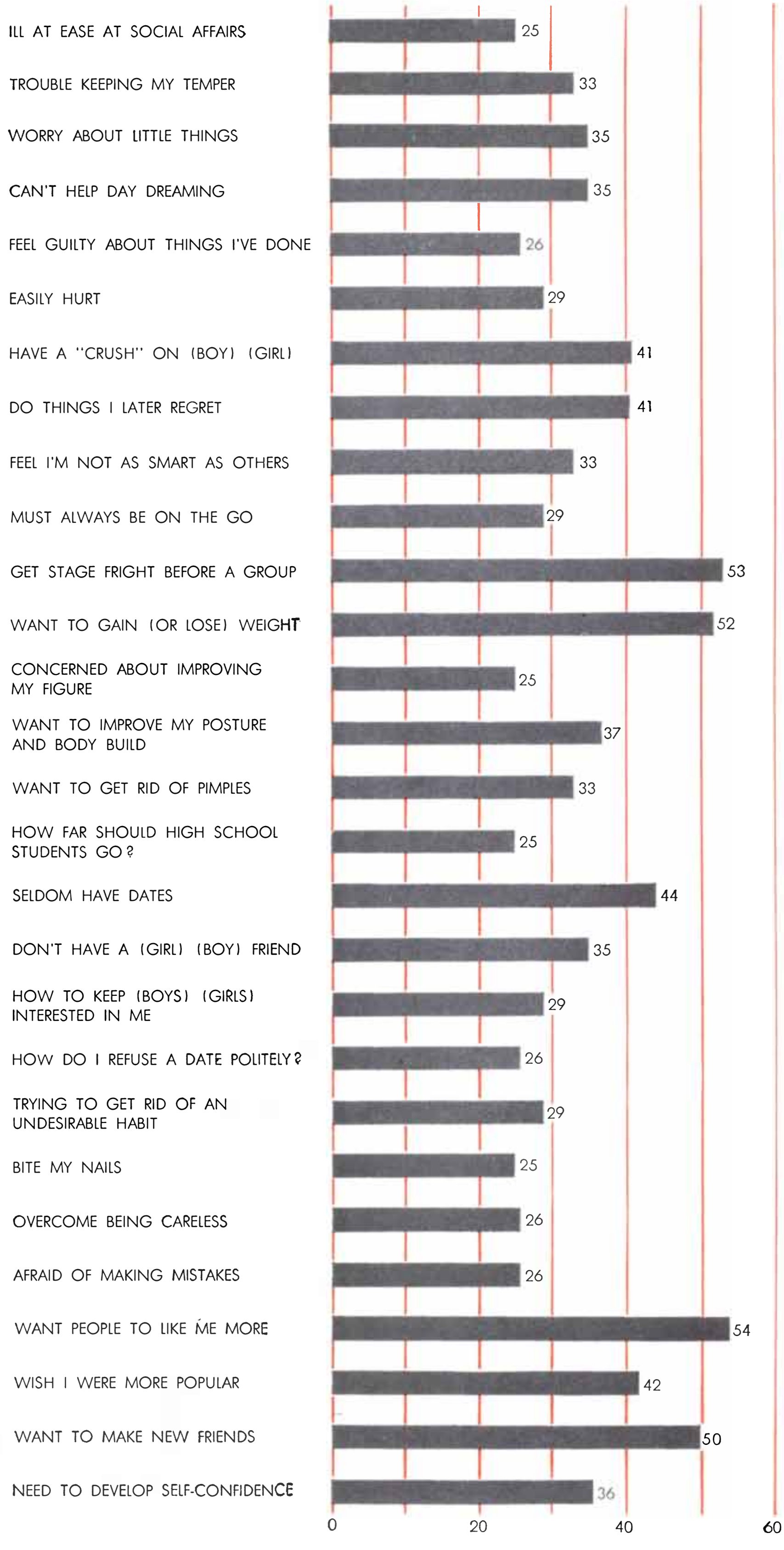
rendered the exercise of our freedoms.

We shall not attempt to analyze the causes of this shift; that is a task for historians and philosophers. But we can venture some comments on the aspects of our culture reflected in the polls of the teenagers. Their attitude derives in large part, of course, from their parents. Riesman asserts that "today's parents make children feel guilty not so much about violations of inner standards as about failure to be popular," *i.e.*, failure to get along with other children. He adds that the pressures of the home and school are re-enforced by our mass media. Vance Packard's book *The Hidden Persuaders* points out that modern advertising, dedicated to increasing mass consumption, deliberately bases its appeal primarily upon our need for identification with the vast majority. It inveigles us to purchase the products which are most popular—the most widely smoked or fastest-growing cigarette, the largest-selling automobile. Our economy, our uninsulated mode of life and our mass communications conspire to keep us under constant social pressure in our daily lives.

In recent decades we have seen the individual steadily depreciated even in intellectual pursuits. There is a rising admiration for "the power of the group mind." We have team research in science and "brainstorming" in industry. In every sphere group decision is replacing individual initiative.

In this light we must take a serious view of the tendency to conformity exhibited by the younger generation. In any circumstances it is always difficult for an adolescent to find himself. The teens are a time of transition, demanding adjustments to profound biological, emotional and social changes. Probably most parents today would testify from personal experience that the teenagers of our day are having an extraordinarily difficult time of growing up and finding themselves.

Ralph Waldo Emerson pointed out that the price of group agreement is descent to the least common denominator. As T. V. Smith and Eduard C. Lindeman remarked in their book *The Democratic Way of Life*, a democracy cannot afford to devalue "the finality of the individual," from whom "all things flow." In our view, the future of our democracy is not promising unless we restore a social climate which will reward independent thinking, personal morality and truly enlightened cooperation in place of going along with the crowd.



PROBLEMS AND DESIRES which most concern teenagers were explored by sentences such as those in this chart. Each bar indicates percentage of teenagers polled who responded.

SUPERFLUIDITY

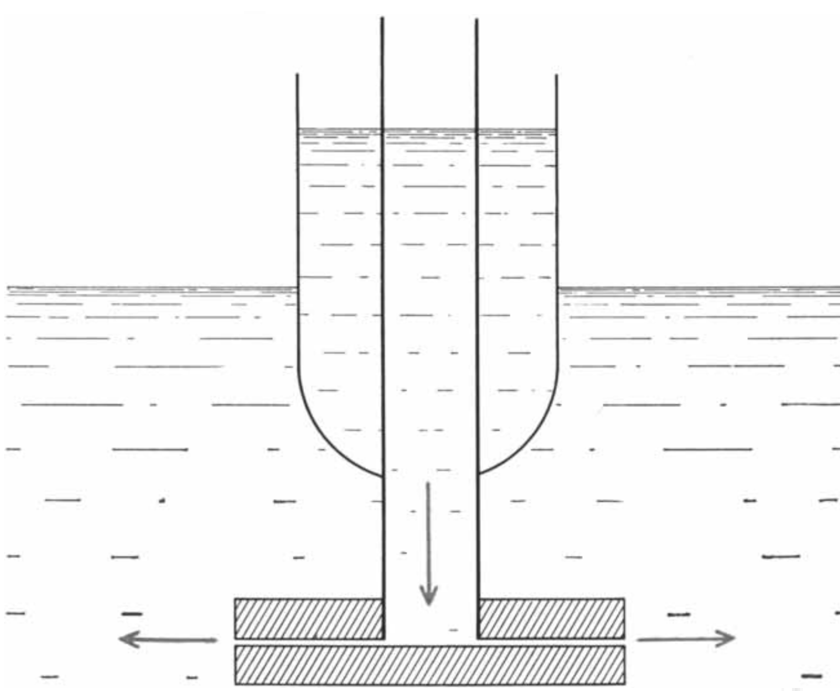
When liquid helium is cooled to 2.2 degrees above absolute zero, it flows without friction. A Soviet physicist describes how this strange fluid exhibits the quantum properties of individual atoms

by Eugene M. Lifshitz

The history of physics is marked by breakthroughs into new, unexpected worlds of discovery. One such event occurred just half a century ago, on July 10, 1908, the day Heike Kamerlingh Onnes of the University of Leiden succeeded in cooling helium gas down to the liquid state. His breakthrough into this low temperature region, close to absolute zero, led to the discovery of two strange properties of matter, totally different from those familiar to us at ordinary temperatures. Both of these properties involve the phenomenon of "frictionless" flow. One of them, soon discovered by Kamerlingh Onnes himself, is superconductivity, the frictionless flow of electrons and the consequent complete disappearance of a metal's resistance to electric current [see "Superconductivity," by B. T. Matthias; SCIENTIFIC AMERICAN, November, 1957]. The other, not discovered until 30 years later, is the superfluidity of liquid helium, the frictionless flow of entire atoms, demonstrated in the liquid's ability to flow through the tiniest tubes or narrowest slits. Our understanding of this remarkable phenomenon is today almost complete. I have been asked by the editors of SCIENTIFIC AMERICAN to give a short survey of what has been learned about superfluidity, first discovered in 1937 by Peter L. Kapitza at the Institute for Physical Problems in Moscow.

Helium is the only substance which remains liquid under ordinary pressure at absolute zero; all others freeze to the solid state if sufficiently cooled. Now according to ordinary or "classical" concepts, at absolute zero all the atoms of a substance cease moving and occupy fixed positions within the body, thus causing it to become solid. The fact that helium remains liquid is the first indication that its properties can be understood only in terms of the entirely different concepts of quantum mechanics.

As students of physics know, quantum mechanics is the peculiar system of laws that governs the properties of matter on the microscopic scale—the world of individual atoms and molecules. But in the case of liquid helium we can see matter displaying "quantum properties" on the macroscopic scale—that is, in its bulk or gross form, where we deal with an enormous number of atoms. We must pause to consider what this means. All gross matter possesses not only the ordinary properties with which we are familiar but also fundamental quantum properties. At ordinary temperatures the random heat motion of atoms and molecules cloaks the quantum behavior of the individual particles, and matter exhibits only its familiar properties; that is, it obeys the rules of ordinary classical mechanics. The quantum theory says that if we reduce a substance to extremely low temperatures, so that its atoms' heat motions become very weak, the fundamental quantum properties of the substance should become observable. However, all substances except one solidify before the quantum properties



EXPERIMENT BY PETER KAPITZA demonstrated the superfluidity of helium II in its ability to flow through an extremely narrow slit between two highly polished glass plates. With the slit narrowed to half a micron, the flow of helium II quickly equalized the levels in tube and reservoir, while the flow of helium I through the slit was scarcely perceptible.

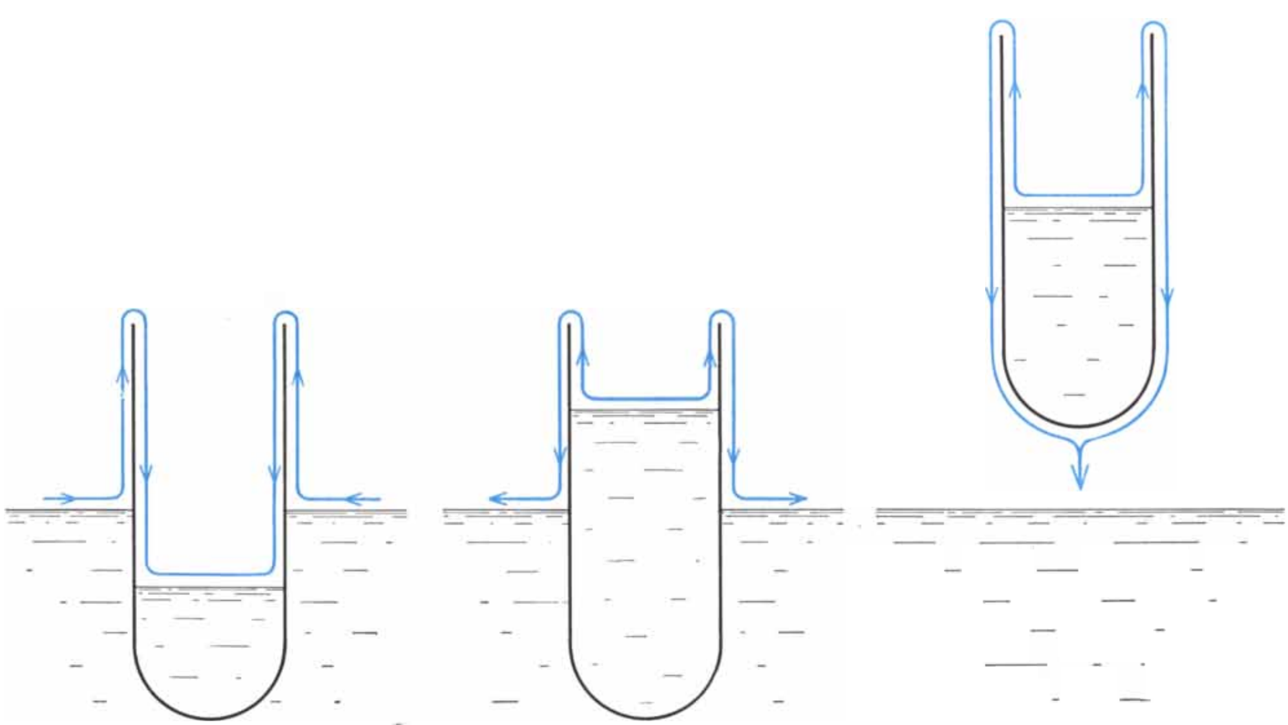
emerge. The single exception is helium: it succeeds in becoming a "quantum" substance before solidification. Once this has happened it need no longer solidify at all, since one of the principles of quantum mechanics is that the motion of atoms need not cease completely at absolute zero. Thus in liquid helium nature has made a "quantum liquid" available to physicists for investigation.

Helium liquefies at 4.2 degrees Kelvin (4.2 degrees centigrade above absolute zero). Upon being cooled to 2.2 degrees Kelvin, helium, although remaining liquid, undergoes another type of transition. It was first observed as an abrupt jump in the liquid's specific heat (*i.e.*, heat capacity). Because the graph showing this abrupt change has the shape of the inverted Greek letter lambda [*see chart at top of next page*], the point of transition (2.2 degrees) became known as the "lambda point." Liquid helium above this point was called helium I; liquid helium below it, helium II. It is the latter which was found to be a liquid with unique properties.

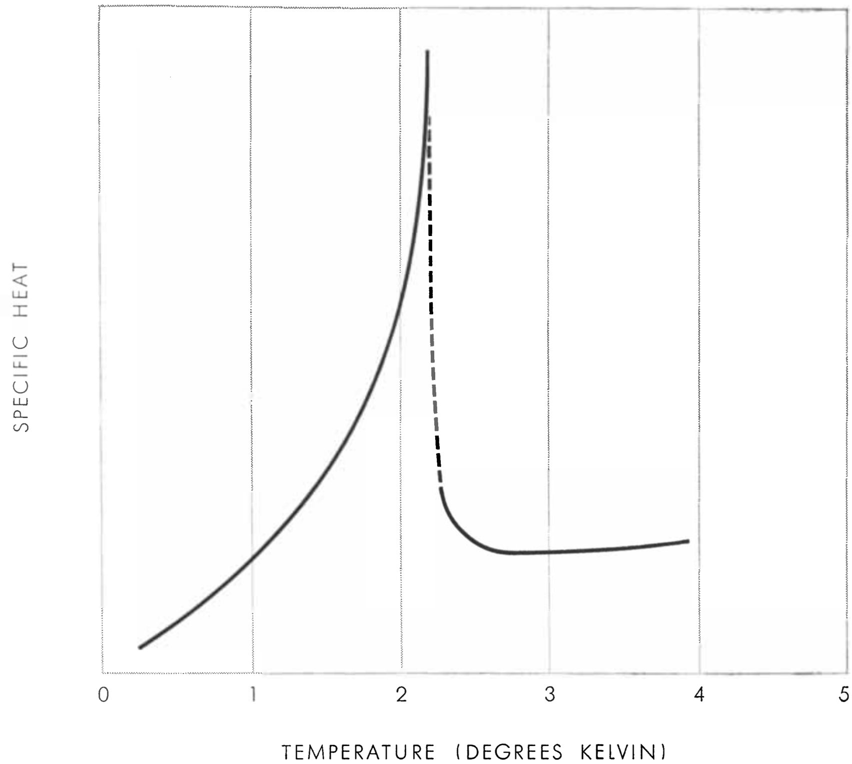
The first indication of these properties came in 1935 from the Kamerlingh Onnes laboratory. W. H. Keesom and his sister Miss A. P. Keesom discovered that helium II is an extraordinary conductor of heat. Experimenting with a capillary tube filled with the substance, they found that heat traveled from one end of the tube to the other at an extremely rapid rate. Helium II appeared to be a far better conductor of heat than the best of known conductors under ordinary conditions: it conducted heat about 200 times faster than copper normally does. (The Keesoms' discovery, incidentally, explained an odd feature of helium II's previously observed behavior: liquefied helium, absorbing heat from its container, bubbles like boiling water, but when the liquid is cooled to the lambda point, it suddenly becomes perfectly still. The reason now became plain: helium II conducts heat away from the walls of the container so rapidly that no bubbles form at the walls, as they do in ordinary boiling. The liquid vaporizes only at its open surface.)

It was an attempt to explain helium II's remarkable conduction of heat that led Kapitza to discovery of its superfluid property. Why did heat travel so rapidly through this material? Kapitza suspected that the swift transport of heat in helium II was due not to any exceptional conductivity of the substance but to movement of the liquid itself, in other words, to what are called convection currents. If this was so, helium II must be extraordinarily fluid; in the terms of physics, it must have an extremely low viscosity, meaning an extremely small internal frictional resistance to flow. The viscosity of a liquid is usually measured by letting it flow through a narrow capillary tube. In the present case, however, such measurement was found to be impracticable and it was necessary to devise a special apparatus involving the flow of a larger amount of liquid than is passed by a narrow capillary. Kapitza achieved success by letting the liquid flow between two polished glass disks forming a slit as narrow as half a micron (a fifty-thousandth of an inch). He found that whereas helium above the lambda point scarcely flowed through this slit at all, helium II passed through it very rapidly. In fact, he arrived at the amazing conclusion that the viscosity of helium II was less than a ten-thousandth that of hydrogen gas! On the basis of his measurements Kapitza daringly suggested that helium II had no viscosity at all, and exhibited a new phenomenon which he called "superfluidity."

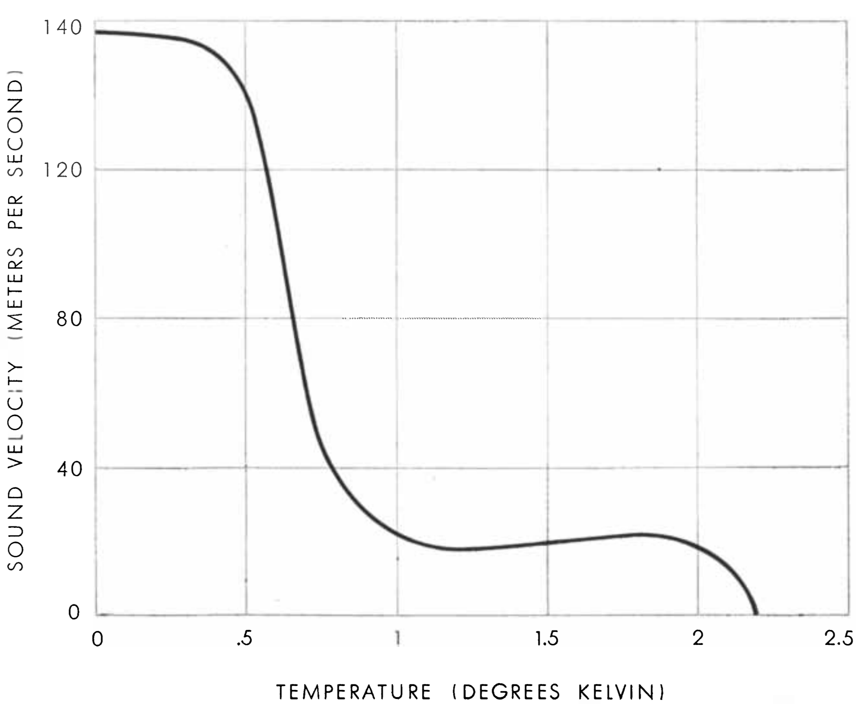
Directly related to the superfluidity of helium II is the remarkable phenomenon of the "creeping film." It had been noted long before that, if liquid helium is poured into a flask separated into two chambers by a partition, somehow the two levels spontaneously manage to equalize in course of time. John



CREEPING FILM provides spectacular demonstration of the superfluidity of helium II. Any liquid that wets a surface forms a film. In the case of helium II, however, the film forms quickly and behaves more or less as a siphon along which the liquid flows. As shown here, it will flow into a flask lowered into a helium reservoir (*left*) or out of it (*center*) or out of a flask withdrawn from the helium bath (*right*) to escape in the form of drops from its bottom. The velocity of this creeping film may be a foot or more per second.



LAMBDA POINT at 2.2 degrees Kelvin marks the transition of liquid helium from the fluid to the superfluid state. At this point there is a sharp drop in heat capacity of the liquid.



VELOCITY OF SECOND SOUND in helium II ascends at temperatures below 1 degree. The velocity of ordinary sound, at 240 meters per second, is hardly affected by temperature.

G. Daunt and Kurt Mendelssohn at the University of Oxford demonstrated by direct experiment that helium flows between the containers by means of a film, some millionths of an inch thick, formed on their walls [*see diagram on preceding page*]. The liquid in the film may travel at a speed of more than a foot per second. The propensity to form a film is in itself not a unique property of helium II. Such films are formed by any liquid which wets a solid surface, but the viscosity of an ordinary liquid is such that the film forms slowly and moves scarcely at all. Helium II is the only fluid which, owing to its superfluidity, forms a swiftly moving film.

Investigation soon disclosed other paradoxical features of helium II's behavior which were difficult to explain. For one thing, experimenters at Leiden and at the University of Toronto found that, although in its flow through a narrow slit it behaved as if its viscosity was zero, the liquid did show some viscosity, albeit small, in another experiment: when a cylinder or disk was rotated in the liquid, the fluid exerted a measurable frictional resistance to the rotation of the body.

Kapitza observed a still more puzzling phenomenon. It emerged in the course of some experiments on the transport of heat in helium II. Seeking to demonstrate that heat was transported via movement of the liquid, he used a flask with a movable vane suspended in front of its opening, so that any outflow of liquid would deflect the vane. He filled the flask with liquid helium and immersed it in a helium bath. When he heated the liquid in the flask (by shining light on a blackened absorbing surface in the flask), the vane was deflected, showing that a stream of liquid was flowing out. This gave a clear proof that the flow of heat in helium II involved some sort of movement of the liquid. But Kapitza was struck by a paradoxical fact. Although liquid flowed out of the flask, the flask remained full!

How could these paradoxes be explained? Here was a fluid which flowed as if it had no viscosity and yet showed a definite viscosity in certain experiments; it was a fluid, furthermore, which flowed out of a flask upon heating, as indicated by the deflection of the vane, yet its flow did not empty the flask!

In 1940-1941 an elaborate theory to explain superfluidity was advanced by Lev D. Landau at Kapitza's institute in Moscow. Some qualitative features of the theoretical picture were independently predicted by Laszlo Tisza at the Collège de France in Paris (he is now at the Massachusetts Institute of Technology).

The theory is quantum-mechanical in its nature, and it rests upon concepts in quantum mechanics which are understandable only to a specialist in the subject. But we can describe the remarkable picture of what takes place in helium II in fairly simple physical terms. We must bear in mind, however, that description in terms of everyday experience cannot really picture the quantum world, which is beyond our direct observation.

Helium II, says Landau's theory, can undergo two motions simultaneously. This is, of course, a statement that defies common sense. In the case of an ordinary liquid, we are able to derive a complete description of its flow by measuring the distribution of velocities in one direction in a cross section of the stream. That is how engineers measure the flow of water in a canal. In the case of liquid helium, however, a complete description of its flow necessitates the knowledge of not one but two velocities at each point.

This situation can be visualized by an analogy called the "two-fluid model." It pictures helium II as composed of two liquids which can move independently "through" each other without any mutual drag. (In reality, of course, there is only one liquid; we must remember that the "two-fluid model" is an analogy.) The two types of motion in helium II have entirely different properties. One of the "components" moves as if it had no viscosity; Landau called this the "superfluid component." The other component moves like an ordinary viscous liquid and is called "normal."

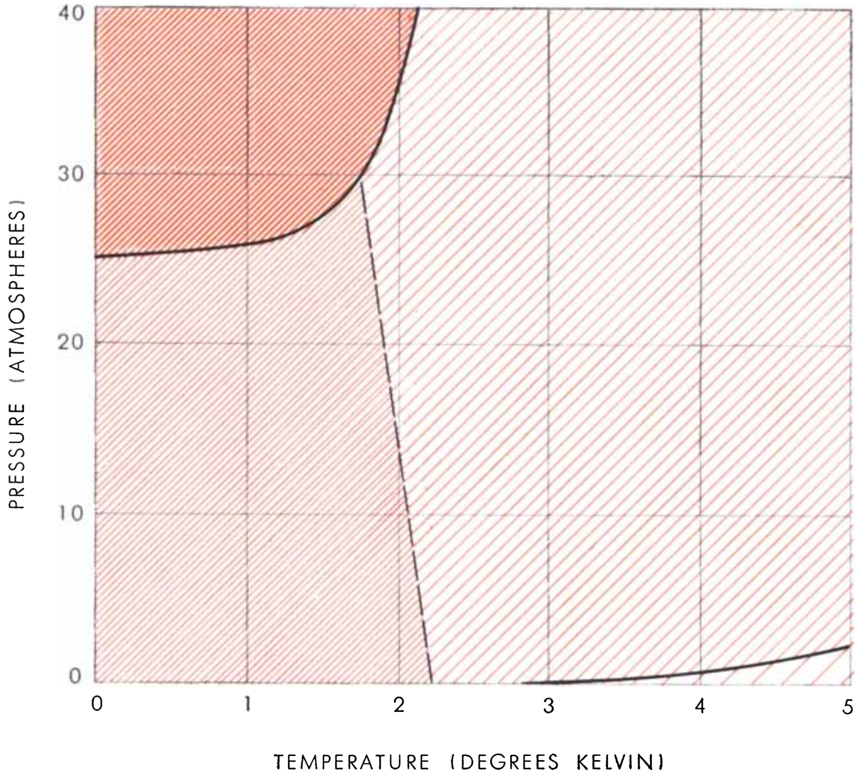
But this does not exhaust the differences between the two kinds of motion in helium II. The most important one is that the normal component transports heat, whereas the superfluid motion is accompanied by no heat transfer whatsoever. One can say, in a sense, that the normal component is the heat itself. Thus the heat acquires a sort of independence in helium II; it separates from the mass of the liquid and acquires ability to move relative to a "background" which itself is at absolute zero. This is in radical contrast to the usual idea of heat as the chaotic motion of atoms, inseparable from the mass of a substance.

These concepts make it possible to explain the strange results of some of the experiments with helium II. To begin with, we can account for the paradox that liquid helium shows no viscosity in its flow through a narrow slit but does display frictional effects on a rotating disk. In the first experiment it is the superfluid component that flows freely through the slit, whereas the viscous normal component is held back and leaks through very slowly; this experiment demonstrates the absence of viscosity in the superfluid component. In the second experiment it is the normal component that is responsible for the friction on the disk; this experiment accordingly measures the viscosity of the normal component.

But we can now draw a further conclusion: Since superfluid flow carries no heat, flow through a slit may be said to filter out "heatless" liquid, leaving the heat in the container. In an ideally thin slit the outflowing fluid should be at absolute zero. In an actual experiment one may expect this fluid to have a lower temperature than that in the container, although not zero. An effect of this kind was observed as early as 1939 by Daunt and Mendelssohn. Kapitza himself was able to show that the fluid pressed out of a container through a fine filter had a temperature as much as three or four tenths of a degree lower than that left behind—a considerable drop for a liquid which had a temperature of only one or two degrees absolute to start.

Landau's theory also explained, in equally simple fashion, the experiment in which Kapitza had caused helium II to flow out of a container and deflect a vane. The heat-bearing fluid that flowed past the vane, causing it to deflect, was the normal component; the flask remained full because a superfluid countercurrent flowed back in.

It remains to explain why this countercurrent did not, for its part, exert a force on the vane, thus counterbalancing the force exerted by the flow of the normal component. The reason is connected with another prediction of theory, the so-called "irrotational" character of the superfluid flow. The exact meaning of this word is not easy to explain in simple terms. What is remarkable is that as early as the 18th century the Swiss mathematician Leonhard Euler, who also worked in hydrodynamics, had predicted on theoretical grounds that the irrotational flow of an ideal nonviscous liquid past a solid body should exert no force on the body. Thus we arrive at a complete explanation of an unusual situation: With the normal component flowing in one direction and the superfluid component flowing in the opposite direction, one can say that there is no net motion of the liquid as a whole; yet the

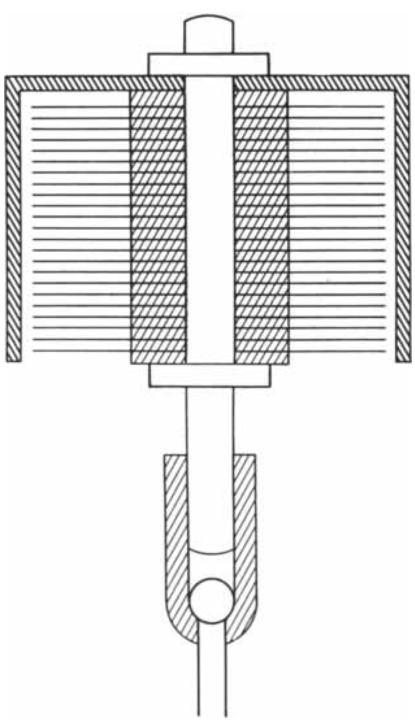


PHASE DIAGRAM of helium shows its transition from the gaseous (*below solid line at right*) to the fluid (*to right of broken line*), the superfluid (*to left of broken line*) and the solid (*above solid line at upper left*) states in relation to temperature and pressure.

vane is deflected, because one of the two components exerts no force.

An elegant experiment performed by Kapitza in 1940 confirms this explanation in a spectacular manner. He fashioned a tiny glass turbine with six bent capillaries radiating from it like the legs of a spider [*see photographs on opposite page*]. Immersed in a bath of helium II and heated by light, this turbine spun rapidly on its pivot, attaining speeds up to 120 revolutions per minute. This clearly evidenced the reactive force of the outflowing normal component. Kapitza now mounted a spider of silver wire on the turbine with vanes to oppose the outflow of helium from the mouth of each capillary. Because the reactive force of the normal component was offset by its push against the vanes, the spinning stopped. If the inflowing superfluid component could exert a force, the turbine would thereupon have begun to spin in the opposite direction. It remained motionless, in beautiful fulfillment of Euler's prediction and Landau's theory.

Landau's theory was verified in still another way. Since the superfluid component of helium II is capable only of irrotational flow, the theory predicted that the superfluid should not rotate as a whole in a whirling container (the way water in a glass rotates when the glass is twirled). E. L. Andronikashvili at Kapitza's institute put this prediction to the test in an experiment using rotating disks to drag the liquid [*see diagram on this page*]. The rotation of the liquid proved much less than would normally be expected, indicating that only the normal component of the helium rotated, while the superfluid component remained at rest. This experimental device, moreover, made it possible to measure the relative amounts of the normal and superfluid components in a given quantity of helium II. The ratio depends on the temperature of the liquid, as the theory predicts. Above the lambda point the liquid is entirely normal. At the lambda point the superfluid component begins to appear, and its "amount" increases as the temperature drops further. At absolute zero helium II should become entirely superfluid.



IRROTATIONAL FLOW of helium II was demonstrated by rotation of stack of thin foil disks in a bath of the superfluid. The drag on the disks was much lower than would have been expected in a normal fluid.

Finally let us consider the phenomenon called "second sound"—a property of helium II which was predicted independently both by Landau and Tisza. The prediction was that two different kinds of waves, propagated at different velocities, could travel through the liquid. According to Landau's theory the two kinds of wave propagation arise from the fact that helium II is capable of performing two motions simultaneously. If both components of the liquid oscillate jointly—that is, if the superfluid and normal components move in unison in the same direction—a sound wave of the ordinary kind arises, such as normally travels through a liquid. But, says the theory, there could also be a second kind of wave, specific for helium II, arising from oscillatory movement of the two components in opposite directions, each passing "through" the other in an oscillation cycle. It turns out that this wave should travel through the liquid at another (in fact, a much slower) velocity than ordinary sound, and that therefore it should be detectable as a second signal.

The phenomenon proved, however, to be difficult to discover experimentally. The first experiments, performed at our institute in Moscow in 1940, failed. Sound waves generated by vibration of a piezoelectric plate were passed through a tube filled with helium II. But only one signal arrived at the other end: no second signal could be detected.

Reviewing the problem in 1944, I found an explanation for the failure of the experiments. Ordinary sound waves, as is well known, are propagated in the form of cyclical compressions and rarefactions which move through the material medium (gas, liquid or solid). But analysis made clear that in the "second sound" wave, with the two components oscillating in opposite directions, there would be almost no compression or rarefaction of the liquid as such. Since a mechanical sound generator predominantly excites the compression and rarefaction waves of ordinary sound in helium II, the second sound turns out to be too weak to be detected.

However, these considerations suggested another way to detect the second sound waves. The opposed oscillations of the normal and superfluid components represent, in essence, oscillations of heat relative to the cold superfluid background. They should therefore cause oscillations of the liquid's temperature. It was natural to expect that such a "thermal wave" might also be radiated by a heater with oscillating temperature and that a heater of this kind might thus be made to serve as a second-sound generator. V. P. Peshkov of our institute performed the indicated experiments. They clearly confirmed the existence of second sound, in excellent agreement with the quantitative predictions of Landau's theory [*see chart at bottom of page 32*]. Second sound has since become one of the most important tools for investigation of helium II.

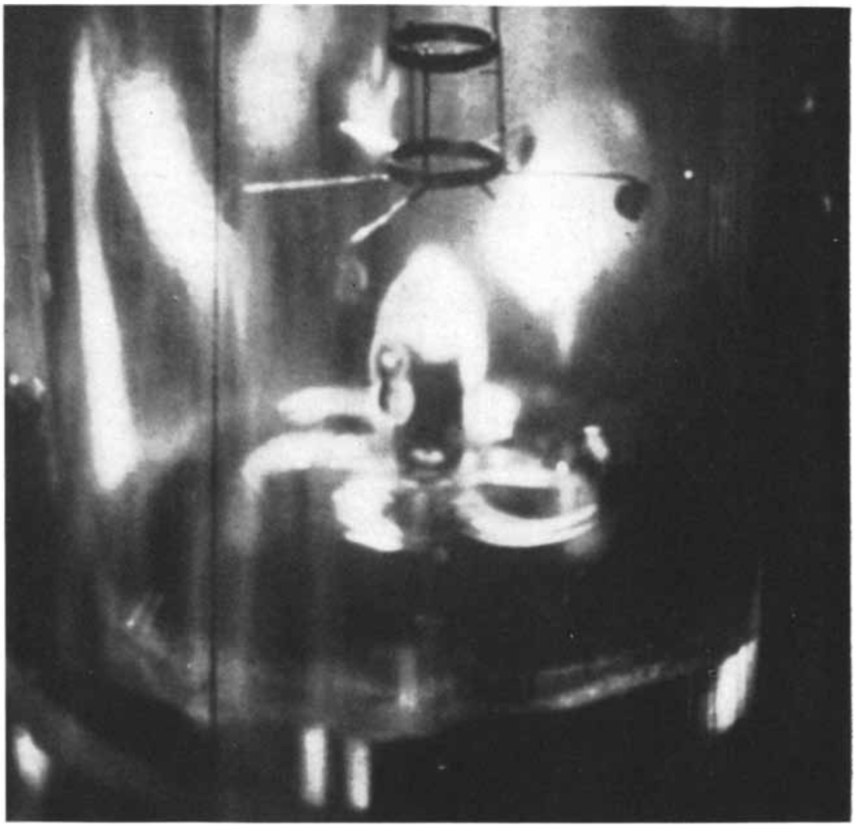
During the past 10 years Landau's theory has been developed further and has been supported by many experiments. Results obtained in a number of the world's low-temperature laboratories have generally been in splendid agreement with the theory. There remain, however, unanswered questions about superfluidity. Low-temperature physicists are particularly intrigued by the so-called "critical" phenomenon, which I have deliberately not mentioned hitherto. The point is that helium II does not actually exhibit superfluidity under any and all conditions. These properties are lost if the liquid is forced to move too rapidly (the critical speed depending strongly on the experimental conditions). Significant progress on this problem has been achieved during the past three years. The seed was planted by Lars Onsager of Yale University at a conference nearly 10 years ago in a remark on turbulence in the flow of fluids that was not particularly noticed at the time. The importance of this remark was later recognized by Richard P. Feynman of the California Institute of Technology, who then developed Onsager's idea. These authors presented convincing arguments for the notion that the critical phenomenon is due to the formation in rapidly flowing helium II of a large number of microscopic vortices. In these vortices the superfluid component moves in a manner somewhat analogous to the way the air moves in a tornado. It would be difficult to detect such vortices directly, but H. E. Hall and W. F. Vinen at the Mond Laboratory in Cambridge have recently performed elegant experiments which give indirect evidence for the existence of the vortices, in particular the additional attenuation they induce in the second sound.

In concluding this short survey of the properties of helium II, I must return to the beginning of the article and correct a mistaken impression I may have created there. Helium is not a single substance; it exists in two stable isotopes, namely helium 4 and helium 3. As found in nature, helium is almost pure helium 4, and what has been said above refers to this isotope.

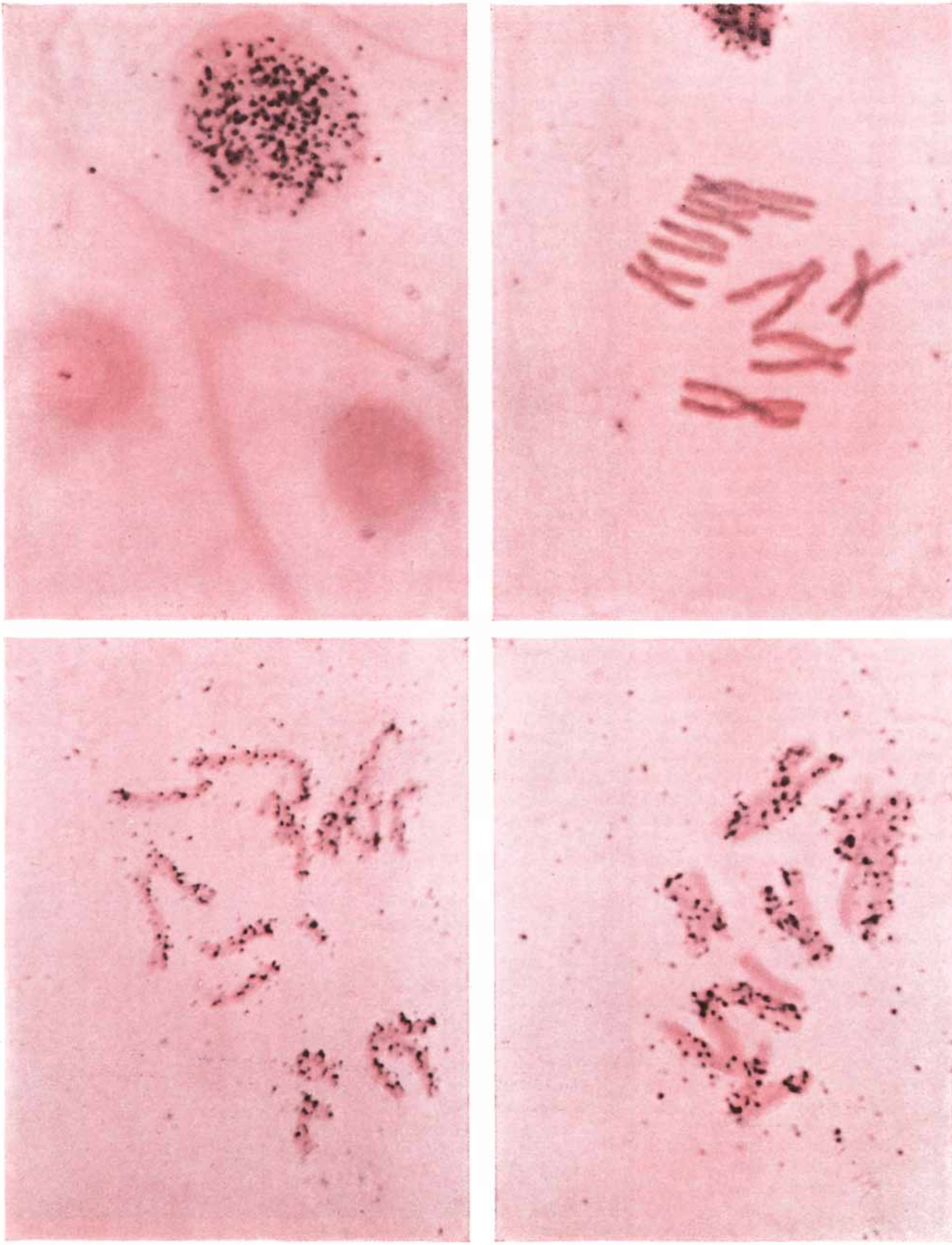
The enormous success of nuclear physics during the past decade has made it possible to obtain helium 3 in quantities sufficient for experimentation. In 1949 S. G. Sydoriak, E. R. Grilly and E. F. Hammel of the Los Alamos Scientific Laboratory showed that helium 3 liquefies at 3.2 degrees Kelvin, and a new "quantum liquid" was made available to physicists.

The isotopes of helium differ in an extremely important way which is related to the fact that the helium-4 nucleus contains an even number of particles (protons and neutrons), whereas that of helium 3 contains an odd number. This gives the two substances radically different quantum properties. (In physical terminology the helium-4 atom is said to obey Bose-Einstein statistics, whereas the helium-3 atoms obey Fermi-Dirac statistics.) There is every reason to believe that all liquids composed of "Bose-Einstein atoms" can become superfluid. As for liquids composed of "Fermi-Dirac atoms," there are in principle different possibilities. Only by experiment can we decide what we are dealing with in helium 3, the only Fermi-Dirac liquid in nature.

Experiments first performed by D. W. Osborne, B. Weinstock and B. M. Abraham at the Argonne National Laboratory have shown that liquid helium 3 does not become superfluid. The properties of this liquid thus lie outside the scope of an article on superfluidity. But I wish to note that in helium 3 physics has been provided with a "quantum liquid" of a new type. Though its properties are somewhat less spectacular than those of helium 4, they are no less interesting.



HELIUM TURBINE designed by Kapitza consists of small double-walled flask turned upside down and hung on the point of a needle in a helium bath. Helium flowing from inside the flask through the six bent capillary tubes causes the turbine to spin when light is shined upon it (*bottom*). This motion is stopped when the six vanes above the turbine are slipped down to oppose the reactive force of the outflowing helium. Inflowing helium II which replaces outflowing helium exerts no force, and the turbine remains motionless.



CHROMOSOMES of Bellevalia, a plant of the lily family, are tagged with radioactive thymidine in experiment on duplication. Radiation from the thymidine strikes photographic film placed over the cells, producing black specks. The upper nucleus in the photomicrograph at top left has taken up the tracer material but its chromosomes have not yet become visible. Chromosomes at top right completed their duplication before the cells were placed in radioactive solution and are not tagged. Those at bottom left duplicated once in radioactive solution. Both members of each pair are labeled. The chromosomes at bottom right duplicated once in radioactive solution and once after cells were removed. Only one member of each pair is tagged, except where segments crossed.

The Duplication of Chromosomes

It is generally assumed that the basic genetic material is DNA (deoxyribonucleic acid). How are the molecules of DNA arranged in the chromosome, and how do they make replicas of themselves?

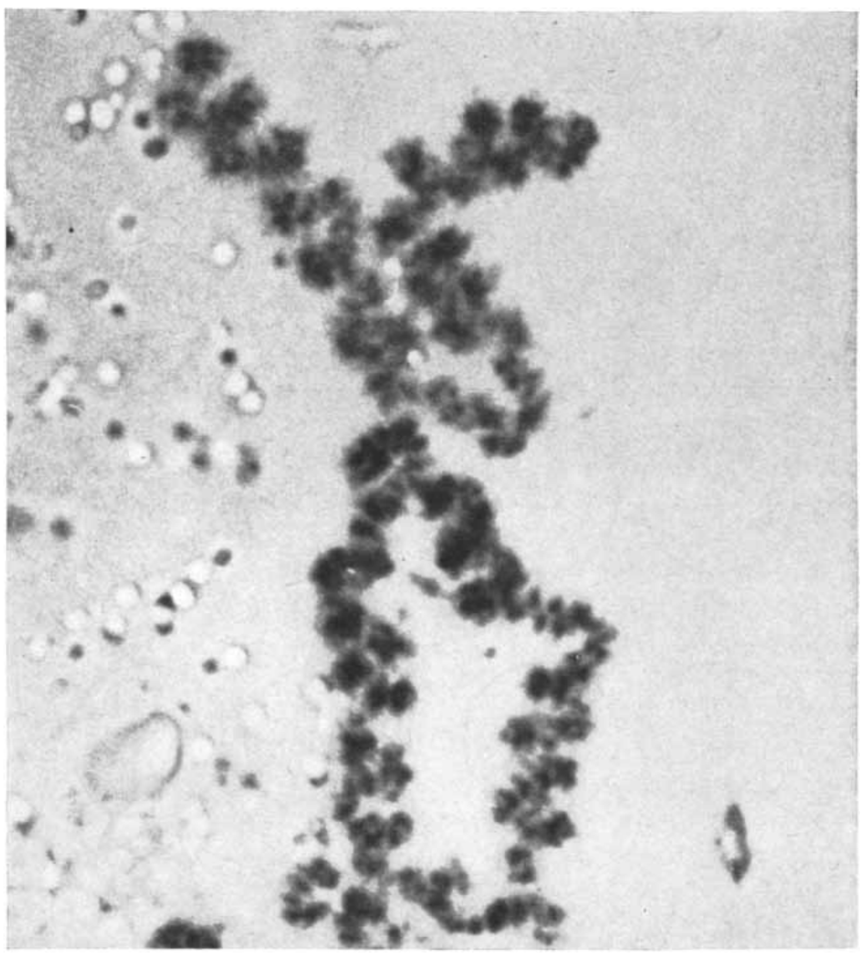
by J. Herbert Taylor

In the search for the secret of how living things reproduce themselves, geneticists have recently focused on the substance called DNA (deoxyribonucleic acid). DNA seems pretty clearly to be the basic hereditary material—the molecule that carries the blueprints for reproduction. F. H. C. Crick and J. D. Watson have found that the molecule consists of two complementary strands, and they have developed the theory that it duplicates itself by a template process, each strand acting as a mold to form a new partner [see "Nucleic Acids," by F. H. C. Crick; SCIENTIFIC AMERICAN, September, 1957].

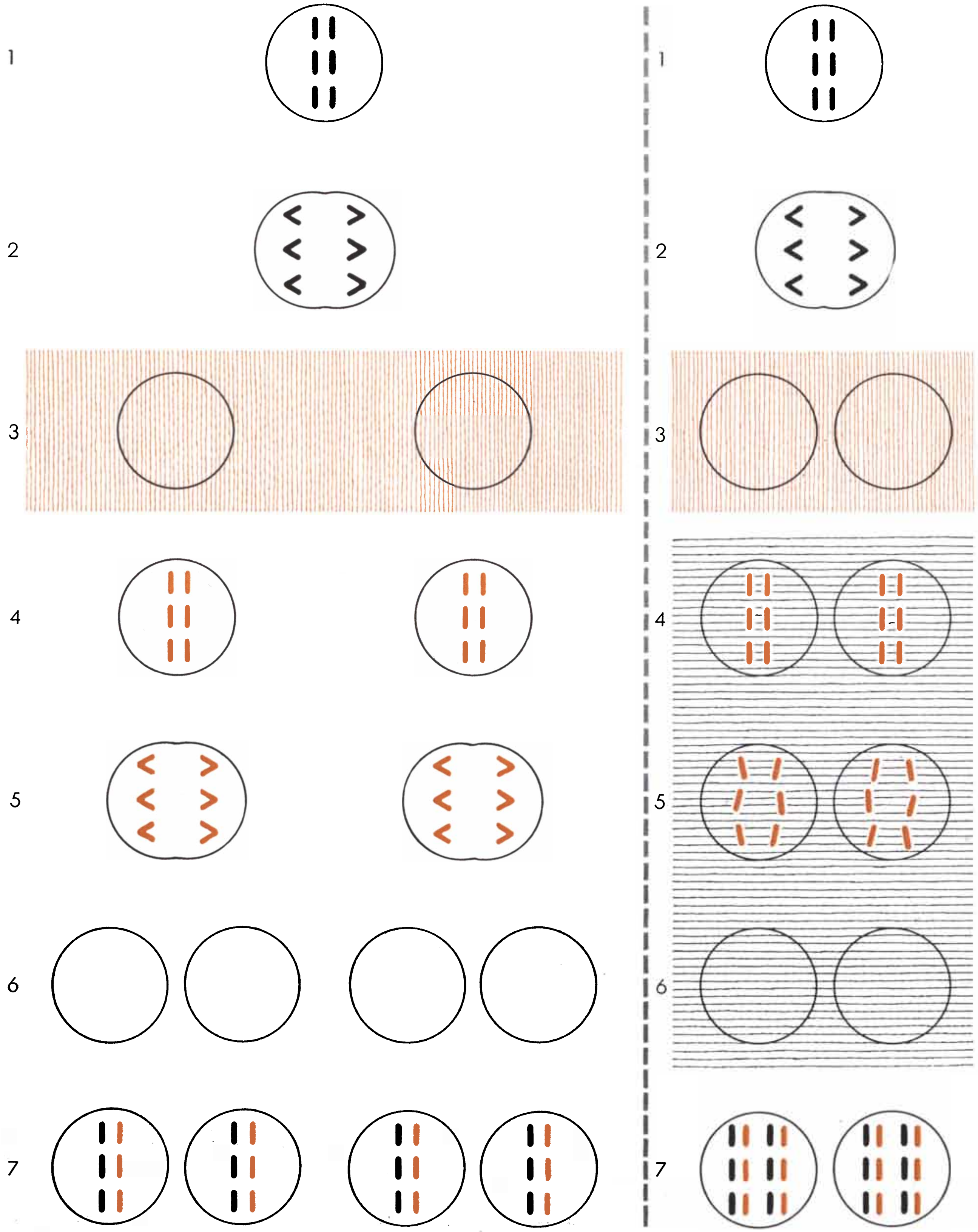
The problem now is: How does this model fit into the larger picture of chromosomes? For half a century we have known that chromosomes, the rodlike bodies found in the nucleus of every cell, are the carriers of heredity. They contain the genes that pass on the hereditary traits to offspring. As each cell divides, the chromosomes duplicate themselves, so that every daughter cell has copies of the originals. How is the reproduction of chromosomes related to the reproduction of DNA? The question is being pursued by two approaches: from DNA up toward chromosomes and from chromosomes down toward the molecular level. This article will report some experimental studies of the behavior of chromosomes which have suggested a general model of the mechanism of reproduction.

Chromosomes take their name from the fact that they readily absorb dyes and stand out in strong color when cells are stained [*see photographs on the opposite page*]. They become visible under the microscope shortly before a cell is ready to divide. At that time each chromosome consists of a pair of rods side by side. When the cell divides, the two members of the pair (called chromatids) separate, and one chromatid goes to each daughter cell.

In the new cell the chromatid disappears. Then as this cell approaches division, each chromatid reappears, now twinned with a new partner. It has made a copy of itself for the destined daughter cell. There are two possible ways it may have done this: (1) by staying intact (even though invisible in the microscope) and acting as a template, or (2) by breaking down and generating small



DOUBLE COILED STRUCTURE of a chromosome can be seen in this photomicrograph, the magnification of which is about 4,000 diameters. Chromosome was partly unwound by treatment with dilute potassium cyanide. The chromosome is from a cell of the Easter lily.



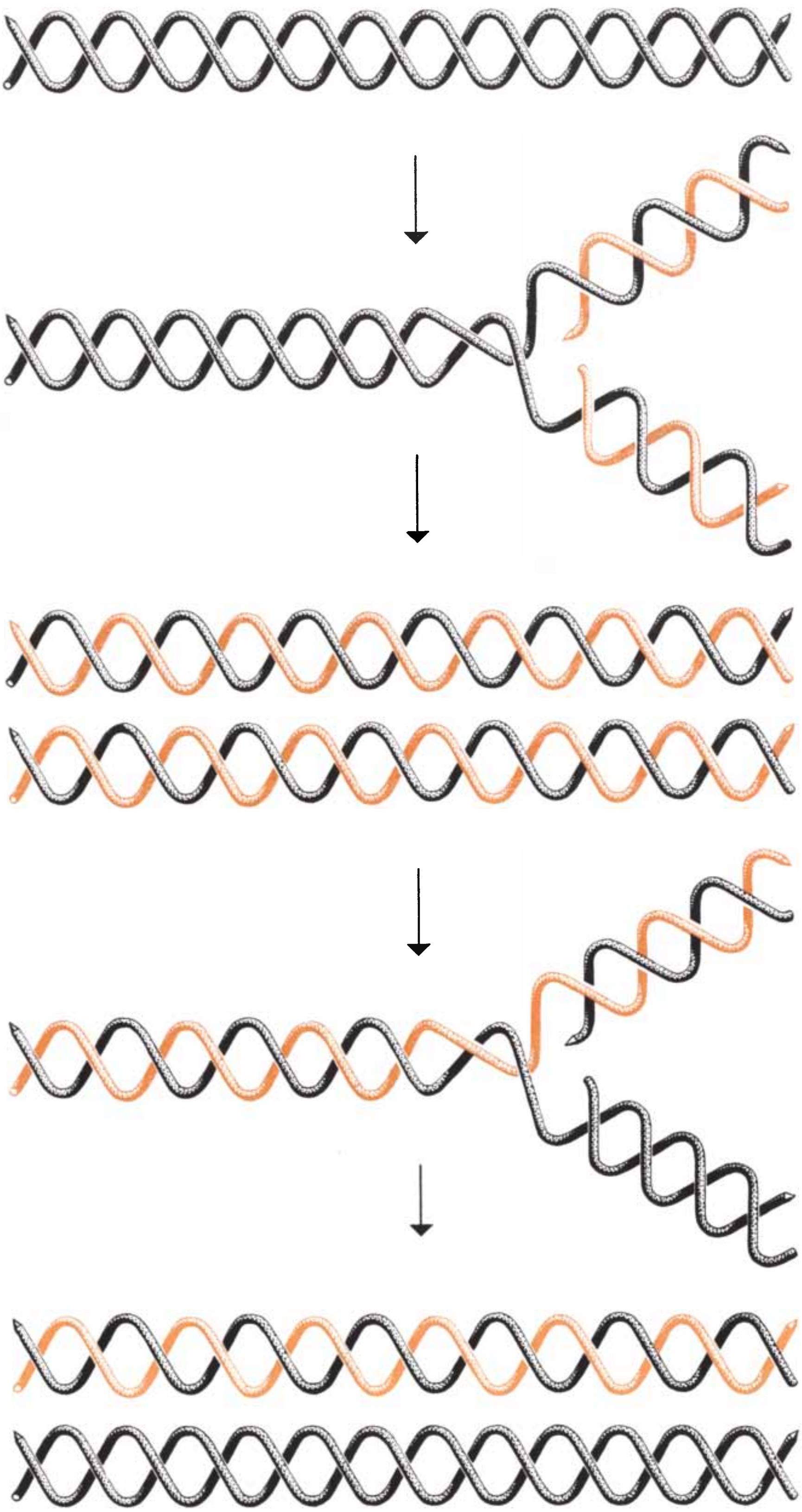
DUPLICATION CYCLES in tracer experiment are diagrammed schematically. Cells to left of the vertical broken line are allowed to divide normally. Those to the right are prevented from dividing when they are placed in colchicine (*black shading*), but their chromosomes continue to duplicate. Black rods represent unlabeled chromatids; colored rods, labeled chromatids. Colored shading indicates radioactive thymidine solution. The empty circles represent stage when chromatids are invisible and duplicating themselves.

units which then reassemble themselves in the form of the original chromatid.

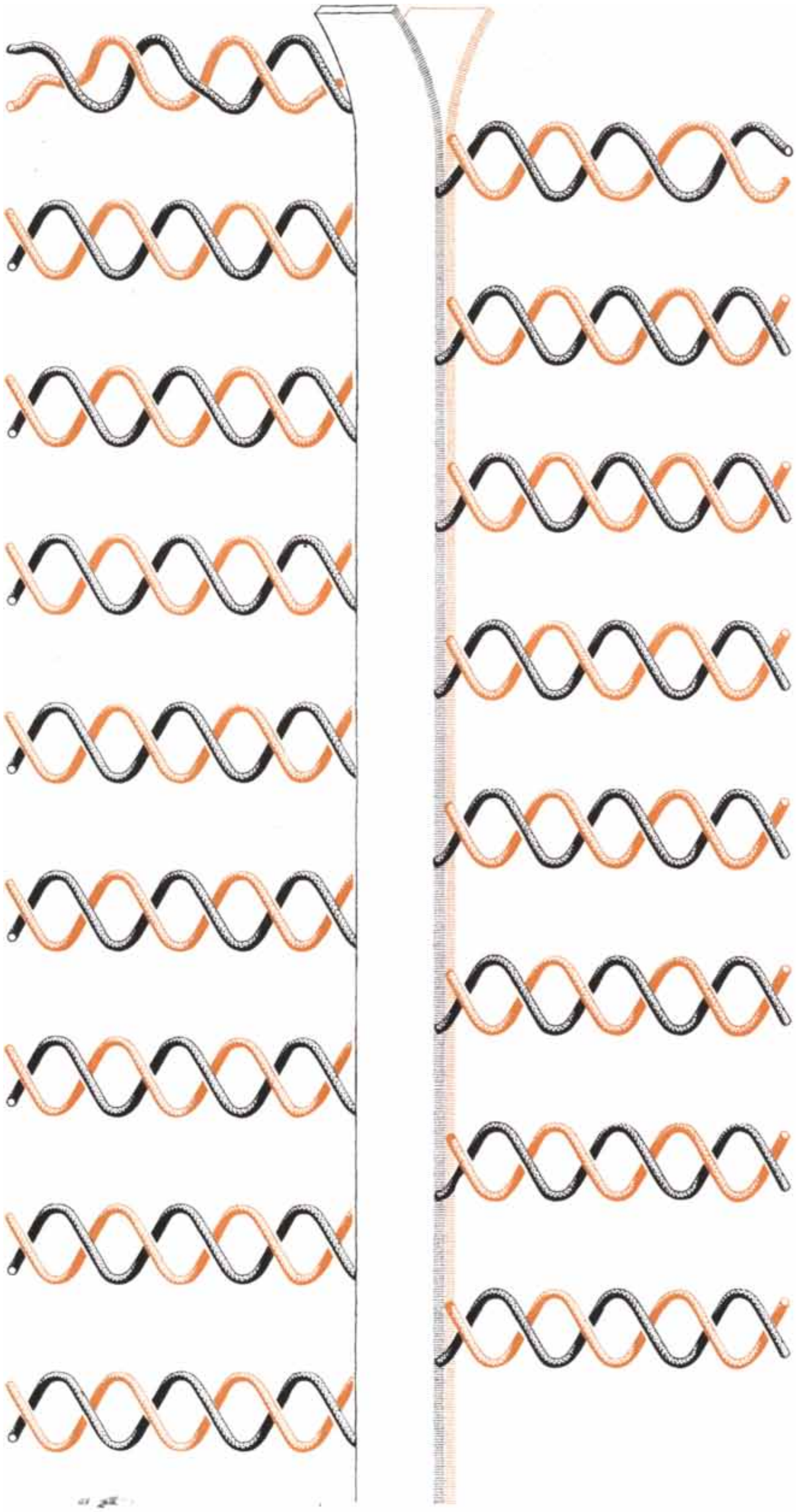
It has recently become possible to resolve this question by means of radioactive tracers. When cells grow in a medium containing thymidine, a component of DNA, all of the thymidine is taken up by the chromosomes; none of it is built into any other part of the cell. Thus if we label thymidine with radioactive atoms (the radioisotopes of hydrogen or carbon), we can follow the transmission of the material through successive replications of the chromosomes. For our own experiments, which I conducted in collaboration with Walter L. Hughes and Philip S. Woods of the Brookhaven National Laboratory, we chose radiohydrogen (tritium) as the tracer. This substance makes it possible to distinguish a radioactive chromatid from a nonradioactive one lying next to it. To localize the radioactivity we use the technique of autoradiography. The cells are squashed flat on a glass slide and covered with a thin sheet of photographic film. Radioactive emanations from the cells produce darkened spots on the film. The emissions from radioactive carbon are fairly penetrating and therefore darken a comparatively wide area of the film; we selected tritium instead because its emissions travel only a short distance—so short that we can narrow down the source to a single chromosome or part of a chromosome.

Our first experiment followed the fate of the thymidine through one duplication of labeled chromosomes. In order to control the situation so that we could identify newly formed chromosomes we treated the cells with colchicine—a drug which prevents cells from dividing but allows chromosomes to go on duplicating themselves. This enabled us to sequester the new chromosomes within the original cells and to tell how many generations had been produced. The cells we studied were those in the growing roots of plants, cultured in a solution containing tritium-labeled thymidine.

We found, to begin with, that in cells that had taken up this thymidine (*i.e.*, produced a new generation of chromosomes preparatory to division), all the chromosomes were labeled, and radioactivity was distributed equally between the two chromatids of each chromosome. This might suggest that the new chromosomes had been formed from a mixture of materials generated by a breakdown of the original chromatids. But when we



DNA MOLECULES consist of two complementary chains wound around each other in a double helix. When they duplicate, they unwind and each chain builds itself a new partner. Shown here are two cycles of duplication. The first cycle takes place in radioactive solution, producing two labeled chains (*colored helixes*). When a labeled molecule duplicates itself again in nonradioactive solution, only one of its descendants contains a labeled chain.



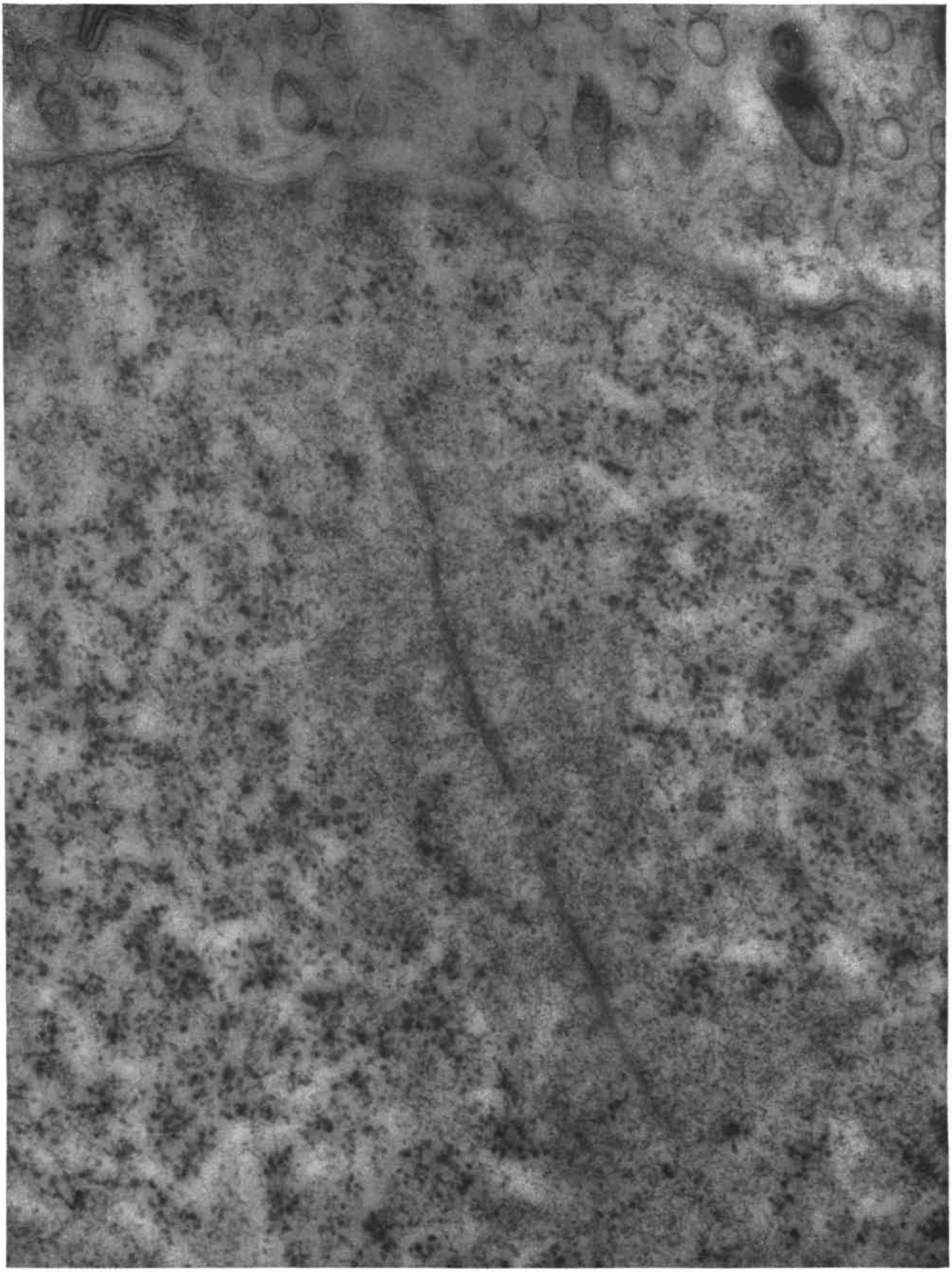
RIBBON MODEL of a chromatid consists of a two-layered central column to which DNA molecules are attached. One chain of each molecule is anchored to the front layer and the other to the back layer. When the chromatid duplicates, the central ribbon peels apart, unwinding the DNA molecules. Each half of the structure then builds itself a new partner.

followed root cells through a second generation of chromosome reproduction, where the second generation was synthesized in a medium containing nonradioactive thymidine, we found to our delight that in each new doubled chromosome one chromatid was labeled and the other was not!

What might this mean? The simplest and most likely answer was that a chromatid itself consists of two parts, each of which remains intact and acts as a template. In the radioactive medium each of the original chromatids, after splitting in two, builds itself a radioactive partner. Therefore all the new chromosomes are labeled. Now when the labeled chromatids split again to produce a second generation, half of the strands are labeled and half are not. In a nonradioactive medium all of them will build unlabeled partners. As a result, half of the newly formed chromatids will be partly labeled, half will have no label at all [*see diagrams on page 38*].

Our picture of the chromatid as a two-part structure fits very well with what we know about the DNA molecule and with the Crick-Watson theory. DNA too is a double structure, consisting of two complementary helical chains wound around each other. And some of our recent experiments indicate that the two strands of a chromatid are complementary structures. It is tempting, therefore, to suppose that a chromatid is simply a chain of DNA. But when we consider the question of scale, we realize that the matter cannot be so simple. If all the DNA in a chromatid formed a single linear chain, the chain would be more than a yard long, and its two strands would be twisted around each other more than 300 million times! It seems unthinkable that so long a chain could untwist itself completely, as the chromatid must each time it generates a new chromosome. Furthermore, the chromatid has the wrong dimensions to be a single DNA chain. When fully extended, it is about 100 times thicker and only one 10,000th as long as the linear DNA chain would be.

Under a high-power microscope we can see that the chromatid is a strand of material tightly wound in a helical coil—in fact, so strongly wound that the coil itself often winds up helically, like a coiled telephone cord which is twisted into a series of secondary kinks [*see photograph on page 37*]. But beyond this the optical microscope cannot resolve details of the chromatid's structure. Assuming that it is made up of pieces of DNA as its



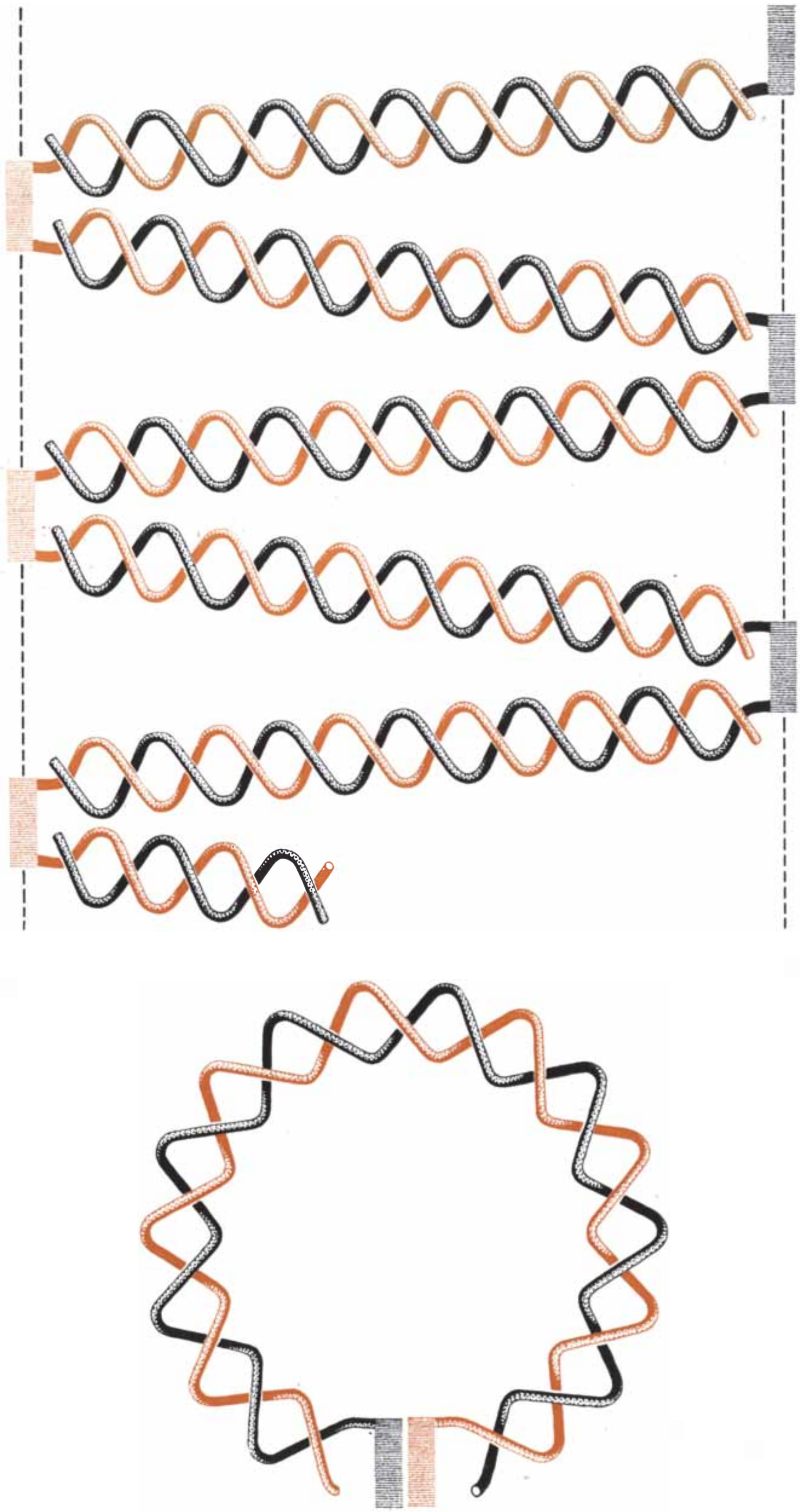
CHROMATID appears as a linear structure running diagonally down the middle of this electron micrograph, made by Montrose J. Moses of the Rockefeller Institute for Medical Research. The magnification is some 50,000 diameters. The line may represent the central column in the author's models and the fuzzy material surrounding the line may be DNA strands running perpendicularly outward.

basic replicating units, what sort of model can we imagine to explain its construction?

We know that chromosomes contain protein. So as a start we may picture the chromatid as a long protein backbone with DNA molecules branching out to the sides like ribs [*see diagram on page 40*]. Because the chromatid splits in two, we visualize the backbone as a two-layered affair whose layers can separate. The ends of the two strands of a DNA molecule are attached to these layers: one strand to one layer, the complementary strand to the other [*see diagram*]. As the layers peel apart, they unwind the strands. The unwinding strands promptly begin to build matching new strands for themselves. Eventually the new strands also assemble a new backbone, and the original chromatid is thus fully duplicated.

This model seems to have all the necessary mechanical specifications except one. The genes in a chromosome are arranged in a fixed linear order. Here the DNA segments, with one end waving freely about, are not so arranged. To meet this objection Ernst Freese of Harvard University has suggested a slightly different model which joins the free ends of the DNA molecules so that they form a definite sequence. Instead of one spine there are two, with the DNA segments crossing between them somewhat like the rungs of a ladder [*see diagram at the left*]. The spines may consist of blocks of protein joined by flexible bonds involving calcium atoms. The DNA rungs zigzag so that they march up the ladder, and the points on the rungs thus have a sequential order.

Now we can suppose that the calcium bonds give the structure considerable flexibility, allowing it to fold and coil on itself. The two spines may come together and so form a long tube [*see lower drawing at left*]; the tube may then coil into a tight helix. Replication in this model is accomplished by a stretching of the chain and unwinding of the DNA strands, each of which has one free end, as the diagrams show.



ANOTHER MODEL of the chromatid places its molecules of DNA between two columns, with one chain of each molecule attached to the left-hand column and the other to the right-hand column. Shaded rectangles represent structural material of the columns; broken lines indicate bonds which may include calcium. When the chromatid becomes visible, the columns come together so that the structure appears as in lower drawing when viewed end on.

Recently Montrose J. Moses of the Rockefeller Institute for Medical Research and Don W. Fawcett of Cornell Medical College, using the electron microscope, have obtained pictures of chromatids which do indeed show a spine structure with DNA branches [*see photograph on page 41*]. It appears that we are beginning to penetrate down to the detailed mechanisms of the duplication of life.

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•

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From our Stuttgart factory we are now importing these *Kodak Retina Reflex Cameras*. They sell for $215 with the basic 50mm *f*/2 *Retina Xenon-C* 6-element coated lens. Interchangeable 6-element components are available to provide a focal length of 35mm for wide angle or 80mm for telephoto work. There must be a good reason why noble optical equipment should be named after a noble gas. German engineers never do anything illogical.

With *f*/2 and the remarkable film sensitivity now obtainable, surprisingly many pictures will be made with no auxiliary light at all. For the rest, the camera provides synchronization with all popular flashbulbs and discharge lamps at speeds up to 1/500 second.

For a happy-moments camera employed occasionally in a bat cave the coupled split-image rangefinder of the *Retina Reflex* would suffice. This camera extends itself beyond aim-and-fire applications. For technical work, as in photomicrography with the *Kodak Retina Microscope Adapter Kit*, *Type C*, the other and larger aspect of its character comes into play.

The rangefinder split-field is but the center of a truthful preview of the entire picture, seen upright and laterally correct. This image is formed at full lens aperture by the taking lens itself, so that even at only six inches film-to-subject distance (as with one of the *Kodak Retina Close-Up Lens Sets* instead of a microscope) the boundaries of the 24mm by 36mm picture inevitably coincide exactly on the ground glass as on the film. Since the entire picture may be examined on its extra-fine surface, the focusing may be adjusted to favor any portion thereof without re-aiming—a simple point worth remembering when comparing cameras of this type.

Phone a camera shop and check whether they have yet received a Kodak Retina Reflex Camera *you can examine. If we had known you were interested, we would have left room here for details on the built-in photoelectric exposure meter, the mechanical linkage of shutter speed to diaphragm setting, and the way the instant before exposure it stops down to the aperture chosen.*

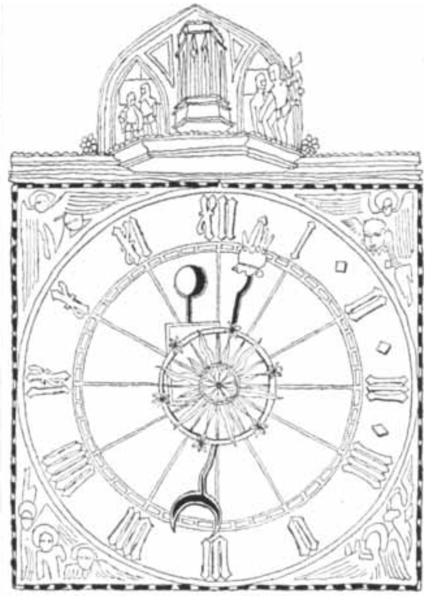
Price stated includes Federal Tax and is subject to change without notice.

*For the instruction of the young, that's how long it takes response to drop off to 1/e what it was before the radiation was turned off. e is the base of natural logarithms and is worth around 2.72.

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

Kodak
TRADEMARK

SCIENCE AND



four years of history and social studies, and a year each of mathematics and science. For the more able youngsters (the top 15 per cent) he would add a "tough program" including three years of a foreign language, three years of mathematics and two of science plus "either another year of mathematics and a tough physics course or three years of a second language." Conant believes that the high schools, "with good guidance," could persuade a high percentage of the boys to elect this program. For the girls, he said, "I hesitate to make an equally bold statement."

Conant on High Schools

James B. Conant, president emeritus of Harvard University, is making a study of U. S. high-school education under a grant from the Carnegie Corporation of New York—a study comparable to the survey of medical schools made by Abraham Flexner 50 years ago. Last month Conant reported some of his conclusions at a meeting of the National School Boards Association. His main impression so far is that by and large the high schools are not doing enough for able students, particularly girls.

Conant has concentrated his attention on general high schools serving small cities and consolidated school districts. Taking only the best of these schools and their "academically talented" students for a special study, he finds that in these schools two thirds of the able boys take three or more years of mathematics and a course in physics. Of the able girls, less than half take as much as three years of mathematics, and they are "conspicuous by their absence" from physics courses. The situation in foreign languages is less satisfactory than in science and mathematics. Most of the general high schools offer no more than a two-year course in any language.

Conant urged that schools improve their counseling programs to persuade good students to elect programs appropriate to their ability. He remarked that the tendency of even able girls in high school to choose "soft programs" is depriving the nation of many potential science and mathematics teachers.

As a minimum academic quota for all high-school students Conant recommended four years of English, three or

News from the Satellites

Last month scientists who have been following the U. S. Explorer satellites reported the facts learned to date at a meeting of the National Academy of Sciences in Washington. The most surprising finding: radiation at the borders of space outside the earth's atmosphere is much hotter than had been suspected.

The two Explorer satellites carry Geiger counters to record cosmic rays. It has turned out that in the outer range of their orbits—above 600 miles—the counters begin to click at a furious rate and then suddenly go dead. Suspecting that the counters are jammed by extraordinarily intense radiation in these regions, physicists have tested the effects of intense X-rays on duplicates of the Explorers' counters in the laboratory. They find that the counters jam at a level which indicates that the Explorers are being bombarded by radiation with an intensity of about 35,000 counts per second.

This is about 1,000 times more intense than the cosmic radiation sounded by rockets in our upper atmosphere. The physicists doubt that the new radiation is cosmic rays; they think it may be a stream of protons or electrons from the sun such as produces auroras. Whatever its source or nature, it must have a major heating effect on the atmosphere. It looks bad for space travelers.

James A. Van Allen, designer of the radiation studies with the satellites, suggested that the new radiation stems from ionized gas from the sun, which may accumulate in the region between 600 and 8,000 miles from the earth, where it is held out by the earth's magnetic field. The intense radiation in a satellite would be X-rays produced by a rain of electrons on its metal skin.

Another report at the meeting described how the temperature inside the Explorers is controlled. The outer surface of the satellites is coated with a patchwork of two materials of different reflecting and conducting properties. By choosing a proper balance between the two, the designers have succeeded in holding the internal temperature within the range from zero to 40 degrees centigrade, which allows the satellites' electronic equipment to function.

The Explorers have confirmed what the Sputniks had previously shown: that the upper atmosphere is denser than had been thought. At 220 miles the air density is about two ounces per cubic mile.

Fusion Research

A few more layers of secrecy were peeled off the U. S. thermonuclear power program at a meeting of the American Physical Society in Washington last month. Reports from three major laboratories provided glimpses of previously undisclosed work.

Lyman Spitzer, Jr., director of Project Matterhorn at Princeton University, described the stellarator, a hitherto classified device. The stellarator produces a magnetic "bottle" for a plasma by means of an externally applied magnetic field, instead of by the pinch effect of electric currents in the plasma.

The essence of the stellarator's design is the shape of its magnetic field. The lines of force wind helically around the axis of the tube containing the gas. Spitzer's group has shown that a stable plasma can be maintained in such a field.

The stellarator is a doughnut-shaped tube surrounded by a series of circular coils which provide the magnetic field. The necessary twist in the lines is produced either by an auxiliary coil, wound in a slant around the tube, or by bending the doughnut into a figure 8. Heating of the gas in the tube takes place in two stages. First it is raised to a temperature of about one million degrees centigrade by a heavy electric current. At this temperature the hot gas no longer resists the flow of current appreciably, so the current cannot heat it further. To raise the temperature higher, a high-frequency generator is hooked up to make the magnetic field pulsate, thus pumping a larger quantity of heat energy into the gas.

The Princeton group has been experimenting with small models which have not attained the temperatures necessary to ignite a self-sustaining fusion reaction (about 100 million degrees). A larger version, to be finished in 1960, is expected to reach these temperatures.

Another type of magnetic container, called the "mirror machine," was described by Richard F. Post of the University of California Radiation Laboratory [see "Fusion Power," by Richard F. Post; SCIENTIFIC AMERICAN, December, 1957]. A system of coils around a straight tube is so arranged that the coils at the ends of the tube carry an extra-heavy current and produce densely crowded lines of magnetic force. The net effect is to form a field shaped something like a football, or a wine bottle with a neck at each end. Plasma particles approaching the ends are reflected back by the converging magnetic lines, just as a ball thrown into the wide mouth of a funnel would bounce out again. By varying the currents through the coils the double-ended bottle can be made narrower, shorter, or both, thus compressing and heating the contained gas. If the mirror machine can succeed in heating the gas hot enough to produce a fusion reaction (which it has not yet done), then power might be extracted by a reverse of the compression process. The hot plasma would be allowed to push back the magnetic walls, delivering energy to them just as expanding steam delivers energy to a piston.

Almost as difficult as containing a hot plasma is the problem of injecting it into the magnetic bottle to begin with. A group at Oak Ridge National Laboratory is developing a device not only for injecting a plasma but also for bringing it up to thermonuclear temperatures. Charged molecules of deuterium (each containing two atoms) are fired from an accelerator into a magnetic field. Ordinarily the particles would be bent in a semicircular path and would return to the injector. The Oak Ridge scheme ingeniously changes the path by breaking down the molecule into its atoms. At the point of the molecules' deepest penetration into the field, an electric discharge dissociates each molecule into one neutral and one charged deuterium atom. The neutral atom escapes from the field; the charged atom, with half the mass of the original molecule, is bent into a tighter circular path and stays in the field. The energy of the injected particles is much higher than that needed to produce nuclear fusion. Thus if enough of them can be accumulated in the trapping field, they may collide with each other at a rate sufficient to set off a self-sustaining reaction. At present the Oak Ridge physicists are running their injector into a mirror machine. They believe that it should also work with the stellarator.

Commenting on the papers, Arthur E. Ruark, who heads the Atomic Energy Commission's thermonuclear power research, emphasized that none of the devices described had yet achieved ignition temperatures. Furthermore, he added, "There is no real proof that a thermonuclear reactor producing net power can be built. We are not yet sure that the plasma will be stable at the relatively high density and temperature which are required."

Outlook for Engineers

Campuses of U. S. engineering schools have more graduates this year than last, but fewer recruiters bidding for their services. Two thirds of a large group of colleges polled recently by *Chemical and Engineering News* reported that recruiting interviews are down, in some cases as much as 75 per cent. A canvass of leading chemical companies indicated that openings for new graduates have decreased by 33 per cent and that the demand for experienced chemists and engineers has dropped 42 per cent from the 1957 level.

Not all companies are cutting back. Almost 30 per cent said their needs are undiminished or even increased. Furthermore, since there were more jobs than applicants in 1957, this year's reduced demand may still provide places for all or almost all of the graduates.

Ten Years of WHO

The World Health Organization is celebrating its 10th anniversary this month in Minneapolis at its annual assembly. As its 300 delegates met, WHO issued a review of its achievements since it was set up by the United Nations 10 years ago.

The organization was able to report that it has wiped out malaria in Italy, French Guiana, Puerto Rico and other areas, has established a world-wide "intelligence service" for the detection of epidemics, has made progress in setting international standards for drugs and health regulations and has given fellowships to train more than 5,000 public health workers in some 70 countries.

WHO now has 88 member nations—more than the U.N. itself—and its services are not restricted to these. In 1956, for instance, it provided technical assistance to nearly 700 health projects in 120 countries and territories. Its agencies carry on a wide range of activities—from training midwives in Bali to carrying on research into the habits of snails that spread bilharziasis in Africa. Using potent weapons such as penicillin and DDT, it has waged large-scale campaigns against malaria, tuberculosis, yaws, trachoma and leprosy. And WHO has put equal effort into long-range programs to strengthen national health services and to provide schools for training doctors, nurses, sanitary engineers and other needed personnel. It acts as a central clearing house for information on diseases, and during the 1957 influenza epidemic this service enabled many countries to prepare stocks of vaccine before the epidemic reached them.

Telescope Aid

The ear of the radio telescope at the Naval Research Laboratory in Washington is being made 100 times keener by fitting it with a synthetic-ruby hearing aid. The 10-carat gem oscillates at the same microwave frequencies as weak radio signals from far-away heavenly objects and thus acts as a noise-free amplifier. The device is a solid-state "maser" ("microwave amplification by stimulated emission of radiation"). The maser principle was first demonstrated in gases by C. H. Townes of Columbia University, and Townes and others are now applying it to the radio telescope.

The maser telescope will be used first to examine radio waves from Venus to check the planet's surface temperature. According to Townes, the short wavelengths used—three centimeters—allow greater precision in observation than longer wavelengths and also simplify technical problems.

Radio Jupiter

Radio astronomers have known for several years that Jupiter emits sporadic radio noise. It was believed to come from thunderstorms in Jupiter's atmosphere. Now a research group at the University of Florida has found that the signals apparently are coming from the solid surface of the planet rather than from its atmosphere. If so, the signals provide man with his first peek through the clouds surrounding the planet.

T. D. Carr and three colleagues have

been listening in on Jupiter at a frequency of 18 megacycles. According to their report in *The Astrophysical Journal*, time variations in the signals indicate that they arise from three distinct sources at widely separate points. The sources have maintained the same relative positions and a constant period of rotation (9 hours, 55 minutes, 28.8 seconds) for more than five years. They could hardly do this unless they were anchored to the rotating surface of the planet. In their distribution of frequencies and their sudden appearances the signals resemble those from a solar burst. The authors suggest that they may be produced by eruptions of hot gas from Jovian volcanoes.

Abstracting Machine

Scientists struggling with the flood of technical literature may soon get some mechanized assistance. H. P. Luhn of the International Business Machines Corporation has programmed a 704 computer to "read" articles (on punch cards) and to click out a crisp summary of their contents. The summary, which Luhn believes is as good as or better than a man-made abstract, consists of a few of the most significant sentences from the article, quoted in their entirety.

To weigh significance the machine lists every word used in the text and counts the number of times each appears. Discarding trivial words such as "the" and "and," the automatic abstracter prepares a table of the most-used words. It then scans each sentence and picks out the ones that contain the greatest concentrations of these words. The highest-scoring sentences are printed as the abstract.

Luhn points out that one advantage of the machine is that it judges significance objectively, not from the prejudiced point of view of a specialist. What its abstracts "lack in sophistication, they will more than make up for by their uniformity of derivation."

Reporting in the *IBM Journal of Research and Development*, Luhn presents as a sample of the machine's work its abstract of the article "Messengers of the Nervous System," by Amedeo S. Marrazzi, which appeared in Scientific American in February, 1957. The article dealt with the communication system of the body as an interaction of hormones and nerve impulses, and discussed mental disorders as disturbances of communication. The IBM 704 picked out four significant sentences as a summary of the article. Its abstract reads:

"It seems reasonable to credit the single-celled organisms also with a system of chemical communication by diffusion of stimulating substances through the cell, and these correspond to the chemical messengers (*e.g.*, hormones) that carry stimuli from cell to cell in the more complex organisms.

"Finally, in the vertebrate animals there are special glands (*e.g.*, the adrenals) for producing chemical messengers, and the nervous and chemical communication systems are intertwined: for instance, release of adrenalin by the adrenal gland is subject to control both by nerve impulses and by chemicals brought to the gland by the blood.

"The experiments clearly demonstrated that acetylcholine (and related substances) and adrenalin (and its relatives) exert opposing actions which maintain a balanced regulation of the transmission of nerve impulses.

"It is reasonable to suppose that the tranquilizing drugs counteract the inhibitory effect of excessive adrenalin or serotonin or some related inhibitor in the human nervous system."

Breath of Life

The best method of artificial respiration is to blow air into the mouth of the victim; so say a group of physicians who have made a thorough comparative test of the various methods of resuscitation. They found that the blowing stratagem is much more effective, and easier for anyone to apply, than the Holger Nielsen push-pull method currently in favor and recommended by the American Red Cross.

Three physicians—Peter Safar and Lourdes A. Escarraga of Baltimore and James O. Elam of Buffalo—conducted the study and report the results in *The New England Journal of Medicine*. They anesthetized volunteer subjects with the drug curare, which paralyzes the muscles. Then they had both trained and untrained persons work on reviving the subjects by the various methods. They used instruments to make accurate measurements of the amount of air moved into the lungs. After hundreds of trials they concluded that the blowing method is superior in every way: it gets more air into the lungs and has the surest success in restoring breathing.

The blowing method, the oldest known to man, presumably fell out of favor for esthetic or sanitary reasons. To meet these objections the doctors suggest a tube instead of mouth-to-mouth contact. They demonstrated the tube technique to 87 operators and all were able to use it successfully.

CATTLE

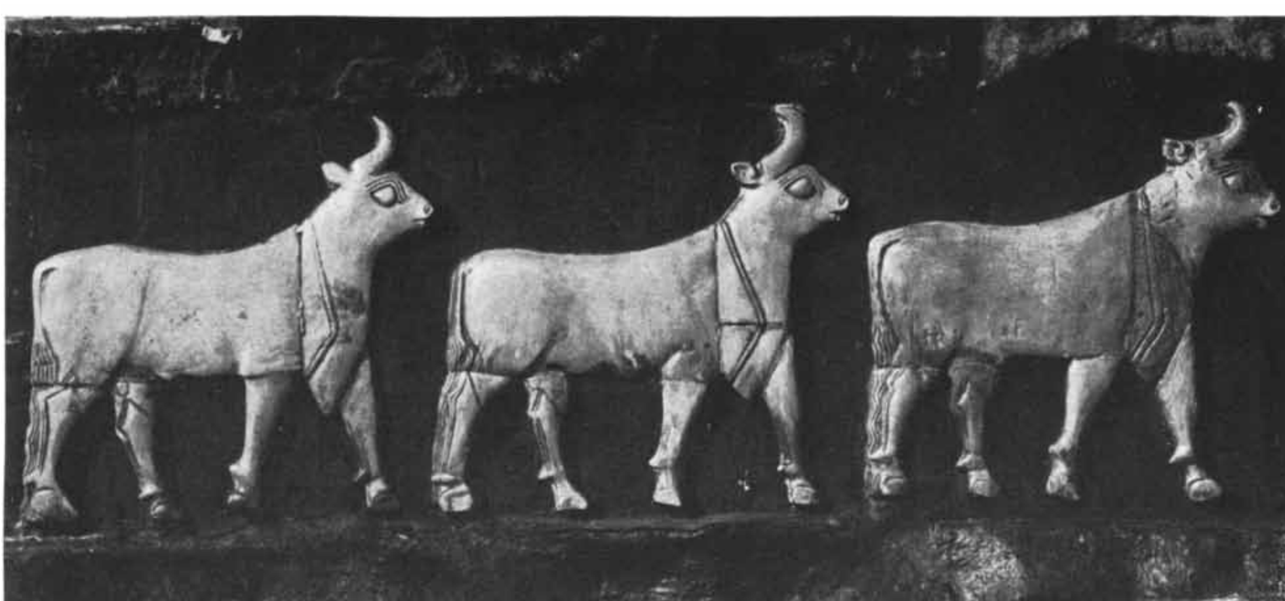
They can convert otherwise useless vegetation into milk and meat. Physiology and genetics are now showing how they can be made to do so more efficiently in widely varying environments

by Ralph W. Phillips

Cattle stand first among the animals serving man. They are outnumbered, it is true, by sheep, and they are outranked in man's esteem by the horse and the dog, but no other domestic animal renders such a variety of important services to human well-being. To the American or European consumer, cattle represent beef, veal, milk, butter, cheese and leather; behind the scenes in the packing house they yield in addition hormones and vitamin extracts, bone meal for feed and fertilizer and high-protein concentrates for livestock feeding. This does not exhaust the catalogue of their utility. More than a third of the world's 800 million cattle are engaged primarily in the generation of brute energy for the tasks of plowing, hauling and milling.

Considered as machines for converting vegetable matter into human food, cattle are not particularly efficient. The best such machine is the pig, which converts about a fifth of what it eats into food for human consumption. A dairy cow converts less than a sixth, a beef steer no more than a twentieth. Even these figures refer to animals bred for food production and raised by up-to-date techniques; the cattle of Asia and Africa, bred mainly for work, are less efficient. Cattle, however, convert foodstuffs which are otherwise useless to man. The efficient pig must subsist almost entirely on concentrated carbohydrates and proteins; its food could, at least in theory, be consumed directly by human beings. But cattle, though they need more food than pigs to yield the same number of calories, feed in part on cellulose, which they digest with the help of certain microorganisms in their enormous stomachs. By using cattle as intermediaries we can process the vegetation of semi-arid grasslands which cannot be farmed in any other way. Recent studies suggest that some day we may even use cattle to produce food from sawdust [see "The Metabolism of Ruminants," by Terence A. Rogers; Scientific American, February].

But if the world's food problem is to be solved, we must find ways to improve



IMPORTANCE OF CATTLE early in human history is shown by their recurrence in wall paintings and sculptures such as this Sumerian frieze. In early civilizations cattle were used not for food but mainly for work, as in most of Africa and Asia today.

the efficiency with which cattle convert fodder, of whatever sort, into meat and milk. Selective breeding of cattle to this end has been going on for several centuries in western Europe. There, and more recently in America, cattle breeders have achieved remarkably good results considering the empirical methods they have relied upon. Only during the past 20 or 30 years have scientific physiology and genetics come into play. Though many important questions remain unanswered, scientists have already done much to help cattlemen improve existing breeds and develop new breeds which can produce efficiently in unfavorable environments.

Breeds

We do not know when or where cattle were first domesticated. Cave paintings and bits of charred bone tell us that primitive man in Europe and Asia hunted wild cattle of various species, and our domestic cattle must be descended from one or more of these. In Europe the wild species are all extinct, though one of them, the aurochs, survived in remote parts of eastern Europe as late as the 17th century. Similar wild species still roam the forests and savannas of southeast Asia. The Americas have no native cattle, nor does Australia. Our best guess is that cattle were domesticated at least 10,000 years ago somewhere in central or southern Asia by nomadic tribesmen who raised them for meat and milk. As agricultural and urban societies developed, cattle came to be used primarily as draft animals. So great was their economic importance in this role that the Egyptians, Assyrians and other ancient peoples worshipped them as gods. Indeed, until the coming of steam they were man's main source of power other than his own muscles; the heavy draft horse is a relatively recent development.

Even in ancient times herdsmen seem to have practiced some sort of selective breeding. The Mosaic law specifically provides that "thou shalt not let thy cattle gender with a diverse kind." Jacob, under his shrewdly drawn contract with Laban, succeeded in making his fortune by judicious cattle breeding. As the 30th chapter of Genesis records, he relied in part on superstition, but he also employed the perfectly sound genetic principle that like tends to produce like. His "speckled and spotted" cattle produced calves of like coloring.

Thousands of years of domestication have produced dozens of more or less distinct breeds of cattle [*see drawings on pages 54 to 57*]. Almost all of them, however, seem to stem from two species: European cattle (*Bos taurus*) and Indian or zebu cattle (*Bos indicus*).

From the original European species breeders in western Europe and especially in the British Isles developed all but one or two of the popular milk and beef breeds in the world today. Their distribution on the world map [*see below*] follows that of the European settlers who took them along to the Temperate Zones of the Americas, New Zealand and Australia. In addition some minor breeds are found in northern and eastern Asia.

The beef breeds, including the white-faced Herefords and the black Aberdeen Angus of our midwestern and plains states, are typically low-set and blocky in appearance, with a relatively small percentage of bone and a good deal of fat. Dairy cattle, by contrast, are lean and angular, bred to turn every possible bit of feed into milk. Their udders are, of course, much larger than those of the beef breeds, and their swollen mid-sections bespeak a digestive tract capable of handling large quantities of grass.

The most important dairy breeds are the Holstein, the Jersey and the Guernsey. The Holstein, largest of the three, is also the most copious producer, but the other two give richer milk and are favored by dairymen who specialize in butter production and farmers who keep a few "family cows" to produce butter and cream as well as milk. The Ayrshire, perhaps the original "friendly cow, all

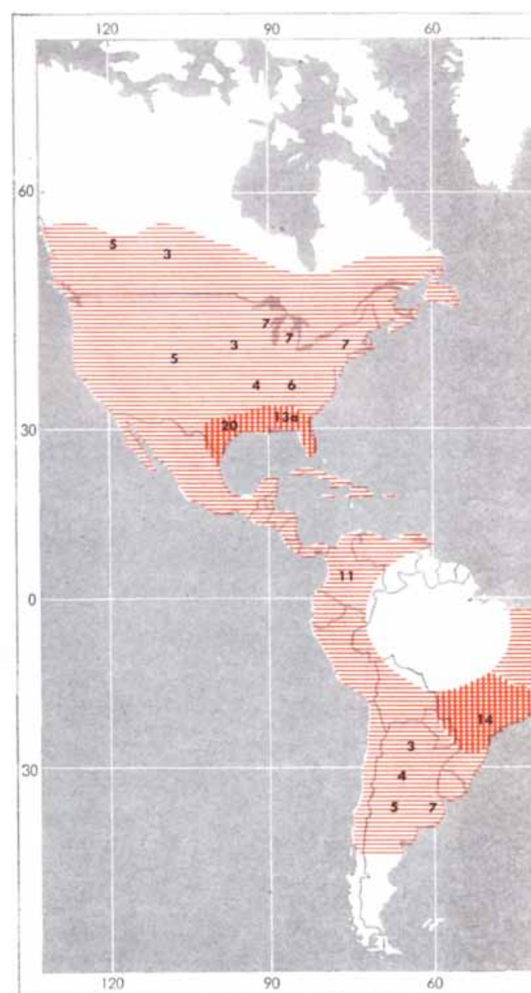
1. AYRSHIRE
2. WEST HIGHLAND
3. ANGUS
4. SHORTHORN
5. HEREFORD
6. JERSEY
7. HOLSTEIN
8. CHAROLAIS
9. BROWN SWISS
10. CHIANINI
11. BLANCO OREJINEGRO
12. WEST AFRICAN SHORTHORN
13. KANKREJ
13a. BRAHMAN
14. ONGOLE
15. SAHIWAL
16. KANGAYAM
17. BORAN
18. MADAGASCAR
19. AFRICANDER
20. SANTA GERTRUDIS
21. EGYPTIAN
22. ANKOLE
23. CHINESE "YELLOW COW"

CATTLE OF EUROPEAN TYPE

NATIVE ZEBU CATTLE

CATTLE OF INTERMEDIATE TYPE

INTRODUCED ZEBU CATTLE



WORLD DISTRIBUTION of the two main species of cattle indicates their adaptation to different climates. European cattle (*Bos taurus*) are found in most temperate regions; they red and white," is less well known, though it is a good milk producer.

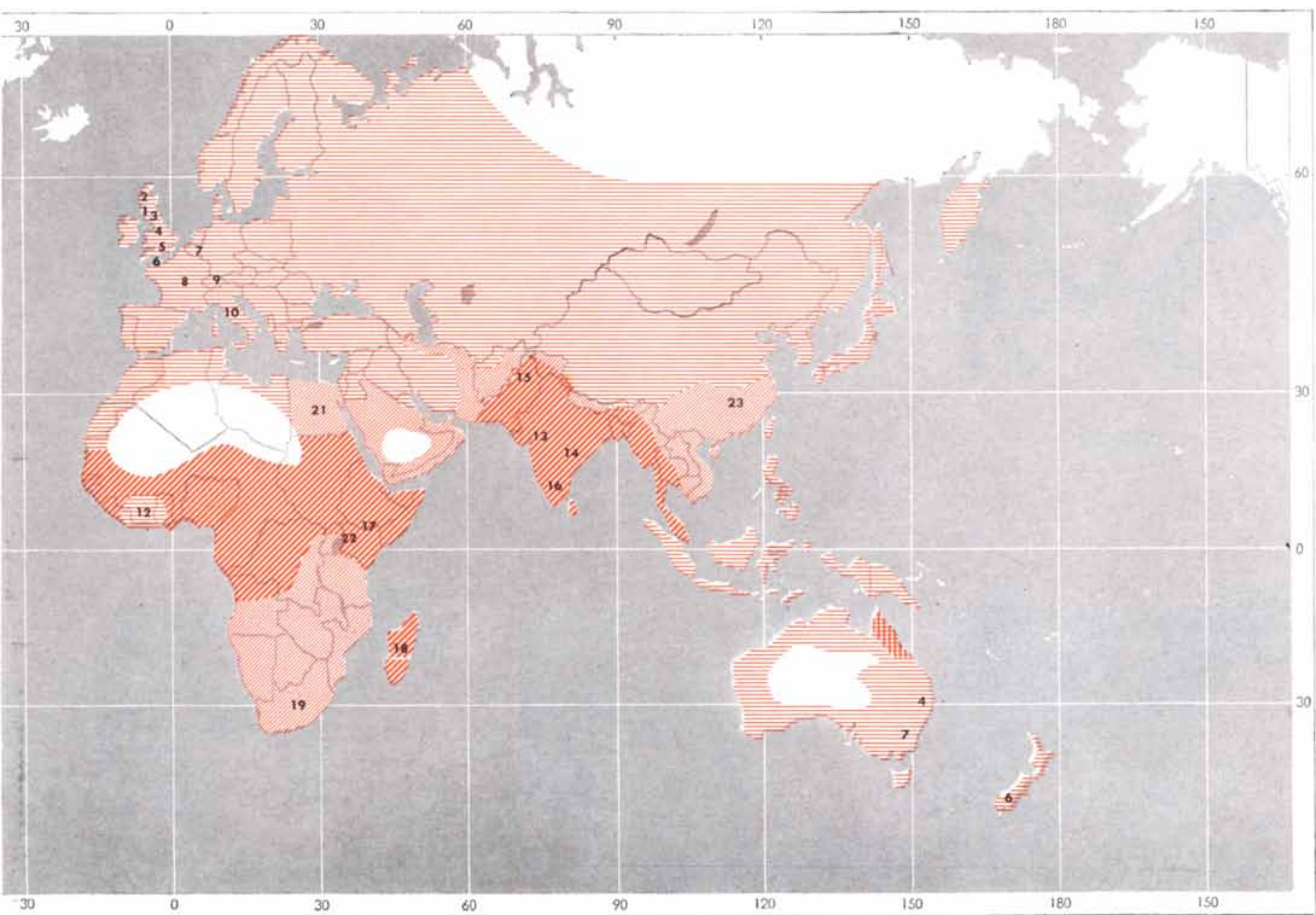
A number of European breeds are dual- or triple-purpose animals, used for milk and meat or for milk, meat and work. The Shorthorn is generally considered a dual-purpose breed, though different strains have been selected primarily for meat or for milk production. The Brown Swiss and the Simmenthal, also a Swiss breed, are triple-purpose animals in their native country. Many other European countries have developed their own dual- and triple-purpose breeds, but few of these have spread to other lands.

The Zebu

The zebu, the other great species of domestic cattle, probably originated in India but long ago spread, or was brought by man, into Africa and parts of southeast Asia. Thousands of years of natural selection have inured it to tropical conditions. In recent decades it has been successfully introduced into Brazil, the U. S. Gulf Coast and other tropical and semitropical regions.

The zebu differs from European cattle most obviously in having a large hump on its shoulders and a heavy dewlap. The biological function of these organs is uncertain. Until recently it was believed that by increasing the animal's surface area they helped to dissipate heat. But recent experiments indicate that even when these parts of its anatomy are surgically removed the zebu remains heat-tolerant. The hump apparently does not provide any important food reserve for the animal, as the camel's does; the zebu's hump does not shrink much when the animal has to get along on sparse food rations. Zebus are generally more alert and more active than European cattle. They do not moo or bellow but emit a kind of coughing grunt.

The zebus of the Indian peninsula have evolved into many breeds, most of which inhabit fairly limited areas. The great majority are work animals, but several rather similar breeds found in Pakistan and India are known for their milking qualities. The best of these milking breeds, the Sahiwal, has been introduced into Jamaica; another, the Gir, is used extensively in Brazil. Experiments with the Sindhi breed are being carried on in the U. S. The "Brahman" cattle of our Gulf States are a mixture of several Indian working breeds, chiefly the Kankrej; their beef qualities have



seldom do well in the tropics. Zebu cattle (*Bos indicus*) originated in India and have spread or been introduced into other hot regions. Numbers suggest the distribution of some important breeds, which are depicted in drawings on the next four pages.

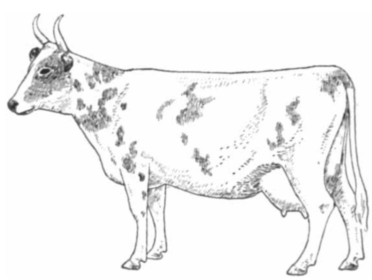
been considerably improved by selection.

In addition to the more or less improved breeds, the zebu cattle of India and Pakistan include large numbers of small and relatively unproductive "village cattle" and "hill cattle"; the latter sometimes are only about the size of a large dog.

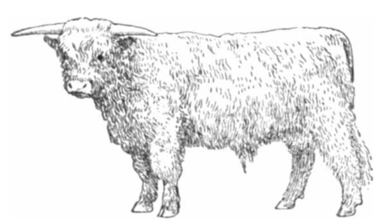
As one might expect, zebus have been crossbred with European cattle where the two species have come in contact. Cattle breeds in southern China, the Near East and some along the northeast shore of the Mediterranean as far west as Italy show evidences of zebu ancestry. In Africa centuries of tribal migrations have so mixed the two species as to make classification difficult. Some African breeds, such as the Ankole, differ from European and zebu cattle in possessing enormous, bulbous horns. Broadly speaking, the cattle of northwest Africa stem from the European species or some similar humpless type; zebus inhabit a wide belt across Madagascar and central Africa; elsewhere the two species have mingled to produce bewildering variety. European cattle, zebus, and their intermixtures account for almost all the cattle in the world. The only significant additions are two close relatives, the bantin of Java and the gayal of Assam and upper Burma, which have been domesticated on a small scale.

We should not, however, overlook a distant cousin which has great economic importance in some parts of the world—the water buffalo. India, with some 140 million cattle, also has more than 40 million buffaloes; Thailand actually has more buffaloes than cattle. In some countries, such as China, buffaloes are used primarily for work; elsewhere, as in India and Egypt, they are kept mainly for milk. Surplus animals are slaughtered for meat almost everywhere, though the meat is of poor quality by our standards. Buffaloes are particularly useful in the tropics because they seem to be better able than cattle to digest the crude fiber that forms a large part of much tropical vegetation. Curiously, however, they resist heat less well than even European cattle. Buffaloes apparently have no sweat glands, except in their muzzles. For this reason and possibly others, their heat-regulating mechanism is inadequate, and in hot weather they must be drenched with water periodically or allowed to wallow in water or mud if their working or milk-producing capacity is to be maintained.

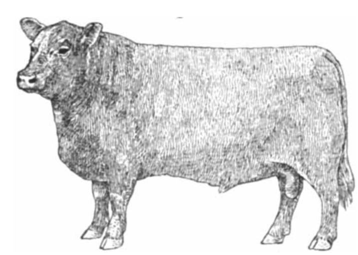
It stands to reason that cattle bred for work will be inefficient producers of food. In the underdeveloped countries of the world, where the food problem is most acute, the usefulness of cattle is still further reduced by primitive slaughtering methods. The hides, too, are often damaged by knife-cuts or are poorly tanned. In India, of course, Hindu religious taboos generally forbid the slaughtering of cattle. A similar situation prevails among the tribal cultures of



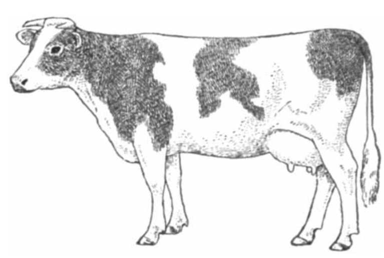
1. AYRSHIRE



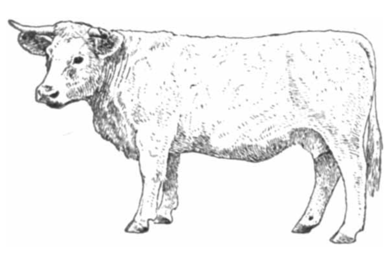
2. WEST HIGHLAND



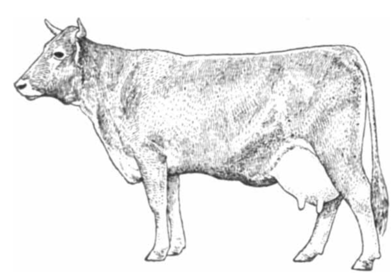
3. ANGUS



7. HOLSTEIN



8. CHAROLAIS



9. BROWN SWISS

EUROPEAN CATTLE include almost all the specialized dairy (1, 6, 7) and beef (3, 5, 8) breeds. Shorthorns are used for both purposes; the Brown Swiss, a dairy breed in the U. S., is used for milk, meat and work in Switzerland. The Chianini, though unspe-

Africa and the Near East, where cattle, along with other livestock, are a kind of currency. (Our own word "pecuniary" comes from the Latin word *pecus*, meaning cattle.) Where a man's wealth is measured by the size of his herds, and the price of a wife is stated in cows, the tribesman will be concerned with the numbers rather than with the quality of his cattle. Some tribes have developed bizarre ways of getting food from cattle without killing them. The Masai of East Africa, for example, bleed their cattle periodically and drink the fresh blood or combine it with other foods.

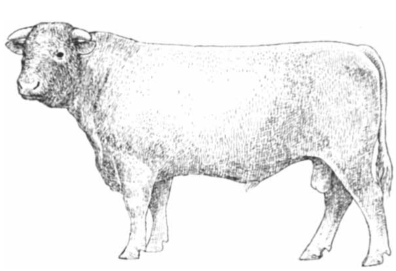
Cattle Breeding

Systematic efforts to improve the productivity of cattle began in Great Britain during the 18th century with the work of Robert Bakewell, the great pioneer in animal husbandry. Bakewell and his successors in Britain and western Europe produced almost all of the dairy and beef breeds we know today. These early breeders, of course, knew nothing of scientific genetics. Their success in developing so many productive breeds testifies that they had a good grasp of the empirical principles and a certain amount of good luck.

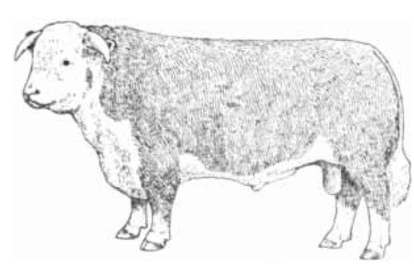
Breeders have been most successful with dairy cattle, because the productivity of a milker is easily measured in pounds of milk and percentage of butterfat content. The best milkers could be chosen as breeding animals, and even bulls could be selected by the productivity of their daughters.

The productivity of beef cattle is more difficult to measure. How quickly they put on weight, which determines how quickly the cattleman can turn over his capital, can be measured fairly easily. But it takes an elaborate analysis of each carcass to judge qualities such as the ratio of meat to bone and the extent to which meat is "marbled" with fat. Lacking any simple measure of quality, breeders have tended to estimate animals by their appearance, selecting breeds with deep, wide bodies, well-developed loins and hindquarters (which contain the more expensive cuts) and a blocky, smooth exterior. Such visual criteria put emphasis on a thick layer of fat under the skin. Breeders have a saying: "Fat is a pretty color." Much of this pretty fat, however, is trimmed away on the butcher's block to please the American taste. Moreover, the amount of fat on the outside of the carcass seems to have little bearing on the fat inside, which makes for tender and juicy meat, or on the proportion of lean meat to bone.

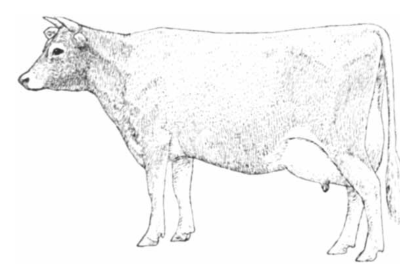
A number of scientists have been working on better methods of evaluating beef cattle on the hoof. In one promising method certain harmless chemicals which are absorbed much more rapidly by fat than by muscle are injected into the animal's bloodstream. By taking blood samples at intervals one can



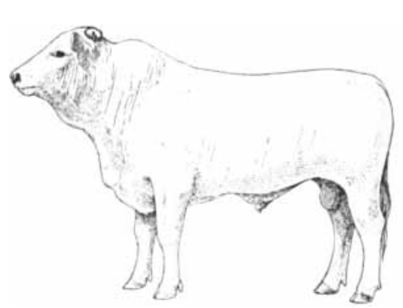
4. SHORTHORN



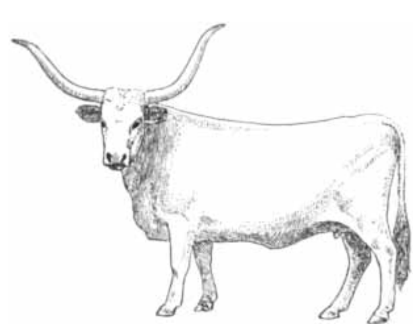
5. HEREFORD



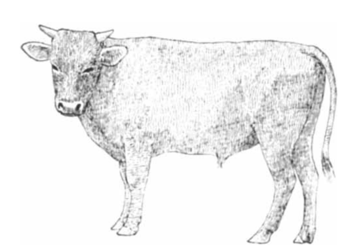
6. JERSEY



10. CHIANINI



11. BLANCO OREJINEGRO



12. WEST AFRICAN SHORTHORN

cialized, is the best beef producer among Italian breeds. The West Highland is adapted to a cold, damp climate; the Blanco Orejinegro and West African Shorthorn (no relation to the Shorthorn) are among the few breeds of European type which thrive in the tropics.

measure the rate at which the chemicals are absorbed and thus estimate the amount of fat inside the carcass.

The most promising work in cattle improvement, however, is drawing upon the science of genetics. Although this is a new undertaking, it has moved ahead rapidly and is already showing results.

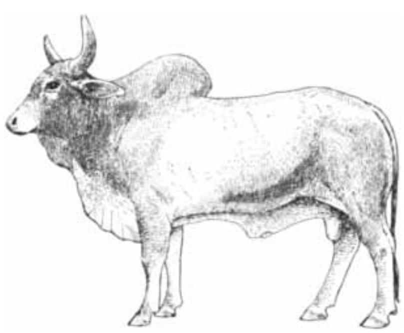
Genetic Traits

A few traits in cattle are known to be inherited by simple Mendelian principles. The black coat and hornlessness of the Aberdeen Angus and the white face of the Hereford are Mendelian dominants, controlled by single pairs of genes. These traits, however, are not of major economic importance. The more significant qualities of milk production, percentage of butterfat, rate of growth and efficiency of feed utilization involve many pairs of genes and are also powerfully influenced by environment. Nonetheless geneticists have made progress in estimating the relative weight of the genetic and environmental factors that determine these traits. By studying the extent to which related animals, such as half-brothers or half-sisters, are more alike than randomly selected animals reared under the same conditions, it is possible to estimate the degree to which a particular trait can be inherited and thus to predict how effective selection for that trait is likely to be.

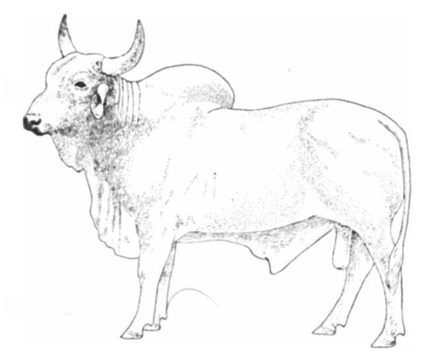
In dairy cows, for example, butterfat production is about 30 per cent inheritable. That is, if we select a group of heifers whose butterfat production averages 100 pounds a year more than the herd-average and breed them to bulls of similar superior stock, the offspring will produce about 30 pounds a year above the average. According to studies by the U. S. Range Experiment Station at Miles City, Mont., the indications are that the birth weight of beef cattle is 53 per cent inheritable and the weight at 15 months (just before slaughtering) is 86 per cent inheritable. The grade of the carcass is estimated to be 33 per cent inheritable.

In the early 1940s the Miles City workers began to select cattle for rapid growth, and they have developed some superior strains. These results have been accomplished by selecting on the basis of performance tests rather than appearance. That looks can be deceiving was illustrated some time ago when a distinguished foreign visitor to the station, after being shown some very good performers, spied a herd of fat, blocky steers just as he was leaving. "Why didn't you show me these before?" he exclaimed. He was startled to learn that these seemingly superior cattle were in fact the poorest producers on the station!

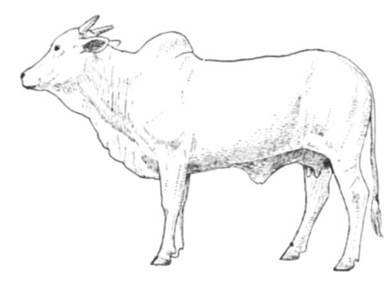
With more experimental work of this sort breeders may soon be able to provide bulls which transmit to their offspring high feeding efficiency, optimum proportions of bone, muscle and fat, a rapid growth rate and perhaps even tenderer meat. For the general public



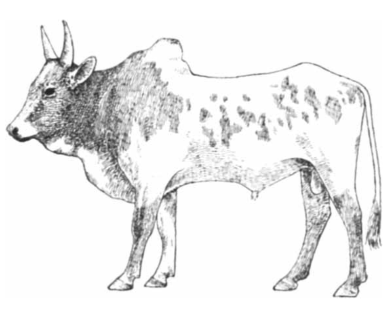
13. KANKREJ



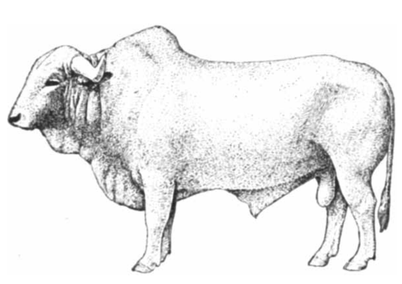
13a. BRAHMAN



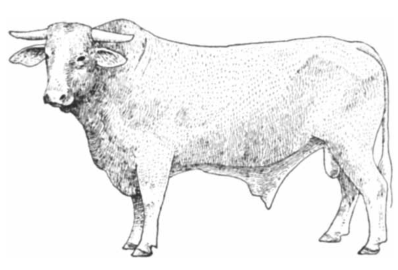
14. ONGOLE



18. MADAGASCAR



19. AFRICANDER



20. SANTA GERTRUDIS

ZEBU CATTLE (13-18) are mostly used for work; the few dairy breeds, such as the Sahiwal, produce far less than European milk cattle. The Brahman is a mixture of several Indian zebu breeds, mainly the Kankrej. Interbreeding between zebus and European

this will mean cheaper and better steaks and roasts.

Backward Areas

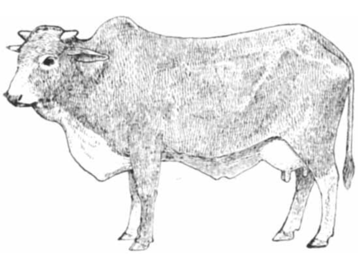
Work of this kind has been carried on so far in the Temperate Zone countries where levels of production are already high. Little or nothing has been done to improve the cattle in more needful regions of the world, even by empirical methods. Effective selection implies a sizable herd to select from, but the average farmer in these regions has only one or two cattle, and often these are work oxen which cannot breed. The farmers owning larger herds can seldom afford to purchase superior breeding stock, nor can the near-subsistence economies of these countries spare much money for large-scale breeding experiments.

Moreover, the attempts that have been made to improve the productivity of zebus have not been very fruitful so far, partly because too little is yet known about the genetic potential of the various strains and partly because in many areas the feeding and management of the cattle are not efficient enough to bring out their full possibilities. The best zebu performances have been far below those of European breeds. In India a few well-handled Sahiwal cows have produced somewhat more than 10,000 pounds of milk in a year. In the U. S., Holsteins have produced as much as 40,000 pounds. The high productivity of European cattle is the result of several centuries of selective breeding. Even assuming that the economic difficulties can be overcome, it would take a long time to raise the best zebu breeds, such as the Sahiwal, to similar levels.

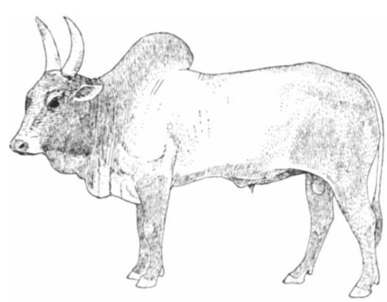
Nor has much attention been given to improving the zebu as a work animal. Some agricultural leaders in the underdeveloped countries hold that such research is a waste of money, believing that draft cattle will soon be replaced by tractors. I myself am not so sure. Small fields, a low economic level, the need for manure and, in rice-growing areas, the water-covered ground are all likely to delay the substitution of tractors for cattle.

It may be that the most rapid improvement of cattle in the underdeveloped areas of the world will be gained by crossing the European and zebu animals. The pure European breeds do not do well in these regions. Their digestive systems are not adapted to the coarse and often scanty grasses; parasites and disease are additional hazards. Worst of all is the heat. In hot climates European cattle suffer from the bovine equivalent of heat exhaustion. They eat poorly and do not seek food actively (as cattle must where pastures are sparse). Their fertility is lowered by poor nutrition and still further reduced by high body temperatures.

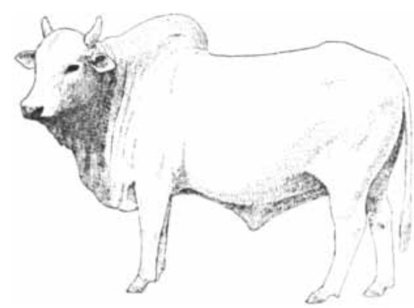
The zebu, of course, thrives in the tropics. Its skin, thicker than that of European cattle, can better resist ticks



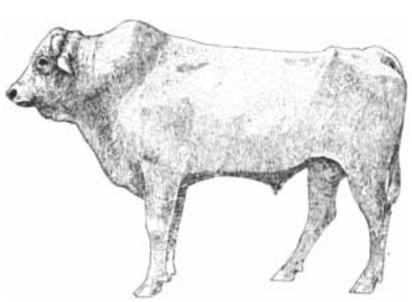
15. SAHIWAL



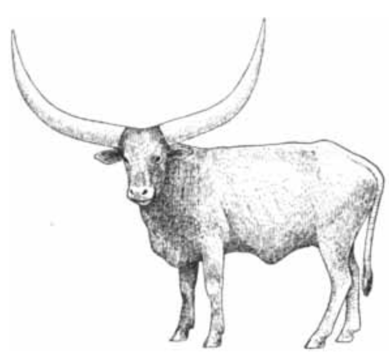
16. KANGAYAM



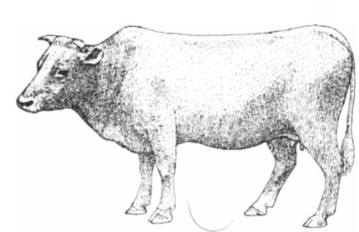
17. BORAN



21. EGYPTIAN

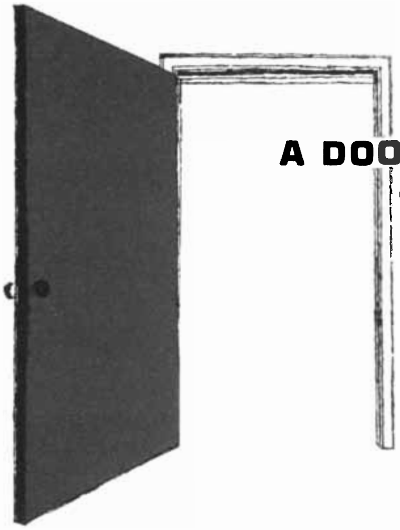


22. ANKOLE



23. CHINESE "YELLOW COW"

cattle in many parts of the world has produced mixtures of quite varied appearances (19-23). The Santa Gertrudis, a recently developed breed based on a Brahman-Shorthorn cross, has in recent years become an important beef producer in the Gulf states.



A DOOR IS OPENED... TO NEW ADVANCES IN FLUORINE CHEMISTRY

Take fluorine (the most reactive non-metal), combine it with almost any element, and the resulting fluorides can range from extremely reactive compounds to unusually inert ones. The fluorides are chemical paradoxes in other ways, too. In a sense, they are "old" and familiar (hydrofluoric acid and the sodium fluorides, for examples). They are also "new"—so new, in fact, that their most important contributions are yet to be realized (so our research people say).

Let's take a look at some recent fluorine developments.

Fluorine transportation. Before you can use it, you usually have to carry it. How

does one transport tonnage quantities of highly reactive elemental fluorine ("the chemical outlaw")? Our research people did the original work in taming fluorine so that it could be handled in bulk as a liquid instead of in small amounts as a gas. Engineers at our General Chemical Division came up with ingenious insulator tank trucks which are essentially giant thermos bottles. Liquid nitrogen is used in a triple-tank system to cool the fluorine below its boiling point, keeping it in liquid—and readily transportable—form.

Fluorides for plastics. A typical paradox: from explosively reactive fluorine, highly stable fluorocarbons like *Genetron* plastics. For example, *Genetron HL,* a high-molecular-weight polymer of trifluorochloroethylene, is impervious to inorganic acids, alkalis, oxidizing agents and most organic compounds, and retains useful properties from 320° below to 390° above zero F. Extruded as a film, it offers high moisture and gas impermeability, and transparency. It is better than laminates for many applications. Uses? Electrical equipment, electronic components, piping and tubing . . . to name a few.

Fluorides for the rocket program. Some of the most powerful oxidizers are fluorine and the halogen fluorides (chlorine trifluoride and bromine pentafluoride). They are playing key roles in a number of liquid propellant rocket systems now under evaluation. Objective: to develop power plants with maximum thrust.

Fluorides for atomic energy. One of the most important fluorides is volatile uranium hexafluoride, the vital atomic raw material which is separated by gaseous diffusion into $U^{235}F_6$ and the slightly heavier $U^{238}F_6$. Until recently, refined UF_6 has been made only in government-owned plants. Now, the Atomic Energy Commission has selected our General Chemical Division to produce UF_6 in privately owned and operated facilities. Allied is the first company to do this. A new process developed by General Chemical research is to be used.

Fluorine chemical applications are legion, as witness the fact that our General Chemical people produce more than 100 different compounds (more than anyone else, by the way). You may be familiar with some fluorine applications, like sulfur hexafluoride as an inert dielectric gas for electronic and X-ray equipment (when we introduced sulfur hexafluoride commercially, it was the first chemical produced from elemental fluorine to be offered to industry) . . . or boron trifluoride, a versatile and efficient catalyst which has solved many problems in organic synthesis. Metal fluoborates for printed circuits (or for alloy plating, and plating of plastics and wire, for that matter). Fluorides for water fluoridation, a well-known contribution to dental care for children. And possibly the best-known and most successful, the family of safe, stable fluorocarbon gases (we call ours *Genetrons),* which serve as propellants in today's aerosol "push-button" spray products and as refrigerants in almost all modern air-conditioning and refrigeration equipment.

IF YOU WOULD LIKE INFORMATION or literature on any of these fluoride developments, just write us on your company letterhead. Or perhaps we might "custom-make" a compound that would "open a door" profitably for you. Address: Allied Chemical, Dept. 68S, 61 Broadway, New York 6, New York.

Allied Chemical

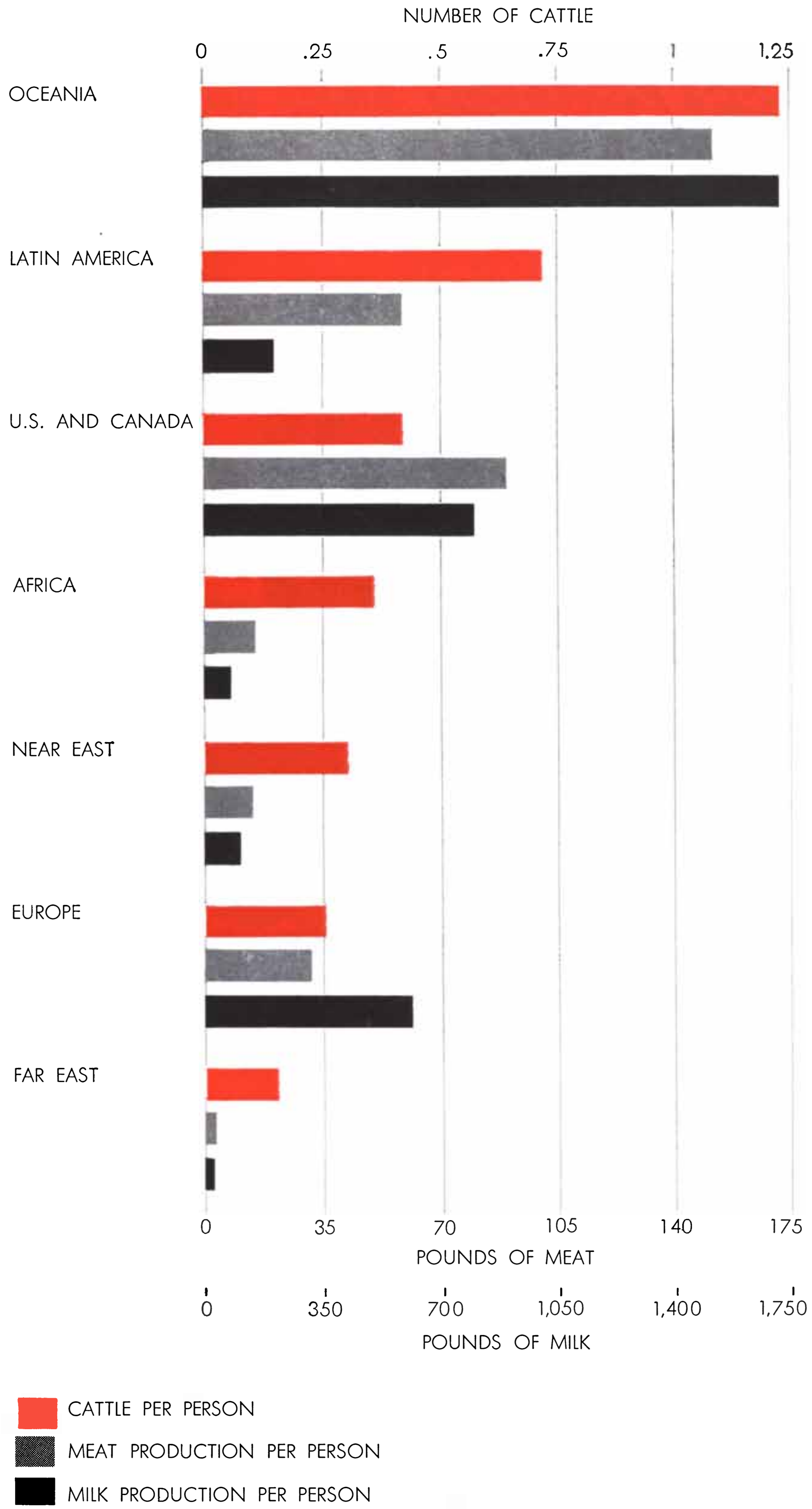
Genetron **is an Allied Chemical trademark.**

and stinging flies. It can digest crude fodder, though not so well as the buffalo. And it keeps cool. For one thing, its coat is thinner than those of the European breeds; for another, most zebus are light-colored and absorb less sunlight. There are indications that the zebu may have more, or more effective, sweat glands than European cattle. Apparently the principal reason the zebu keeps cool is that it produces less body heat, even though it is typically more active than European cattle. How it manages this metabolic trick is a mystery which investigators are currently trying to unravel.

Efforts to combine the zebu's resistance to heat and the European breeds' high productivity have already achieved considerable success. An outstanding example is the Santa Gertrudis, a breed developed from a Brahman-Shorthorn cross, which during the past 20 years has become an important producer in our Gulf States. Crosses between Jerseys and various milking breeds of zebus also are yielding good results. The Jamaica Hope, a Jersey-Sahiwal cross, already approaches the U. S. average in milk production.

A less urgent but equally challenging objective is the development of breeds adapted to the cold climates of northern Canada and Siberia. The Mongolians and Tibetans have long crossed cattle with the yak to produce an animal combining some of the yak's hardiness with the cow's milking capacity. Unfortunately only the females of these crosses are fertile. The Canadian government has crossed cattle with bison to produce the "catalo," and has even bred a cattle-bison-yak, but neither of these combinations has yet shown any particular economic advantages.

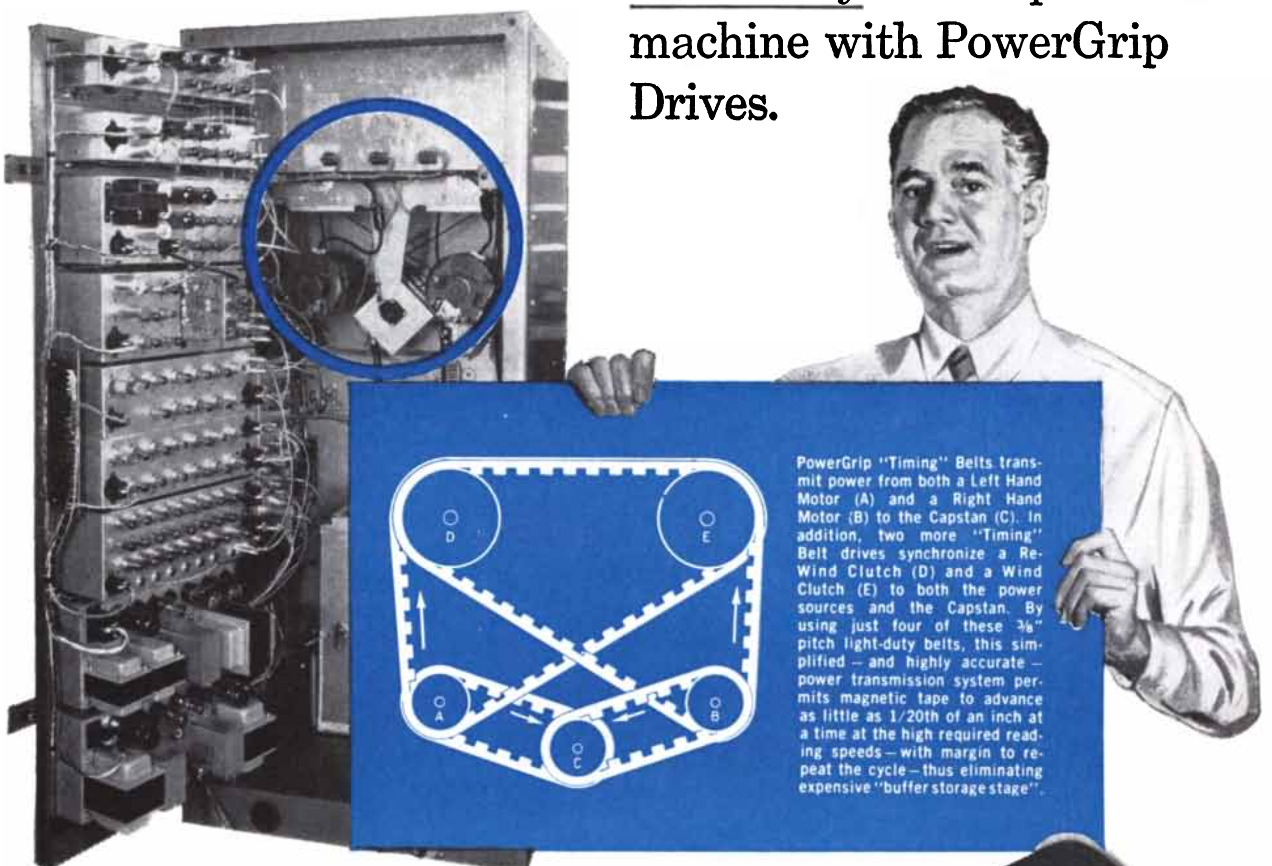
Not very much is known about the cattle breeds in the underdeveloped areas of the world. It may well be that combinations of these types with the better-known breeds would produce more productive breeds of cattle for specific conditions. One obstacle to such experimentation is that infections such as the hoof-and-mouth disease and rinderpest are prevalent among cattle in many underdeveloped regions, and it is dangerous to import breeding animals or even semen from such areas. But we can hope that the obstacles will be overcome, so that better cattle and better raising methods will become available to meet the growing world population's need for protein food and to add more meat to the diet of the many peoples in underdeveloped countries who now get very little.



NUMBERS AND PRODUCTIVITY of cattle in proportion to population vary in different regions. High figures for Oceania reflect large cattle industries and low population of Australia and New Zealand. In Latin America dairying is much less important; cattle in most areas are of poor quality. U. S., Canada and Europe have fewer but more productive cattle. In Africa, Near East and Far East cattle are used mainly for work and produce little food.

US RUBBER *PowerGrip* "TIMING" BELTS

"GRIP" POWERS tells how they improved the sale-ability of this precision machine with PowerGrip Drives.



The Shepard Servo Transport Digital Tape Reader, shown here, is used to match the speed of electronic information being fed from high-speed data processing machines to the speed of the apparatus which transcribes the electrical impulses into readable typewritten copy.

By incorporating PowerGrip "Timing"® Belt drives into this system, the following sales advantages were gained:

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• *vibration-free transmission*...belts run smoothly and quietly with constant angular velocity.

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Says E.J. Quinby, Product Manager: "We use these belts because exhaustive research by us has proven them superior in speed—accuracy—reliability — durability — silence — freedom from periodic adjustment."

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The "Talking Boards" of Easter Island

The island's inscribed tablets have been even more puzzling than its celebrated stone heads. The writing of the tablets has recently been deciphered by the author of this article

by Thomas S. Barthel

The fascinating job of deciphering the early writings of mankind is beginning to run short of material. For well over a century scholars have found plenty to occupy them in the hieroglyphs and cuneiform tablets of the ancient civilizations of the Near East. But that task is now just about completed. The decipherment of these writings, which began early in the 19th century when Jean-François Champollion brilliantly cracked the Egyptian hieroglyphs by means of the Rosetta Stone, has come to its last glorious chapter with the recent solving of the Hittite and Minoan scripts.

There are still, however, some challenging riddles in other parts of the world. Among the scripts not yet fully solved are the early writing systems of India and China and the beautiful hieroglyphs of the ancient Mayan Indians in Central America. My tale is about the strange "talking boards" of Easter Island—the tiny, lonely island in the mid-Pacific which has long been one of the most enigmatic spots on the earth.

Easter Island has held a magnetic enchantment for scholars ever since it was discovered in 1722. The explorers who first set foot on the island found it inhabited by simple tribesmen not very different from other islanders of the South Seas. But Easter Island immediately attracted attention for what has become one of the wonders of the world—gigantic stone statues which towered or lay toppled all over the island. These awe-inspiring figures, with their thin-lipped, staring faces, have mystified investigators for more than two centuries. All sorts of fantastic theories have been offered, and are still offered, as to why and how they were built. Some have suggested that they represent a glorious ancient civilization—a golden age—in the South Seas.

Easter Island also yielded up something which, though not nearly as widely known, has proved intellectually far more exciting than the statues. It did not come to light until about a century and a half after the island was discovered. In 1862 slave-hunters from Peru raided the island and carried off most of its population. Soon afterward a French missionary, F. Eugène Eyraud, came to the island to start a mission for its survivors. Visiting their drab huts, he discovered boards and sticks covered with rows of carved symbols. The inhabitants apparently put no meaning on these inscriptions and were using the boards for firewood and canoe material. But scholars in Europe were immediately intrigued. If the marks on the boards were actually inscriptions, this was the first native writing that had been found anywhere in the South Sea islands.

Missionaries and visitors to Easter Island managed to salvage a number (pitifully small) of the inscribed boards

EASTER ISLAND WRITING covers this large "talking board," one of those investigated by Barthel. It was used by the island's *rongorongo* men or chanters. The writing turns around at the end of each line, so that every other line appears to be upside down.

and sticks. They were distributed to various museums in Oceania, Europe and America. The marks on the wooden tablets became a subject of argument. An eminent institute in Berlin declared that they were not writing at all but merely designs for printing on cloth. Gradually, however, scholars accepted the fact that they were indeed written symbols. Generations of investigators puzzled over the boards, seeking to relate the Easter Island script to other early writing systems. Various theories tried to connect it with the rock painting of the Australian aborigines, the picture writing of the Cuna Indians of Panama, the hieroglyphs of the Egyptians. In the 1930s a Hungarian linguist, Wilhelm von Hevesy, discovered a strong likeness between the Easter Island writing and inscriptions found in the ruins of a 3,000-year-old civilization in the Indus area of northern India. But on close study the likeness turned out to be only superficial, and no link whatever could be detected between the Easter Island and Indus cultures. After repeated disappointments, scholars became weary of the problem, and many concluded that the marks on the "talking boards" were mere memory aids, like the knotted strings that the Marquesas Islanders used to memorize lists of their ancestors' names, or the notched sticks that helped Maori priests of New Zealand to remember their endless chanted verses.

In 1953 I decided to open a fresh investigation of the whole intricate problem. I started with a background essential for such a task: a thorough acquaintance with cryptography and primitive writing systems and a general knowledge of Polynesian cultures. The investigation has been carried out with large doses of painstaking work, intuition and that final indispensable ingredient—luck.

My first task was to collect all the available inscriptions from Easter Island. One might suppose that, after all the studies and heated debates, there would be a complete tabulation of the salvaged writings—a *Corpus Inscriptionum*. But a perusal of the pertinent literature soon disclosed that only piecemeal treatments of the subject existed. So I appealed directly to museums around the world—in Honolulu and Vienna, Santiago de Chile and Leningrad, Washington and London. Thanks to their curators' cooperative response, reproductions of the tablets—photographs, plaster casts, pencil rubbings—began to pour into my study at Hamburg University. When the returns were all in, I had a collection of inscriptions with a total of 12,000 signs to analyze.

The Easter Island tablets are flat wooden boards completely covered with rows of tiny incised symbols. Under a magnifying lens these minute signs (a third of an inch to half an inch long) show surprising elegance and beauty—precise and complex in detail yet boldly drawn. They make up a teeming world of little running men, flying birds, turtles, celestial objects and strange geometrical forms. To reduce the multitude of signs to an orderly list that could be analyzed and dealt with statistically, I identified the signs by numbers. This cataloguing work was long and tedious, but by the time it was finished I was well

EASTER ISLAND is a lonely dot in the middle of the Pacific Ocean. As shown in this map, it lies midway between the Society Islands (to the west), home of its Polynesian culture, and the Republic of Chile (to the east), which now governs the island.

enough acquainted with the symbols to begin to see some patterns.

I now had to decide what the signs stood for—alphabetical letters, syllables, words or ideas. If you find that a writing system is composed of 20 to 30 basic elements, you can safely assume that they are an alphabet; if the units number around 100, they probably stand for syllables. Since the Easter Island inscriptions had hundreds of different signs, I judged that each represented a whole word or idea.

The next step was to begin to look for meanings. The only direct lead that held out any hope at all was a cold trail nearly a century old. One of the early investigators of the Easter Island talking boards was Bishop Tepano Jaussen, a French missionary at Papeete on the island of Tahiti. He had a collection of the wooden tablets, and one day he learned that there was living on Tahiti a native of Easter Island who in his youth had been trained as a *rongorongo* man—a professional chanter. Bishop Jaussen hunted up this man, named Metoro Tauara, and asked him to read the tablets. Metoro, whose name should become famous, picked up four tablets in succession and chanted a song from each in the Polynesian language. The bishop joyfully wrote down each rendition.

When he tried to translate the songs into French, however, Jaussen's hopes were dashed to the ground. Metoro's songs made no sense whatever. The words were Polynesian words, but they did not hang together: they told no story and sometimes did not even form coherent phrases or pictures. Jaussen attempted to connect the word elements of Metoro's songs with the signs on the tablets, but he did not succeed in deciphering the meaning of any of the symbols. Most investigators decided that Metoro was a fake: he had only pretended to read the boards.

Looking back at this long-dismissed incident, I clutched the faint hope that Metoro might not have been a complete pretender. Perhaps something could be made of his readings after all. Unhappily this idea immediately ran afoul of an embarrassing difficulty: Jaussen's transcription of Metoro's songs had disappeared! No one knew whether it was any longer even in existence. Under the circumstances, a bit of detective work was called for. I began a search for Jaussen's missing notebook, starting in Tahiti, going on to France and Belgium and winding up in triumph in Italy. In a monastery in the charming village of Grottaferrata, near Rome, I discovered the dusty notebook, bearing the four songs of Metoro.

Those lines of Polynesian syllables in Jaussen's shaky hand became my "Rosetta Stone." Once more I carefully compared Metoro's chants with the inscriptions on the four wooden tablets. Gradually a few of the signs began to become identifiable with consistent meanings. A knowledge of the Polynesian languages, as well as cryptographic analysis, proved to be decisively helpful in deciphering the signs. I'll never forget the moment when the first textual fragment began to make sense. In one row of an inscription I found that geometrical symbols evidently representing the sun and the moon were preceded by an abstract sign combining two sticks. Now the sun and moon are commonly depicted in mythologies as twins, and I recalled that a Maori (*i.e.*, Polynesian) proverb actually refers to these celestial twins with the metaphorical expression "two sticks." Thus this sign became my first clue to decipherment of the Easter Island script.

As I worked through Metoro's four tablets, I began to see why his songs had turned out to be mere gibberish. Metoro had been in the position of a schoolboy asked to explain a university textbook. Possessing only a rudimentary knowledge of the old script, he had read some of the signs correctly but guessed wrong on most of them, so that his over-all translation of the text was meaningless.

Once it became clear that the Easter

	SIGNS	PRONUNCIATION	MEANING
SINGLE GLYPHS		TOKI	ADZ
		VAI	WATER
		TANGATA	MAN
COMBINED SIGNS		RUTU TE PAHU	BEAT THE DRUM
		KOHAU RONGORONGO	TALKING BOARD (SCRIPT TABLET)
SIGNS DENOTING QUALITIES		KOTI	CUT
		MOE	SLEEPING, DEAD
		TEA	WHITE
METAPHORICAL EXPRESSIONS		PUA	1. FLOWER 2. WOMAN
		REI KURA	1. PRECIOUS ORNAMENT 2. FIRST-BORN SON
EXAMPLES FOR REBUS WRITING		PURE	1. BIVALVE 2. PRAYER
		RAPA	1. DANCING-PADDLE 2. BRILLIANCY
		TAPA	1. BARK-CLOTH 2. TO COUNT

SIGNS in the Easter Island picture writing are of the types shown in this chart. The types include metaphor (*e.g.*, the signs for "precious ornament" or "first-born son") and rebus writing or puns (*e.g.*, the sign for "bark-cloth" or "to count," both pronounced *tapa*).

Island writing did not stand alone but was related to the spoken languages of the Polynesian islands, its decipherment proceeded more readily. What was more, reading of the tablets shattered the theory that Easter Island did not belong to Polynesia but had been colonized from America. Names, phrases and allusions on the talking boards showed unequivocally that the Easter Islanders stemmed from the same culture as the Polynesians on the South Sea islands thousands of miles to the west.

Hamburg University is now publishing a complete account of my translation of the tablets to date. Let me summarize here the nature of the writing system and what the tablets tell us about Easter Island's history.

There can no longer be any doubt that the talking boards contain true writing. Its signs follow strict formal rules, unlike the picture writing of some Indian tribes in America. However, whereas most ancient writing systems tended to reduce the symbols to purely abstract lines, the Easter Island script is made up in large part of stylized outlines of pictured objects. Among its basic elements are certain head forms, body positions corresponding to pantomimic expressions, and very characteristic stylizations of hands which seem to suggest a gesture language. Animals and plants are represented more or less naturalistically. But many of the geometrical signs are so abridged that they no longer give an obvious clue to the meaning.

The script has only about 120 basic elements, but they are combined in various ways to form more than 1,000 compound signs. Most of the signs are used as ideograms, usually in the form of words. Thus a divided element stands for the word "cut"; a sleeping bird represents the word "dead"; a rope, characteristically white in color, stands for the word "white." The language is often metaphorical and poetic: a flower designates "woman," and the symbol for "first-born son" is a representation of a precious ornament.

The Easter Island scribes made a start toward phonetic writing, expressing abstract ideas with sounds in the manner of present-day rebus writing (*e.g.*, the familiar puzzle which shows pictures of an ant and a rose to represent "Aunt Rose"). Since the Polynesian languages are rather rich in homonyms (words of the same sound with different meanings, such as "ate" and "eight"), the scribes often could use a concrete word to stand for an abstract one. For instance, they used the picture of a clam to represent the word "prayer," because the spoken word for a bivalve (*i.e.*, *pure*) was the same as for prayer. Similarly the picture of a dancing-paddle (*rapa*) also stood for "brilliance" (likewise *rapa*), and the symbol for bark-cloth (*tapa*) also meant "to count."

The Easter Island writing had not matured, however, to a phonetic system which could reproduce an entire spoken sentence. Consequently the tablets had to reduce the songs of the rongorongo men to an abbreviated form, like a telegram. The tablet was a kind of cue-card consisting of catchwords which gave the singer only the gist of his verses: he had to fill in the missing words himself. Naturally this makes it difficult for us to reconstruct the full story epitomized in the tablets. Nevertheless, read in the context of what we know about Polynesian folklore, they tell a great deal.

First, we have to note that the talking boards that survive are mainly religious and ritualistic; they contain almost no mention of historical events on Easter Island. The Islanders had another writing (the so-called "tau script") which recorded their annals and other secular matters, but this has disappeared. The tablets we have are mainly eulogies to the deities, instructions to priests and the like. Some of them speak of the mythical beginning of the world, when Tane separated the sky from the earth and put up gigantic props to hold up the heavens. The descriptions of rituals disclose that the supposedly idyllic South Seas were a scene of rampant cannibalism, tribal wars, human sacrifices and victimization of children. Most of the tablets speak only of males. But women do come in for mention in tablets which are strongly preoccupied with fertility. These texts always call a spade a spade, and a translator has to render them with delicacy.

Of the subjects that have most mystified archaeologists looking into Easter Island's past, such as the stone statues, there is unfortunately little mention in these tablets. But what seems to me of far greater interest is the abundance of references linking Easter Island with the rest of the Polynesian world.

That the Easter Island script was not invented on the island itself but was imported from elsewhere in the South Seas is clearly proved by the writing itself. To cite just one example: the script has a special symbol for the breadfruit tree, which never grew on Easter Island but was one of the most important food plants of the more tropical South Sea islands. There are also signs for other plants not native to Easter Island. Further, some stylistic details of the script are strikingly similar to the ancient wood-carving art of the New Zealand Maoris and the Marquesas Islanders. And a decisive proof of Easter Island's connection with cultural centers in Polynesia emerged when I deciphered some geographical names on the tablets. They mention "Rangi-tea" (modern Raïatéa in the Society Islands) and deities and temples on Tahiti and Borabora. The tablets even contain the ancient name for Pitcairn Island, which, centuries before the arrival of the mutineers from the *Bounty*, seems to have been the last jumping-off place for Polynesian wanderers sailing eastward in the Pacific toward the rising sun, seeking a new homestead. Easter Island, a thousand miles east of Pitcairn, was the final stop.

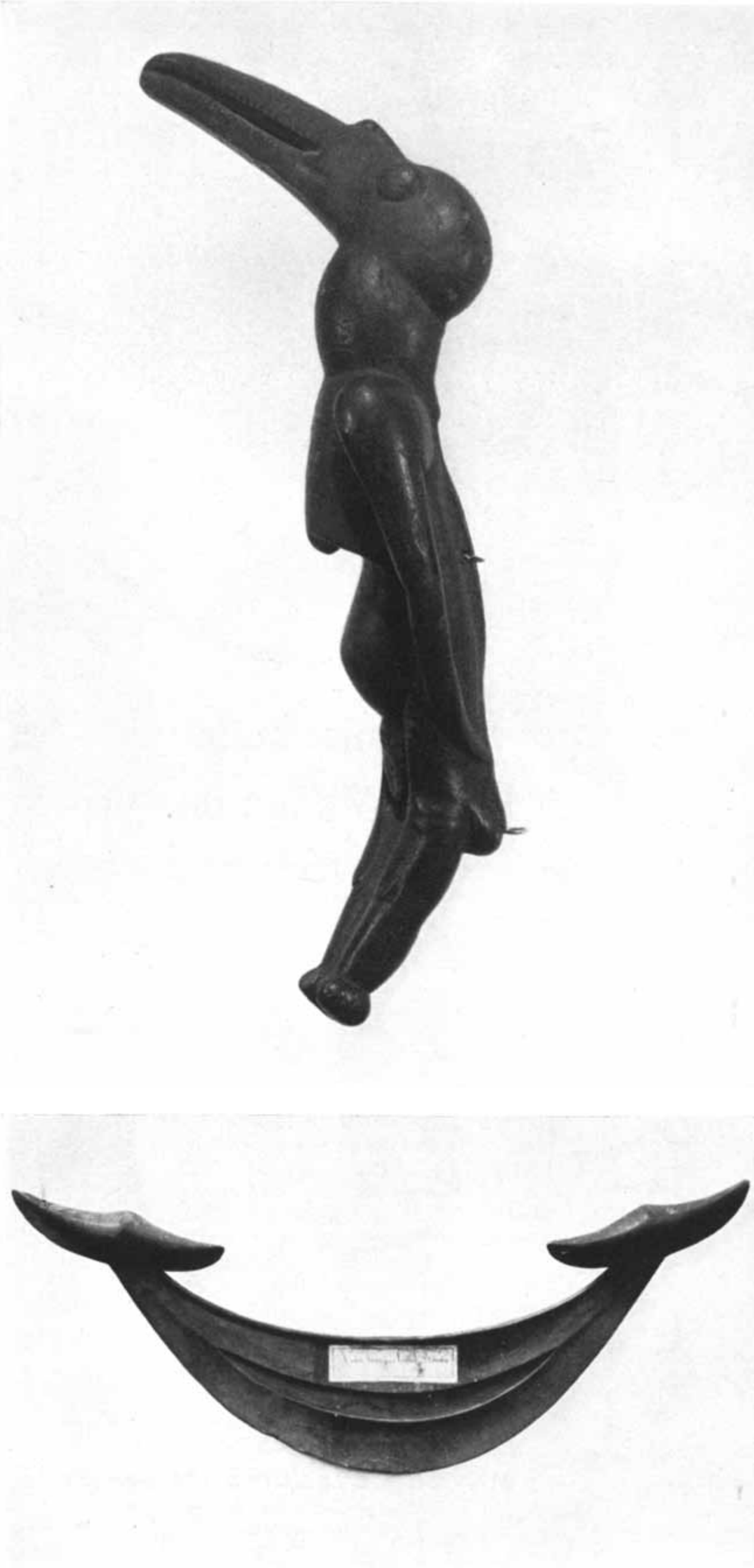
The native legends of Easter Island say that the island was originally settled by a people under a chief named Hotu-Matua, who brought with them the talking boards and all their other belongings. Archaeologists are reasonably sure that this immigration took place in the 14th or 15th century. The story told by the tablets now leaves no doubt that the

PU, RUTU TE PAHU, REI, KURA, ATARIKI, HENVA, TOKO RANGI, TANE

BLOW THE SHELL TRUMPET AND BEAT THE DRUM
FOR THE PRECIOUS ORNAMENT
FOR THE FIRST-BORN SON OF THE EARTH
FOR THE PROP OF THE HEAVEN
FOR TANE

INSCRIPTION in the Easter Island writing includes several signs shown in the chart on page 64. Below the signs is their transliteration; below that, their translation into English.


MULTIMET alloy



ARTIFACTS from Easter Island resemble its writing. The bird-man (*top*), like many birdlike signs in the writing, stems from the island's bird cult. The neck ornament (*bottom*) resembles the sign for "ornament." The rectangle on the neck ornament is a museum label.

settlers came from somewhere in the heart of Polynesia—perhaps Raïatéa, which is known to have been a starting point for large-scale voyages of Polynesian groups to distant Hawaii and New Zealand. It also seems to disprove conclusively the recent theory of Thor Heyerdahl that the Easter Islanders came from Peru.

But the Easter Island tablets—last remnants of a "literature in wood"—still leave us with an important and puzzling problem. Who invented this extraordinary script, and why did it survive only on Easter Island?

We can theorize on this subject from two different points of view, depending on our philosophy of how human culture develops. One view would suggest that the script was a spontaneous, independent invention by a group of Polynesian intellectuals who kept it as their own secret possession; the other concept, holding that human culture has grown only gradually by the diffusion and cross-fertilization of ideas, would argue that the Easter Island writing developed from some earlier writing system.

Speculating along the first line, we might suppose that a particular group of rongorongo men, somewhere in Polynesia, created the script and took their private system of writing with them to Easter Island. Their invention might well have been the result of experiments with notched sticks used as memory aids. The peculiar alternation of the rows of writing on the wooden tablets, each successive line reversing direction (a system called boustrophedon), suggests that the symbols were originally incised on sticks; furthermore, one Polynesian name for the Easter Island script is *kohau rongorongo*—literally "talking sticks." Finally, the strongly mnemonic nature of the catchword system certainly supports the idea that the writing grew out of a memory-aid device.

On the other hand, everything we know about the early writing systems in the Old World indicates that they borrowed or developed from one another. In the Easter Island writing we can see some faint resemblances to certain ancient Chinese scripts. Possibly the Chinese and the Polynesian writing were both connected with an ancient cultural center somewhere in southeast Asia.

The decipherment of the Easter Island tablets only heightens our interest in the intriguing search for the original home and the history of the ancestors of the Polynesians—an intrepid people who sailed forth into the vast Pacific and made their homes on its far-flung islands.

Photo courtesy Exide Industrial Division, Electric Storage Battery Co., Philadelphia, Pa.

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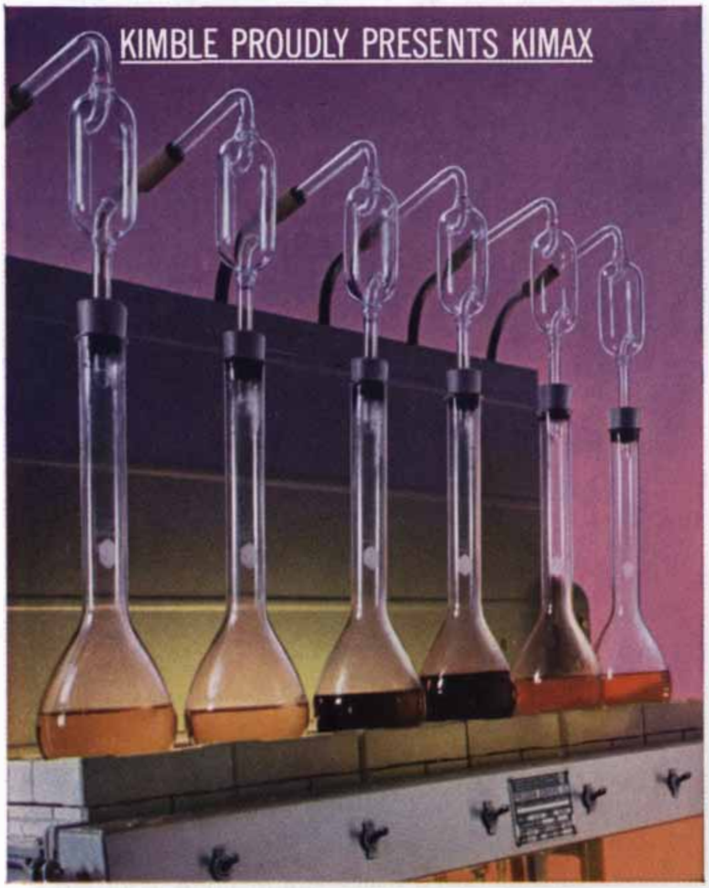

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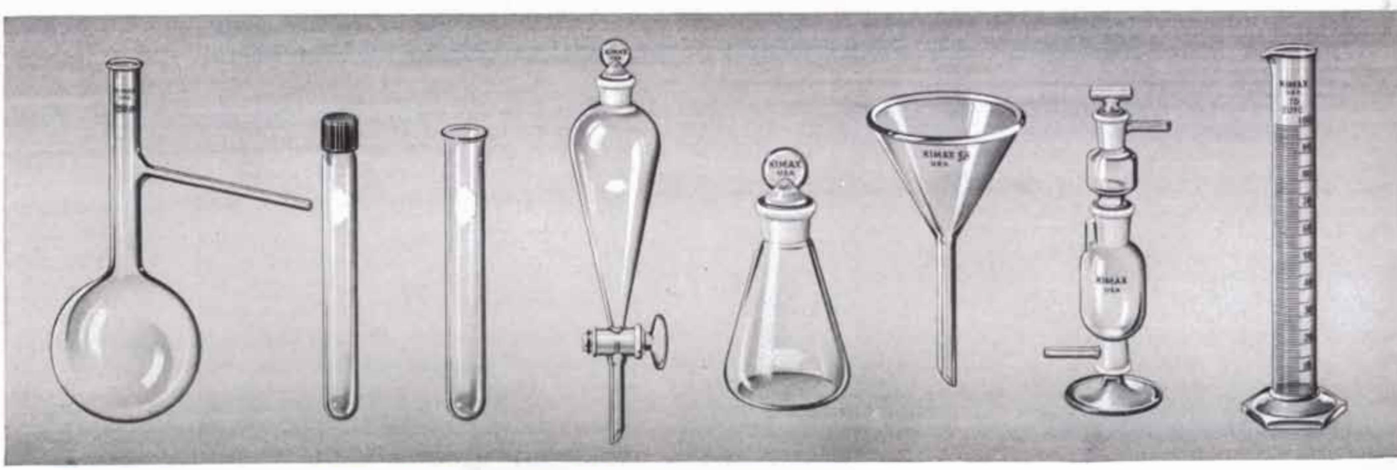

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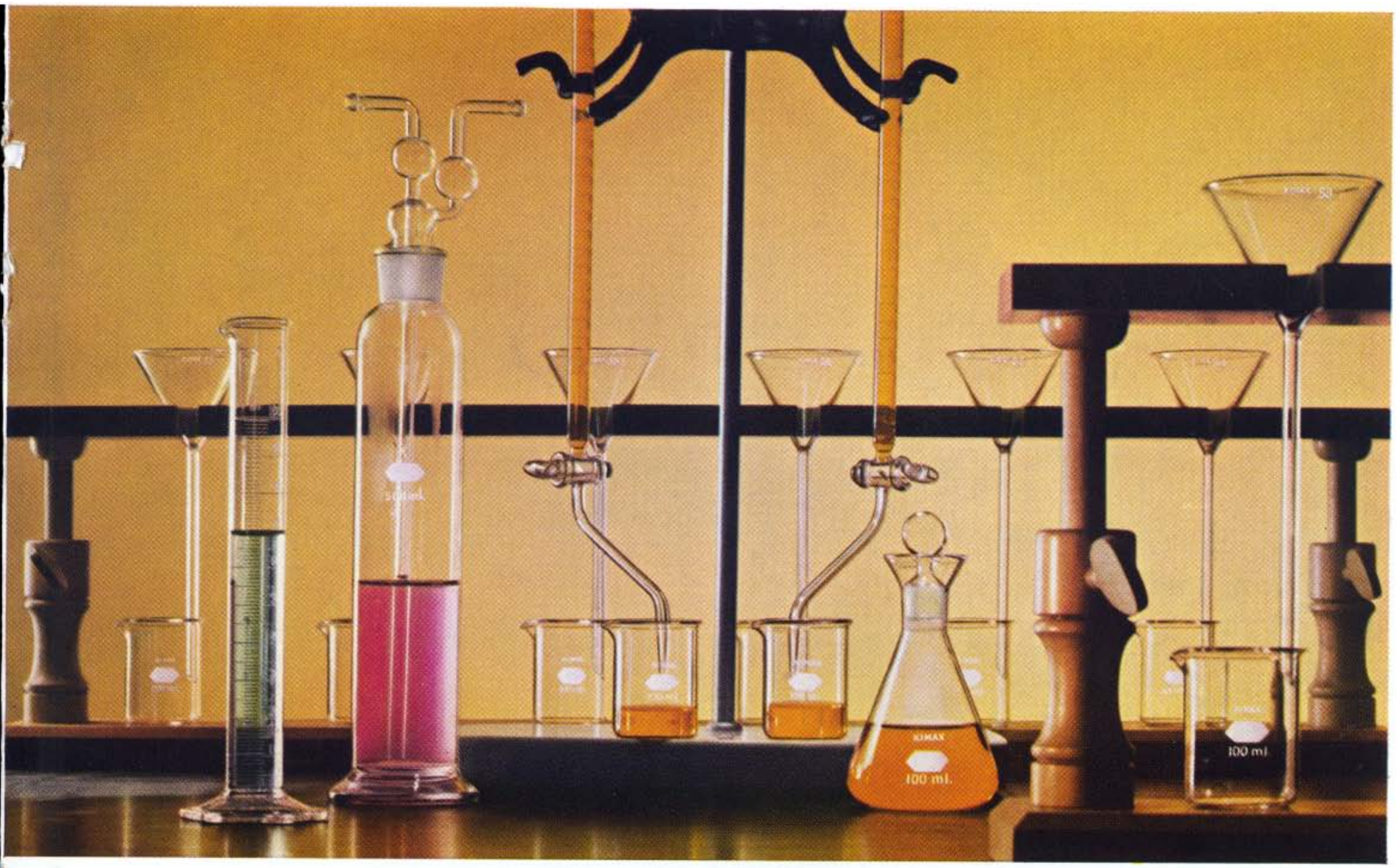
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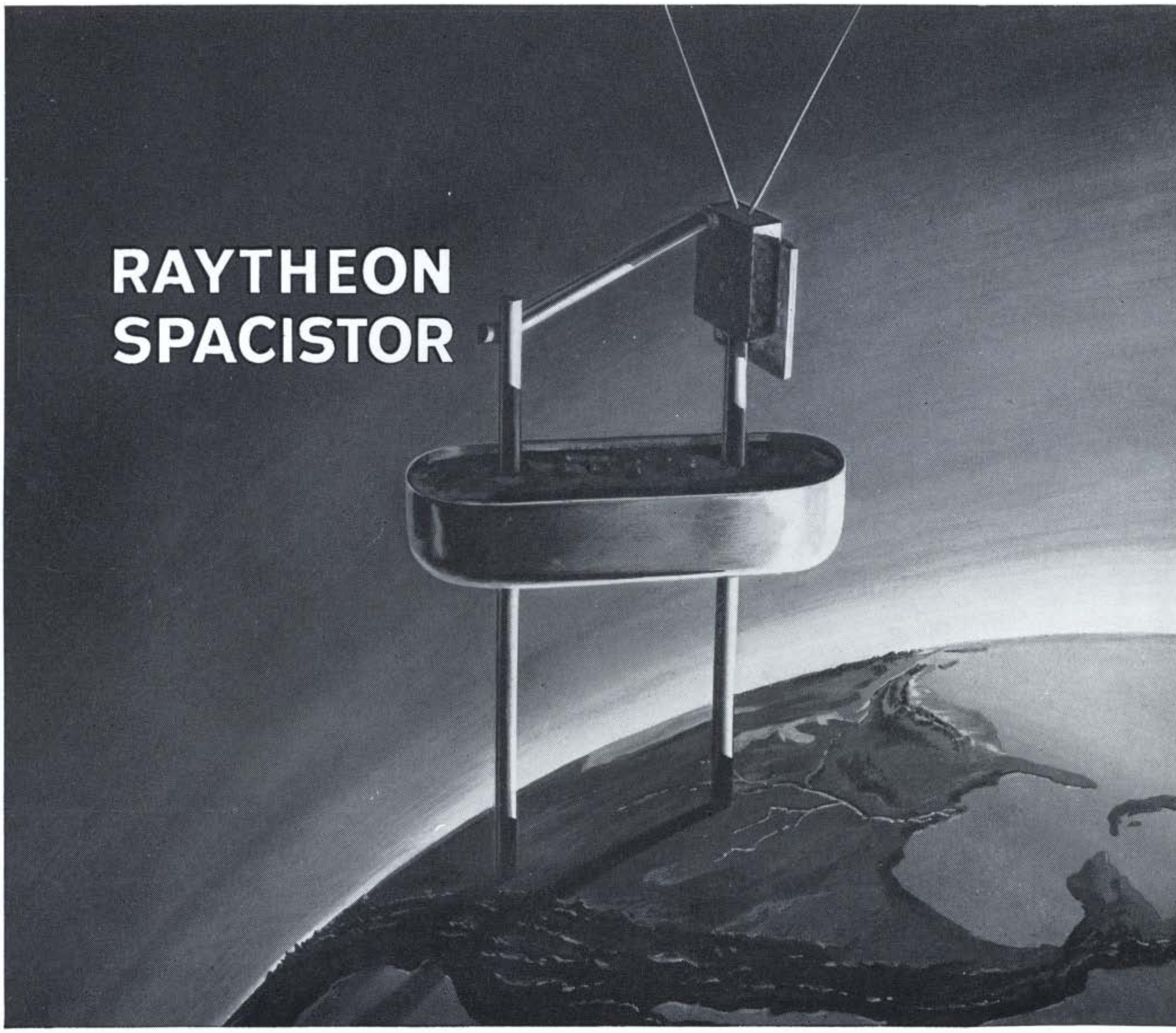

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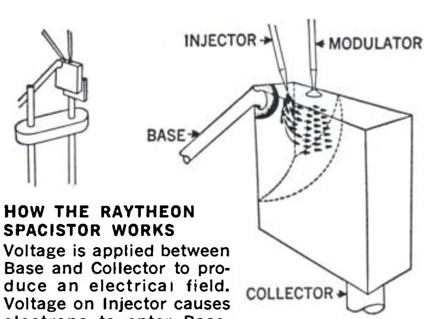

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GOUT AND METABOLISM

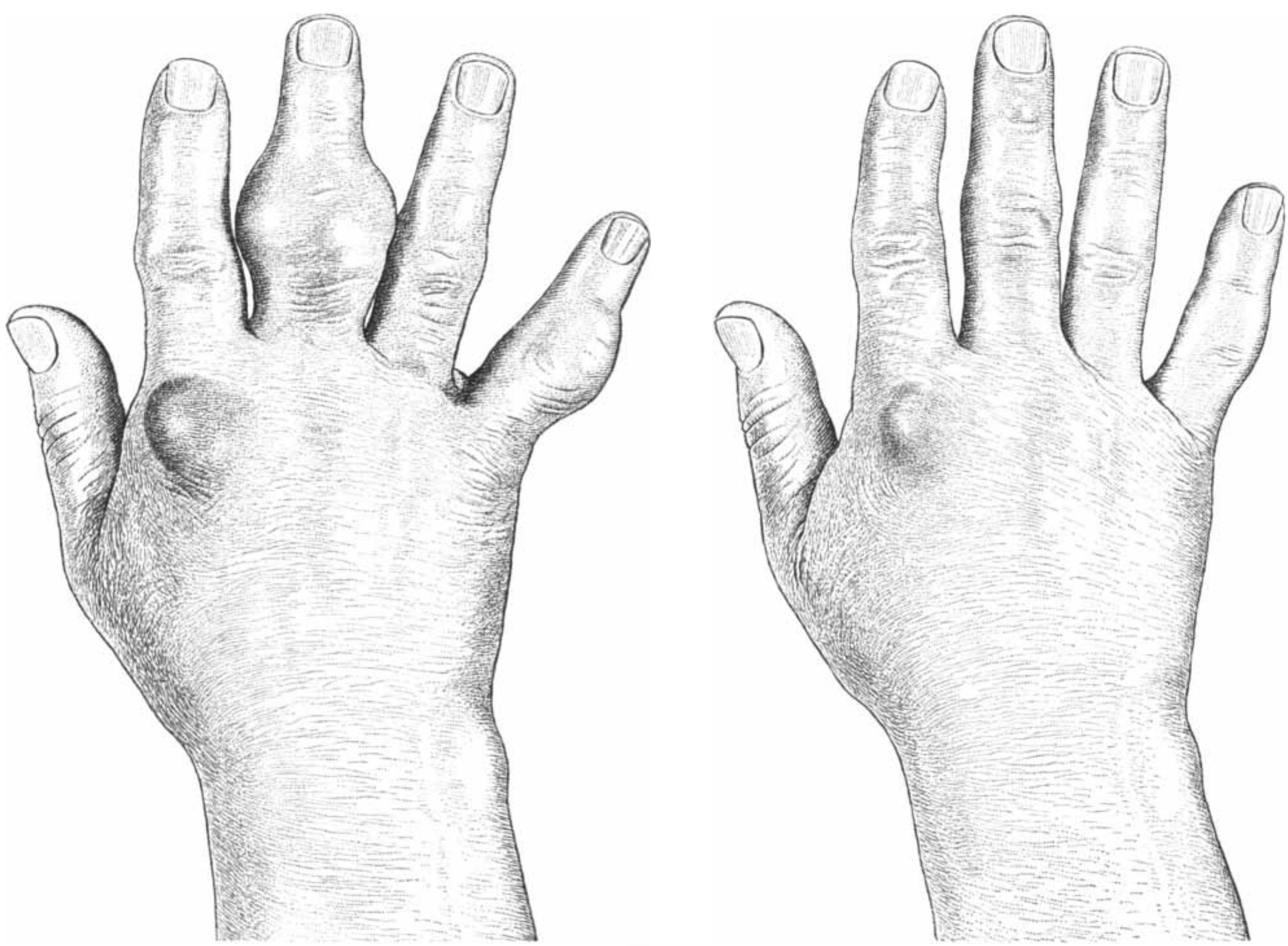
There is no convincing evidence that gout is caused by high living. It is associated with a high level of uric acid, but no connection between this level and the symptoms of the disease has been found

by DeWitt Stetten, Jr.

Gout, a disease peculiar to man, has afflicted our species as far back as history goes. Hippocrates described the disease as early as 400 B.C., and clearly distinguished it from other ailments of the joints. In fact, among all the afflictions of man, gout has always enjoyed a special notoriety. There is no pain like the exquisite pain of an acute gout attack, most vividly described by the English essayist Sydney Smith: "When I have gout, I feel as if I am walking on my eyeballs." Even our nursery folklore, the Mother Goose rhymes, singles out gout for mention:

Lazy Tom with jacket blue
Stole his father's gouty shoe.
The worst of harm that Dad can wish him
Is that his gouty shoe may fit him.

This verse takes note of two of gout's distinctions: it tends to run in families and it is mainly a disease of males, seldom attacking women. More remarkable is the fact that it seems to be



GOUTY HAND at left is covered with hard salts of "tophi" which result from the accumulation of uric acid in cartilage. Although the joints of the patient may be painful, the tophi are not. At right is the same hand after treatment with a substance which promotes the excretion of uric acid by the kidney. These drawings are based on a study made by E. C. Bartels of the Lahey Clinic in Boston.

partial to great men. The list of its famous victims is almost a roster of the most distinguished personages in history. Among the men who are reputed to have suffered from gout are Alexander the Great, Kublai Khan, Isaac Newton, Charles Darwin, William Harvey, Benjamin Franklin, Martin Luther, John Calvin, John Wesley, Cardinal Wolsey, John Milton, Ben Jonson, William Congreve, Thomas Gray, Johann Wolfgang von Goethe, James Russell Lowell, Alfred Tennyson, Edward Gibbon, Henry Fielding, Horace Walpole, Samuel Johnson, Lord Chesterfield, Francis Bacon, Stendhal, Guy de Maupassant, and John Churchill, First Duke of Marlborough. Truly this is an impressive array of victims, considering that the total incidence of gout in a population, as estimated from modern figures, is only about two per thousand.

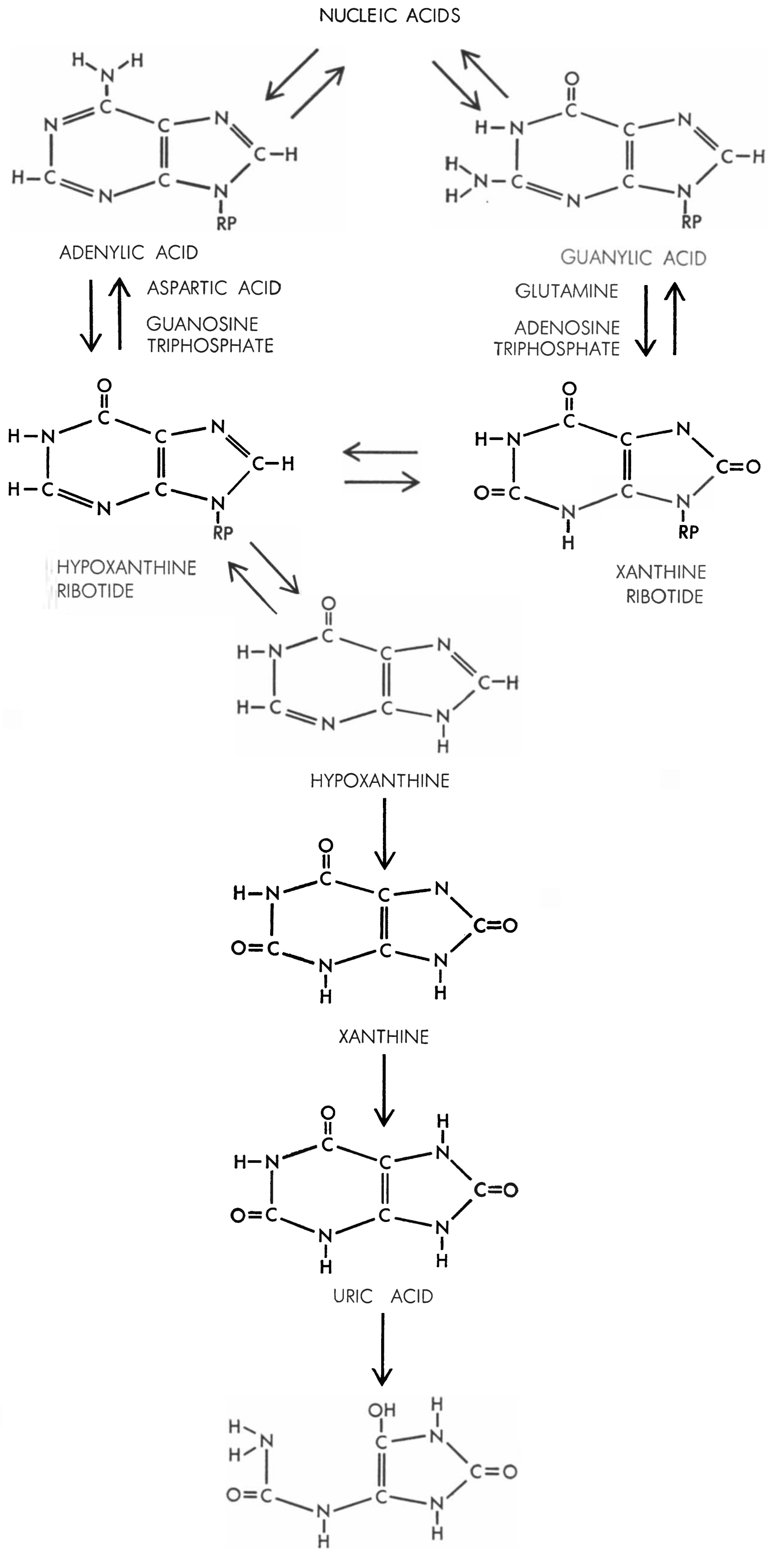
If gout has attracted more than its legitimate share of medical and literary attention, it still remains, unhappily, a very puzzling disease. Its cause eludes us, and we do not yet have a satisfactory treatment. We have known for a long time that gout is associated with a metabolic defect which shows itself by a high level of uric acid in the blood. But all attempts to find the connection between the excess of uric acid and the arthritic symptoms of the disease have failed.

Let us look first at the symptoms. The acute attack usually starts abruptly, without clear or consistent advance warning. It may start in the joints of the fingers, wrists, elbows, knees, ankles or feet; wherever it starts, sooner or later it generally involves the big toe. The joints become inflamed, swollen and excruciatingly painful. The sensitivity of the affected tissues is legendary. The vibrations caused by a person walking in the room, the weight of a bed sheet on the gout-stricken toe, are all but unendurable.

Whatever the basic cause, various stresses seem to be able to precipitate the attack—a bone fracture, an operation, emotional stress, overeating, too much drinking. The attack may last one to six weeks, or even longer. It usually subsides eventually even without treatment, and may not reappear for months or years. About 550 A.D. a Greek physician, Alexander of Tralles, discovered that an extract of the meadow saffron gave prompt relief from the acute attack. This drug, now identified as colchicine, has been the sheet-anchor of the treatment of gout for 14 centuries. It suffers from the drawback of being a fairly poisonous substance (producing unpleasant gastrointestinal effects), and there have been periods when it fell into disrepute. But physicians have always come back to it as the most effective available therapy.

Apparently the only inflammation or pain that responds to colchicine is that of gout; because of this specific action

ENGLISH CARTOON published in 1799 is characteristic of many jocose references to gout in the 18th and 19th centuries, when the disease was a symbol of self-indulgence. The stout gentleman at the right has gout not only in both feet but also in one hand.



URIC ACID is a product of the breakdown of nucleic acids. This diagram outlines the principal pathways in this metabolic activity. The substances named beside the double arrows are required for those steps. The symbol RP stands for the ribose phosphate radical. In man uric acid is excreted directly; in most other mammals it is first converted into allantoin.

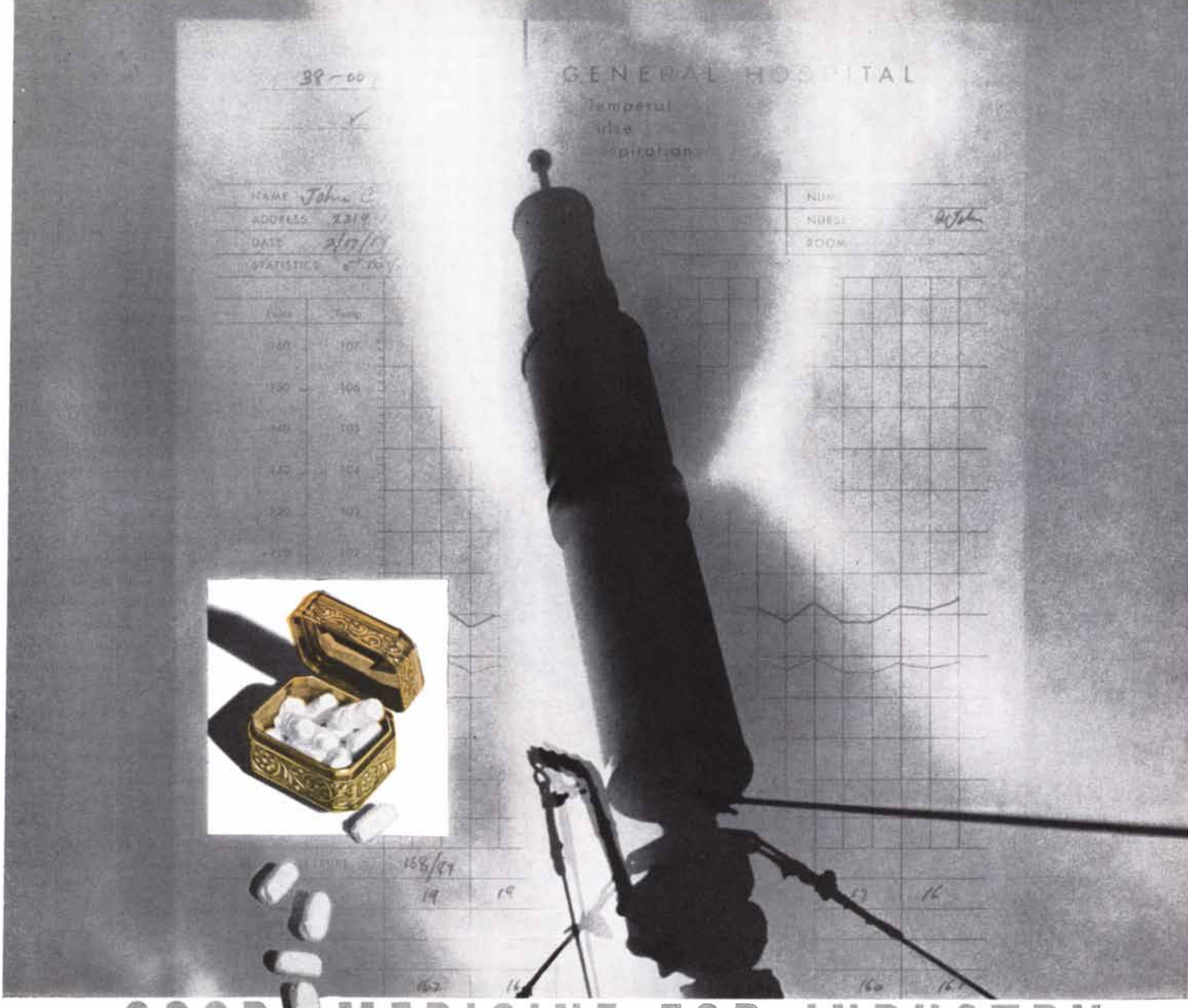
the drug is a good diagnostic test to distinguish gout from other forms of arthritis. But just how it acts to relieve the gouty attack is a mystery. In recent years it has been learned that colchicine's outstanding property is its ability to stop the process of cell division (mitosis) in rapidly growing tissues. This, as we shall see, may offer a possible clue to its action against gout.

There is one symptom of gout which gives us a starting point for studying its chemistry. This symptom is a familiar badge of the disease: the round lumps on the ears and joints that balloon to the size of a golf ball or even larger [*see illustration on page 73*]. These hard masses, called tophi, grow in the cartilaginous tissues. Unlike the inflammations of the acute attack, the tophi are completely painless. They are made up largely of salts of uric acid, and arise directly from the high concentration of uric acid in the gouty individual's body fluids. Because uric acid and its salts are practically insoluble, the salts crystallize and grow into hard concretions. It was the discovery of these salts of uric acid in the tophi of sufferers from gout that directed attention to the underlying metabolic defect.

Uric acid, like gout, has a distinguished history. The compound was first identified in 1776 by Karl Scheele of Sweden, better known as one of the discoverers of oxygen. Not long afterward William Wollaston, the English chemist and physicist, made the discovery that salts of Scheele's uric acid were present in the tophi of gout. And half a century later the British physician Sir Alfred Garrod found that the uric acid level in the blood could be used as a diagnostic test for the disease.

Today uric acid is recognized as an important substance in the general economy of the body. It is a breakdown product of the metabolism of proteins. In birds and reptiles almost all of the nitrogenous waste from this metabolism is excreted as uric acid. Mammals convert most of their nitrogenous waste to urea, which is highly soluble and therefore easily excreted in the urine. But mammals also produce some uric acid. Most mammals do not stop there: they degrade uric acid further to a substance called allantoin, and this compound, rather than uric acid, appears in the urine. Their conversion of uric acid to allantoin is carried out by an enzyme of the liver called uricase. Man and the higher apes, however, lack this enzyme, and uric acid is their end product.

Normally the amount of uric acid in



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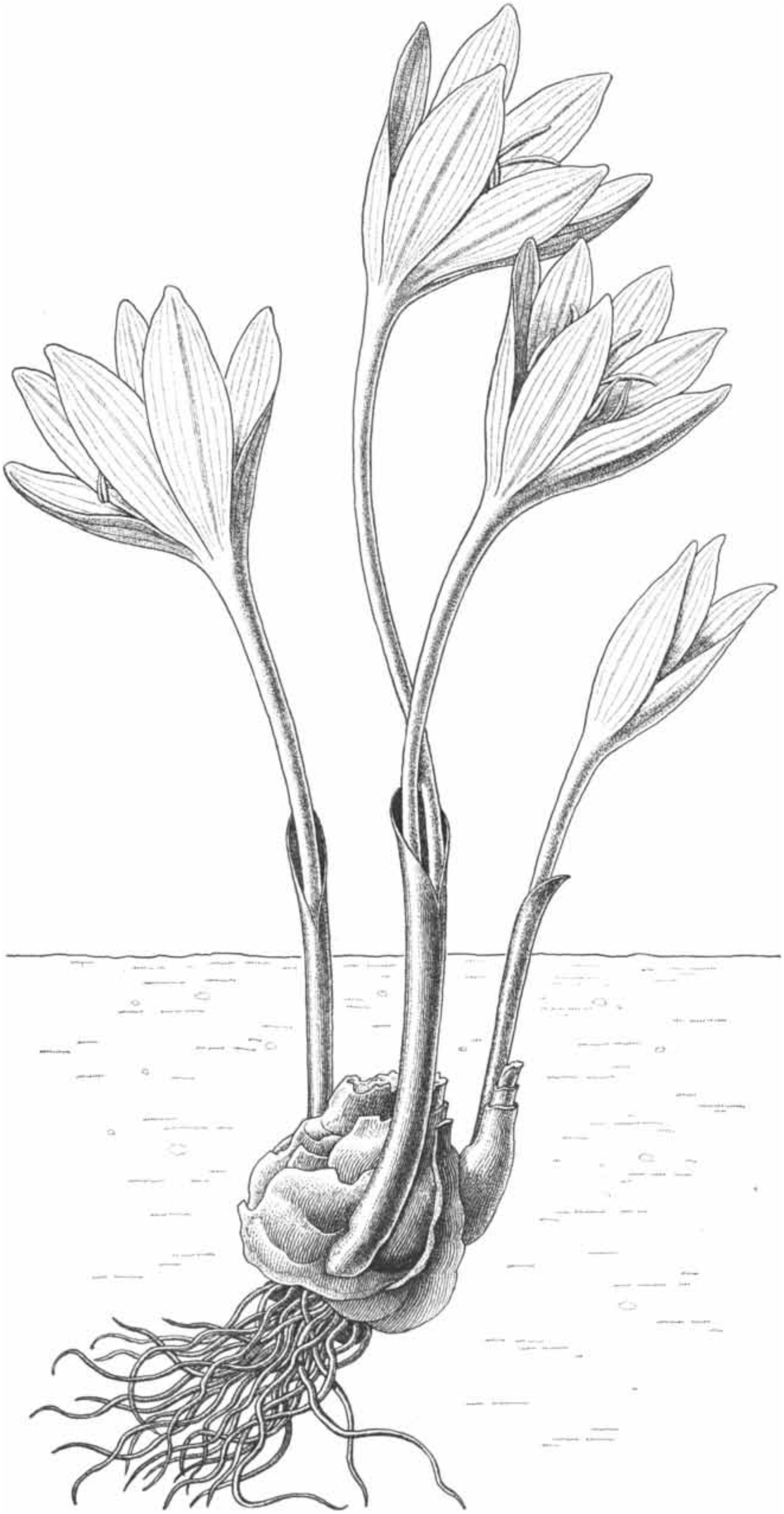

MEADOW SAFFRON, a pink or purplish wildflower which blooms in the fall, is the source of colchicine, a substance used to relieve the pain of gout. Colchicine is obtained from the seeds and bulbous root of the plant. The efficacy of the extract was discovered by Alexander of Tralles in 550 A.D. It is still the most effective treatment for the pain of gout.

the body is very small: the total pool in man is about one gram, and about half a gram is discharged in the urine each day. But in the person with gout the amount of uric acid in the body may rise to 20 or 30 times the normal level. There seems to be something birdlike about the metabolism of a gouty man: his metabolic machinery produces an amount of uric acid which is abnormal for a mammal.

Chemically uric acid is a member of a very common class of substances—namely, the purines. Among the purines are adenine and guanine, which are building stones of the nucleic acids (DNA and RNA) and other essential constituents of all living cells. The cells of man and other higher animals synthesize purines from amino acids and other materials. We also obtain purines in our food, especially from high-protein foods such as meat. The regulatory process which adjusts the supply of purines to the needs of the body gets rid of any excess of usable purines by degrading them to uric acid [*see diagram on page 76*]. Uric acid is then removed from the blood by the kidneys and excreted in the urine.

What makes uric acid accumulate in the blood of people with gout? There are, of course, various possible explanations. It was long thought that the main cause was an over-rich diet, supplying too much purine. It is true that gout seems to be particularly common among wealthy people. But it also afflicts many people who live on protein-poor diets. Another popular theory has held that gout may arise from some kidney defect which impairs the organ's ability to eliminate uric acid. Most gouty patients, however, show no such defect. The prevailing conclusion today is that the high level of uric acid in these patients is due to excessive production of the substance by their cells rather than inability to get rid of it.

The most convincing evidence comes from tracer experiments. When we label a potential building material for uric acid (such as the amino acid glycine) with a tracer isotope, we find that gouty patients tend to convert more of this material to uric acid than normal persons do. In other words, people with gout transform an unusually large proportion of the amino acid in their food into uric acid. Part of this excess of uric acid is excreted in the urine. But unfortunately the human kidney has only a limited ability to get rid of the substance. It is much less efficient in this respect than the kidney of a bird (whose urine is *now commercially available*

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Property	Value
Atomic number	49
Atomic weight	114.76
Boiling point	2000°C (3632°F)
Crystal structure	Face-centered tetragonal
Density at 20°C (68°F)	
g/cc	7.31
lbs/cu. in.	0.264
troy ozs./cu. in.	3.85
Electrical resistivity (microhm-cm)	
(solid) 20°C (68°F)	9
(at melting point) 156°C (313°F)	29
Electrochemical equivalent	
In +++ (mg/coulomb)	0.39641
Electrode reduction potential	
In +++ (H_2 = 0.0 volt)	0.34
Latent heat of fusion (cal/g)	6.8
Latent heat of vaporization (cal/g)	468
Linear coefficient of thermal expansion/1°C	33×10^{-6}
Mechanical properties:	
Tensile strength, psi	380
Elongation (% in 1")	22
Brinell hardness	0.9
Modulus of elasticity, psi	1,570,000
Melting point	156.17 ± .05°C (313.1 ± .1°F)
Nuclear Data	
Stable Isotopes (113,115)	2
Thermal neutron cross section (2200 m/s)	
Absorption (barns)	190 ± 10
Scattering (barns)	2.2 ± 0.5
Solidification shrinkage	2.5%
Specific heat (cal/g/°C)	
(solid) 20°C	0.057
Specific volume (cc/g)	
20°C (68°F)	0.136
Thermal conductivity (cal/sq. cm/cm/°C/sec)	
20°C	0.057
Valence	Usually 3, but also 2 and 1
Vapor press. (mm Hg)	
1249°C (2280°F)	1
1466°C (2671°F)	10
1756°C (3193°F)	100
1863°C (3385°F)	200
1982°C (3600°F)	400

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partly made up of solid salts of uric acid). Furthermore, man also suffers from the handicap that he cannot convert uric acid to the more easily excreted substance allantoin, as other mammals can. Consequently if he produces too much uric acid, it accumulates in his body.

What causes the overproduction of uric acid in the first place? Here we have only a few grounds for speculation, and one of the clues is the ameliorating effect of colchicine. The speculation has to do with the production of sperm cells. We know that: (1) gout occurs predominantly in males; (2) eunuchs never have the disease, as Hippocrates observed; (3) colchicine inhibits the multiplication of sperm cells, presumably by preventing mitosis. From these facts we may infer that males are more prone to gout than females because the production of their sperm cells involves an extra amount of activity in synthesis of nucleic acids and their breakdown to uric acid. (We know, indeed, that a disease such as leukemia, which also generates cells at a high rate, occasionally produces gout as a secondary effect.) Possibly colchicine's effect in relieving gout derives from its arrest of the manufacture of nucleic acids.

All this gives us a plausible picture of the metabolic side of gout, but it still leaves us entirely in the dark about how the overload of uric acid is related to the acute symptoms—the agonizingly painful attack on the joints. The arthritic side of the disease is full of puzzles. The acute attack is not necessarily accompanied by any rise of the uric acid level in the blood or urine. To investigate this matter further, large injections of uric acid have been given to gouty patients during their quiescent intervals: such injections do not provoke an acute attack. Many persons with a chronically high level of uric acid never suffer from gouty arthritis. On the other hand, drugs that speed up the excretion of uric acid do not relieve a gouty attack. In short, no link of any kind between uric acid and the inflammation of the joints has yet been discovered.

Some investigators are beginning to believe that there is no direct connection. They suspect that the inflammation of gout may be produced by some other agent—a substance which, like uric acid, also is a product of the metabolism of nucleic acids. Alexander Gutman and his associates at Mt. Sinai Hospital have recently found a new purine (a variation of guanine) whose abundance in the urine increases during an acute attack of gout. Possibly this or some related compound is the real culprit of the attack.

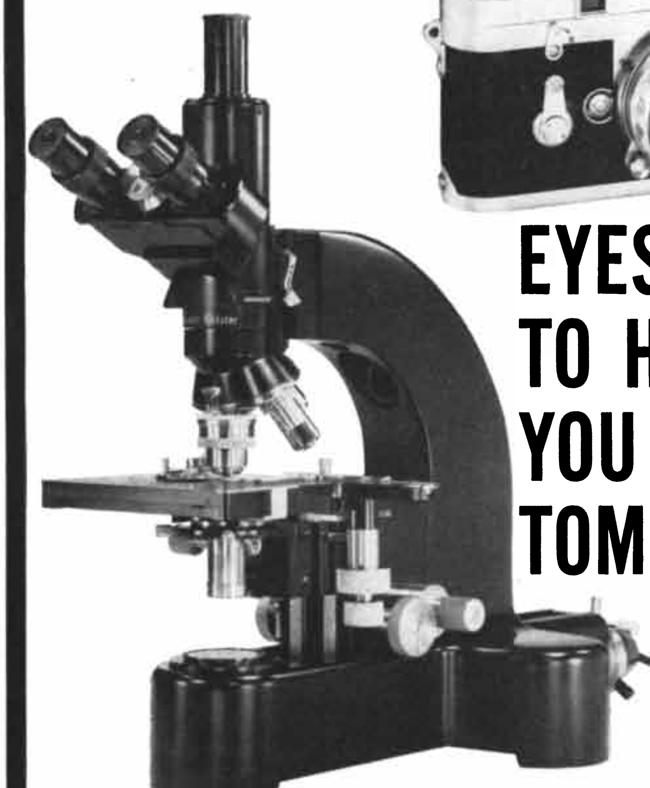
For centuries students of gout have speculated on why the disease shows such a partiality for illustrious persons. Havelock Ellis, in his *A Study of British Genius*, observed that gout seems to be the one disease that characteristically singles out great minds; he concluded that "this association cannot be a fortuitous coincidence." In a recent note in *Nature* another student, E. Orowan, offered a theory. He suggested that uric acid, like certain other purines (e.g., caffeine), may have a stimulating effect on the cerebral cortex. Noting that man and the higher apes are the only mammals with significant concentrations of uric acid in their blood, he argued that their superior mental capacity may derive from an accident of mutation which destroyed their ability to make the enzyme that converts uric acid to allantoin. (He tactfully refrained from mentioning that men have a substantially higher concentration of uric acid in their blood than women.) Orowan went on to contend that intellectual vigor is most often found among people who live on a diet rich in meat.

I must hasten to add that the distinguished British physiologist J. B. S. Haldane promptly wrote a rebuttal to Orowan's view in *Nature*. He asserted, among other things, that there is no evidence of unusual intellectual capacity in the segment of the U. S. population (about 1 per cent) which is known to suffer from an elevated level of uric acid in the blood. As far as I am aware, no actual survey of this question has been made. It would be interesting indeed to carry out a statistical study to see whether there is any correlation between intellectual achievement and the uric acid level.

In Gilbert and Sullivan's *The Gondoliers,* the Grand Inquisitor bellows:

A taste for drink, combined with gout,
Had doubled him up forever.
Of that there is no manner of doubt–
No probable, possible shadow of doubt–
No possible doubt whatever.

So far as scientific study of the disease is concerned, investigators are still thwarted and stimulated by the many uncertainties about this ancient and honorable affliction. Its riddles (and its victims) await the arrival of a scientist endowed with the Grand Inquisitor's remarkable capacity for removing doubt from a perplexing situation.



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Dr. William W. Piper joined the staff of the General Electric Research Laboratory in 1951, after receiving his Ph.D. in Physics from Ohio State University (1950) and his B.S. from Columbia University (1946). His fields of interest include theoretical and experimental studies of electroluminescence, crystal growth, electrical and optical properties of transparent crystals, and atomic field computations.

Research in electroluminescence

Single crystals led General Electric's Dr. William W. Piper to new understanding of light sources

Electroluminescence, the process in which electrical energy is converted directly into light within a phosphor, has been known for many years. Only in the last decade, however, have scientists obtained detailed knowledge of its characteristics. Early studies were carried out with samples consisting of large numbers of microscopic phosphor particles. The complexity of this experimental system made it difficult to interpret the data obtained in terms of a fundamental explanation of electroluminescence.

Shortly after Dr. William W. Piper joined the staff of the General Electric Research Laboratory, he learned how to grow single crystals of zinc sulfide phosphors. His studies of these single crystals soon led to the successful identification of the means by which electroluminescence occurs in this material.

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CLIMATE AND THE CHANGING SUN

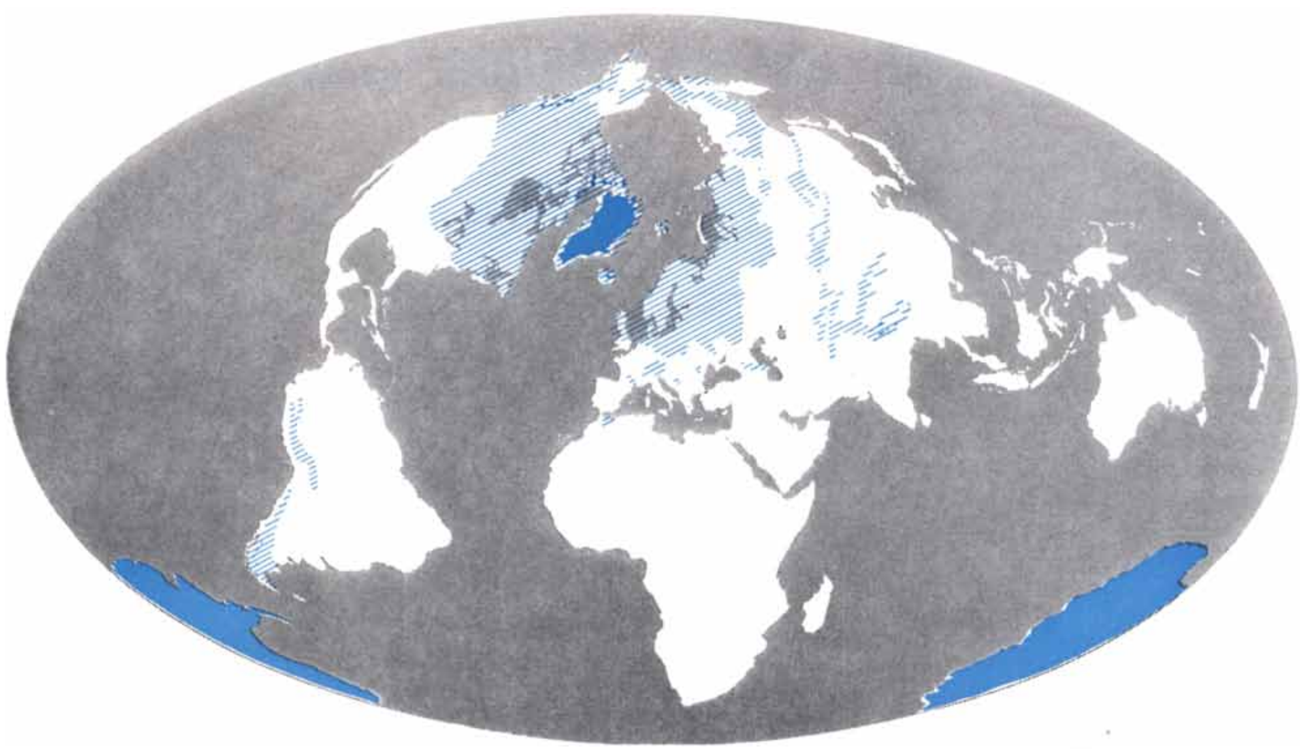
It is generally assumed that the rate at which the sun has radiated energy during geologic time has been reasonably constant. The author indicates how this rate may have varied and caused ice ages on earth

by Ernst J. Öpik

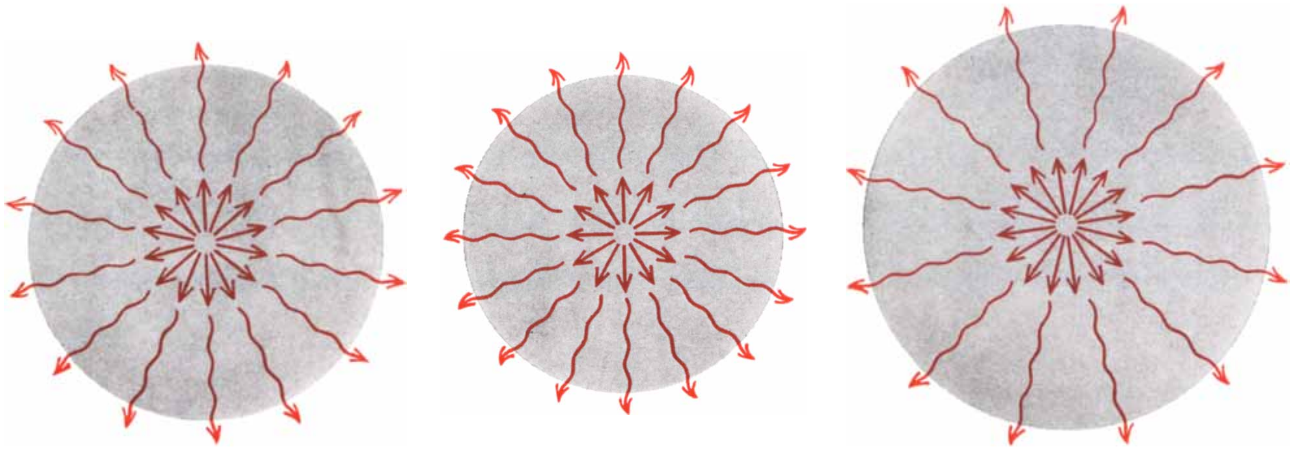
If the sun's heat were to drop only 13 per cent, the whole earth would soon be covered with a mile-thick mantle of ice. Contrariwise, if the sun's radiation were 30 per cent hotter than it is, life on the earth would be destroyed by a heat wave. Even very slight changes in the sun's heat would have profound effects on the earth's climate, winds, waters, geology and life itself. We know that the climate of the earth has in fact changed drastically over the eons of time. Many theories have been offered to explain these long-term swings: dust clouds from volcanic explosions, changes in the tilt or orbit of the earth, and so on. None of them has proved convincing. In the end we always come back to the simplest and most plausible hypothesis: that our solar furnace varies in its output of heat.

The trouble with this idea has been that it is difficult to see what physical process in the sun could produce the kind of fluctuations we see reflected in the climatic history of the earth. According to our reading of the rocks, the earth has had long periods of warm climate punctuated by comparatively short ice ages. This peculiar pattern cannot be accounted for by any simple scheme of alternate waxing and waning of the sun. I believe, however, that with certain reasonable assumptions about the composition of the sun it is possible to picture a solar mechanism which would produce just such a pattern of heat variation. This article will present the new hypothesis and some interesting implications concerning the long-term trend of temperature and life on our planet.

Let us look first at the facts we have to explain. In very ancient rocks of Canada and Southern Rhodesia there are traces of primitive plants which suggest that the climate of the earth three billion years ago was not radically different



ICE SHEETS covered the colored areas on this map at the height of the Quaternary ice age, which began about a million years ago. Ice sheets still cover the areas in solid color. The size of the Antarctic ice sheet is exaggerated by the projection of the map.



RADIATION FROM THE SUN normally equals the amount of energy produced by thermonuclear reactions in the hot core (*first drawing*). If more energy is given off at the surface (*outer arrows*) than is being produced in the core (*inner arrows*), the sun shrinks in size to release more energy (*second drawing*). Conversely, if the sun produces more energy than it radiates, it expands in size (*third*).

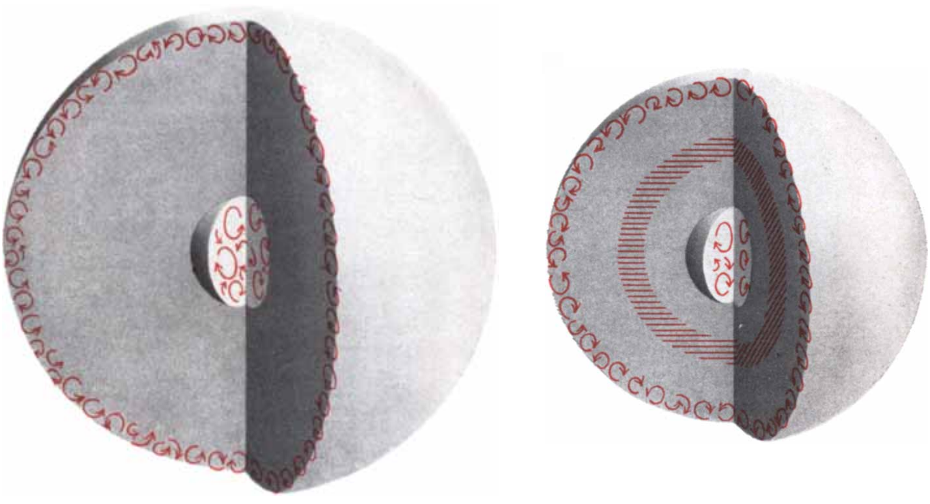
from what it is now. The rocks tell us further that ice ages have visited the earth only at long-separated intervals. We have evidence of one period of glaciers about a billion years ago, another some 750 million years ago, another 480,000 million years ago, again about 240 million years ago, and we are now in one which started a million years ago. In short, ice ages have come roughly every quarter of a billion years. Each has lasted only a few million years. The rest of the time the earth has been comparatively warm.

During 90 per cent of the past 500 million years the world-wide average temperature has been about 72 degrees Fahrenheit. Palm trees grew all over the U. S., and New York State was as warm as present-day Florida. Currently the global average temperature is 58 degrees. We are in a relatively warm "interglacial" interlude of our ice age; it has had four cold waves during which the world average temperature fell as low as 42 degrees. That these cold waves were world-wide, rather than confined to a single hemisphere, has been proved by measurements of the temperatures of ancient seas with the oxygen-isotope thermometer invented by Harold C. Urey [see "Ancient Temperatures," by Cesare Emiliani; SCIENTIFIC AMERICAN, February]. These measurements show that 18,000 years ago, at the peak of the last glaciation, the temperature of the tropical Caribbean was around 73 degrees, against 84 degrees today.

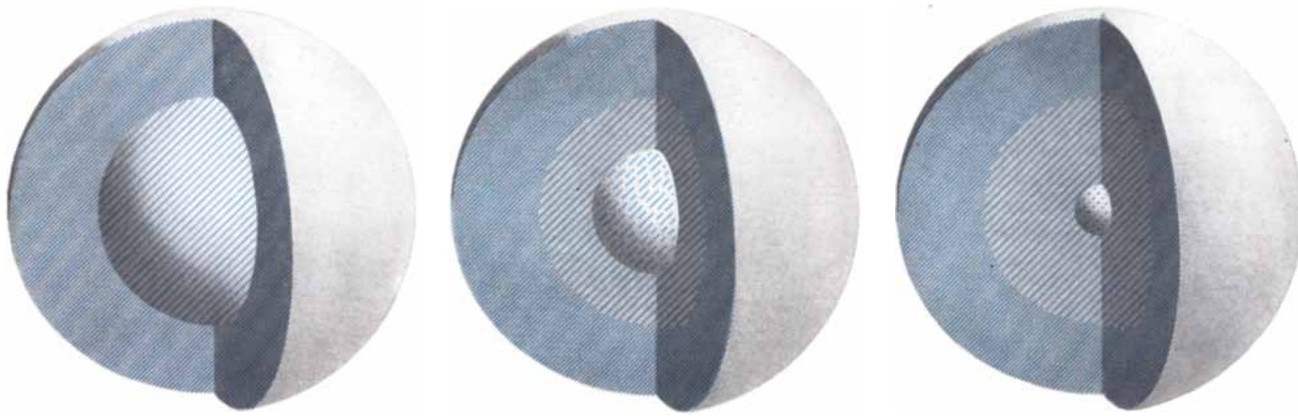
A world-wide fall or rise of temperature strongly indicates a change in the heat output by the sun; it is hard to explain in any other way. Furthermore, the regular repetition of the ice ages at approximately 250-million-year intervals suggests some sort of cycle in the sun; no haphazard process such as volcanic explosions or other modifications of our atmosphere could generate a rhythm of this kind.

We can account for the wide swings of climate on the earth merely by assuming that the heat output of the sun has fluctuated by 8 or 9 per cent from its present norm. A fall of 8 per cent from this level would reduce the global average temperature to the 41 degrees of the coldest glacial periods; a rise of 9 per cent would make the global average 72 degrees.

Let us now try to explain how such changes in the sun may come about. As is well known, the sun produces its heat by the nuclear process of fusion, converting its fuel, hydrogen, into helium. This nuclear burning goes on only in the hot core. The sun radiates enough heat from its surface to supply 2.2 billion earth-balls like ours. By and large we should expect the sun to keep its rate of radiation more or less constant. If it radiates energy away faster than it is being generated in the core, the sun will contract, raise its internal temperature and so restore the energy balance; if its surface loses energy too slowly, the sun will expand and again reach a balance of energy production and outgo. So the sun usually maintains an equilibrium and a nonfluctuating output of sunshine,



THEORETICAL CYCLE OF THE SUN starts with the sun in its normal state corresponding to a warm period on earth. Convection currents (*arrows*) promote nuclear reactions in the core, which is relatively small but rich in hydrogen fuel (*first drawing*). As hydrogen from the surrounding mantle diffuses into the core, the metallic elements tend



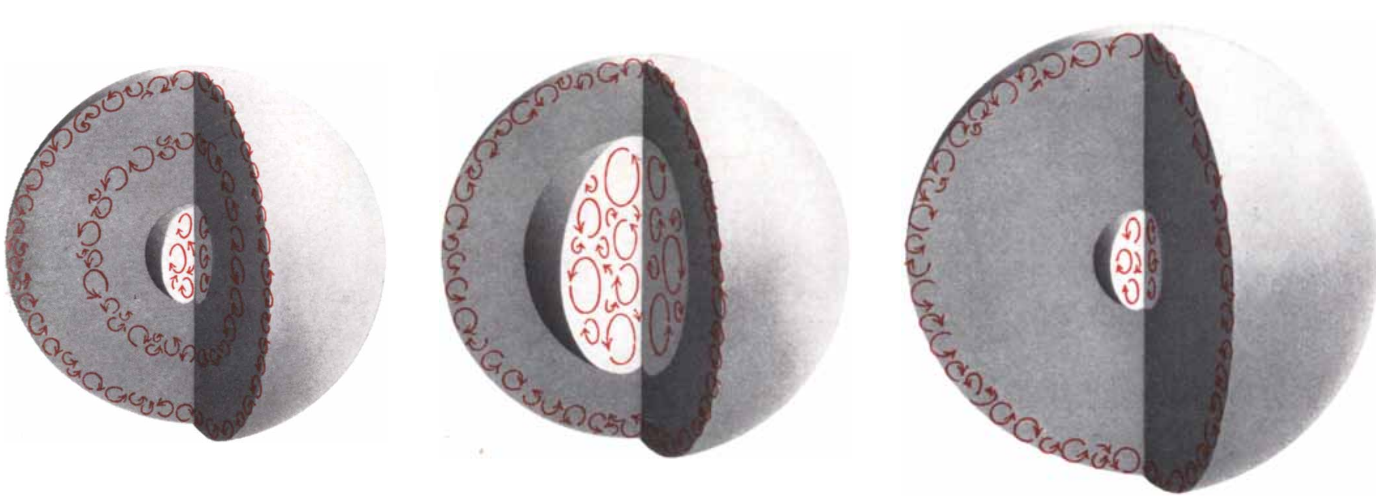
SIZE AND HYDROGEN CONTENT of the sun's core are presumably decreasing while the sun is getting hotter. At comparable stages of the sun's cycle four billion years ago (*first*), 50 million years ago (*second*) and one billion years from now (*third*) the core becomes progressively smaller. The concentration of hydrogen (*color*) in the core drops from 31 per cent to 10 to 1.25 per cent.

which accounts for the long warm periods on the earth.

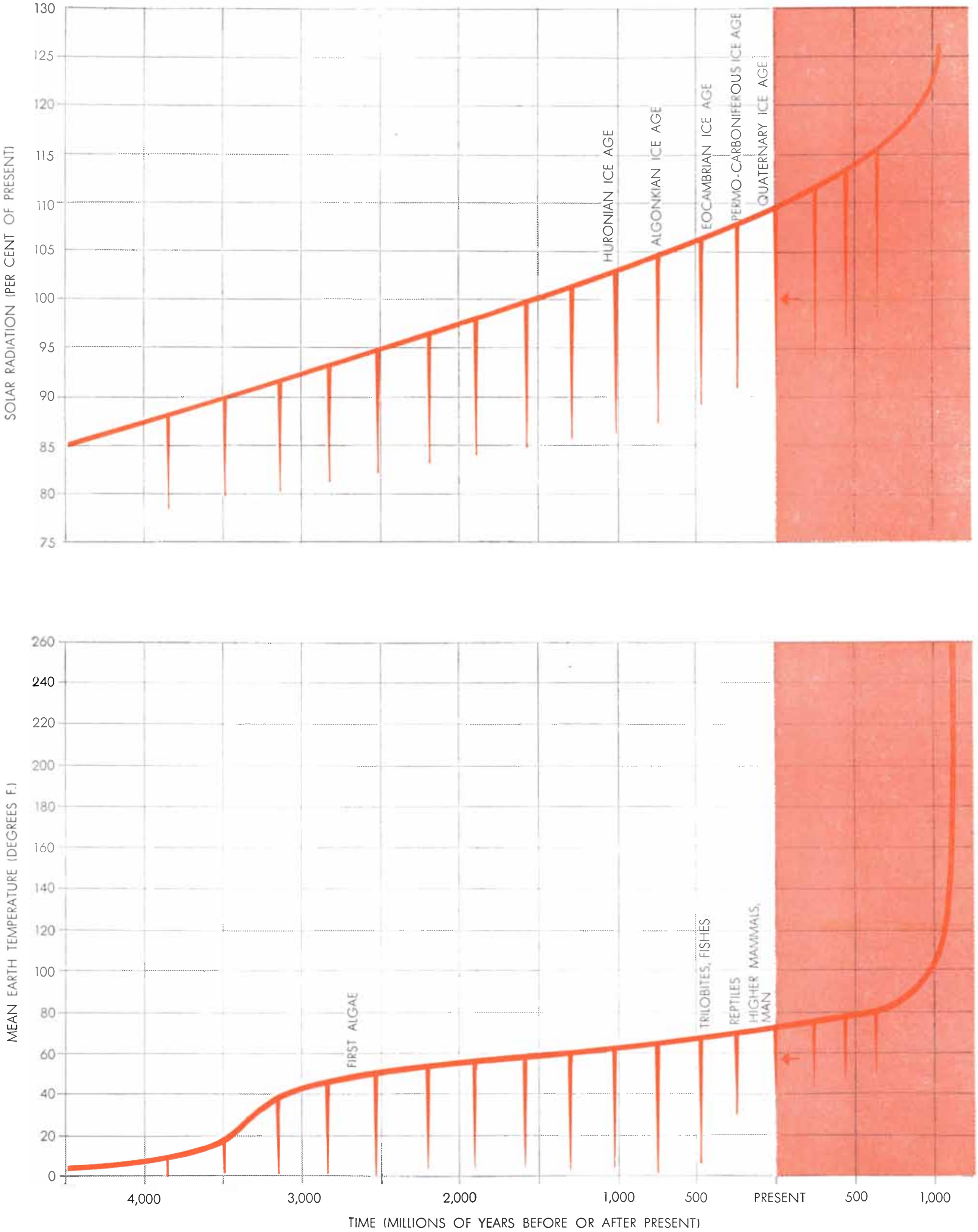
But we must reckon with the effect of other material in the sun besides its fuel. These other elements include carbon, nitrogen, oxygen, neon, magnesium, silicon and iron. For simplicity's sake let us lump them together and call them "metals." Now the effect that concerns us here is their interference with the radiation of heat from the core. By absorbing some of this heat they reduce the transparency of the gas to transmission of energy: they act like smoke in air.

We can picture the following process. Within the hot core the nuclear burning of hydrogen stirs and mixes the gas like water in a boiling kettle. The hydrogen in this cauldron does not mix with the inactive hydrogen outside the core. But as the fuel burns and is converted to helium, hydrogen slowly diffuses into the core from the surrounding mantle. It leaves behind the "metals," which are heavier and diffuse more slowly. The concentration of "metals" around the core therefore rises. This tends to block the radiation of heat outward from the core. As a result, at a certain stage convection currents develop in the immediate surroundings around the core. The currents bring more hydrogen into the core and it grows in size. More hydrogen means more fuel. The enlarged core produces more heat than can be transported to the sun's surface. Consequently the sun expands. In doing so it spends energy to overcome the contracting force of gravitation. The net effect is to reduce the amount of energy that can be radiated away by the sun in the form of heat and light. Thus when production of heat in its core increases to 10 per cent above normal, the sun actually becomes 10 per cent dimmer [*see diagrams at top of opposite page*]. On the earth, 93 million miles away, an ice age begins.

Meanwhile in the expanded sun a reverse process sets in. The expansion lowers the temperature of the core and diminishes its production of energy. The core shrinks, the sun brightens, and within a few million years everything is normal again. The ice age now ends. It



to remain behind because they diffuse more slowly. Finally the metals become a barrier (*hatching*) to energy radiating from the core. This causes the sun to contract (*second*). The metal barrier itself becomes hot and develops convective currents (*third*), which spread to form a large core with increased hydrogen content and hence increased energy output (*fourth*). The sun then expands, using up twice the excess energy; the reduced radiation may cause an ice age on earth. The sun now returns to its normal state (*fifth*).



CALCULATED CHANGES in the radiation of the sun (*top*) are related to the apparent temperature on earth (*bottom*) during geologic time. At first the radiation was so weak that the earth had a permanent ice cover, but the radiation gradually increased. It continued to increase more and more rapidly except for short-term drops which corresponded to ice ages on earth. At present (*arrows*) the earth is in the Quaternary ice age, and its average temperature is 58 degrees F. In the future (*colored band*) there may be more ice ages, followed ultimately by a heat age. At this point the life evolving since the Algonkian ice age will be extinguished.

will not be repeated for hundreds of millions of years, because hydrogen diffuses into the core of the sun so slowly that it takes this long to build up again the "metal barrier" around the core that starts the disturbance.

How much confirmation can we find for this theory in quantitative terms? In the first place, we must make an assumption about the amount of "metals" in the sun. The theory does not work unless the amount of elements other than hydrogen and helium in the core of the sun comes to some 3 per cent. Most authorities put the amount in the sun at less than one tenth of 1 per cent. Their estimate is based on the quantity of these other elements in the gas of interstellar space. But interstellar space also contains dust, and we can be fairly sure that the "metals" frozen in this dust have a total mass amounting to about 1 per cent of that of the gas. Assuming that the cosmic dust forms the nuclei of the particles of matter from which stars condense in space, we may deduce that the stars must contain more than 1 per cent of "metals," especially in their deep interior. It seems to me that 3 per cent is a fair estimate.

Given this composition, we can account for the behavior of the sun as I have described it. We can calculate further that it would take some six million years for the core to develop its disturbance and about 500,000 for the sun to reach its final expansion (amounting to less than 1 per cent of its radius). These figures agree well with what is known about the duration of the ice ages.

The theory does not yet satisfactorily explain the short-term fluctuations within an ice age. In the current ice age we have had four glacial peaks separated by warm interglacial periods. One of the earlier ice ages had at least five peaks; by analogy we may expect a fifth advance of the glaciers, perhaps 75,000 years from now. These fluctuations seem to be world-wide and have been most difficult to understand. My own guess is that they may represent a kind of "flickering" of the disturbance in the sun—like a candle flame blown by the wind. They may be connected with the irregular mixing of matter in and around the core of the sun during the disturbance, or with allied events at the sun's surface. In any case, they do not basically dispute the main thesis that the ice ages stem from disturbances of the sun.

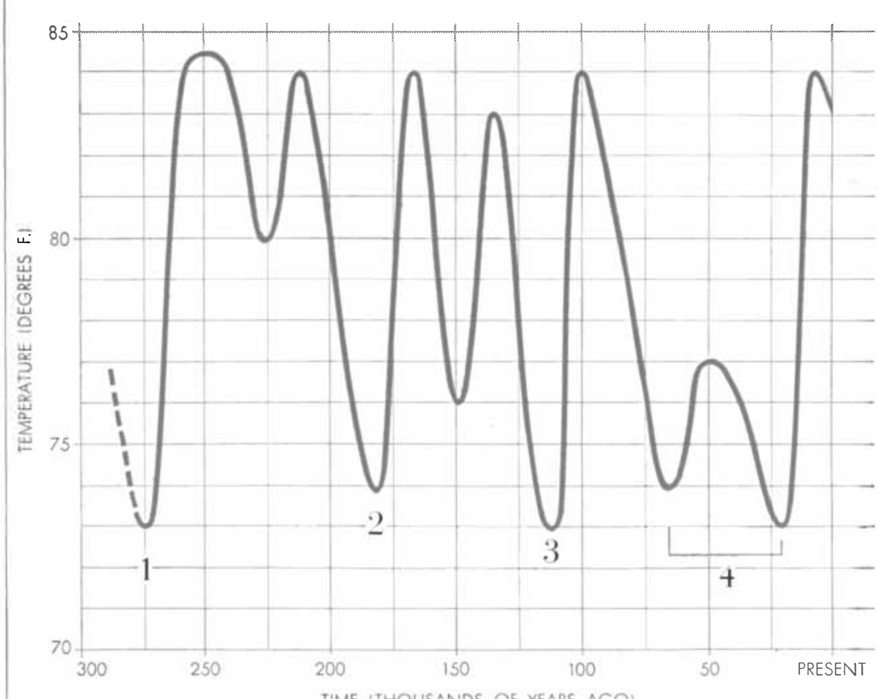
The theory now gives us a new view of the evolution of the sun. It used to be thought that a star steadily grows cooler as it burns up its fuel. But modern knowledge of the physics of the stars has dispelled this notion. The amount of radiation emitted by a star depends not on the heat production of its internal furnace but mainly on the star's mass, volume, structure and composition. According to the hypothesis I have outlined, the composition and relative size of its core are crucial. As the core consumes its fuel and shrinks, the radiation from the star actually increases. So our sun is becoming hotter rather than cooler, and the long-term trend on the earth should be toward a hotter and hotter climate.

Let us see what the calculations will show on the basis of the assumed composition of our sun. It is at least 50 per cent hydrogen. But only about a quarter of this is in the core, where the temperature is hot enough to burn it as nuclear fuel. Since there is very little mixing between the core and the outer parts of the sun—only a slow trickle of hydrogen into the core by diffusion—the core eats up its fuel. In a billion years it consumes an amount of hydrogen equal to more than 3,000 times the mass of the earth. So doing, it converts the hydrogen to helium. The hydrogen content of the core declines, and as a result the core shrinks in size. A reasonable estimate is that the core of the sun has shrunk from 10 per cent of the total radius of the sun originally to about 6 per cent now.

Taking all things into account—the assumed original composition of the sun, the changes in its core, the trickle of hydrogen into the core—I have calculated the long-term trend in the sun's heat output. It is assumed that hydrogen constituted 33 per cent of the core originally and has now declined to 10 per cent (the scanty evidence we have suggests that 10 per cent is not too wide of the mark). On this basis we see a picture of the evolution of the earth which goes from a frigid climate at the beginning to a boiling climate about one billion years hence [*see chart on page* 92].

According to these calculations, before three billion years ago the normal climate of the earth, even in the long undisturbed phases of the sun, must have been that of a permanent ice age. After three billion B.P. ("Before the Present") the sunshine warmed up sufficiently to free a considerable part of the earth from glaciers, but for some two billion years ice continued to be widespread (as indeed Pre-Cambrian rock deposits show). Around 1.5 billion B.P. the average world temperature in the long "warm" spells was about 58 degrees—just about what it is today in our present ice-age phase.

In the current era of the sun's and the earth's history, beginning about 500 million years ago, the average global temperature has been about 72 degrees, aside from the brief ice-age interludes. When our ice age ends a few million



SURFACE TEMPERATURES IN THE CARIBBEAN during the Quaternary ice age were derived by Cesare Emiliani. Numbers indicate periods of glaciation. Temperatures are well below those of the warm Tertiary Period, which averaged 98 degrees F. in the same area.

The wires shown above are used in the MATADOR surface-to-surface guided missile and are protected by ZYTEL nylon resin. They withstand heat and cold, can be pulled through openings without damage. (The USAF TM-61 MATADOR is manufactured by the Martin Company, Baltimore, Maryland.)

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	MILLIONS OF YEARS	HYDROGEN CONTENT IN CORE (PER CENT)	HEAT OUTPUT OF SUN (PER CENT OF PRESENT)	MEAN TEMPERATURE OF EARTH (DEGREES F.)
PAST	4,500	33	85	2
PAST	3,000	28	92	41
PAST	1,510	20	100	58
CURRENT PERIOD	500	10	109	72
CURRENT PERIOD	PRESENT	10	100	58
FUTURE	660	5	115	79
FUTURE	920	2.5	120	86
FUTURE	1,040	1.25	126	93
FUTURE	1,092	.62	141	109
FUTURE	1,114	.31	167	138
FUTURE	1,118	.16	211	176
FUTURE	1,122	.08	325	257

CALCULATIONS based on Öpik's theory were made assuming that at the beginning the sun contained 3 per cent metals, 44 per cent helium and 53 per cent hydrogen. Except for the "present," dates chosen occur during times when the sun was in a normal state. Ice aided in lowering the earth's temperature both 4.5 billion years ago, when there was a permanent global ice age, and three billion years ago, when ice still remained around the poles.

years from now, it will return to that level. Thereafter the sun will resume its warming trend, raising the earth temperature at the rate of one degree per 100 million years at first and accelerating the warmup as time goes on. A billion years or so from now the average temperature will be 100 degrees—too hot for human life as we know it. Indeed, life for any sort of organism will have become impossible in the tropics and may be supportable only in the neighborhood of the poles. Some 82 million years later, if our timetable is correct, the output of heat by the sun will be more than three times what it is now, and the average temperature on the earth will be above the boiling point of water.

These future developments are a matter of only philosophical interest to the human race. Man has existed on this planet for only a million years, and if we are to judge by the transience of other species of living things, we can hardly expect our species to endure for more than 100 million years. It is possible, however, that some new species of intelligent beings will be living on the earth at the time of the coming heat wave. If so, they may be able to make a technological adaptation to the heat—perhaps some kind of "air conditioning" on a global scale. They will have millions of years at their disposal to work out the methods.

The picture of gradually warming climate, broken by ice ages at long intervals, gives us a new perspective on the evolution of life on the earth. In all likelihood, before half a billion years ago the ice ages were so severe that they extinguished all life on the earth. If, for instance, the sun's heat output during an ice age fell about 17 per cent below normal, as it has in more recent times, then the average earth temperature during the Algonkian ice age 750 million years ago must have been low enough to cover the whole earth with glaciers. Therefore after each of the early ice ages the evolution of life must have had to start again from the beginning. The intervals between ice ages were not long enough to allow the higher forms of life to evolve.

Apparently the Eocambrian ice age 480 million years ago was the first in which the entire earth was not covered with ice. For the first time in the history of the earth the tropical belt remained ice-free, and life could take refuge there. This means that life has had 750 million years (since the Algonkian ice age) to continue uninterruptedly its glorious march of evolution. If our hypothesis is correct, it will have many hundreds of millions of years more to go on to still higher levels of evolution.

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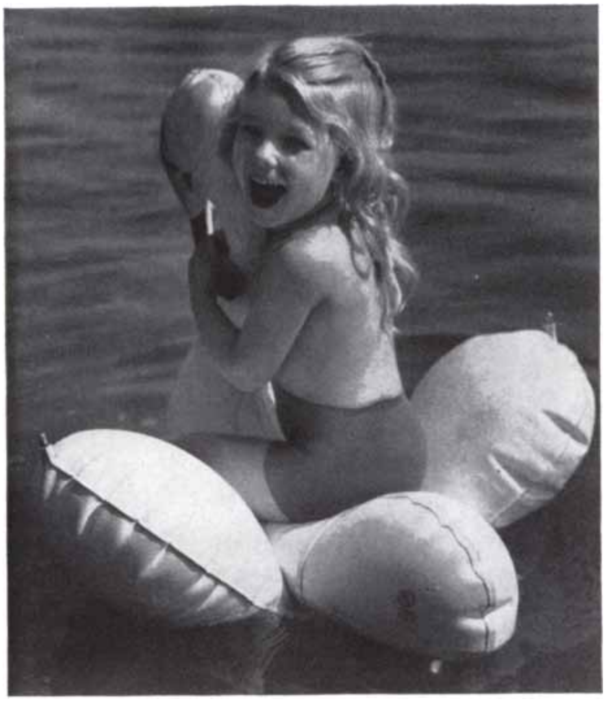

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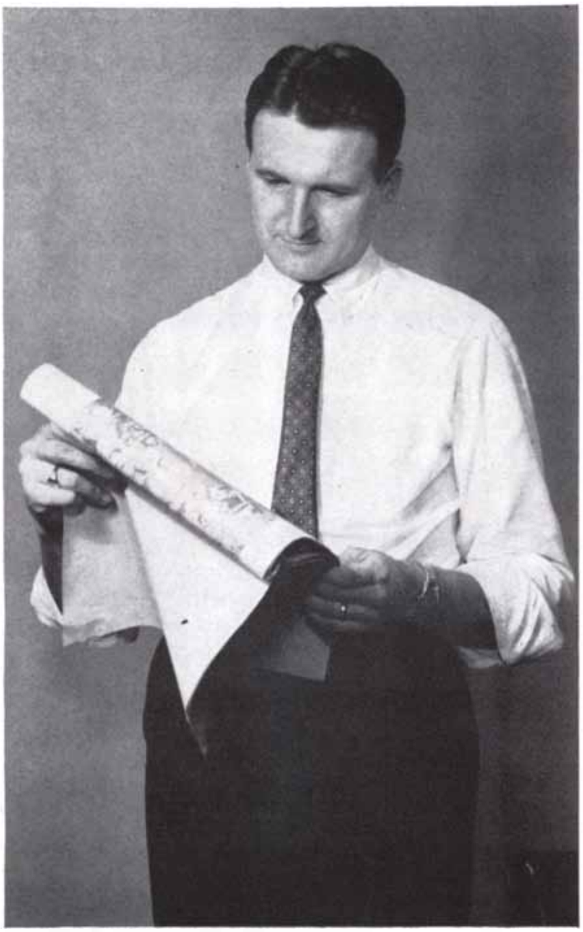

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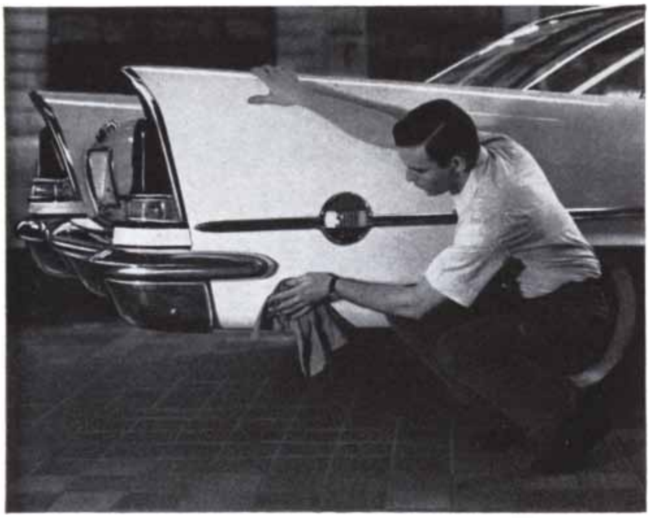

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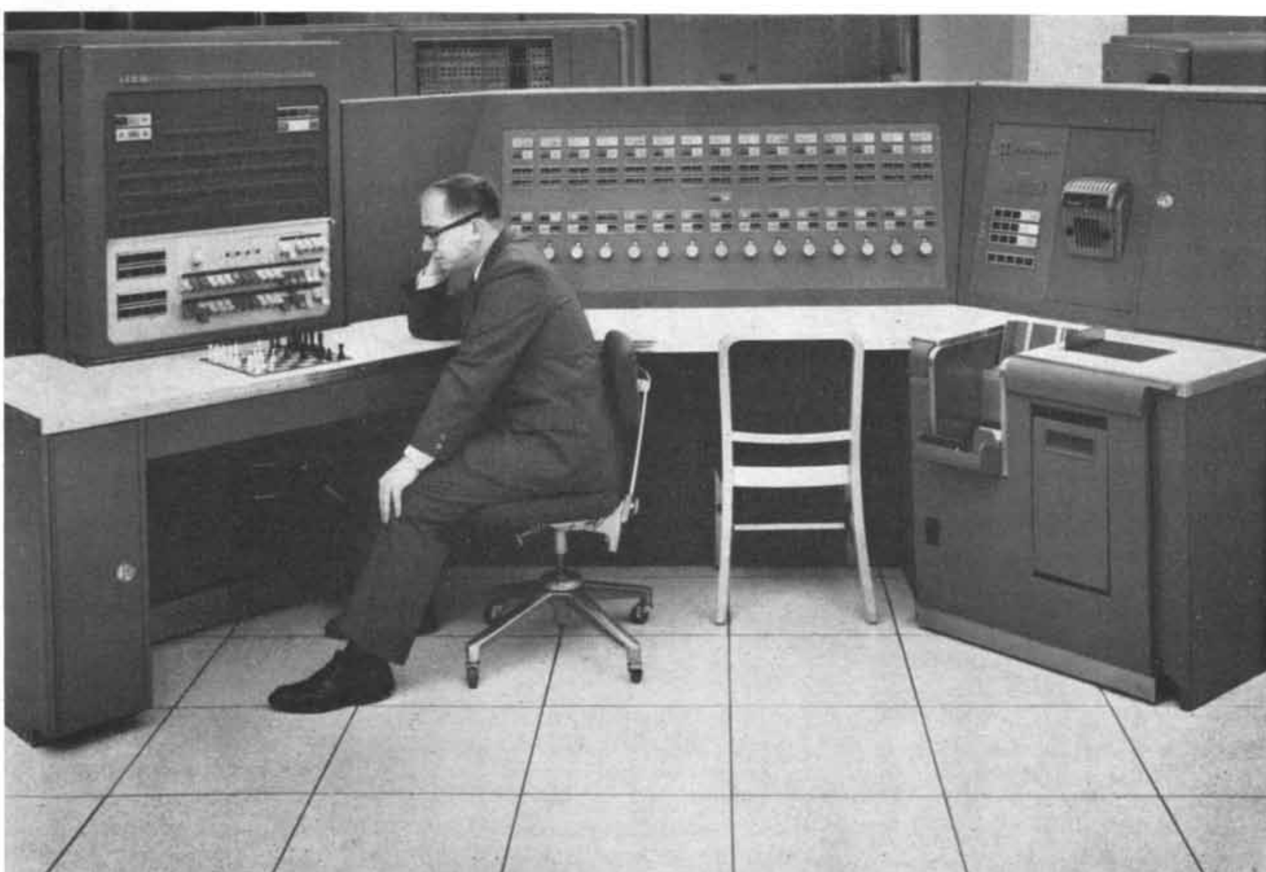
Computer v. Chess-Player

Can a machine be made to think creatively? One reply is: First, can a machine be made to play a good game of chess? How a computer was programmed so that it could defeat an inexperienced human opponent

by Alex Bernstein and Michael de V. Roberts

Chess is not only one of the most engaging but also one of the most sophisticated of human activities. The game is so old that we cannot say when or where it was invented; millions of games have been played and thousands of books have been written about it; yet the play is still fresh and forever new. Simple arithmetic tells why. On the average, each move in chess offers a choice of about 30 possibilities, and the average length of a full game is about 40 moves. By this reckoning there are at least 10^{120} possible games. To get some idea of what that number means, let us suppose that we had a superfast computing machine which could play a million games a second (a ridiculous supposition). It would take the machine about 10^{108} years to play all the possible games!

So no conceivable machine could play a perfect game of chess, examining all possible moves. This is what makes the problem of programming a computer to play chess so intriguing. A present-day computing machine, with all its speed of calculation, is about as limited as a human being, on any reasonable time scale, in exploring the likely consequences of a chess move. Since it cannot study all the possibilities, the machine must play the game in human

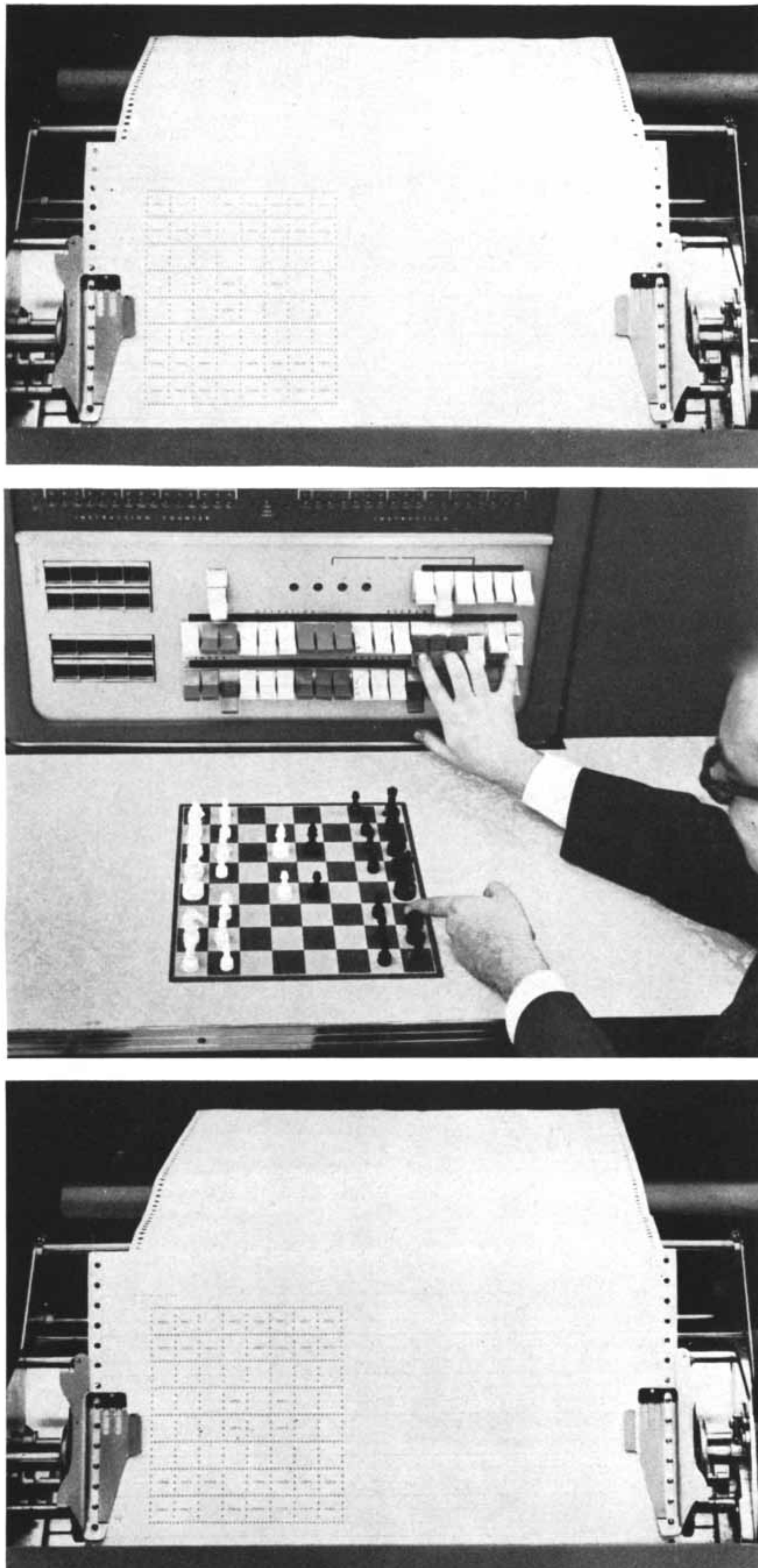


OPPONENTS IN CHESS GAME depicted here are Alex Bernstein, co-author of this article, and an IBM 704 computer. The game is played on an ordinary chessboard, but information about each move is fed into the machine by controls above the board.

terms—that is, it must detect the strategy and anticipate the judgments of its human opponent. In other words, lacking the omniscience that would enable it to win no matter what its opponent does, it must try to outwit the opponent.

Needless to say, devising a program which would give a machine this property—what amounts to the capacity to think—has proved a very difficult job. The late A. M. Turing, the ingenious British theoretician on thinking machines, was one of the first to try his hand at designing a chess-playing program for a computer, but his machine (MADAM) played a very weak game, made stupid blunders and usually had to resign after a few moves. The problem has interested a number of computer experts in the U. S. [see "A Chess-Playing Machine," by Claude E. Shannon; SCIENTIFIC AMERICAN, February, 1950], and several groups are currently working on chess programs. We want to report here what we believe is the first satisfactory program—one with which the machine plays a game sophisticated enough so that its opponent has to be something more than a novice to beat it. The program was written by four collaborators—the authors of this article, who work for the International Business Machines Corporation, and Timothy Arbuckle and M. A. Belsky of the Service Bureau Corporation. It is designed for the IBM 704, the very rapid digital computer which has performed as many as one billion calculations in a single day in computing the orbit of an artificial satellite.

The program is a set of explicit instructions to the computer on how it must act in each of the specific situations with which it may be confronted. The instructions are given to the machine on a reel of magnetic tape. The operation of the computer is itself fascinating to watch. You sit at the console of the machine with a chessboard in front of you and press the start button. Within four seconds a panel light labeled "Program Stop" lights up on the console, and you now make your choice of black or white: to choose black you flip a switch on the console; if you want white, you simply leave the switch as it is. Suppose you have picked black. To begin the game you press the start button again. The machine now "thinks" about its first move. There is nothing spectacular about this. Some lights flash on the console, but the computer is working so swiftly that it is impossible to say just what these flashes mean. After about eight minutes, the computer



MACHINE TYPES OUT A MOVE in the form of a diagram of the chessboard (*top*). Bernstein makes the move on the board, then makes his own move and communicates it to the machine (*middle*). The machine types this move (*bottom*) before it makes its own.

prints out its move on a sheet of paper.

Let us say the machine's (White's) first move is king's pawn to the king's fourth square. The print-out then is W1 P-K4. The machine proceeds to print the chessboard with the positions of the pieces, designating its own by the letter M and its opponent's by the letter O [*see illustration below*].

Now the "Program Stop" light goes on again and the computer waits for its opponent to reply. You punch your replying move on an IBM card and put this card in a section of the machine which reads it. To signal that it is the machine's turn you press the start button again. The machine prints your move and the new board position and then goes on to calculate its second move. If you have made an illegal move, the computer will refuse to accept it, printing out "PLEASE CHECK LAST MOVE." So the game proceeds. At the end of the game, after a mating move or a resignation, the machine prints the score of the game, and to its opponent: "THANK YOU FOR AN INTERESTING GAME."

In explaining the program of instructions to the machine it will be helpful if we start by contrasting it with an ordinary job performed by a computer—say calculating John Doe's pay check. The machine in the latter case simply takes the data—so many dollars for a 44-hour week, so much for overtime at a certain rate, so much deducted for social security and income tax—and quickly computes what the check has to be. There is one, and only one, correct answer. But in a chess game there are only two questions to which absolutely definite and unavoidable answers can be given: "Is this move legal?" and "Is the game over?" To all other questions there are various possible answers, though some may be more acceptable than others. The problem is to equip the machine with a system of evaluating the merits of the alternatives. This, as

```
                     MACHINE

* * * * * * * * * * * * * * * * * * * * * * * * *
*     *     *     *     *     *     *     *     *
* MRK * MNT * MBS * MKG * MQN * MBS * MNT * MRK *
*     *     *     *     *     *     *     *     *
* * * * * * * * * * * * * * * * * * * * * * * * *
*     *     *     *     *     *     *     *     *
* MPN * MPN * MPN *     * MPN * MPN * MPN * MPN *
*     *     *     *     *     *     *     *     *
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* OPN * OPN * OPN * OPN * OPN * OPN * OPN * OPN *
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* ORK * ONT * OBS * OKG * OQN * OBS * ONT * ORK *
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                     OPPONENT
```

CHESSBOARD TYPED OUT BY MACHINE represents the machine's pieces by M and the opponent's pieces by O. The second and third letters in each of the small squares represent rook (RK), knight (NT), bishop (BS), king (KG), queen (QN) and pawn (PN). In chess terminology the move shown here is P-K4 (pawn to king's column, fourth row).

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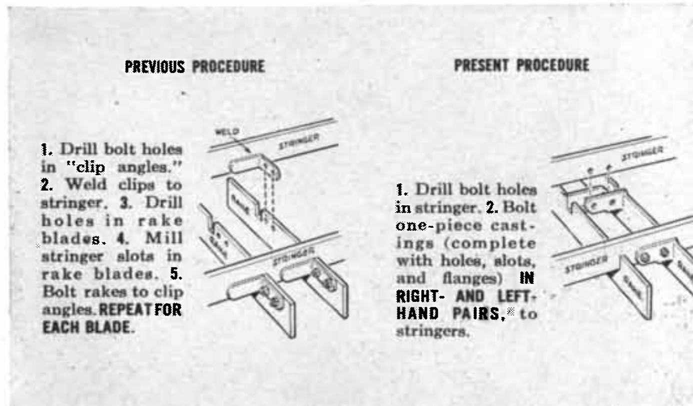
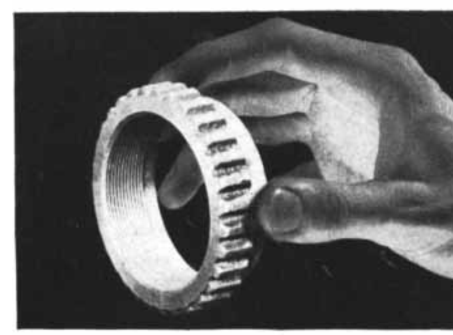


Part redesigned, simplified, assembly costs lowered. Classifier rake blade, Shellcast® by Cooper Alloy for Dorr-Oliver Inc., was originally made by welding cast and machined elements. Close-tolerance, smooth-surface shell castings made possible design change to one-piece cast unit, eliminating welding and much of the assembly costs.

Casting of thin-walled close-dimensioned parts. Tennessee Eastman filter frame plate previously required a good deal of careful milling on thin inner web. Combined use of shell core in a sand mold held tolerances, eliminated milling operation.



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SPECIALISTS *in Stainless Steel valves, fittings, castings; Plastic pumps, pipe, valves, fittings* we have remarked, is what makes the task interesting. If cut-and-dried answers to all possible situations could be worked out by a computer, chess would immediately lose its fascination.

Obviously the machine's first job is to size up the board. The instructions therefore direct it to start by examining the state of the squares. The computer painstakingly and single-mindedly considers square by square, giving the same minute attention to squares of little interest as to those of key importance. It asks about each square whether it is occupied, by whose man, whether it is attacked, whether it is defended, whether it can be occupied. The information is summed up in tables compiled by the machine. All this takes about one tenth of a second, which is a long time by computer standards. The computer then proceeds to consider its best move.

Here we reach the most difficult and controversial part of the program, for to find a workable basis for the machine's decisions we must make some hypotheses about how a human being plays chess. To begin with, we have to decide on what basis a human player (or the machine) will select the moves that are to be given serious consideration (full consideration of all possible moves being out of the question). There are two distinct philosophies about this. One is that the player concentrates on the moves that look most plausible in the immediate situation. The other is that the player's approach to the selection is dictated by a grand strategy, and as far as he can he looks for moves which will further his plan. We built our program on the second hypothesis.

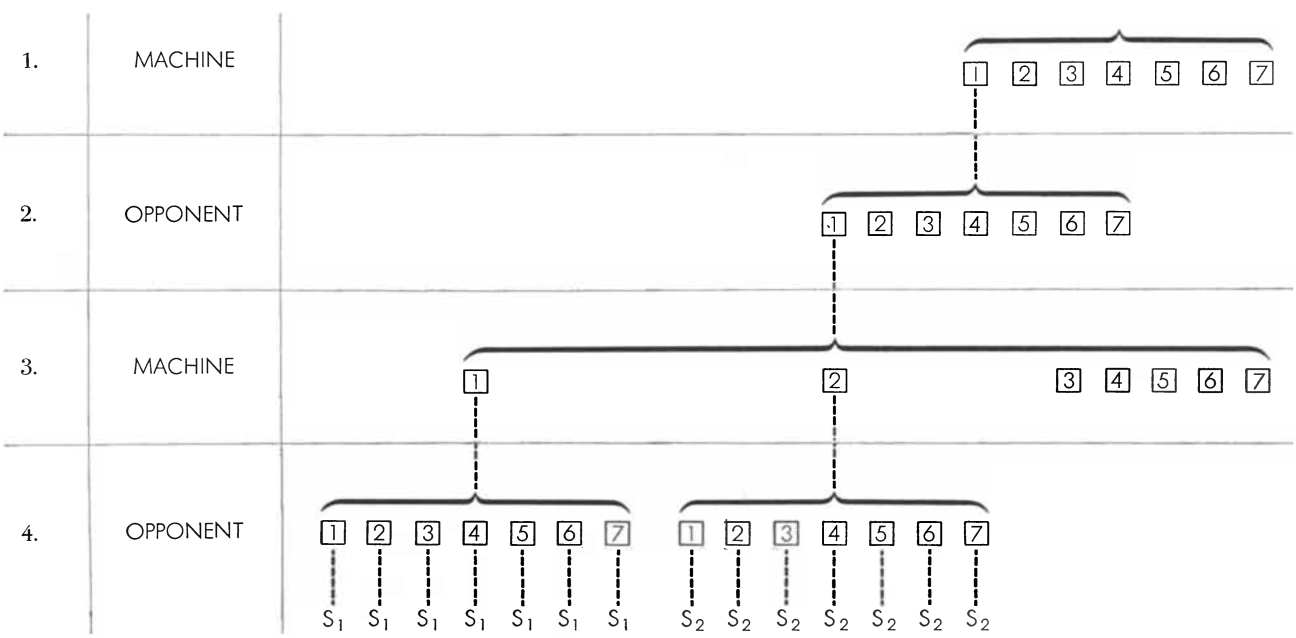
Of the various possible moves it might make (usually about 30) the machine selects seven for detailed analysis. It picks these on the basis of eight questions, which it asks in the following order:

1. Am I in check, and if so, can I capture the checking piece, interpose a piece or move away?
2. Are any exchanges possible, and if so, can I gain material by entering upon the exchange, or should I move my man away?
3. If I have not castled, can I do so now?
4. Can I develop a minor piece?
5. Can I occupy an open file?
6. Do I have any men that I can put on the critical squares created by pawn chains?
7. Can I make a pawn move?
8. Can I make a piece move?

Let us take the opening move for illustration. Examining the initial setup of the board, the machine finds that questions 1, 2 and 3 must be answered "No." The answer to question 4 is "Yes"; the machine notes that it can move either knight and has four possible knight moves (N-KR3, N-QR3, N-KB3, N-QB3). To questions 5 and 6 the answer is "No." It is "Yes" to question 7. Any of the eight pawns may be moved, but the instructions tell the machine to give priority to P-K4, P-K3 and P-Q4. These three pawn moves, with the four knight moves, provide the machine with seven moves for study.

It now proceeds to test each of the seven in turn through four moves ahead, considering its opponent's possible replies and its own possible counter-responses in each case. The machine starts with one of the seven moves and asks itself what it might reply were it the opponent. It generates seven possible replies, on the basis of the questions listed above, and now it takes the first of these and considers its own possible responses. After generating seven plausible responses, it again takes the first of these and in turn generates seven plausible replies by the opponent to this move.

The machine has reached the fourth level: initial move, reply, counter-reply and now the opponent's seven potential responses to its counter-reply [*see diagram below*]. It goes on to examine each of these seven moves to see which one would net the highest value for its opponent. The value, or score, is measured by four considerations: (1) gain of material (a pawn counting as one unit,



MACHINE MAKES A MOVE by the procedure suggested in this diagram. First, the machine selects, on the basis of eight questions, its seven most logical moves (*row 1*). Second, the machine selects its opponent's seven most logical responses to the first of these seven moves (*row 2*). Third, the machine selects its seven most logical counter-responses to the first of its opponent's responses (*row 3*). Fourth, the machine selects its opponent's seven most logical responses to the first of its seven counter-responses (*row 4*). Fifth, the machine scores its opponent's seven responses to the first of its seven counter-responses (S_1). Sixth, the machine selects its opponent's seven most logical responses to the second of its seven counter-responses. Seventh, the machine scores its opponent's responses to the second of its seven counter-responses (S_2). The machine continues in this manner until it has examined all moves.

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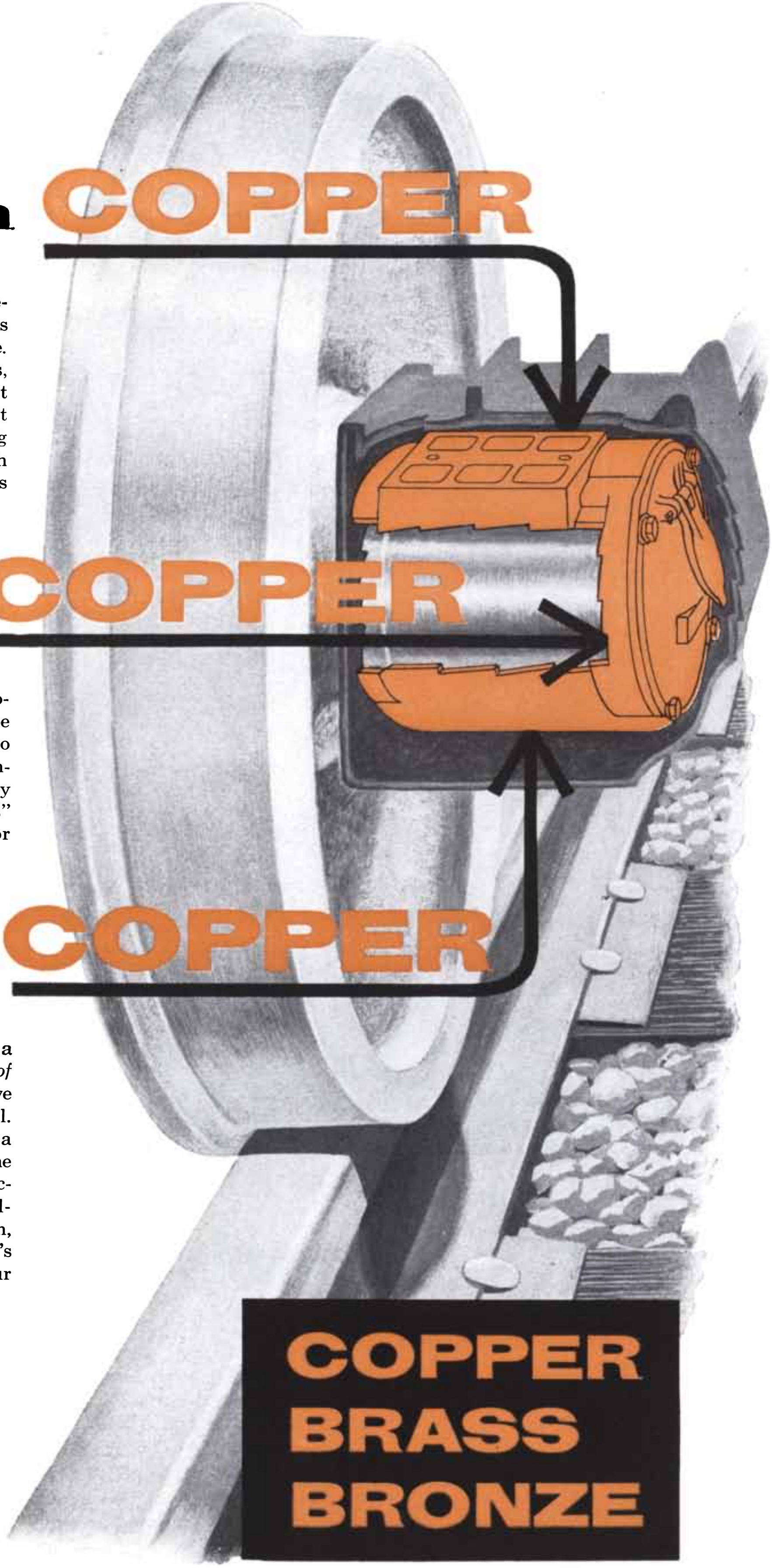

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a knight or bishop three, a rook five and the queen nine); (2) defense of the king; (3) mobility of the pieces; (4) control of important squares. After the machine has determined the score for the opponent's best move in level 4, it carries this back as the score for its own move 1 in level 3.

In this manner the machine investigates all the possible sequences of plays, taking each of the seven moves at every level of the "tree," and arrives at scores for all the outcomes at the fourth level. In all, it examines 2,800 possible positions. After this examination, the machine then chooses as its first move the one that will lead to the highest score both for itself and for its opponent. It acts, in other words, as if its opponent will make his best possible moves within the limits it is programmed to explore.

These limits—four half-moves ahead with seven choices at each step—are dictated by the time factor. It takes the machine close to eight minutes to decide on each move in most cases. If it had to weigh eight plausible moves instead of seven at each level, it would take about 15 minutes for a move. If it carried the examination through to one more level ahead, a single move would take some six and a half hours. So the present program is considered about the limit for a machine operating at the speed of the IBM 704.

How does the machine make out with this program? In the first place, the machine is never absent-minded. It makes no blatant blunders such as letting a piece be caught *en prise,* as every chess master has done at some time or other. When its opponent is careless enough to expose a piece, the machine takes instant advantage of the opportunity to capture it. Secondly, in its choice of individual moves the machine often plays like a master, making what an expert would consider the only satisfactory move [*see example on page 105*]. Thirdly, the machine is certainly not in the master class in the play of a complete game.

A typical game played by the machine against a skillful opponent is illustrated here [*at the right*]. We have deliberately chosen a game which the machine lost, because we want to emphasize the point that a machine is not infallible and also because it is more instructive to watch the computer lose than to watch it win. The machine's opening moves in this game are quite acceptable. But by middle game the machine betrays its chief weakness: namely, a heavy bias toward moving attacked pieces rather than defending them (a weakness which could

	MACHINE (WHITE)	OPPONENT (BLACK)
1.	P — K4	P — K4
2.	B — B4	P — QN3
3.	P — Q3	N — KB3
4.	B — KN5	B — N2

Black is preparing for a direct attack on the center, via P — Q4.

5.	B × N	Q × B
6.	N — KB3	P — B3
7.	O — O	P — Q4
8.	P × P	P × P
9.	B — N5 ch	N — B3
10.	P — B4?	P × P

White 10 N × P is better because if black replies Q × N, then R — K1. Since the pawn is defended by the queen, N × P seemingly loses material, and the move is discarded.

11.	B × N ch	Q × B
12.	P × P?	P — K5

White 12 is bad, R — K1 is better.

13.	N — N5	Q — N3
14.	N — KR3	P — K6
15.	P — B3	B — B4
16.	R — K1	O — O
17.	N — B3	

Fiddling while Rome burns.

		P — K7 dis ch
18.	N — B2	B × P
19.	P — KN3	P × Q = Q
20.	N (QB3) × Q	Q — B7
21.	P — N3	R (QR1) — Q1
22.	P — KR4	R × N
23.	Resigns	

ACTUAL GAME between computer and human opponent is described in conventional chess terminology. The comments of the human opponent have been interpolated.

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MACHINE

MRK	MNT		MKG	MQN			MRK
MPN	MPN	MPN			MPN	MPN	MPN
			OQN		MBS		
					OPN		
					OPN		
OPN	OPN	OPN					OPN
ORK			OKG		OBS	ONT	ORK

OPPONENT

MASTERLY MOVE was made out of this position by the machine. The move was Q-K2 (queen to king's column, row 2). Experts would consider this the only satisfactory move.

be corrected only by increasing the time for considering moves). At the tenth move White (the machine) makes a weak move which puts Black in a strong position; by the thirteenth move White's position is clearly hopeless, and 10 moves later, seeing the inevitability of a forced mate, the machine resigns.

Our contests with the machine show that anyone good enough to construct a three-move trap can beat it. Knowing how it selects its moves for consideration, you can often think of moves which you can be confident the machine will not consider. The machine will invariably accept a "sacrifice" (but then, so did the grand master José Capablanca). It will offer a sacrifice only to avoid being mated or if it can see an almost immediate mate of its opponent.

Yet notwithstanding its weaknesses, the IBM 704 plays a respectable and not-too-obvious game of chess—a game about which one can ask such questions as "Why did it make that move?" and "What does it have in mind?" We can even say frequently that "It made an excellent move at this point," or "At this stage it had a good position."

Undoubtedly our chess player is only a prototype for far more skillful players to be built in the future. Probably they will not go much farther in depth of planning: even with much faster computers than any now in existence it will be impracticable to consider more than about six half-moves ahead, investigating eight possible moves at each stage. A more promising line of attack is to program the computer to learn from experience. As things stand now, after losing a game the machine quite happily makes the same moves again and loses again in exactly the same way. But there are some glimmerings of ideas about how to program a machine to avoid repeating its mistakes, and some day—not overnight—we may have machines which will improve their game as they gain experience in play against their human opponents.

A scientific discovery is as truly a human invention as a sonnet or a symphony. Nature is not a mine of hard facts, all in order and ready to be surfaced by the scientist's pick and shovel. The little that we know is not what nature has told us but what scientists have asked. The asking of the question is the creative act in science. It is the originality and sensitivity, the depth and breadth of the questioner that determine the worth and significance of what the investigation in the end discloses. But here the process of creation in science departs from that of the arts. The truth disclosed by the artist need only be apprehended. The work of the scientist must be verified by observation and experiment. In this confronting of theory with fact, the creative process takes nature in its grasp. ℂ The symbolic congress in the lecture hall at the University of Padua on the opposite page brings together some of the leading innovators whose questions have inspired and directed the advance of science up to our own times. Lecturing at the rostrum is Galileo Galilei. At his feet are creatures of mysticism and magic from the past. Grouped closely around the globe are René Descartes, William Gilbert, Augustin Fresnel, Albert Einstein and Isaac Newton. Reaching toward Galileo is Joseph Black. Below him is Count Rumford and above Christian Huygens. Standing near the base of the columns are André Marie Ampère and Michael Faraday. On the third tier can be seen Benjamin Franklin, Thomas Young, Max Planck, Hans Christian Oersted, Hendrik A. Lorentz, James Joule, Lord Kelvin and James Clerk Maxwell.


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MATHEMATICAL GAMES

About Henry Ernest Dudeney, a brilliant creator of puzzles

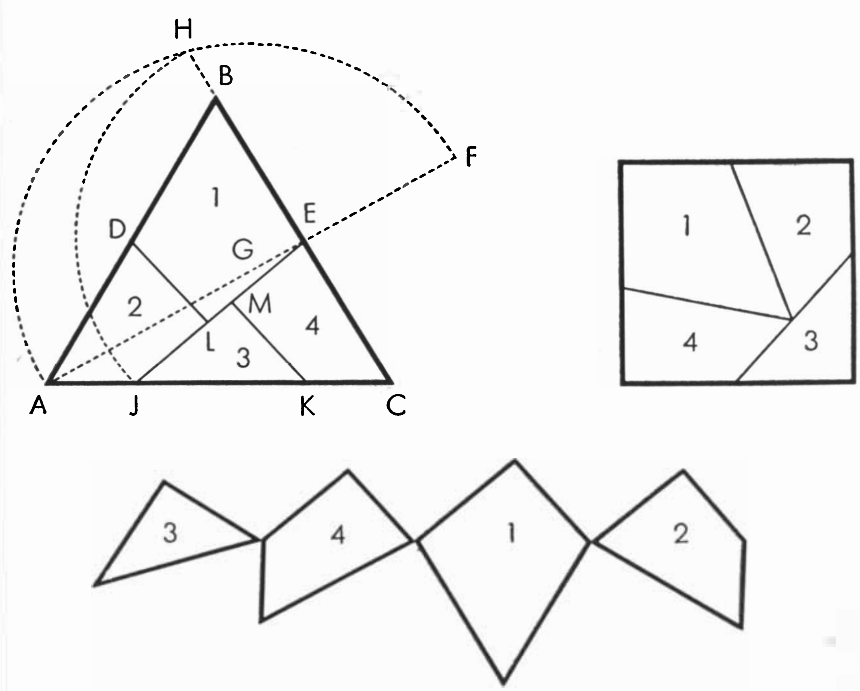
by Martin Gardner

The name Henry Ernest Dudeney has appeared several times in this department. He was England's greatest inventor of puzzles; indeed, he may well have been the greatest puzzlist who ever lived. Today there is scarcely a single puzzle book that does not contain (often without credit) dozens of brilliant mathematical problems that had their origin in Dudeney's fertile imagination.

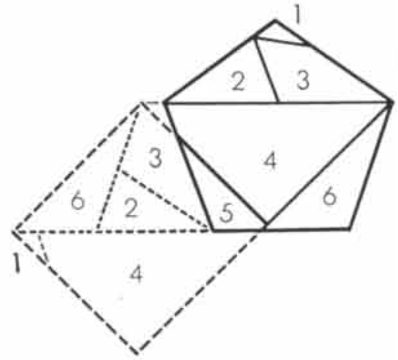
He was born in the English village of Mayfield in 1857. Thus he was 16 years younger than Sam Loyd, the American puzzle genius whose work was discussed here last August. I do not know whether the two men ever met, but in the 1890s they collaborated on a series of puzzle articles for the English magazine *Tit-Bits*, and later they arranged to exchange puzzles for their magazine and newspaper columns. This may explain the large amount of duplication in the published writings of Loyd and Dudeney.

Of the two, Dudeney was probably the better mathematician. Loyd excelled in catching the public fancy with manufactured toys and advertising novelties. None of Dudeney's creations had the world-wide popularity of Loyd's "14-15" puzzle or his "Get off the Earth" paradox involving a vanishing Chinese warrior. On the other hand, Dudeney's work was mathematically more sophisticated (he once described the rebus or picture puzzle, of which Loyd produced thousands, as a "juvenile imbecility" of interest only to the feeble-minded). Like Loyd, he liked to clothe his problems with amusing anecdotes. In this he may have had the assistance of his wife Alice, who wrote more than 30 romantic novels that were widely read in her time. His six books of puzzles (three are collections assembled after his death in 1931) remain unexcelled in the literature of puzzledom.

Dudeney's first book, *The Canterbury*



Dudeney's method of cutting a triangle so that it can be reassembled into a square



A pentagon reassembled into a square

Puzzles, was published in 1907. It purports to be a series of quaint posers propounded by the same group of pilgrims whose tales were recounted by Chaucer. "I will not stop to explain the singular manner in which they came into my possession," Dudeney writes, "but [will] proceed at once . . . to give my readers an opportunity of solving them." The haberdasher's problem, found in this book, is Dudeney's best-known geometrical discovery. The problem is to cut an equilateral triangle into four pieces that can then be reassembled to form a square.

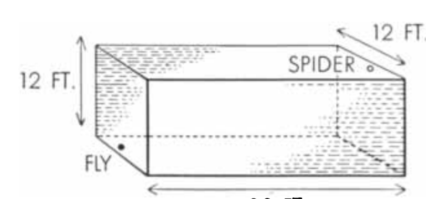
The figure at upper left in the illustration on page 108 shows how the cuts are made. Bisect AB at D and BC at E. Extend AE to F so that EF equals EB. Bisect AF at G, then, with G as the center, describe the arc AHF. Extend EB to H. With E as the center, draw the arc HJ. Make JK equal to BE. From D and K drop perpendiculars on EJ to obtain points L and M. The four pieces can now be rearranged to make a perfect square, as shown at upper right in the illustration. A remarkable feature of this dissection is that, if the pieces are hinged at three vertices as shown in the figure at the bottom of the illustration, they form a chain that can be closed clockwise to make the triangle and counterclockwise to make the square. Dudeney rendered the figure into a brass-hinged mahogany model, which he used to demonstrate the problem before the Royal Society of London in 1905.

According to a theorem first proved by the great German mathematician David Hilbert, any polygon can be transformed into any other polygon of equal area by cutting it into a finite number of pieces. The proof is lengthy but not difficult. It rests on two facts: (1) any polygon can be cut by diagonals into a finite number of triangles, and (2) any triangle can be dissected into a finite number of parts that can be rearranged to form a rectangle of a given base. This means that we can change any polygon, however weird its shape, into a rectangle of a given base simply by chopping it first into triangles, changing the triangles to rectangles with the given base, then piling the rectangles in a column. The column can then be used, by reversing the procedure, for producing any other polygon with an area equal to that of the original one.

Although Hilbert's procedure guarantees the transformation of one polygon into another by means of a finite number of cuts, the number of pieces required may be very large. To be elegant a dissection must require the fewest possible pieces. This is often extremely difficult to determine. Dudeney was spectacularly successful in this odd geometrical art, often bettering long-established records. For example, although the regular hexagon can be cut into as few as five pieces that will make a square, the regular pentagon was for many years believed to require at least seven. Dudeney succeeded in reducing the number to six, the present record. The illustration at the top of this page shows how a pentagon can be squared by Dudeney's method. For an explanation of how Dudeney arrived at the method the interested reader is referred to his *Amusements in Mathematics*, published in 1917.

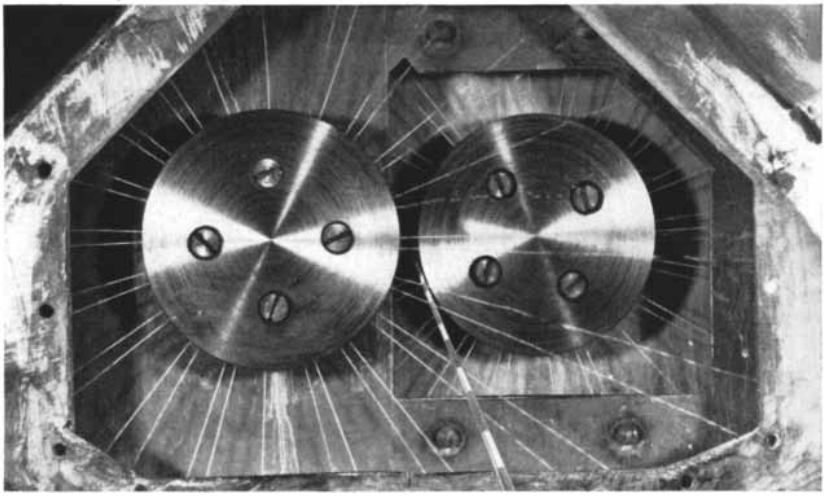
Dudeney's best-known brain-teaser, about the spider and the fly, is an elementary but beautiful problem in geodesics. It first appeared in an English newspaper in 1903, but did not arouse widespread public interest until he presented it again two years later in the London *Daily Mail*. A rectangular room has the dimensions shown in the illustration at the bottom of this page. The spider is in the middle of an end wall, one foot from the ceiling. The fly is at the middle of the opposite end wall, one foot above the floor, and too paralyzed with fear to move. What is the shortest distance the spider must crawl in order to reach the fly?

The problem is solved by cutting the room so that walls and ceiling can be folded flat, then drawing a straight line from spider to fly. However, there are



The problem of the spider and the fly

How to color code plastic insulated telephone wire at 2000 feet per minute



Ink jets from spinning disks produce dash code on plastic covered wire, as shown.

Cables used in telephone central offices contain hundreds of wire conductors which must be identified and connected to their corresponding terminals. To take advantage of the superior qualities of plastic – which is replacing textiles as insulation for wires used in these cables – a way had to be found to color code the plastic. The use of solid colors alone wouldn't do the job since there were not enough different colors.

Some time ago, Bell Telephone Laboratories suggested a coding system of colored dots and dashes, and asked Western Electric to develop a means of applying these markings.

Our engineers decided to place the coding operation at a point where the wire emerges from the extrusion machine with a hot, semi-hardened coating of polyvinyl chloride . . . before it reaches the cooling trough and take-up reels. Since coding had to be done at a speed of over 2000 feet per minute – to match that of the production line – the relatively slow contact printing devices then available were not satisfactory. In addition, contact printing itself was undesirable because the coding instrument might damage the soft plastic as it came from the extruder. In short, there were no machines available that would code plastic insulated wire at the extrusion speeds required by Western Electric.

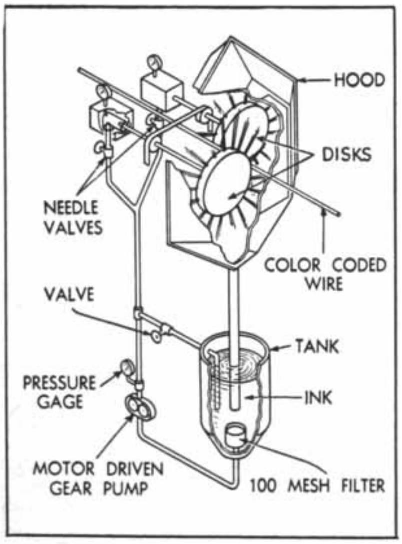
The basic problem in developing a high-speed coding machine was how to apply the marking ink. Initially, trials of a modified paint gun apparatus proved futile due to inability to control the size and location of the ink markings.

A concept for a new machine employing rotary ink ejectors was finally developed. These are hollow motor-driven disks, having removable rims into which .018″ holes are drilled in desired combinations.

To color code both sides of the wire, two of these spinning disks are placed in tandem and the wire passes between them. It passes close to the outside rim of each disk and ink fed into the hollow of the disks is forced out in radial streams, impinging on the plastic wire coating. By varying the arrangement of holes in the rims it is possible to apply various combinations of dots to the rapidly moving wire. Dashes are recorded by drilling holes in the rims so close together that the dots on the wire merge into a dash before the ink dries.

By simply changing the rims, it is possible to switch from one code to another. To shift ink colors, the system is flushed with a cleaner and the new ink added. The ink supply can be varied to suit the speeds of the wire and the disks.

The development of this machine permits the production of color coded plastic insulated wire at high extrusion speeds. It is one more step in the constant improvement of telephone equipment made by Western Electric as manufacturing and supply unit of the Bell System. This is another example of the way Western Electric's engineering ingenuity continues to bring you dependable telephone service . . . at low cost.



Schematic drawing of color coding unit.

many ways in which the room can be folded flat, so it is not as easy as it first appears to determine the shortest path. The puzzle is a familiar one, but for readers who may not know it, the solution will be withheld until next month.

A less well-known but similar geodesic problem, which appears in Dudeney's *Modern Puzzles* (published in 1926), involves a cylindrical glass. The glass is four inches high and six inches in circumference. On the inside, directly opposite and one inch from the top, is a drop of honey. On the outside, one inch from the bottom, is a fly. What is the shortest path by which the fly can walk to the honey, and exactly how far does the fly walk? The solution, also withheld until next month, is a neat one.

It is interesting to note that although Dudeney had little familiarity with topology, then in its infancy, he frequently used clever topological tricks for solving various route and counter-moving puzzles. He called it his "buttons and string method." A typical example is afforded by the ancient chess problem shown in the top illustration at right. How can you make the white knights change places with the black knights in the fewest number of moves? We replace the eight outside squares by buttons [*middle illustration*], and draw lines to indicate all possible knight moves. If we regard these lines as strings joining the buttons, it is clear that we can open the string into a circle [*bottom illustration*] without changing the topological structure of the elements and their connections. We see at once that we have only to move the knights around the circle in either direction until they are exchanged, keeping a record of the moves which can be made on the original square board. In this way what seems at first to be a difficult problem becomes ridiculously easy.

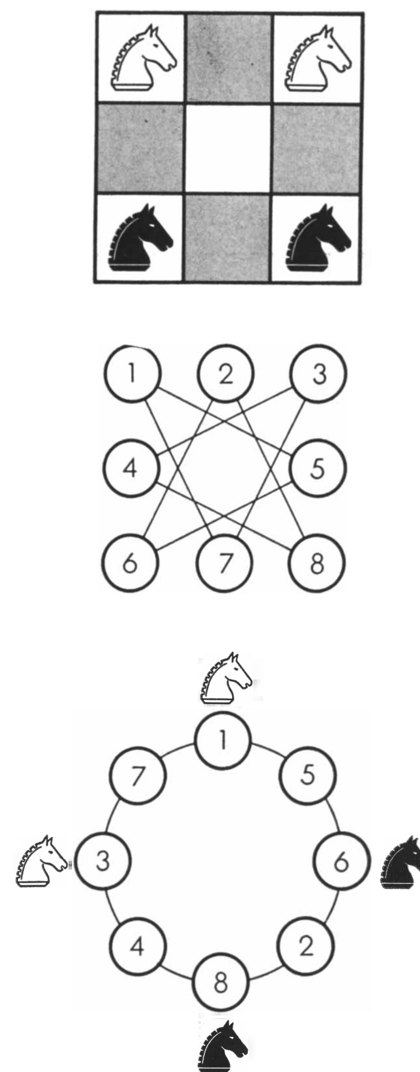
Of Dudeney's many problems involving number theory, perhaps the hardest to solve is the question posed by the doctor of physic in *The Canterbury Puzzles*. The good doctor produced two spherical phials, one exactly a foot in circumference and the other two feet in circumference. "I do wish," said the doctor, "to have the exact measures of two other phials, of a like shape but different in size, that may together contain just as much liquid as is contained by these two."

Since similar solids have volumes that are in the same proportion as the cubes of corresponding lengths, the problem reduces to the Diophantine task of finding two rational numbers other than 1 and 2 whose cubes will add up to nine. Both numbers must of course be fractions. Dudeney's solution was:

$$\frac{415280564497}{348671682660} \text{ and } \frac{676702467503}{348671682660}$$

These fractions had denominators of shorter length than any previously published. Considering the fact that Dudeney worked without a modern digital computer, the achievement is something to wonder at.

Readers who like this type of problem may enjoy the much simpler search for two fractions whose cubes total exactly six. A published "proof" by the 19th-century French mathematician Adrien Marie Legendre that no such fractions could be found was exploded when Dudeney discovered a solution in which each fraction has only two digits above and two below the line. These fractions, too, will be published in this department next month.



The "buttons and string method"

THE AMATEUR SCIENTIST

How to make a pendulum that will demonstrate the rotation of the earth

Conducted by C. L. Stong

One day in the middle of the last century the French physicist Léon Foucault inserted a slender rod in the chuck of a lathe and plucked the free end of the rod so that it vibrated like a reed. When he started the lathe, he observed that the turning rod continued to vibrate in the same plane. Later he tried much the same experiment with a vertical drill-press. From the chuck of the drill-press he suspended a short pendulum consisting of a length of piano wire and a spherical weight. He set the weight to swinging and started the drill-press. The pendulum also continued to vibrate in the same plane. For a time nothing much came of these observations, but in them was the seed of an experiment destined to settle a classic scientific controversy.

In the year 1543 Nicolaus Copernicus had sent a copy of his new book, *On the Revolutions of the Celestial Orbs*, to Pope Paul III with a note containing a historic understatement: "I can easily conceive, most Holy Father," he wrote, "that as soon as people learn that in this book I ascribe certain motions to the earth, they will cry out at once that I and my theory should be rejected." Cry out they did, and some, including a few scientists, were still crying out in 1850, when Foucault was invited to stage a science exhibit as part of the Paris Exposition scheduled for the following year. Being not only a gifted physicist but also something of a showman, he selected as the site of his exhibit the church of Sainte Geneviève, also known as the Panthéon.

From the dome of the Panthéon he hung a pendulum consisting of 200 feet of piano wire and a 62-pound cannon ball. On the floor, immediately below the cannon ball, he sprinkled a layer of fine sand. A stylus fixed to the bottom of the ball made a trace in the sand, thus recording the movement of the pendulum. Great care was taken during construction to exclude all forces except those acting vertically to support the system. Tests were even made to assure symmetry in the metallurgical structure of the wire. Finally the ball was pulled to one side and tied in place with a stout thread. When the system was still, the restraining thread was burned.

The pendulum made a true sweep, leaving a straight trace in the sand. In a few minutes the thin line had expanded into a pattern resembling the outline of a two-bladed propeller. The pattern grew in a clockwise direction, and at the end of an hour the line had turned 11 degrees and 18 minutes. This could be explained only on the basis that the earth had turned beneath the pendulum. Copernicus was vindicated.

It is easy to visualize what had happened if one imagines a pendulum erected at the North Pole. The pendulum is hung, perhaps from a beam supported by two columns, in line with the earth's axis. The supporting structure corresponds to Foucault's lathe or drill-press—or the dome of the Panthéon. So long as the pendulum is at rest the whole affair simply turns with the earth, making one complete revolution every 23 hours and 56 minutes (the sidereal day). The pendulum is now drawn out of plumb and carefully released. The direction of the swing persists, and the earth turns beneath the pendulum. To an observer on the earth the plane of vibration appears to rotate in a clockwise direction, because at the North Pole the earth turns counter-clockwise. The same effect would be observed at the South Pole, except that there the rotations would be reversed. If the swing of the pendulum appears to turn clockwise at the North Pole and counter-clockwise at the South Pole, what happens at the Equator? Substantially no deviation is observed. Here the entire system—the earth, the supporting structure and the pendulum—is transported almost linearly from west to east [*see illustration at the right*].

At the poles the rate at which the swing of the pendulum appears to rotate is 15 degrees per sidereal hour; at the Equator it is of course zero degrees per sidereal hour. The rate varies with latitude; the higher the latitude, the higher the rate. This neglects certain fine deviations caused by the curvature of the earth's orbit around the sun and by other perturbations. But it holds for the gross, easily observed, motion.

With the help of a few simple geometrical concepts it is easy to see why a pendulum appears to rotate more slowly as it approaches the Equator. Imagine an arc along an intermediate parallel of latitude through which the earth has turned during a short interval, say an hour or so [*AB in illustration on the next page*]. The angle subtended by the arc at the earth's axis increases at the rate of 15 degrees per hour—one full turn of 360 degrees per sidereal day. Now as-

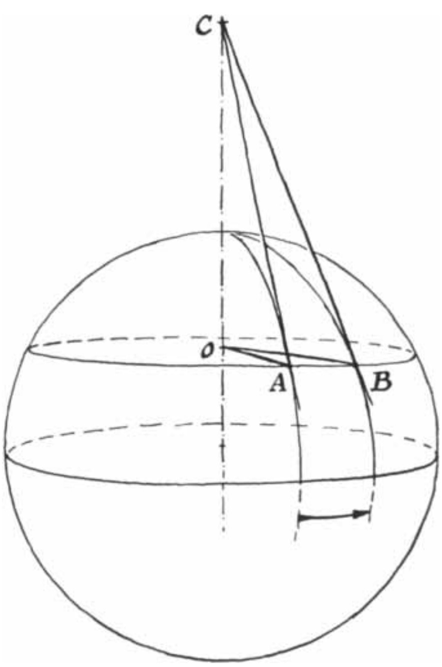
Pendulums at the North Pole and Equator sume a pair of tangents [*AC and AB*] to the earth's surface subtended by the arc which meet on a projection of the axis at a point in space above the pole. The angle between the tangents increases in size at the same rate with which the pendulum's plane of vibration appears to rotate. The reason it does so becomes clear if one assumes that the pendulum continues to vibrate in the plane of the first tangent as it is transported to the position of the second. At the pole the two angles are equal; both increase at the rate of 15 degrees per hour. At the Equator the angle subtended by the arc at the earth's axis continues to increase at the rate of 15 degrees per hour. But the pair of tangents subtended by the arc at the Equator meet the projected axis at infinity. The angle vanishes, and its rate of increase does the same. Therefore the pendulum's rate of rotation is zero. Foucault demonstrated that the apparent rotation of the pendulum varies with the trigonometric sine of the latitude at which it is installed. Its rate at points between the poles and the Equator is equal to 15 degrees per hour multiplied by the sine of the latitude.

Amateurs who set up pendulums at New Orleans will observe an apparent rotation of about 7 degrees and 30 minutes per hour. They must wait two days for a full revolution. Those in Manila must wait four days; those on Howland Island in the South Pacific, about 40 days!

About the best way to gain an understanding of the Foucault pendulum is to make one. Like many such enterprises, this seems simple until it is tried. Many amateurs who have felt the urge to set up the apparatus have abandoned the idea because they had no Panthéon in which to hang a 200-foot pendulum and no cannon ball for a bob. This is no problem. Pendulums 10 or 15 feet long can be made to work handsomely with bobs weighing as little as five pounds. The most vexing problems encountered in making a pendulum have to do not with its size but with starting the bob in a true swing, maintaining the trueness of the swing, and supplying energy to the bob.

Foucault's method of starting the bob is still the most elegant. Many starting devices have been tried: mechanical releases, magnetic releases, mechanisms which accelerate the bob from dead rest, and so on. It is generally agreed that burning a thread is the simplest and best of the lot.

Until recent years the problem of making the pendulum swing true resisted some of the world's best instrument makers. It seemed clear that any method of suspension must have radial symmetry such as one would expect of the suspension device depicted on page 118. To assure this Foucault and subsequent experimenters took great pains in procuring wire of uniform characteristics and in designing the fixture to which the wire was attached. Roger Hayward, the illustrator of this department, tells me that the wire for the Foucault pendulum in the Griffith Observatory in Los Angeles was specially drawn and tied to a long two-by-four beam for shipment from an eastern mill to the West Coast. The designers were afraid that coiling the wire would destroy its symmetry. The pivot to which the wire was attached at first consisted of a set of gimbals with two sets of knife-edges at right angles to each other. Despite these precautions the completed pendulum insisted on performing figure eights and ellipses. Hayward, who had designed other exhibits for the Observatory, suggested that the wire simply be held in rigid chuck. This invited a break at the junction of the wire and the chuck, which could cause the wire to lash into a crowd of spectators. To minimize this hazard a crossbar was clamped to the wire just above the ring-shaped driving magnet. Thus if the wire had broken, the crossbar would have been caught by the magnet ring. Clamping the wire in a chuck cured the difficulty. The wire has now been flexing for more than 20 years without any apparent ill effect.



The geometry of the pendulum's swing

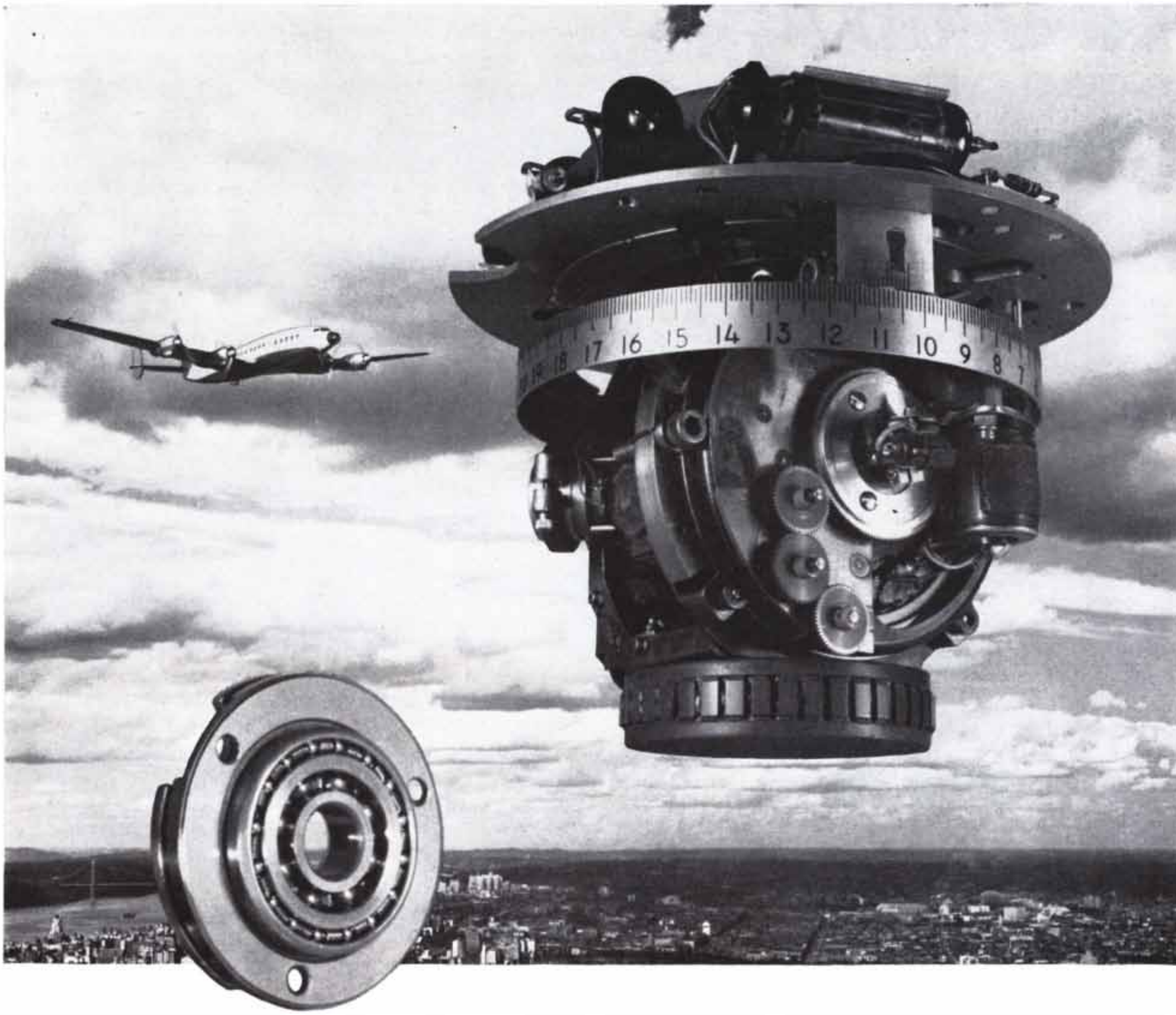
At about the time the Griffith pendulum was installed a French physicist named M. F. Charron devised a method for maintaining the true swing even when the forces acting on the pendulum are measurably asymmetrical. Charron set out with the objective of designing a vise which would grip the wire rigidly and would also provide a long radius through which the wire could flex. He used a ferrule which at its upper end fitted snugly around the wire and at its lower end flared away from the wire [*see illustration at top of page 120*].

The diameter of the hole at the lower end precisely accommodated the swing of the pendulum. It was observed that, when the pendulum swung true, the wire simply made contact with the inner surface of the ferrule at the end of each beat. But when the pendulum performed ellipses or other configurations, the wire rubbed against the inner surface of the ferrule and the energy responsible for the lateral component of motion was dissipated through friction. Stephen Stoot, a Canadian amateur, has suggested a modification for small pendulums which accomplishes the same result. He fixes a carefully centered washer around the wire just far enough below the point of suspension so that the wire touches the washer at the end of each swing [*bottom of page 120*].

The third basic problem is how to supply the pendulum with a periodic push in the precise direction in which it needs to go. No completely satisfactory mechanical solution has been devised. A variety of electrical drives are in use, however. Most of these feature a ring-shaped electromagnet which acts on an armature carried by the wire near the point of suspension. Power is applied during the portion of the swing in which the wire is approaching the magnet, and is interrupted when the wire moves away.

The arrangement in use at the Griffith Observatory is typical. Current for the ring magnet is supplied through a relay. The action of the relay, in turn, is controlled by a photoelectric cell. A beam of light, folded by mirrors so that the beam crosses itself at a right angle near the wire, actuates the photoelectric cell [*see illustration on page 122*]. When the suspension passes through the center of the ring magnet, a vane on the wire breaks the beam. The relay then operates, and applies current to the magnet. After an appropriate interval, during which the wire approaches the magnet, a time-delay relay breaks the circuit automatically.

In 1953 R. Stuart Mackay of the Uni-



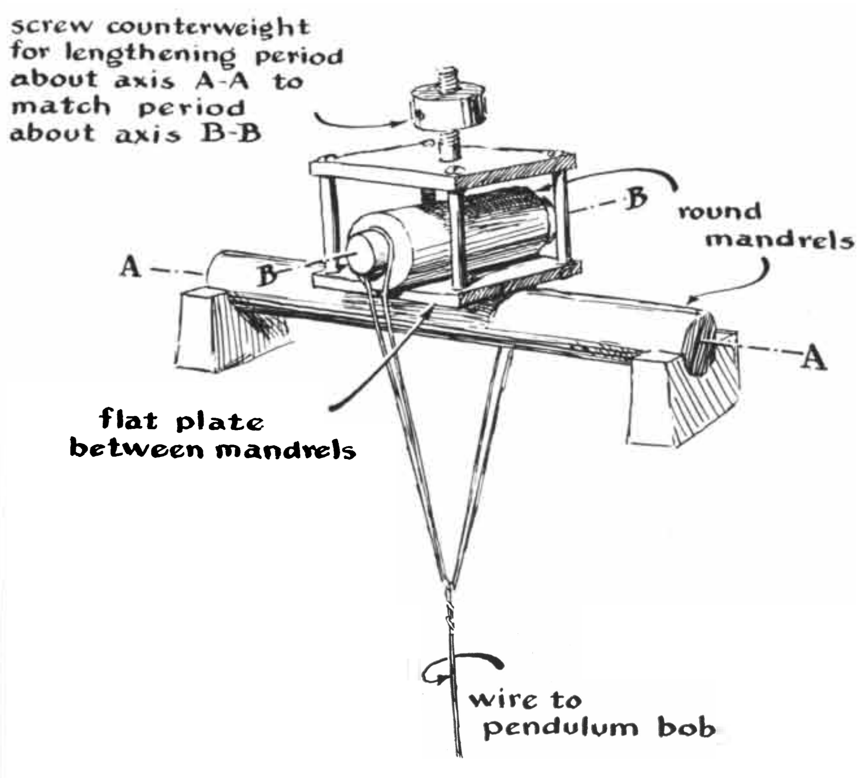
versity of California described in the *American Journal of Physics* a novel method of driving Foucault pendulums. His apparatus consists of a simple coil bridged by a condenser into which power is fed continuously, and over which the bob swings freely. The method takes advantage of phase-shift effects which are essential to the operation of ordinary doorbells and buzzers. It requires no contacts, light beams or other arrangements to interrupt the current.

"If one energizes a coil with alternating current," writes Mackay, "and sets an iron pendulum bob swinging immediately above it, the current through the coil will increase or decrease depending upon whether the bob is moving toward or away from the coil. The magnetic property of the iron influences the magnetic field set up by the coil and therefore the coil's inductance. The inductance, in turn, influences the flow of current. The fluctuations in the amplitude of the alternating magnetic field do not occur instantly. The effect is such that the current, and consequently the attractive force of the coil's magnetic field, is greater when the bob approaches the center of the coil than when it recedes. If the circuit is essentially inductive, enough energy will be transferred to the bob to maintain the pendulum's swing.

"The effect can be made stronger by placing a capacitor in series with the coil so that the combination resonates slightly below the 60-cycle frequency of the power line. In effect, the system is then working on one side of the resonance curve, where a given change in inductance causes a pronounced change in current.

"Some Foucault pendulums, particularly those set up as public displays, feature bobs of bronze or other nonmagnetic materials. These may also be driven by the coil. One takes advantage of the fact that such bobs can act as the secondary winding of a transformer. The magnetic field of the stationary coil and that set up by current induced in the bob are in opposition. Hence the coil and the bob are mutually repelled. As the bob approaches the coil the flow of current increases in both. But because of electrical lag in the circuits the current, which starts to rise with the approach of the bob, does not reach its peak until the bob has traveled somewhat beyond the center of the coil. Accordingly the bob is subjected to a greater net repulsive force when it is moving away from the coil than when it is approaching the coil. Energy is thus made available to drive the pendulum.

"The forces acting between the coil and a nonmagnetic bob are smaller than



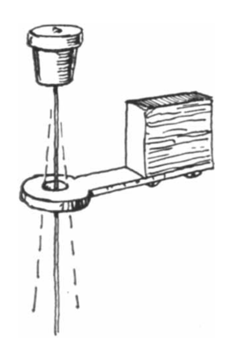
Conventional pivot for a Foucault pendulum

those between the coil and a magnetic bob. Moreover, energy dissipated by currents induced in the bob causes greater damping in the system. The effect can be shown easily by substituting a short-circuited coil for the bob. The change of current in both coils, induced by changes in inductance, can be enhanced by resonating each circuit near the power-line frequency, as in the case of magnetic bobs. When the capacitor of the bob coil is made slightly too large for resonance, the circuit becomes a trifle inductive. The force between the coils is then repulsive; sustained oscillations result. If the capacitor is too small, an attractive force is produced which will not sustain the motion. A circuit diagram of the two coils appears in the accompanying illustration [*top of page 124*]. It is possible, of course, to attach a driving coil tuned for repulsion to the bottom of a nonmagnetic bob.

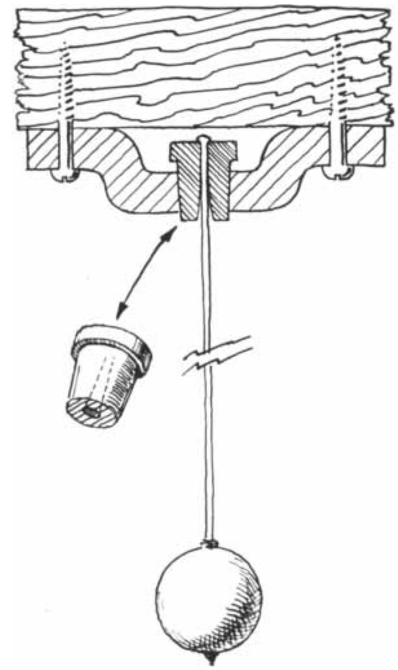
"The first coil I tried was wound with No. 16 wire. It was eight inches in diameter, two inches thick and had a two-inch hole in the center. It was used simply because it chanced to be on hand. The coil resonated at 60 cycles when it was placed in series with a 25-microfarad paper condenser. On the application of 10 volts it drove a three-inch iron bob on the first try. Considerably more power was delivered when the magnetic field was altered by laying the coil on a six-inch circle of 1/16-inch sheet iron. Should one wish to enhance the effect further, the coil may be inserted into a cylindrical core of iron [*bottom of page 124*].

"Which of the two drive systems is preferable, magnetic or nonmagnetic? A performance analysis indicates little choice either way, though the magnetic bob is probably simpler to make. It is true that over a number of cycles any small perturbing force can produce a marked effect on the swing of a Foucault pendulum, usually resulting in a slightly elliptical orbit. The 'plane' of oscillation of a pendulum swinging in an elliptical path will precess in the direction of tracing the ellipse at a rate roughly proportional to its area. Thus, if one does not take care, a Foucault pendulum can appear to turn at the wrong rate, or even to indicate that the earth is turning backward. It is tempting to suppose that the nonmagnetic bob will tend to avoid the 'magnetic potential hill' that it 'sees,' that is, the repulsive force will tend to deflect the bob to one side if the swing does not pass directly through the center of the magnetic force. In contrast, a magnetic bob might appear to favor the center of the 'potential valley' it 'sees,' even though its normal swing would not necessarily bisect the field of force. Thus in either case one might expect some induced perturbation. In practice, neither has much effect on crosswise amplitude if a fairly heavy bob is used. Interestingly enough, since the motions in the two directions responsible for the ellipse are 90 degrees out of phase, and since changes in the magnetic field are controlled by the major motion, there is a slight tendency to damp out the minor motion.

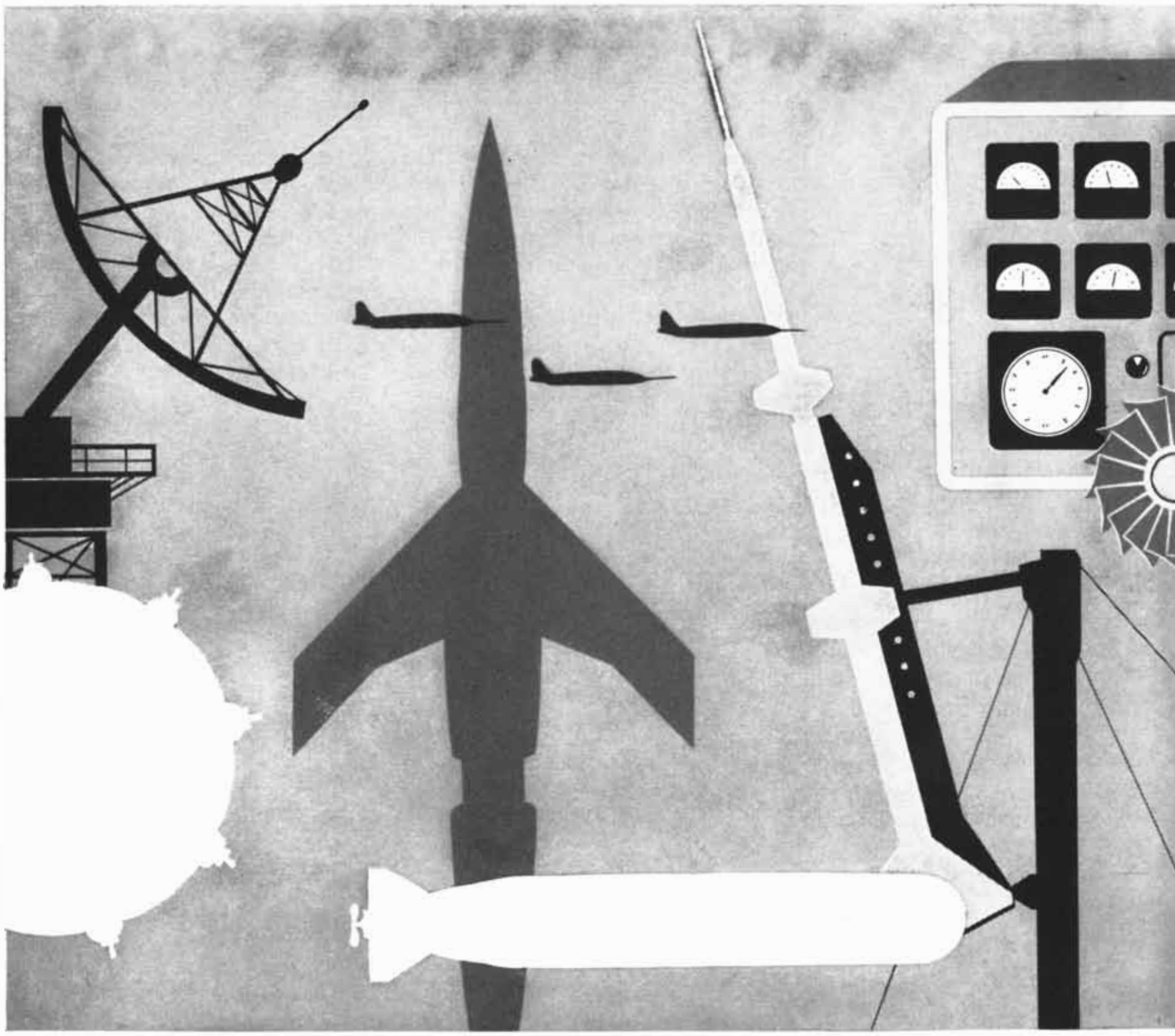
"The matter of perturbing effects warrants further discussion, particularly from the viewpoint of comparing these systems with the conventional ring-magnet drive. It might seem that driving the pendulum from the top by means of a ring magnet would result in minimum sensitivity to asymmetries, but this is not strictly true. A pendulum is less sensitive to asymmetries at its top. But a greater



An amateur's version of a Charron pivot



Charron pivot for a Foucault pendulum



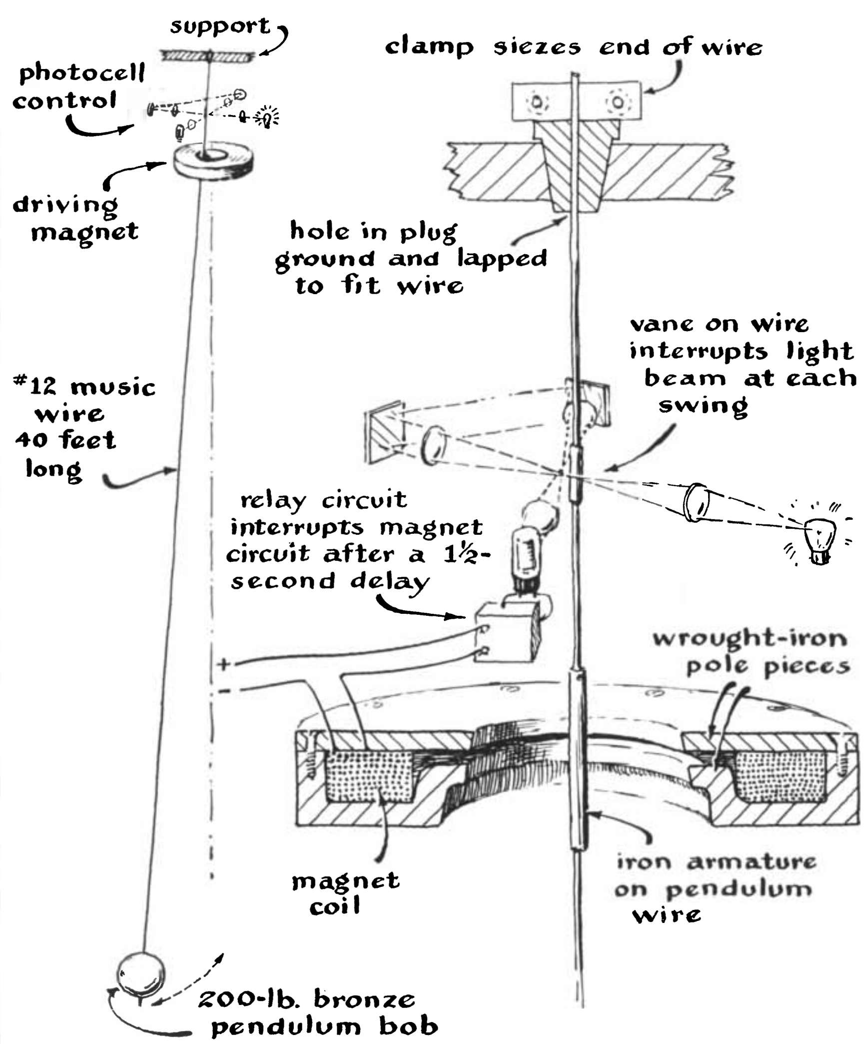
driving force is also required there. It is the percentage of asymmetry which interests us.

"An air-core coil is, of course, simpler to construct, install and maintain than the ring-magnet drive. It must be said, however, that this method of drive does suffer somewhat in comparison with the ring-magnet system in that the whole field is not turned on and off in the course of providing useful drive. The steady useless component of the field is not necessarily symmetrical. Consequently asymmetry may be added to the system continuously. This means that in this system the magnet must be made more perfect than in a system wherein the field changes the required amount by going fully off. When desired, the magnetic field of the air coil can be trimmed for symmetry with small tabs of magnetic iron.

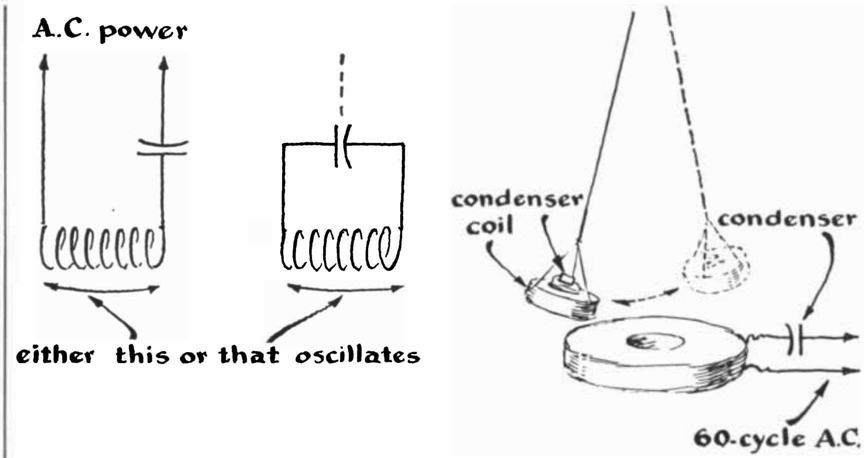
"For the purpose of most demonstrations, however, extreme precision is unnecessary. With reasonable care in alignment the angular velocity of the pendulum's apparent deviation should fall within 15 per cent of the anticipated value."

Last January Roger Hayward, the illustrator of this department, described a homemade apparatus with which one could see features of one's own retina. Since then readers have submitted scores of variations on the technique, a few of which are simpler than Hayward's.

"Your item on how to see blood vessels in your own eye," writes Richard A. Fireman of Chicago, "would seem to be a beautiful example of doing things the hard way. Here's an easy way to do it. Make a pinhole in a piece of cardboard or heavy paper. Place the pinhole as close to your eye as possible, relax the eye, look at some bright field (such as the sky) and jiggle the paper rapidly from side to side, keeping the pinhole always within your field of vision. If your eye is constructed the same as mine,



Conventional electric drive for a Foucault pendulum



One version of the Mackay electrical drive for a Foucault pendulum

you should then see an elaborate pattern of blood vessels projected upon the optically widened pinhole. Furthermore, if you hold the pinhole steady (perhaps three inches from your eye), again stare at a bright field and wink a few times (close the eye part way, then open it again), you should see the tears rolling down the cornea of your eye. It is important in both of these experiments that the eye be relaxed, and that it be focused at infinity."

Edward Prenner, a physician of New York City, substitutes a flashlight for the pierced cardboard. "It is only necessary," he writes, "to hold an ordinary pen-sized flashlight against the lower lid of the closed eye, and wiggle the flashlight rapidly from side to side. This gives a beautiful silhouette of the retinal vascular tree. It will be noticed that it is not quite possible to see the center from which the vessels radiate. This is another demonstration of the celebrated blind spot at the entrance of the optic nerve."

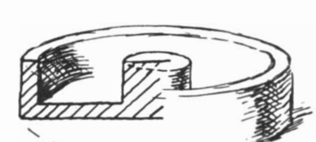
"Much the same effect can be perceived by directing the light beam against the white of the eye," says Heinz Norden of New York. "It is possible," he writes, "to train a pencil of light through the sclera, the tough whitish outer covering of the eyeball, in such a way that it will be reflected from one part of the retina to another. The first point of incidence is then visualized with the utmost clarity at the second point.

"Incidentally, the ability and habituation of the eye to ignore minuscule obstructions and flaws in vision can be studied in ways other than those Hayward describes, with little or no instrumentation and fascinating results. It is a process that might be called 'seeing seeing.' Almost everyone is familiar with the clusters and strings of tiny O-shaped figures, resembling microscopic images of bacteria, that appear against a bright field of vision when the lids are narrowed and that are called *mouches volantes.* These have been explained as shadows of inclusions in the vitreous humor, or as white blood corpuscles traveling through the cornea.

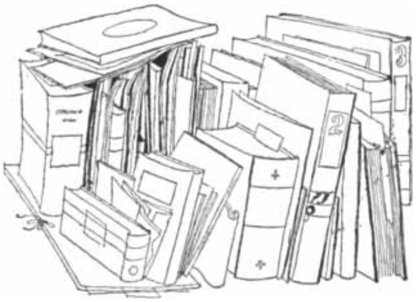
"With training and stronger light, especially from the side, they are readily perceived—or so it seems to me—as only the most prominent of an apparently three-dimensional reticular structure that fills the entire visual field. When, in such visualization, the eye is made to follow a pencil held before it, this cell network appears to remain fixed with reference to the cornea. I am convinced that it *is* the rear surface of that tissue.

"Most people are aware of a dance of tiny white points when they gaze at a brightly illuminated field, such as the clear sky, a dance that reminds one amazingly of Brownian movement. No less a personage than Albert Einstein insisted to me that these were 'shadows of blood corpuscles in the retina.' I remain unconvinced. Could they not indeed be what they appear to be—shadows of the giant molecules suspended and buffeted about in the tear secretion which constantly bathes the eyeball?

"It is fascinating to speculate that subjective evidence of the molecular structure of matter and of the cellular structure of organic matter may have been literally in front of our eyes long before man thought of the microscope."



Magnetic core to intensify Mackay drive



BOOKS

The late John von Neumann on computers and the brain

by S. Ulam

The Computer and the Brain, by John von Neumann. Yale University Press ($3).

This book by John von Neumann is published more than a year after his death. It is hardly more than an introduction to a monograph on a subject which preoccupied him during the last years of his life. It has been prepared from an incomplete manuscript of the Silliman Lectures which he was to give at Yale University in 1956. As Mrs. von Neumann explains in the introduction to the book, the lectures were written during his fatal illness. In places the presentation of the material lacks his characteristic style. Nevertheless the book, like everything von Neumann wrote, remains highly original and intensely stimulating.

Von Neumann became interested in the possibilities of electronic computing machines during the Second World War. In the beginning he was primarily concerned with the logic of the operation of such machines, but he was the first to devise a means by which a machine with fixed circuits could deal flexibly with a variety of mathematical problems. Before he had entered the field, the solution of each problem required a different set of connections.

It was the problems of mathematical physics that arose at the Los Alamos Scientific Laboratory which created the need to plan massive computations on the new machines. The solution of one of these problems may require billions of elementary steps: additions, multiplications, and so on. Beyond the mere bulk of repetitive computations the problem may involve combinations and logical operations of considerable complexity. The program of calculation must be prepared in advance, first in a general form. This is done by means of a flow diagram, which is then elaborated by a detailed set of instructions—a "code." This very scheme of a flow diagram and a code is due to von Neumann, along with many other concepts now commonplace in the art of computing.

It was von Neumann's belief that computing machines would not only help solve existing problems but also open new perspectives in mathematics and physics. Obviously the machines could be used to test tentative theories by computations too laborious and too lengthy for manual methods. But, more important, they could provide the imaginative investigator with new "experimental" material which could suggest new theories.

From the beginning von Neumann was intrigued by the similarities and differences between the operation of computing machines and the working of the human brain. He envisaged a general theory of automata, and even of organisms, but his ideas remained undeveloped. The present book is an approach to an understanding of the nervous system from the point of view of the mathematician. Von Neumann stated that, since he was not a nerve physiologist or a psychologist, he would restrict himself to the logical and statistical features of the elements of the brain. He felt that a mathematical study of the nervous system would not only lead to a better understanding of this system but also could affect the future development of mathematics itself.

The book is divided into two parts: (1) the computer and (2) the nervous system. The first describes in terms comprehensible to the layman (but with insufficient detail) what the characteristics of a computing machine are, how it works and what it can do. The discussion concerns both digital and analogue computers. Present machines have organs to perform the basic arithmetical operations: addition, subtraction, multiplication and division. In the digital computer these operations are performed on numbers stored as a sequence of markers. In the analogue machine numbers are represented not by symbols but by physical quantities, for example, an electric current. The strength of the current can be added and subtracted; multiplication and division are more difficult, but can be accomplished by special devices. A mathematical machine also needs a memory in which numbers generated by one operation can be stored until they are needed for another.

The second part of the book deals with the nervous system in much the same language. The assumption has been made that the operation of the nervous system is digital, a view that is strongly suggested by the facts of nerve physiology. The basic unit of the nervous system is the nerve cell, or neuron, which generates and propagates nerve impulses. The nature of this impulse is not simple; in some respects the impulse is electrical, and in others it may be considered chemical and mechanical. The distinction between these terms may be clear in the macroscopic world, but on the scale of molecules they tend to merge.

A nerve impulse travels along the axon which branches out from the neuron. Associated with the impulse is a potential of about 50 millivolts, which lasts for about a thousandth of a second. During this disturbance there are chemical changes in the axon, and probably mechanical changes also. All these changes are reversible; after the impulse has passed, the axon reverts to its original state.

The digital character of the nervous system has the basis that the neuron may fire a nerve impulse or it may not. Thus the operation of the nervous system corresponds to the binary system of a digital computer, in which there are only two basic symbols: 0 and 1 ("yes" and "no"). It takes a neuron somewhere between a hundredth and a ten-thousandth of a second to react to a stimulus. The reaction time of a vacuum tube or a transistor, either of which may be a component of a digital computer, is between a millionth and a ten-millionth of a second. With respect to speed, then, the artificial components are ahead by a factor of 10,000 or 100,000.

When it comes to the size and number of components the situation is entirely different. The size of a neuron varies widely from cell to cell. However, to compare the size of the logically active part of a nerve cell with that of the logically active part of a vacuum tube or transistor we can use rough linear dimensions. The thickness of the neuron's outer membrane, in which most of the changes associated with the nerve impulse occur, is of the order of a ten-thousandth of a centimeter. The corresponding quantity in the vacuum tube, the distance between grid and cathode, is between a tenth and a hundredth of an inch. In the transistor the distance between the "emitter" and the "control electrode" is less than a hundredth of an inch. Thus in linear dimensions the natural components are more compact by a factor of the order of 1,000.

The volume occupied by the human brain is of the order of 1,000 cubic centimeters; the number of neurons is estimated at 10 billion or more. This allows a space of about a ten-millionth of a cubic centimeter for each neuron. Today a few thousand vacuum tubes would certainly occupy tens of cubic feet. By replacing vacuum tubes with transistors this space could be reduced by a factor of 10 or so. But the economy of packing in the natural system still leads that in the artificial ones by a factor like 100 million or a billion.

The energy consumption of natural and artificial components can also be compared. The human brain dissipates energy at the rate of about 10 watts: a billionth of a watt per neuron. A vacuum tube dissipates about 50 watts; a transistor, perhaps a tenth of a watt. Here again the natural components lead the artificial by a factor of the order of 100 million or a billion.

So nature seems to favor a system with relatively slow components but a great many of them. Electronic computers utilize fast components, but relatively few of them. This suggests that the human nervous system handles many items of information simultaneously, whereas modern computing machines tend to do one thing at a time, or relatively few things at a time. In other words, the function of the nervous system is largely "parallel" and that of computers is essentially "serial." This very important point is brought out in von Neumann's discussion. It should be noted that, in general, parallel and serial operations cannot simply be substituted for each other. Not all serial operations can immediately be converted into parallel ones. For example, a step in a sequence of calculations performed by a computer may depend on the result of other steps. Conversely, a parallel procedure generally cannot be adapted to the serial processes of a computer without creating new requirements for the computer, specifically in its memory.

Von Neumann now discusses the functions of the nervous system which go beyond the simple digital picture. He introduces a mathematical scheme which distinguishes between different kinds of neurons. Some neurons, for example, respond to external stimuli such as light and sound; others, called internal receptors, respond only to nerve impulses. Some light receptors respond not to the level of illumination but to changes in it. Some neurons are activated by the stimulation of certain of their branches, and not by the stimulation of others. All this suggests that the nervous system functions not only like a digital computer but also like an analogue machine. A realistic mathematical description of this versatile system has yet to be written.

So far we have considered organs which correspond to the arithmetical components of a computer. What about memory? At the outset of his discussion von Neumann states that we are as ignorant of the nature and location of the human memory as were the Greeks, who placed the mind in the diaphragm. We only know that the capacity of this memory is remarkably large. A memory contains a certain maximum amount of information, which in the usage of modern information theory can be converted into binary digits ("bits"). As an example, a computer memory which can hold 1,000 eight-digit decimal numbers has a capacity of 26,640 bits. The memory of a large electronic computer has a capacity of 100,000 to 1,000,000 bits. Now let us assume, first, that in the human memory nothing is ever truly erased (there is some evidence for this assumption); second, that a receptor in the nervous system receives about 10 distinct digital impressions a second; third (as before), that there are 10^{10} neurons; and, fourth, that the life span is 60 years, or 2×10^9 seconds. Thus we have 10×10^{10} times 2×10^9, or 2×10^{20} bits. Compared to the 10^5- or 10^6-bit memory of a large computer, this is an impressive number.

Modern ideas on the nature of memory are still vague and unsatisfactory. One idea is that the stimulation of a nerve cell slightly changes the requirements for further stimulation; the memory would reside in the change of these conditions. Another proposed scheme is that connections among nerve cells change with stimulation; here the memory would reside in the change of connections. Von Neumann speaks of the genetic mechanism as a memory. It could be argued that certain chemical systems of the body which perpetuate themselves represent memory elements. This is reminiscent to those who are familiar with electronic computers, because a memory element in such a machine automatically regenerates its state. Von Neumann argues that some systems of nerve cells which act in a cyclic or periodic manner constitute a memory. This reminds one of computer "flip-flops," in which two vacuum tubes control each other.

After this discussion von Neumann returns to the interplay of digital and analogue mechanisms in living organisms. Here the genes provide a cogent example. The genes themselves are part of a digital system, that is to say, they bear a code which determines the characteristics of the organism. The effect of the genes, however, is to produce biological catalysts (enzymes), whose role is rather like that of analogue components in a computer.

The book also takes up the concept of the "complete" code. This is a set of instructions which describes each and every step in the solution of a problem by a machine. It can be contrasted to the more general idea of the "short" code, which assumes a machine with capabilities beyond those of present computers. The short code is a brief set of instructions for a machine which will elaborate and complete these instructions by itself. The concept of the short code has already been applied, in a limited way, to actual computers. It is possible to present a machine with a "verbal" description of a problem; the machine will then write the complete code by itself and follow it.

Ultimately, of course, both machine and organism must have a complete code. The question now arises: How precisely are these instructions supposed to be carried out? In a computing machine they must be carried out very precisely, or the errors will quickly add up. Von Neumann believed, however, that in the nervous system the notation is not exclusively digital but is to some extent statistical. He discusses this point with reference to his earlier work on how to build reliable machines from nonreliable components.

Von Neumann's final paragraphs are

devoted to the speculation that there are two kinds of communication in the human brain. The first involves logic and is akin to mathematics as we now know it; the second is a kind of general language. This language, which may correspond to the short code, must be quite different from languages in the usual sense. It may, for example, operate with analogies.

This little volume will leave the reader with a sharper awareness of the loss represented by von Neumann's premature death. It was not given to him to pursue these speculations and render them into mathematical form. But his ideas will have great value to further investigations.

We are only beginning to realize the potentialities of the large electronic computer. In the opinion of this reviewer the next steps in its evolution will involve not only greater speed and larger memory capacity but also a more intimate connection between the machine and its user. The usefulness of the machine would be greatly increased if the results of its computations could be quickly displayed and if its orders could be quickly changed. If the machine can be made to operate more like the human nervous system, it may stimulate the imagination of its user to a greater degree. Certainly it seems that future machines will perform many operations in parallel channels. Work is under way at several centers which will enable a machine to prove elementary theorems in certain simple mathematical domains. Such machines may be capable of a modicum of genuine learning. The material outlined in von Neumann's book awaits conversion into mathematics.

Short Reviews

SCIENCE AND HUMAN VALUES, by J. Bronowski. Julian Messner, Inc. ($3). Bronowski's essay considers the power of science for good and for evil. This is not, he reminds us, a new problem; it is as old as weapons and tools. But it has never before confronted mankind with a dilemma and with fears so massive, so immediate and so inescapable. Civilization is "face to face with its own implications." The atom bomb that fell on Nagasaki—which the author visited in November, 1945, for the British chiefs of staff—destroyed an industrial slum and created a desolate ash heap. Both the slum and the ash heap attest the misuse of science. The question is: Who is responsible? Those whose interest lies in the humanities are apt to blame the scientists, for plainly "no mandarin ever made a bomb or an industry." The scientists say, with equal contempt, that "the Greek scholars and the earnest explorers of cave paintings do well to wash their hands of blame; but what in fact are they doing to help direct the society whose ills grow more often from inaction than from error?" In these terms the dispute is unsolvable; it is as pointless as a dispute between the two ends of a worm as to which is to blame for the fishhook through the middle. Science is here to stay. It is part of civilization, as are other creative activities. Together these activities make a whole; they give society its coherence, its life. Science has a "place in the canons of conduct," and it has a responsibility. By the example of its spirit, the precept of its method, the light of its discoveries, science has much to offer man, not only in enlarging his command of the physical world but also in shaping his conduct and determining his survival. Bronowski deals with three great themes. The first is the nature of scientific activity. Here he stresses the likeness between the creative acts of the mind in art and in science. This likeness attends both method and purpose. Art and science are explorations, explorations in search of "unity in variety." This was the phrase Coleridge used to define beauty. But the search is not confined to poetry, painting and the arts. Science itself is "nothing else than the search to discover unity" in the variety of our experience. The scientist does not mechanically record facts; he selects from an infinite assortment of bits and pieces and makes patterns. The artist does not copy nature; he creates by making felicitous images, by fusing different aspects of nature. So did Newton in linking the falling apple with the captive moon; so did Faraday in linking electricity with magnetism; Maxwell in linking both with light; Einstein in linking time with space, mass with energy and "the path of light past the sun with the flight of a bullet." And the act of creation, though original, does not stop with its originator. "The work of art as of science is universal because each of us recreates it. We are moved by the poem, we follow the theorem, because in them we discover again and seize the likeness which their creator first seized." Bronowski's second theme is the nature of truth. How do men seek it? There is one way in science, another in ethics. Science begins with appearances. In time these are associated by resemblances and differences. Names and symbols are attached; laws and concepts are created. The laws may themselves nest in one another and form a larger structure. Thus a new unity comes into being. But neither in this unity, nor in any of its parts, are eternal truths to be found. Laws and concepts are constantly checked and tested by logic and experiment. The method is more lasting than its products. A system of ethics also derives from central concepts, but we are apt to ascribe an unchangeableness and self-evidence to these concepts which we do not ascribe to the concepts of physics or even of mathematics. In other words, we say that the world of what is is subject to test, but the world of what ought to be is not. Bronowski disagrees. Whatever churchmen and philosophers may pretend, he says, such concepts as justice, humanity and the full life "have not remained fixed in the last four hundred years." The test of a concept of conduct and human values, such as self-interest or the greatest happiness of the greatest number, is whether it really works—"without force, without corruption, and without another arbitrary superstructure of laws which do not derive from the central concept." This is the pragmatic test of fact, the "habit of simple truth to experience," which has moved civilization. Where the habit is lost, the society is lost. Bronowski concludes by examining the values by which men live. The habit of truth which characterizes the pursuit of science binds scientists into a kind of society. And in this society other values have grown up as a consequence of the process of systematically testing truth in action. Among them are independence in thought, love of originality, respect for dissent, freedom of expression, tolerance. These constitute the ethic of science, but observe that they also constitute the ethic of a decent society. In the society of scientists each man by exploring for truth earns "a dignity more profound than his doctrine." And in any society of equal men whose guiding principle is truth, there will be a sense of human dignity, a respect for others founded in self-respect. This, then, is what science has to give: not discoveries or judgments, but a method of truth and a spirit of exploration. "Science has nothing to be ashamed of even in the ruins of Nagasaki. The shame is theirs who appeal to other values than the human imaginative values which science has evolved." *Science and Human Values* is a profoundly moving, brilliantly perceptive essay by a truly civilized man.

FRANKLIN AND NEWTON, by I. Bernard Cohen. The American Philosophical Society ($6). This massive book deals

with certain aspects of the history of 18th-century physics. The author attempts to show the influence of Newton and Newtonianism on a most active period in the growth of experimental science; in particular, on Benjamin Franklin's work in electricity. Cohen has gathered a variety of evidence to prove that of Newton's writings the *Opticks* rather than the more famous *Principia* was the major inspiration to 18th-century physicists. His masterwork of dynamics presented a severely formal system. It awed men and fell upon their minds like a divine revelation. On many fundamental matters it was thought to be closed, complete and perfect (though it was recognized that some of the theories, for example his views on fluid mechanics, required reworking and extension). In any case it was a difficult treatise which did not invite the attention of those untrained in higher mathematics, however creative their imagination and ardent their passion for experiment. The *Opticks*, on the other hand, was less severe and more hospitable. It reported vividly and understandably Newton's beautiful experiments on light and color: better yet, it presented a series of remarkable "queries" on the nature of physical phenomena; on the ether, atoms and the structure of matter; even on "final causes" and the meaning of the universe. It sent eager amateurs as well as single-minded practitioners flying off along many different paths of speculation and experiment in electricity, mechanics, optics, heat, chemistry, physiology and other branches of thought. The 18th century marked the beginning of a "genuine empirical science," and the Newtonianism of the *Opticks*, as Cohen believes, was the main impetus to this development. In the course of supporting his argument he examines in detail physical theory in the age of Newton; the rise of electricity as a Newtonian science; the corpuscular philosophy and the views of Pemberton, Boerhaave, Gravesande, Desaguliers, Gauger and Hales; the very important but still not fully appreciated electrical researches of Franklin; the reception accorded Franklin's theories. *Franklin and Newton* is a book of considerable merit. It is ably written and reflects sure knowledge of scientific activities and the contemporary literature. Some of the discussion of Franklin's researches is especially interesting and rouses admiration for Cohen's ability to break down descriptions of experiments and make them completely comprehensible to the modern reader. The book, however, is seriously flawed by pedantries. It is much too long and repetitious. When the author finds a treasure in a mass of dross, he insists on describing everything he found. Innumerable digressions retard the story so that it sprawls instead of flowing. It is thought necessary to recount bibliographical minutiae, to examine relentlessly shadowy questions of priority, to subject to merciless analysis, both in the text and in a separate appendix, some nine different meanings Newton gave to the word hypothesis. Cohen includes a chapter on the "scientific personality" of Franklin and Newton which offers little more than a summary of the usual commonplaces—Newton portrayed as the "tortured introvert," Franklin as the "happy extrovert." A case might be made that the digressions are not irrelevant and that everything in this prolix monograph has a purpose; yet the result overwhelms and blurs the focus, so that one emerges with a much less clear notion of what the author intends to prove than one could have got from a more disciplined and restrained recital.

The Earth and Its Atmosphere, edited by D. R. Bates. Basic Books, Inc. ($6). Once Round the Sun, by Ronald Fraser. The Macmillan Company ($3.95). The World in Space, by Alexander Marshack. Thomas Nelson & Sons ($4.95). To the nonscientist the name International Geophysical Year conveys little information. It sounds like a celebration, or a high-flown member of the category which includes National Hat Week or Visit-Your-Local-Tavern Month. The I.G.Y. is of course a major scientific event. It is the largest research program ever undertaken on an international cooperative basis. More than 5,000 scientists representing 64 nations are participating in this enterprise, which aims to increase our knowledge of the planet we inhabit. All the physical aspects of the earth are being studied—the atmosphere, the oceans, the land. What changes are taking place in the earth's climate? What can be learned about the origin and age of the earth, about its interior and crust? What can new methods and instruments teach us about ocean currents, cosmic rays, solar flares, magnetic storms, the composition of the ionosphere, meteors, auroras, the airglow? Before this year began we knew less, according to the noted geophysicist Sydney Chapman, about the Antarctic than about the moon. We will soon know much more, thanks to the massive assault on that continent by many groups of scientists. Each of the books listed above describes the I.G.Y. program, each explains the questions and problems cen-

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tral to the work. The Bates symposium offers the most comprehensive account. Contributors include Chapman, Gerard Kuiper, K. E. Bullen, D. R. Bates, E. J. Öpik, E. T. Eady, J. A. Ratcliffe, A. C. B. Lovell, J. B. S. Haldane. This is a solid, valuable survey. Fraser's brief monograph covers much of the same ground, at a more popular level. It is well written, but a certain amount of hurry and compression at times impairs the exposition. The book lacks an index, which is a nuisance in a story that covers so many topics. The Marshack version of the I.G.Y. is an acceptable and well-illustrated journalistic report. It is accessible to high-school students. If you want to know something about the program, but not too much, this book will do.

THE VERTEBRATE VISUAL SYSTEM, by Stephen Polyak; edited by Heinrich Klüver. The University of Chicago Press ($45). It is impossible to make a proper appraisal of this enormous volume of 1,400 pages in a short review. The late Stephen Polyak was a distinguished anatomist who devoted 30 years to the study of vision and the relation of the eye and its function to the central nervous system. The present work, embodying the results published in his previous books (including his well-known *The Retina*), is a summary not only of a lifetime of research, but a survey of the findings on the visual system reported by others in the world literature. The bibliography alone runs to 300 pages and contains some 10,000 references. Polyak's treatise comprises a 200-page history from ancient times of the investigation of the eye and the development of the optical sciences, a detailed section on the anatomy and histology of the retina and the visual pathways and centers of the brain, a section on pathology, and a concluding section on the origin, development, comparative anatomy, physiology and biology of the vertebrate eye. There are more than 500 illustrations. The author's learning is everywhere evident, as is a single-minded devotion to the subject. Whatever he encountered in his wide-ranging studies was incorporated into his philosophy of vision. Man has become what he is and has achieved, in Polyak's view, because he can see. This book is therefore as ready to pronounce on the relation of the eye to man's moral and intellectual qualities as on the structure of the foveal photoreceptors. Polyak was in ill health through the last years of his life; nevertheless he was able to complete the huge manuscript. Still, a great deal remained to be done; this task, born of friendship and admiration, was skillfully performed by Heinrich Klüver, so that we have the author's final legacy in just the form he would have wished.

THE NEW LANDSCAPE IN ART AND SCIENCE, by Gyorgy Kepes. Paul Theobald and Co. ($15.50). Professor Kepes of M.I.T. is known as a painter, typographer, photographer and exhibition designer. His earlier book, *Language of Vision*, many times reprinted, is valued as a contribution to the theory of art. The present volume should further enhance his reputation. It is primarily a picture book "arranged to bring attention to a newly emerged aspect of nature, hitherto invisible but now revealed by science and technology." Kepes provides a running commentary but there are also supporting essays, interspersed through the book, by Siegfried Giedion, Fernand Léger, Kathleen Lonsdale, Charles Morris, Bruno Rossi, Paul Weidlinger, Norbert Wiener and others. Few of the essays add to the reader's understanding; they are apt to be rather cosmic. But Kepes's observations are helpful, and the pictures as a group are a fine gallery of the new landscape illuminated by the instruments of science and human imagination. In this selection appear James Clerk Maxwell's diagrams of lines of force, mathematical curves and models, ancient implements, weapons and vases, designs by Johannes Kepler, Leonardo da Vinci and Albrecht Dürer, artifacts of industry from pipelines and road markers to runways and marshaling yards, aerial photographs of cities, undersea photographs, a photomicrograph of the chigger vector of tsutsugamushi disease, snapshots of crystal growth, the smoke pattern of the wake of a propeller, electric-spark patterns, radiographs of faulty heating coils and of snakes (the two are almost indistinguishable), oscilloscope patterns, strain diagrams, magnetic domain patterns, the lacework portrait of an alternating current, paintings by Pablo Picasso and Paul Klee, a picture of a dielectric in the process of breakdown, views of modern architecture, soap bubbles and Radiolaria. By his discriminating choices and happy juxtapositions Kepes deepens our appreciation of the likenesses which bind together the most disparate elements of nature and suggest the underlying order and relatedness of the large and small, seen and unseen shapes of the world.

PUZZLE-MATH, by George Gamow and Marvin Stern. Viking Press ($2.50). Puzzle connoisseurs will find this a discriminating collection of twisters. There are even a few fresh ideas, which is almost unheard of in this branch of literature. Included are puzzles of logic (that of the 40 unfaithful wives is very pretty), probability, railroad trains, geometry and mechanics. Sample twister: Piling dominoes on top of each other as building blocks, what is the maximum offset that can be obtained by raising the columns indefinitely? Answer: You can build an offset as large as you please, for each domino can be so laid on the one beneath that the cumulative protrusions in a given direction form the harmonic series $1/2 + 1/4 + 1/6 + 1/8 \ldots$, which diverges. If a barge loaded with scrap iron is floating in a canal lock, and the crew of the barge throws the scrap iron overboard, what happens to the water level in the lock? Answer: The water level goes down. Reason: A floating object displaces a volume of water equal to its weight, but a submerged object displaces only the amount of water equal to its volume.

INSTINCTIVE BEHAVIOR, edited by Claire H. Schiller. International Universities Press ($7.50). In this volume are collected eight papers regarded as classics in the development of the science of ethology. In Europe the comparative study of behavior has been chiefly in the hands of zoologists, and it is the extraordinarily ingenious, patient and imaginative work of this group that is here recorded. Represented are Jacob von Uexküll in a pioneer monograph "A Picture Book of Invisible Worlds," which deals with the question of how the world appears to animals; Konrad Lorenz in papers on companionship in bird life, the nature of instinct and the comparative study of behavior; Lorenz and N. Tinbergen in an essay on the egg-retrieving behavior of the greylag goose; Tinbergen and D. J. Kuenen in an article on feeding behavior in young thrushes; Paul H. Schiller in a report on the manipulative patterns in the chimpanzee. Originally published in German, these studies were, as Karl Lashley says in the introduction, almost unknown in the U. S. The editor has translated them, a task of considerable difficulty because ethology, as a comparatively new science, contains many technical words for which there are no precise English equivalents.

THE ORIGIN OF LIFE ON THE EARTH, by A. I. Oparin. Academic Press, Inc. ($6.80). The third edition of this work by the noted Russian biochemist is revised and enlarged to take account of research in different fields on the transformation of matter on the way to the origin of life. Since its first appearance as a small booklet in 1924, this has been a most stimulating book, and the incorporation of later developments and insights has augmented its value and fascination.

Notes

FLORA OF THE MARSHES OF CALIFORNIA, by Herbert L. Mason. University of California Press ($10). Descriptions of the flowering plants and ferns occurring in the wet lands of California. Full taxonomic data, geographic and ecological range of each species, and hundreds of illustrations of the more important species.

EXPLORING THE ATMOSPHERE'S FIRST MILE, two vols., edited by Heinz H. Lettau and Ben Davidson. Pergamon Press, Inc. ($20). Accounts of a series of experiments performed in open prairie country in Nebraska to study the profiles of wind, temperature and other meteorological quantities in the atmospheric boundary layer.

THE FISHES OF OHIO, by Milton B. Trautman. Ohio State University Press ($6.50). An admirable handbook, generously illustrated by hundreds of drawings, keys, maps and color photographs, giving a wealth of information about the appearance, distribution and habitat of Ohio fishes.

HISTORY OF THE PRIMATES, by W. E. Le Gros Clark. MAN THE TOOL-MAKER, by Kenneth P. Oakley. The University of Chicago Press, Phoenix Books ($1.25 each). These two British Museum manuals are recent additions to an admirable library of paperbacks. Each volume is a model of its kind: clear, readable, authoritative, well printed and well illustrated.

GREEK ARCHITECTURE, by A. W. Lawrence. Penguin Books ($12.50). This volume in the attractive Pelican History of Art series describes Greek architecture from the Neolithic and Early Bronze Age to the time of Christ. It includes 170 line-drawings and 152 pages of half-tone plates.

RADIO ASTRONOMY, edited by H. C. van de Hulst. Cambridge University Press ($9.50). Eighty papers on various aspects of radio astronomy, delivered at an International Astronomical Union symposium held in 1955 at Jodrell Bank in Britain.

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