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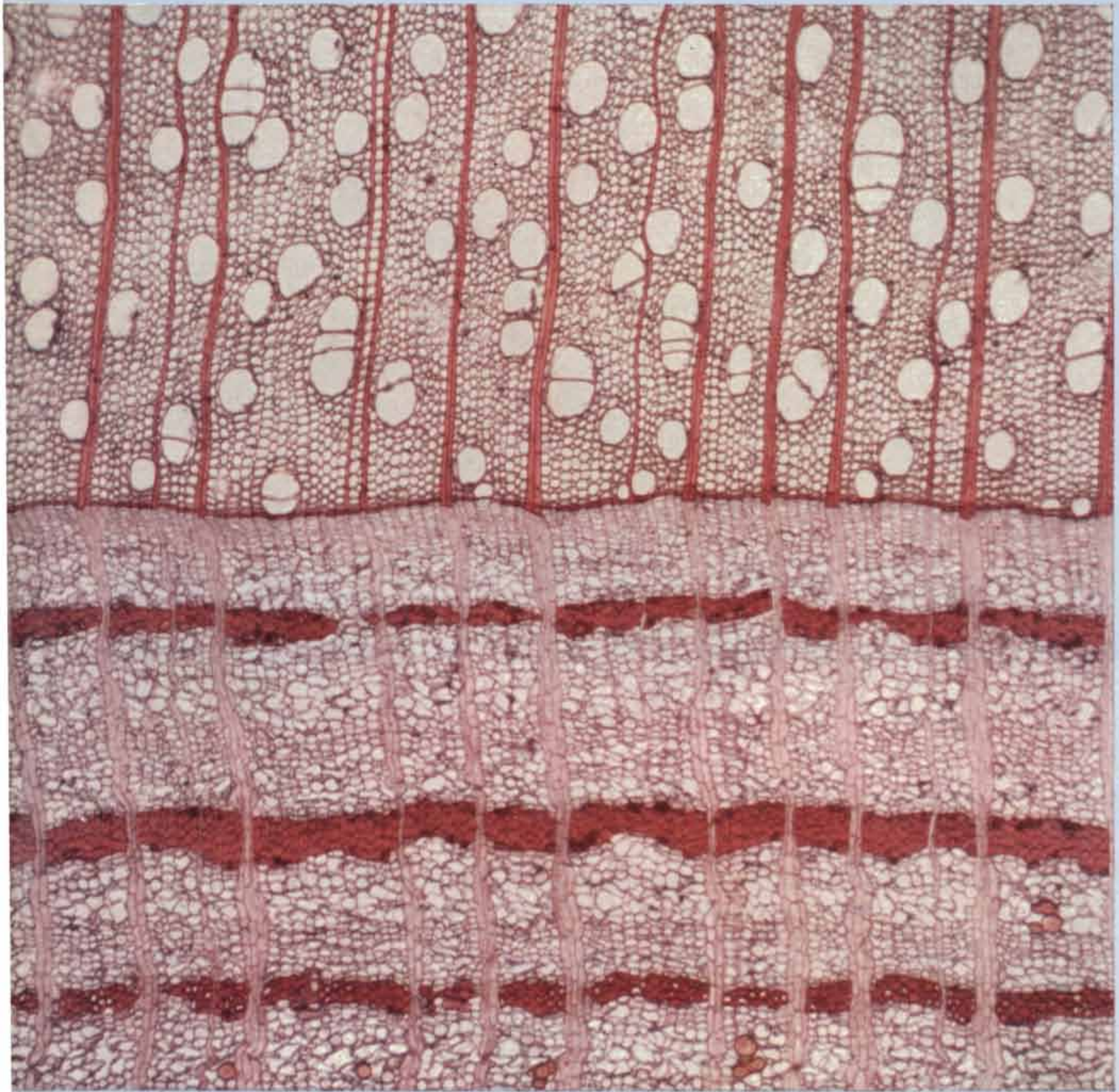

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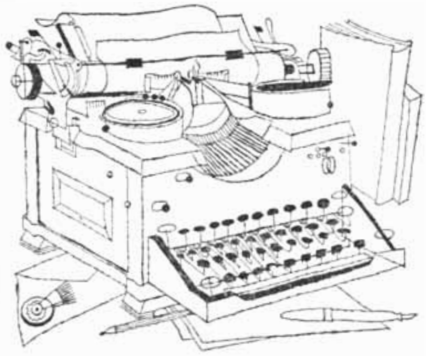

LETTERS

Sirs:

I have just completed reading the paper on D'Arcy Thompson by John Tyler Bonner [SCIENTIFIC AMERICAN, August], and wish to write of my appreciation while it is still warm. I, too, believe that "science could use more men like Thompson," both because of his scientific contributions, and because of the beauty and clarity of his writing.

I know D'Arcy Thompson only through *On Growth and Form*, and that only by accident. Some years ago I was engaged on a mathematical analysis of a problem on the appraisal of ore reserves, and a colleague called my attention to Thompson's book. I have been grateful to him ever since—grateful for the sheer pleasure I received from his pleasing phraseology, and grateful for the stimulation of his ideas. It is unfortunate that *On Growth and Form* is not better known among my fellow geologists; they could learn much from it. I would not care to guess what proportion of geologists *are* acquainted with it, but I do know that the proportion is small. Nature, it appears, set up only a few rules of conduct to guide her in biologic matters; are we to expect that she set up a different set to guide her in geologic matters? I do not think she did. A logarithmic equation defines the shape of the nautilus or the rows in the head of the giant sunflower; so also does a logarithmic equation describe the relative amounts of rock and metal in an ore deposit or the velocity of water in a stream as it moves toward the sea.

S. G. LASKY

Minerals and Fuels Division
U. S. Department of the Interior
Washington, D. C.

Sirs:

The elegant account of the work of D'Arcy Thompson by John Tyler Bonner prompts me to communicate a classroom practice that I have pursued for years. It bears directly on Thompson's ideas of the form, symmetry and structure of organisms.

In the standard course in analytic geometry we study an array of familiar loci (the straight line, power functions, conics) and a number of curves (algebraic and transcendental) characterized by special geometric properties. These last possess intriguing *esthetic* form and symmetry, and I call explicit attention to the fact that forms in Nature subscribe to these mathematical (geometrical) properties, ofttimes identically. After we have plotted such curves as the spiral of Archimedes, the logarithmic spiral, the hyperbolic spiral, the cubical parabola, the semi-cubical parabola, the Cissoid of Diocles, the lituus, the cardioid, the various-leaved roses, and so on (there are literally scores of special curves), I suggest that students find leaves of trees and petals of flowers which "fit" these curves.

Illustrations are endless: a certain pine grows two needle-like leaves (pine needles) in a cluster which fit the semicubical parabola ($X^3=ay^2$); some fit the Cissoid of Diocles ($y^2=X^3/2a-x$); the twining tendril of beans and other clinging vines fit certain spirals, like Euler's spiral, or the lituus ($r^2\Theta=a^2$); leaves and flower petals in abundance fit the various "roses."

JULIUS SUMNER MILLER

West Los Angeles, Calif.

Sirs:

In my recent article "Running Records" [SCIENTIFIC AMERICAN, August] it was obvious from the curves that all

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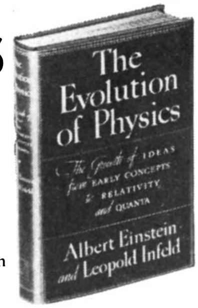

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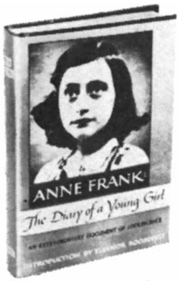

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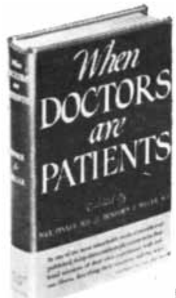

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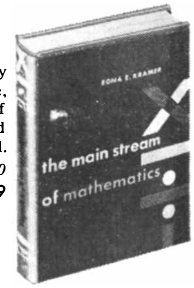

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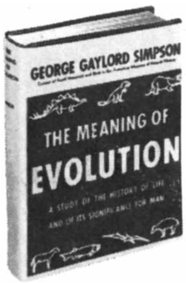

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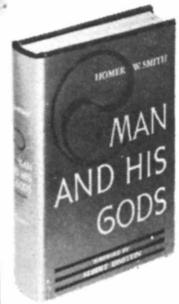

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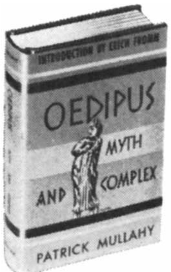

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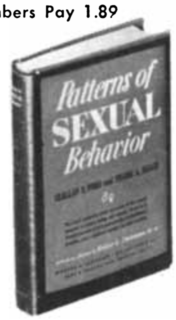

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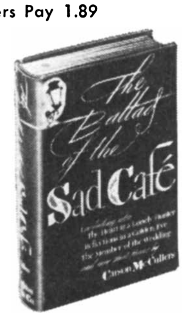

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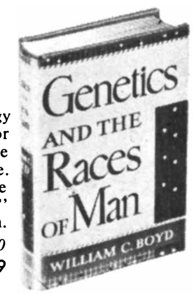

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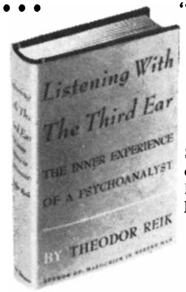

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of the Olympic running records could be improved. In the shorter distances this improvement amounted to only a few tenths of a second, but in the longer distances the records were relatively poorer and considerable improvement was indicated to bring the records onto the curve. It seems of interest to analyze briefly, in the light of the rate curves, the performances in the Olympic games just past.

New Olympic records were established in the following events: 400 meters, 1,500 meters, 5,000 meters, 10,000 meters and the Marathon. Thus in all these events the records have been brought more in line with the best performances which are the bases of the rate curves. In the 400-meter event the old record could have been broken by .4 second. George Rhoden of Jamaica broke the record by .3 second, which leaves only about .1 second improvement to be expected in this event. The time in the 1,500 meters, while spectacular, could still be improved by 2.2 seconds.

The great Czech distance-runner Emil Zatopek set new records in the 5,000 meters, 10,000 meters and the Marathon. In the 5,000-meter event the old record could have been broken by 17.2 seconds; Zatopek broke it by 9.4 seconds. In the 10,000-meter run the old record could have been broken by 57 seconds; Zatopek broke it by 42.6 seconds, which is still 14.4 seconds short of his own world-record time of 29 minutes 2.6 seconds.

For obvious reasons there can be no official world Marathon record unless the event were run entirely on a track. In the article a dotted line was drawn to extend the rate curve to include the best Boston Marathon record. The time in the present Olympics betters the Boston record by 4:41.8. It appears that this may be the best Marathon record of all time.

M. H. LIETZKE

Oak Ridge National Laboratory
Oak Ridge, Tenn.

Sirs:

My enjoyment of "Chemical Agriculture," the article in your August issue by Francis Joseph Weiss, was marred by the first paragraph, which was a usurpation of credit on behalf of the U. S. The eradication of locusts on the Persian Gulf in March, 1951, was definitely not the first time a plague of migratory locusts had been stopped in its tracks. It is pure chauvinism to credit the U. S. with control of migratory locusts in the Old World.

The credit for this victory over one of man's most historic insect enemies belongs entirely to the scientists of Europe, Africa and Asia, who have co-

ordinated their widespread observations and studies of locusts through the Anti-Locust Research Center. This international body has headquarters at the British Museum of Natural History, and is under the able direction of B. P. Uvarov. Over the past seven years it has done a herculean task in coordinating the locust research of nearly every country in Africa, the Near and Middle East and southern Europe. The eleven bulletins and four memoirs so far published by the Center are without exception outstanding scientific reports; some will certainly become landmarks in the history of biology. This Center, by charting and analyzing locust observations coming to it from thousands of sources scattered over three continents, has been able to uncover or lead to the discovery of "outbreak areas." Many of these have been known for several years, and are watched closely for signs of plagues in the making. Migration patterns are known to a point where advance warnings are now sent to countries hundreds of miles from incipient outbreaks. And finally the Center scientists have developed the aerial control techniques now used effectively against migratory locusts, after years of painstaking and often heroic experimentation.

MAURICE W. PROVOST

Biologist
Florida State Board of Health
Jacksonville, Fla.

Sirs:

Thank you for the interesting and much-needed article on ruling engines by Albert G. Ingalls [SCIENTIFIC AMERICAN, June]. The article, together with Mr. Ingalls' remarks in his column "The Amateur Scientist," at last gives us a good account of progress to date in this most exacting branch of mechanics.

While the nature of the article naturally precludes mention of everyone who has had a try at ruling engines, I wonder at the omission of one group who had what I always have considered an important part in rebuilding the Michelson-Gale machine. This ruling engine was extensively rebuilt for Bausch & Lomb by David Mann and his group in Lincoln, Mass. The photograph at the lower right on pages 46 and 47 prominently displays part of the work of the Mann group, the diamond carriage.

To those familiar with the history of the Michelson-Gale machine the article might imply that Richardson and Wiley found it necessary to rebuild Mann's work as well as that of Michelson and Gale.

C. L. PECKINPAUGH, JR.

U. S. Geological Survey
Washington, D. C.

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50 AND 100 YEARS AGO

OCTOBER, 1902. " 'By concentrating by fractional crystallization the greater part of the radiferous barium at my disposal,' reports Mme. Curie, 'I have succeeded in obtaining about one decigramme of perfectly pure radium chloride. This has enabled me to determine the atomic weight of radium. It results from my experiments that the atomic weight of radium is 225 with a probable uncertainty of not more than one unit.' "

"Dr. H. W. Wiley, Chief of the Division of Chemistry of the Department of Agriculture, will open in the autumn, under the authority of Congress, a kind of laboratory boarding house for the purpose of testing the effect of various preservatives, coloring matters, and food admixtures upon normal, healthy persons. The young men in the scientific bureaus of the Department of Agriculture will be drawn upon first, and after them the resident college students of the city of Washington. Dr. Wiley intends to ascertain the relative harmfulness of various substances as a part of the movement toward pure food legislation. The effect of borax on foods has not been quite definitely determined. The German government contends that the small amount of boric acid used in curing meat is not harmful. Dr. Wiley's experiments will either substantiate or refute that belief. Each boarder is to keep a diary and record of all facts concerning himself. He is to eat only what is set before him, and, in accordance with Scriptural injunction, is to ask no questions, for the sake of his conscience if not of his stomach."

"The death of Virchow, following the passing of Pasteur, Helmholtz and Darwin, seems to leave the world without men of science as great as those it has lost. Great Britain, in the establishment of its new Order of Merit, has selected Lord Kelvin, Lord Lister, Lord Rayleigh and Sir William Huggins as the four students of science to be honored. Lord Lister is the only man whose work could be placed beside Virchow's. Lord Kelvin is the only living physicist who might be ranked with Helmholtz. Darwin has no peer."

"No man who has brains and muscle, and who is not afraid to work, need ever starve in this country, where land is so plentiful. Let us note one fact here, however, which is often overlooked. The great wave of agricultural development has swept over the West and is rolling toward the Pacific. These pioneers skim the cream. When the soil gets exhausted they move on to new ground. This is not an entirely beneficial production. We are sending, it is true, vast amounts of grain and foodstuffs to Europe, and money is coming back, but in what proportion? The mineral ingredients of these breadstuffs are lost to us, and soon we shall have to replace them, which will cost us more, perhaps, than we have received."

"A Belgian engineer has devised a means of seeing electrically through long distances. Two small synchronous A.C. motors, each about the size of an egg, the one mounted at the transmitting station and the other at the receiving station, are driven by a current derived from the same generator, so that they rotate at exactly the same speed. Each of the armatures at about its middle carries a small lens or objective. Although it turns with the armature, each lens is free to oscillate through five degrees from the axis of rotation. There are ten oscillations per second. At the transmitting station the lens is fitted with a screen or diaphragm so that only a small portion of its surface is exposed at a time. The image which is projected by the lens remains on a point of the axis of rotation. A selenium composition, the electric conductivity of which varies according to the intensity of the light to which it is exposed, is placed on the axis of rotation. The lens, rocking while its axis of oscillation turns about the axis of rotation normal to the former, may be said to 'see' a spiral in space. The current passing through the circuit in which this transmitting body is included, will vary at each instant with the luminous intensity of points to which the lens is successively exposed. At the receiving station the circuit includes a conducting body, the luminous intensity of which varies instantly with the intensity of the current. This receiving body is placed in the principal focus of the lens, which turns and oscillates at the receiving station. Through the medium of this lens the luminous image of the receiving body is projected in the form of a spiral on a white screen placed before the lens."

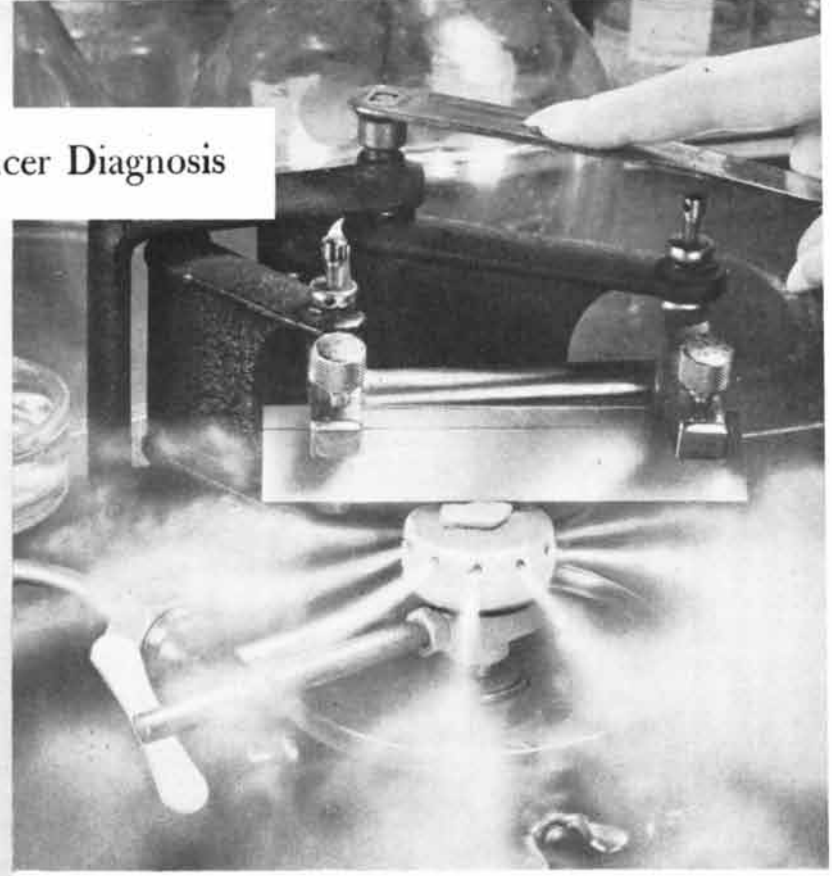
"The time is fast coming when the good old-fashioned phrase, 'dispensation of Providence,' as so often used, will

have to be replaced by the more easily understood but less pleasant, although entirely synonymous words, 'the effect of ignorance,' or 'the punishment of incapacity,' or again, 'the result of neglect,' or yet again, 'the spew of dishonesty.' In fact, the object lessons of Nature are so plain that a philosopher might think them to have been especially designed for the intelligence of an average politician. Take, for instance, the cases at Plymouth. The discharges of a typhoid patient were thrown into a brook, and the brook ran into the reservoir of the town. Soon there were 2,000 cases of typhoid. About the same thing occurred in the village of Lausanne, Switzerland. Such are the object lessons of Nature."

OCTOBER, 1852. "What is combustion?—what is heat?—are questions not easily answered, if indeed they can be answered at all. No single hypothesis has been framed which can account for all the facts observed, and perhaps the most ingenious theories of our philosophers may be as far from the true nature of heat as was the fanatical phlogistic theory of Stahl. Researches show that there exists a constant and very intimate relationship between heat, light, and all the Protean forms of electricity, magnetism, and chemical action; that they may all be made to produce one another interchangeably, either as forces or effects, and that probably they are all, not distinct, or merely related forces, but only modifications of a single force pervading all space, of which also gravitation may be a residual quantity. These researches have at least proved that heat and light are not material substances added to or subtracted from bodies under their influence. An increasing majority of philosophers have adopted the undulatory theory of light, heat, and electricity, which supposes all space, and the interstices of all matter, to be filled with an exceedingly rare and elastic fluid which has been called the ether."

"Two years ago the cities in England and Scotland were like smoked hams, owing to the dense volumes of smoke which filled the atmosphere by the use of bituminous coal. Now the situation has changed; the sky is no longer like a smoke-house. This has been accomplished by an Act of Parliament making it penal for factories to let all their smoke escape. The smoke is burned by simple contrivances of furnaces. A Commission of the Government first established that the burning of smoke was perfectly practicable, and Parliament then enforced the fact by law. The factory and mill owners soon found out how to fulfill the conditions of this law, and the result is, they save a great deal of fuel by the operation. Like many

PROBLEM: Cancer Diagnosis



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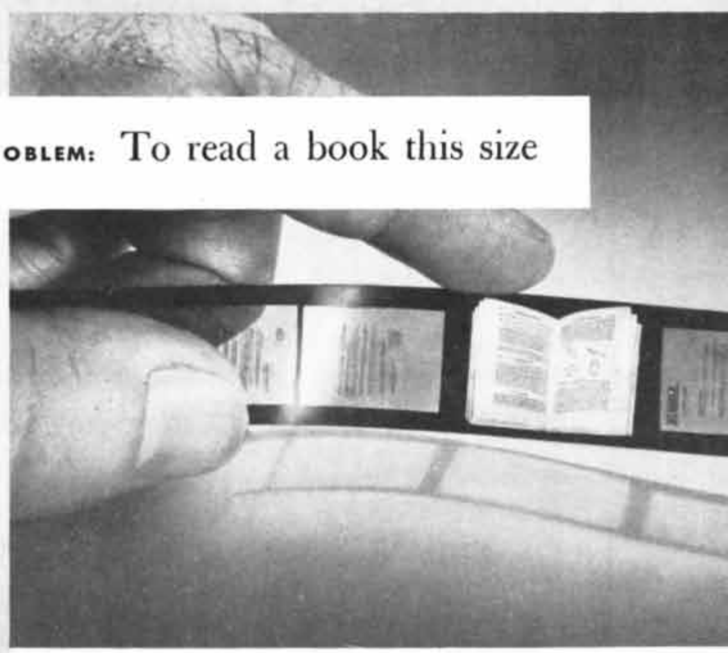

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other good things, this important improvement at first met with a great deal of opposition; there are some men who cannot judge when a good turn is done to them, and we can say that this is true in respect to many useful inventions."

"Food undergoes in the stomach a necessary process of digestion, which is performed by the gastric juice. The permanent opening made in the stomach of a soldier in Canada by a musket ball, and described by Mr. Beaumont, as well as the experiments performed with animals, prove irrefragably that the process of digestion, in animals which resemble man in their organization, is the same whether the action goes on in the stomach or in a vessel. It follows from this that it is very easy to obtain any quantity of the gastric juice, either from animals that have been killed at the slaughter-house, or preferably from living animals furnished with a permanent aperture in the stomach, so that the gastric juice may be taken out when required. By this means invalids and others, troubled with dyspepsia, may be supplied with the means of digestion, either by taking the natural gastric juice in a liquid state or by having it dried and reduced to powder."

"M. Secchi, of Rome, has made a series of photometric experiments on the disk of the sun by means of a thermoelectric pile. He has found that the heat of the borders of the disk is nearly half that of the center, which confirms, as regards radiation of heat, what was already known for light and chemical action. M. Secchi's observations did not extend to the spots of the sun; yet in a few trials they were found to produce a sensible diminution of temperature."

"We all remember what a poor show the American division made at the start of the London World's Fair. The taunting remarks of the London *Times* almost gave us the blues. But the old proverb, 'A bad beginning has a good ending,' proved to be true as gospel in our case. First Hobbs began and knocked the whole science out of the famous English Bramah and Chubb locks, and carried off, with a lightsome snap of his fingers, the prize of $1,000 in gold; then came the triumph of McCormick's reaper, and, finally, the yacht *America* put on the capstone of triumph by beating the whole of the Royal Squadron. The London *Times*, which aforetime had been so bitter, ate up its previous language, and declared that in things useful and of practical utility, America fairly bore the bell at the Great Exhibition."

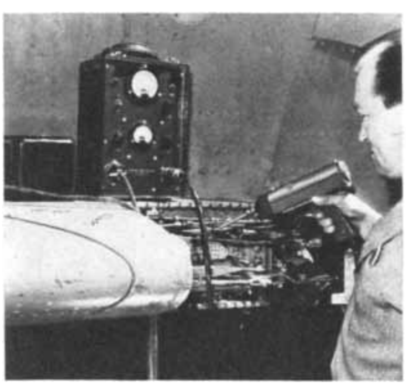
"Madame Poitevin, a French lady, recently descended from a balloon near London by a parachute. This was one of the most daring feats ever performed."

NEW MERCURY VAPOR DETECTORS

These new, completely redesigned detectors can determine harmful concentrations of vapor for laboratory or industrial users of mercury compounds. The new G-E Mercury Vapor Detectors are available in either electronic or chemical models. Photo above shows operator placing a selenium sulphide paper in the chemical detector at a silicon rubber plant. See Bulletin GEC-312.*

NEW ELECTROMAGNETIC PUMP

Designed to pump liquid metals and other low-resistance conducting fluids, the G-E Electromagnetic Pump can be used to move any conducting fluid that has a specific resistance equal to or less than type 347 stainless steel. Liquid metals such as sodium, sodium-potassium alloys, and lithium can be pumped successfully at temperatures as high as 1000 F. More information is given in Bulletin GEC-876.*



EASY LEAK DETECTION

Detection of leaks in closed systems is easy with the G-E Type H Leak Detector. This new tool for fast laboratory or production testing is so sensitive it finds leaks of one ounce per century in tanks, boilers, piping and other closed systems into which halogen compounds can be introduced as tracers. Photo above shows Leak Detector in use at an aircraft manufacturer's plant. For more information see Bulletin GEA-5610.*

*** To obtain these publications, contact your nearest G-E Apparatus Sales Office, or write to General Electric Co., Section 687-102, Schenectady 5, N. Y.**

COMPARATOR is demonstrated by Division Engineer Dr. G. W. Dunlap, of G. E.'s General Engineering Lab.

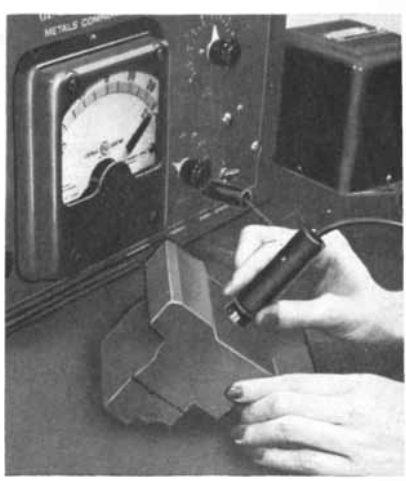
G-E Metals Comparator provides fast test of metal quality

The G-E Metals Comparator was developed to perform fast, nondestructive tests of the quality of ferrous and nonferrous metal parts.

By calibrating the comparator on a reference specimen, parts can be compared for such characteristics as composition, heat treatment, hardness or permeability. Testing to meet permeability standards of fabricated parts is a rapidly expanding application. Users find it tests equally well on raw or finished stock.

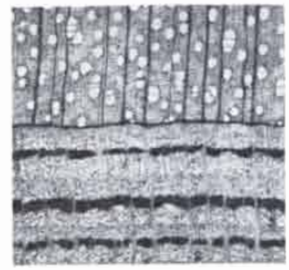
Used by manufacturers of aircraft, refrigerator and electrical parts for gradation of metals, it is also used by the tool and die, machine tool, and automotive industries for identification of correct heat treatment.

Here is an example of the type of developmental engineering . . . a specialty at General Electric . . . which provides more and better instruments and processes for modern industry.



COMPARATOR used with test head on large or hard-to-get-at surfaces.

GENERAL ELECTRIC



THE COVER

The photomicrograph on the cover shows a small section of a thin slice cut across the stem of a box elder. At the top of the section is the woody tissue of the stem; the holes in it are the vessels through which water is elevated to the top of the plant (*see page 78*). The bottom of the picture shows the inner bark. Between the wood and the bark is the cambium, a layer of growing tissue one cell thick. The slide from which the photomicrograph was made was prepared by T. H. MacDaniels, and was furnished by I. W. Bailey of Harvard University.

THE ILLUSTRATIONS

Cover photograph by Keturah Blakely

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How two inches of steel made a yardstick

HERE is one of the busiest machines in our research laboratories. It is a *constant-pressure* test lathe that quickly provides an indication of how fast a steel can be machined.

This unique testing device consists of a standard lathe fitted with special control equipment by which the horizontal pressure on the cutting tool is kept constant during the machining operation. By actually machining a test bar on this lathe and measuring the number of revolutions necessary to advance the cutting tool exactly two inches, we obtain—in a matter of minutes—a precise record of the steel's machinability.

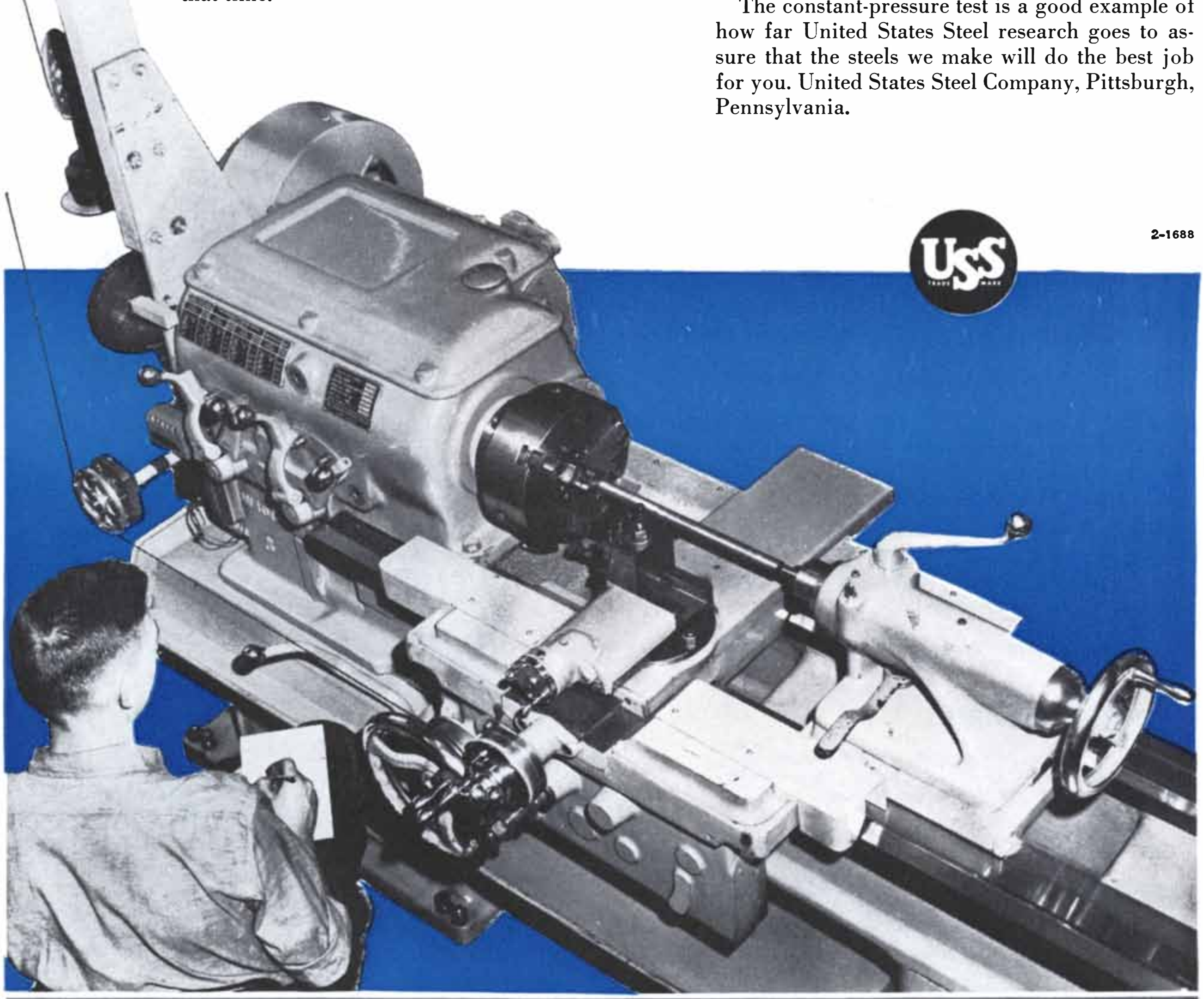
Before this development, the normal way to test machinability was to machine a sample of steel until the cutting tool failed. This sometimes took days and often required more steel than was available. Now, with the constant-pressure lathe, many steel compositions can be *accurately* checked in that time.

Typical of what this has meant to steel users is our development of MX Free-machining Bar Stock.

Bar stock is used in producing the millions of machine parts that are made on screw machines—those high-speed automatic machines that can simultaneously perform many operations such as drilling, forming, threading, chamfering and tapping at a rate of 1000 or more parts per hour. Here, machinability is of first importance, and often spells the difference between profit and loss.

So when we set out to give the screw machine industry steels that would have the utmost in machinability, we called on the constant-pressure test lathe to speed up this research. With its help, hundreds of compositions were quickly and accurately screened. The result was MX—the fastest-cutting Bessemer screw stock yet developed, one that has enabled many screw machine operators not only to increase production and reduce tool wear but to cut their costs as well.

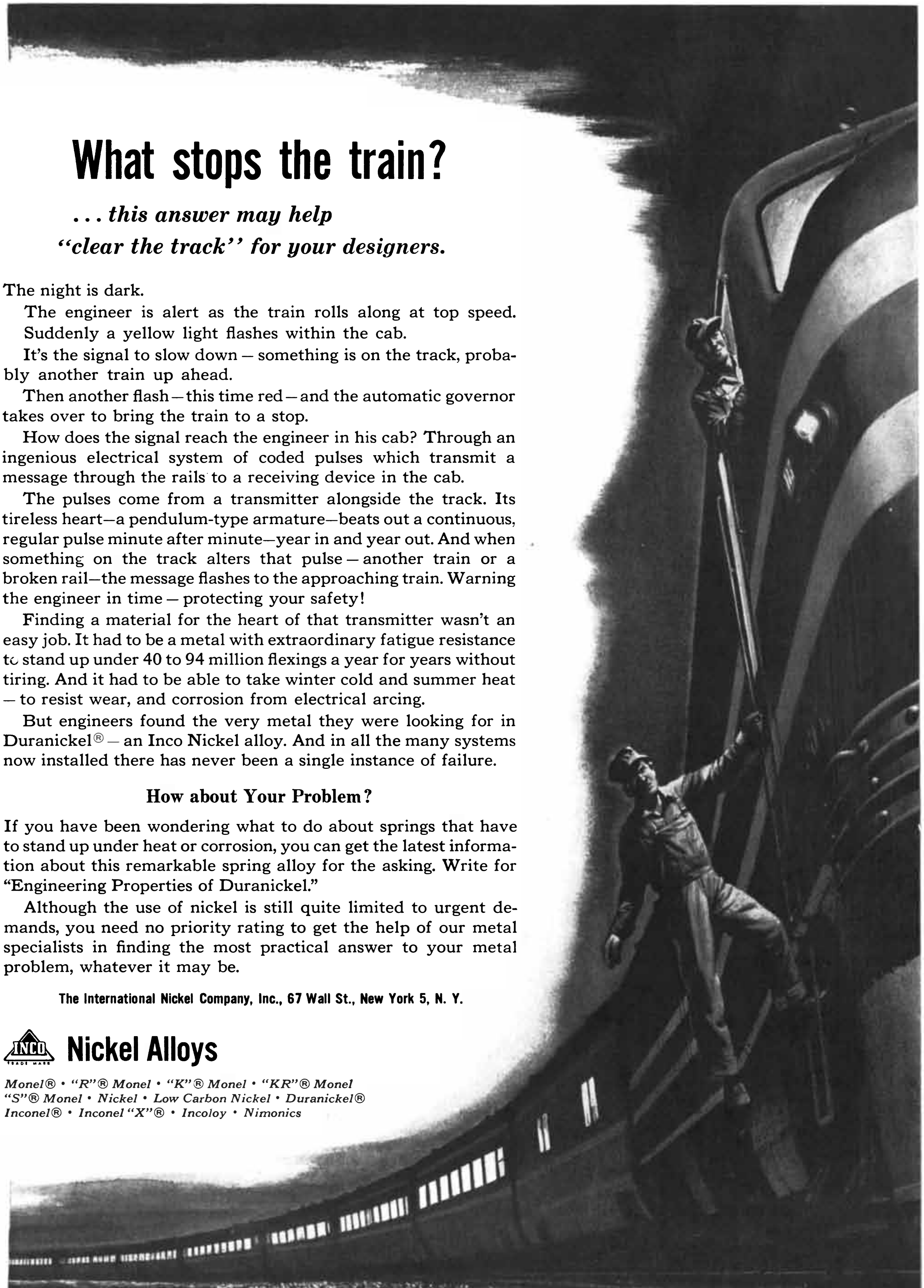
The constant-pressure test is a good example of how far United States Steel research goes to assure that the steels we make will do the best job for you. United States Steel Company, Pittsburgh, Pennsylvania.



USS

2-1688

UNITED STATES STEEL



What stops the train?

. . . this answer may help "clear the track" for your designers.

The night is dark.

The engineer is alert as the train rolls along at top speed. Suddenly a yellow light flashes within the cab.

It's the signal to slow down — something is on the track, probably another train up ahead.

Then another flash — this time red — and the automatic governor takes over to bring the train to a stop.

How does the signal reach the engineer in his cab? Through an ingenious electrical system of coded pulses which transmit a message through the rails to a receiving device in the cab.

The pulses come from a transmitter alongside the track. Its tireless heart—a pendulum-type armature—beats out a continuous, regular pulse minute after minute—year in and year out. And when something on the track alters that pulse — another train or a broken rail—the message flashes to the approaching train. Warning the engineer in time — protecting your safety!

Finding a material for the heart of that transmitter wasn't an easy job. It had to be a metal with extraordinary fatigue resistance to stand up under 40 to 94 million flexings a year for years without tiring. And it had to be able to take winter cold and summer heat — to resist wear, and corrosion from electrical arcing.

But engineers found the very metal they were looking for in Duranickel® — an Inco Nickel alloy. And in all the many systems now installed there has never been a single instance of failure.

How about Your Problem?

If you have been wondering what to do about springs that have to stand up under heat or corrosion, you can get the latest information about this remarkable spring alloy for the asking. Write for "Engineering Properties of Duranickel."

Although the use of nickel is still quite limited to urgent demands, you need no priority rating to get the help of our metal specialists in finding the most practical answer to your metal problem, whatever it may be.

The International Nickel Company, Inc., 67 Wall St., New York 5, N. Y.

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Established 1845

CONTENTS FOR OCTOBER, 1952 **VOL. 187, NO. 4**

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

OCTOBER, 1952 VOL. 187, NO. 4

Insects v. Insecticides

The increasing resistance of flies and mosquitoes to DDT is causing private and public concern. It is unlikely, however, that we will have to return to sticky paper and fly swatters

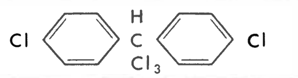
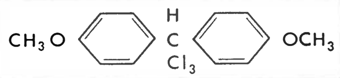
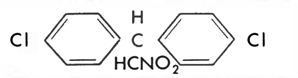
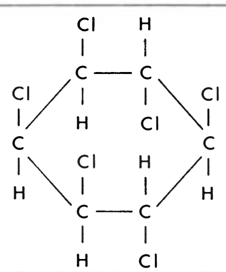
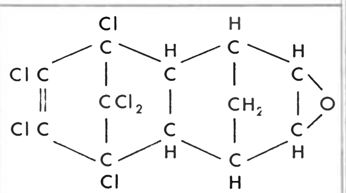
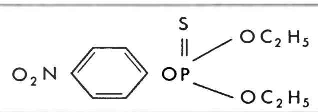
by Robert L. Metcalf

IT became a matter of common observation during the past summer that DDT no longer kills houseflies and mosquitoes with its original potency. There were complaints as long ago as 1948. Housewives, dairymen and hog farmers in many parts of the U. S. first blamed the pesticide manufacturers and pest-control contractors for skimping on their product or performance. Meanwhile, however, scientific investigation had shown that the explanation and cure of the situation must be sought in other quarters. By fundamental biochemical and genetic processes flies, mosquitoes and other pests have acquired a surprising immunity to DDT and many of the other synthetic organic pesticides that made their triumphant entry during World War II and its immediate aftermath. Today it is clear that these chemicals have won only a battle, not the war, against insects.

There was good reason at the time for believing that man at last had the weapons for ridding himself of hordes of insects and the plagues which they disseminate. DDT, lindane, toxaphene, chlordane and dieldrin had extraordinary effectiveness against a great variety of insects. They not only killed on fresh contact but provided long-lasting residual control when sprayed on the interiors of homes and buildings. Moreover, they could be produced cheaply and in unlimited quantities.

The first achievements which ushered in this new era of insect control seemed to be decisive. The mass application of DDT powder arrested an epidemic of louse-borne typhus in Naples in the initial period of Allied occupation in 1944. After the war the residual spraying of dwellings, barns and other shelters, and the larviciding of breeding places with DDT, virtually eliminated the anopheline mosquito vectors of malaria from Sardinia; on that island malaria is still a rarity. Conquest of this and other mosquito-transmitted diseases such as yellow fever, dengue, filariasis and encephalitis seemed certain. Wholesale spraying of towns and villages with DDT reduced the once ubiquitous housefly nearly to the vanishing point, and there was even talk of its extermination. In 1947 and 1948 we were hearing that "the flies in Iowa can now be counted on the fingers of one hand" or that "Idaho investigators were unable to find a single fly for their experiments." It was small wonder that scientists and laymen alike received with marked

TOXICITY of insecticides is tested at University of California by applying a microliter droplet containing a measured amount of poison to a housefly.

INSECTICIDE	MOLECULE	NON-RESISTANT	DDT-RESISTANT 1948	LINDANE-RESISTANT 1949
DDT		0.03	11	>100
METHOXYCHLOR		0.07	0.96	1.4
PROLAN		0.09	0.15	0.1
LINDANE		0.01	0.08	0.25
DIELDRIN		0.03	0.05	0.86
PARATHION		0.015	0.02	0.023
PYRETHRINS		1.0	0.94	1.6

RELATIVE TOXICITY of various insecticides to houseflies is compared in terms of micrograms of toxicant per gram of solution. Resistance to DDT and lindane gives flies no immunity to parathion and natural pyrethrins.

skepticism the first reports of the failure of DDT to kill flies.

IN 1947 R. Wiesmann of Switzerland reported that a strain of flies from Sweden, where poor control had been obtained with DDT the year before, was resistant to several hundred times the normal dosage of DDT. The same year the Italian entomologist G. Sacca described another strain of flies resistant to DDT. Such reports soon became common in the literature. Whereas from .03 to .1 micrograms of DDT was ordinarily lethal to the housefly, some of the resistant flies could survive the direct application of 100 micrograms. Such insects lived and reproduced normally in cages literally frosted with DDT.

Entomologists turned to other chemicals for fly control. At first lindane, chlordane and dieldrin all proved highly effective against these DDT-resistant flies, even when used in dosages of one-tenth to one-half of those originally required with DDT. Investigators were momentarily reassured. The flies might develop resistance to these newer chemicals after several years, but by then still newer insecticides would be available, or the flies would have lost their resistance to DDT. Then came discouragement. From southern California R. B. March and the author reported that lindane ceased to be effective after three monthly applications at a poultry ranch where there was a population of DDT-resistant flies. We found that this new strain of flies was also far more resistant to DDT than before and, furthermore, that the flies were resistant to dieldrin although they had never been exposed to this chemical. A similar experience was reported by H. F. Schoof and his co-workers of the U. S. Public Health Service. They had found dieldrin most promising for fly control in a city-wide campaign at Phoenix, Ariz. Residual applications in the fall of 1949 obtained effective fly control for 9 to 11 weeks. By the spring of 1950, however, the same applications showed only short-term results, and by midsummer dieldrin had no measurable effect on the fly population at all.

About this time it appeared that DDT-resistant races of mosquitoes were developing. This was first reported for the common house-mosquito in Italy by E. Mosna, who was able to continue satisfactory control by using chlordane and lindane. Florida salt-marsh mosquitoes and California pest mosquitoes also developed resistance, first to DDT and then to toxaphene and aldrin, which were subsequently used in control operations. At present larval mosquitoes from several areas of California show from 10 to 1,000 times their former resistance to these insecticides. As a result some mosquito-control agencies are now returning to the "old fashioned" oiling of the breeding waters.

From the Korean war area just recently has come word that a strain of human body-lice is showing resistance to DDT powder containing some 40 times the normally lethal concentration. Military sanitarians have been forced to employ pyrethrum and lindane powders for louse control.

The ability of important disease-carrying insects to develop immunity to toxicants that formerly threatened them with extinction is most disturbing to public health workers. Much of their thinking has been oriented around the successful use of insecticides. The same is true in the field of agriculture. The first results were so spectacular and apparently so decisive that it is clearly expedient to bend every effort to find out why the tables have been turned. Let us inquire closely then into what is known about insect resistance to insecticides and what can be done about it.

THAT insects may acquire resistance to insecticides is not a recent discovery. This was demonstrated early in this century by investigators who were coping with the several varieties of scale that bedevil fruit growers. In 1915 A. L. Melander of Washington State College showed that an acquired resistance accounted for the diminishing effectiveness of the lime-sulfur sprays that had been used for years to control San Jose scale on apples. A year later H. J. Quayle of the University of California at Riverside established the same explanation for the unsatisfactory results which were being obtained in limited areas with hydrogen-cyanide fumigation against California red scale infesting citrus. The use of the gas had been standard practice since 1886. Now such high concentrations of the poison are needed to secure a satisfactory kill, in some areas twice as much as before, that fumigation has been virtually abandoned because of the expense and to prevent damage to the trees.

More recently several other important cases of insect resistance have been brought to light. In the California citrus groves, again, thrips were effectively controlled for several years by a bait-spray of tartar emetic and sugar, developed in 1939. As early as 1941, however, the citrus thrips in a localized area were showing resistance; this resistance has now spread so widely that tartar emetic is of little use. DDT was widely employed in 1948, but by 1951 the thrips were giving signs of DDT-resistance. At present the most satisfactory thrip control is obtained with dieldrin. In South Africa the blue tick developed a marked resistance to sodium arsenite cattle-dips in 1938; arsenical solutions strong enough to injure the cattle did not give effective control. In 1946 lindane dips were found to be extraordinarily effective, a concentration of 50 parts per million being employed. Yet by 1948 1,000 parts per million would not give complete control of the tick.

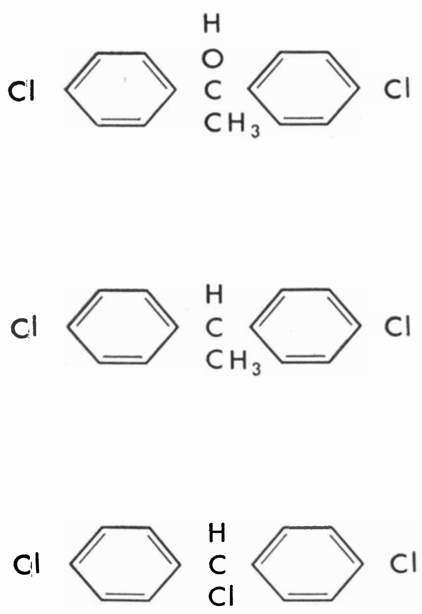
An important feature in recent observation and study is the side resistance to other toxicants that insects develop as they acquire resistance to the one to which they are exposed. The specificity of resistance has obvious importance in the planning of practical control measures; it is also an important clue to an understanding of the process of resistance. In our work at the University of California at Riverside March and I have concentrated on this aspect of the housefly's versatile resistance to the new insecticides. In this work we applied one-microliter droplets of acetone containing measured amounts of the toxicants directly to the bodies of anesthetized flies. When we compared the relative amounts of insecticides required to kill 50 per cent of the fly population, we found that the strain of flies highly resistant to DDT showed considerable resistance to a number of structural analogues of DDT, such as methoxychlor and others shown in the molecular diagrams on the opposite page. In general, the closer the structural resemblance to DDT, the higher the relative resistance. Among the members of this DDT group, methoxychlor departs furthest in structure. It proved, accordingly, to be the most effective against the DDT-resistant fly, and is still being used, though with diminishing returns, as a residual spray. We found that lindane, chlordane, heptachlor, aldrin and dieldrin, which belong to a somewhat different group of chlorinated hydrocarbon insecticides, were only slightly less effective against the original DDT-resistant strain and also gave satisfactory control of the same strain in the field. However, a high degree of resistance to these materials was quickly superimposed upon the DDT-resistance. It also appears that the members of this second group of chlorinated hydrocarbons have a common mode of action, since flies that develop resistance to one also become resistant to the others.

An interesting exception that helps to prove the rule is prolan. This toxicant may be considered an analogue of DDT in which the trichloromethyl group ($-CCl_3$) has been replaced by a nitroethyl group ($-C(NO_2)CH_3$). Initially we found it to be as effective against DDT-resistant strains as it was against non-resistant strains. The variation in the molecules suggests that this difference in action may be connected to the presence of the nitro group in place of the chloromethyl group which the other DDT analogues have in common. There is additional evidence, however, that the modes of action of these compounds are still in some way related. We found that after eight generations flies which are resistant to the DDT and lindane groups begin rapidly to show immunity to prolan; by the 12th generation immunity is practically complete. In contrast we find that neither of the strains of resistant flies is appreciably resistant to parathion, an entirely unrelated organic phosphorus toxicant, or to the natural pyrethrins, which come from chrysanthemum flowers.

A similar but less clear-cut picture has been developed with regard to the specificity of resistance in mosquitoes. None of the strains resistant to the various chlorinated hydrocarbons shows resistance to the organic phosphorus insecticides. The specificity of hydrogen-cyanide resistance of the California red scale has been studied by D. L. Lindgren of the University of California at Riverside, who has found that the resistant strain is also more resistant to ethylene oxide and methyl bromide. However, Lindgren could show no difference in susceptibility to oil or parathion sprays.

THUS FAR nothing in the study of insect resistance to chemicals suggests that it differs in any fundamental way from the same process in bacteria and protozoa, about which we know a great deal more. We can therefore expect to find that such resistance results either from the selection of the most resistant individuals present in a normal population, or from a continuous increase in resistance reflecting a specific interaction between the chemical and the chemistry of the organism. In many cases both processes may be involved. One way to measure the rate at which the resistance of an insect population increases is to expose each generation to a dosage of insecticide which permits the survival of only a few of the most resistant individuals to propagate the succeeding generation. Such experiments yield a characteristic curve, shown on the next page, which indicates that resistance develops in two steps. The first is a long drawn-out period of gradually increasing resistance which may extend over 20 to 30 generations and result in a 5- to 10-fold increase in resistance. In the second a very rapid increase within several generations results in virtual immunity to the toxicant. W. N. Bruce of the University of Illinois has made the interesting discovery that, by treating both larvae and adult flies and selecting the survivors for breeding, the development of resistance may be considerably accelerated. With this technique he has been able to develop a high degree of resistance to all of the chlorinated hydrocarbon insecticides. Against other toxicants such as the pyrethrins and the organic phosphorus compounds, he has found only a slight increase of resistance after exposing many generations. Thus in our laboratories the continuous selection with parathion of some 60 generations of adult flies yielded a mere 5-fold increase of resistance, and the exposure of both adults and larvae showed no greater increase. In contrast, the selection with lindane of 41 generations of flies resulted in a 10,000-fold increase above the initial resistance. We know that parathion is toxic to insects because it inactivates an essential nerve enzyme, cholinesterase. Perhaps it is not too much to hope that certain poisons may attack biochemical processes of such fundamental importance that the organism cannot develop true immunity.

FROM experience in the field and the laboratory we know that resistant insects are able to pass along this characteristic to their offspring. As yet the genetic picture of this accomplishment



SYNERGISTS which activate DDT against resistant flies are similar in structure, harmless when used alone.

is far from clear, and it is confused by conflicting results secured by various investigators. The study is complicated because we have no practical way to measure the resistance of individual insects, and must work with populations rather than with individuals. The genetic factors are further obscured because much of the work has been carried out using field-collected strains. These are far from uniform in their characteristics, and various investigators have secured divergent results working with strains collected from different sources. It is apparent that, in selection for insecticide resistance, other characteristics have simultaneously been selected. Thus it has been reported that resistant houseflies may differ from susceptible strains in degree of pigmentation, in length of larval life cycle, in egg-laying ability, in resistance to heat and cold, in behavior, and even in the appearance of altered wing venation. Such variations often reflect differences in metabolism. It is not surprising that strains of normal and DDT-resistant flies should show differences in rate and volume of respiration and in the activity of their enzymes, such as cytochrome oxidase and cholinesterase. The significance of these variations in insecticide resistance is not yet understood; many of them may be entirely fortuitous.

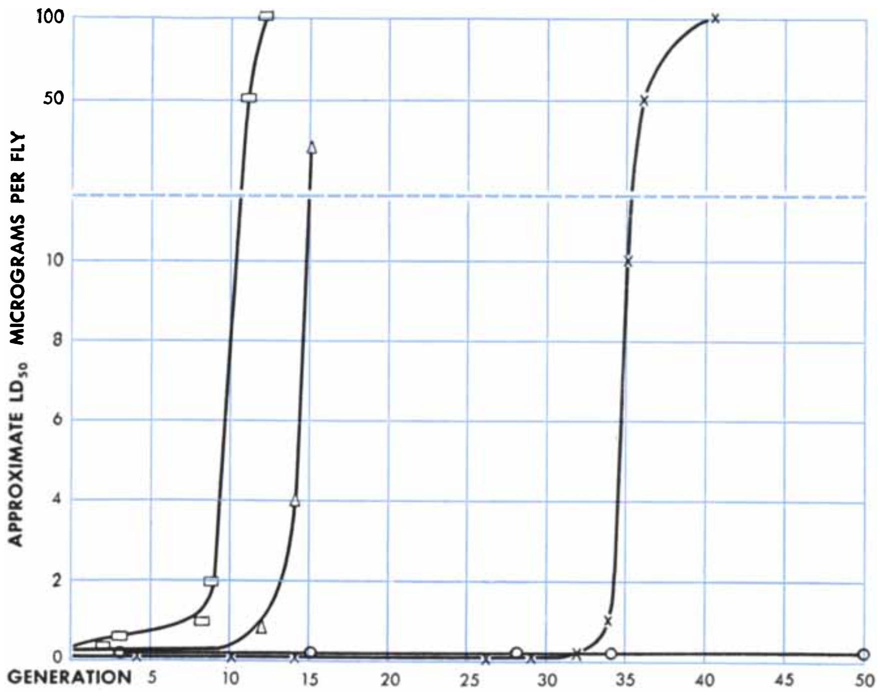
R. C. Dickson of the University of California at Riverside has found that hydrogen-cyanide resistance in the red scale is inherited through a sex-linkage and depends on a single gene or a group of closely related genes. Matings of resistant and non-resistant scales produced female offspring of intermediate resistance and male offspring having their mothers' resistance. Working with a strain of DDT-resistant houseflies, C. Mary Harrison of the London School of Hygiene and Tropical Medicine has found that the resistance to knockdown by DDT was inherited in a simple Mendelian pattern. Non-resistance was dominant and the resistance appeared to be controlled by a single pair of genes. However, where mortality rather than knockdown was used as the criterion, most investigators have found that crosses of resistant and non-resistant flies have resulted in offspring of intermediate resistance and with a wide degree of heterogeneity. Resistance of this type is apparently governed by several pairs of genes.

For practical purposes it might be hoped that resistance to a given insecticide would decline after exposure to it ceases. Treatment with the chemical might then be resumed at suitable intervals. Investigation of this possibility, however, has not been encouraging. Laboratory studies with DDT-resistant houseflies have shown variable results but indicate that in some strains the resistance may persist unchanged for 30 or more generations. Even after that period, although the average resistance of the population may decline, a number of individuals will be produced whose resistance is at the highest level. Similar results have been obtained with the laboratory-reared red scale, whose hydrogen-cyanide resistance has been maintained unchanged for 150 generations.

Results in the field have been no more encouraging. March and L. L. Lewallen have collected flies for several years from the same farms and dairies in southern California and found a progressive increase in resistance to DDT and lindane. Since almost no DDT has been used for fly control in this area for the past several years, it must be concluded that the build-up of resistance has resulted from the selection pressure of other insecticides. Similarly the hydrogen-cyanide resistance of the red scale has been maintained unchanged, and the resistant strain continues to increase in abundance although there has been little fumigation in the resistant areas for many years. The tartar emetic resistant citrus thrip has also persisted and spread despite the abandonment of this chemical in resistant areas.

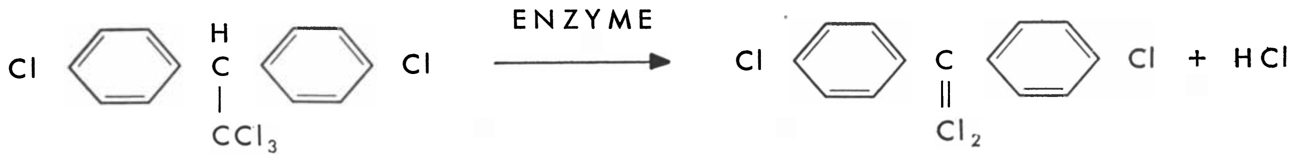
Since the natural course of events does not improve the situation in our favor, we must inquire more thoroughly into the nature of resistance in the individual insect organism. Early efforts looked for simple physiological explanations. Thus it was suggested that resistant red scales were able to protect themselves against hydrogen cyanide by closing the spiracles, or breathing pores, for extended periods following exposure to low dosages of gas. However, it was subsequently found that the differential in resistance between the two strains of scale could be detected in short initial exposures before the closure of spiracles was observed. In the case of the DDT-resistant housefly it was first suggested that these flies had developed a thicker, more impervious cuticle which prevented the absorption of the chemical. However, direct injection of DDT into the body cavity of the fly shows no change in relative resistance, and several investigators have found that resistant flies absorb DDT through the cuticle just as rapidly as non-resistant flies.

It was early apparent to investigators that we must attack the physiology of resistance in terms of its biochemistry and not merely its mechanics. One interesting lead came from the fact that DDT-resistant flies are often fairly susceptible to knockdown by the insecticide. The discovery of flies struggling



□ PROLAN FROM DDT-LINDANE RESISTANT LARVAE AND ADULTS TREATED
Δ DDT FROM NON-RESISTANT LARVAE AND ADULTS TREATED
x LINDANE FROM NON-RESISTANT ADULTS TREATED
o PARATHION FROM NON-RESISTANT ADULTS TREATED

INCREASING RESISTANCE in successive generations of flies exposed to various insecticides is plotted in terms of micrograms required per fly to kill half of the flies exposed (LD_{50} means lethal dose to 50 per cent of the flies).



DETOXIFICATION OF DDT by enzyme reaction in resistant flies converts DDT molecule (*left*) to harmless DDE molecule. The reaction removes a hydrogen and a chlorine atom from the central group and yields hydrochloric acid (HCl) as a by-product. Toxicants less susceptible to reaction kill DDT-resistant flies.

on the floor of a residually treated barn would lead to the cursory opinion that they were non-resistant. When these flies were collected and caged for several hours, however, as many as 80 per cent would completely recover. This suggested the possibility that resistant flies were able to detoxify DDT into a non-lethal metabolite, a possibility which was confirmed by J. Sternberg and C. W. Kearns of the University of Illinois and by A. S. Perry and W. M. Hoskins of the University of California at Berkeley. These investigators applied measured amounts of DDT to both resistant and non-resistant flies and then, after macerating and extracting the body contents, determined the breakdown products of DDT by means of a spectrophotometer. They found that the resistant flies were able to detoxify the DDT at a high rate. This is accomplished by enzyme action which removes a single chlorine atom from the trichloromethyl group of the DDT molecule, converting it into the non-toxic ethylene derivative known as DDE, shown in the diagram above. The enzymes in resistant strains of flies carry through this dehydrochlorination process much more rapidly than those in non-resistant strains. Flies surviving the treatment had metabolized greater amounts of DDT than flies which had been killed. An interesting point which these workers demonstrated was that the survivors also still retained enough unaltered DDT in their bodies to kill non-resistant flies. There is no clear-cut explanation for this tolerance on the part of the flies. It may be that only a fraction of the total dosage of DDT is available at any time to the site where it is supposed to take effect, and that it is detoxified as fast as it arrives. Alternatively, the resistant flies may store the DDT in regions of the body where it can exert no harmful effects.

It was a logical step from the discovery that flies detoxify DDT by dehydrochlorination to the hope that the analogues of DDT which are most difficult to dehydrochlorinate would prove relatively more toxic to the resistant flies. This turns out to be the case. Methoxychlor, which is decomposed in alkali solutions only about 1/200 as fast as DDT, has a relative toxicity to the resistant flies of about 20 times that of DDT. In contrast, dibromo-DT, which is decomposed about 1.5 times as fast as DDT, has a relative toxicity slightly less than DDT. Other toxic analogues of DDT behave in similar fashion. Prolan, the nitroanalogue which by definition is not subject to dehydrochlorination, fits perfectly into this scheme. It is almost equally toxic to DDT-resistant and to non-resistant flies. For some other reason, however, even prolan loses its potency after a few generations.

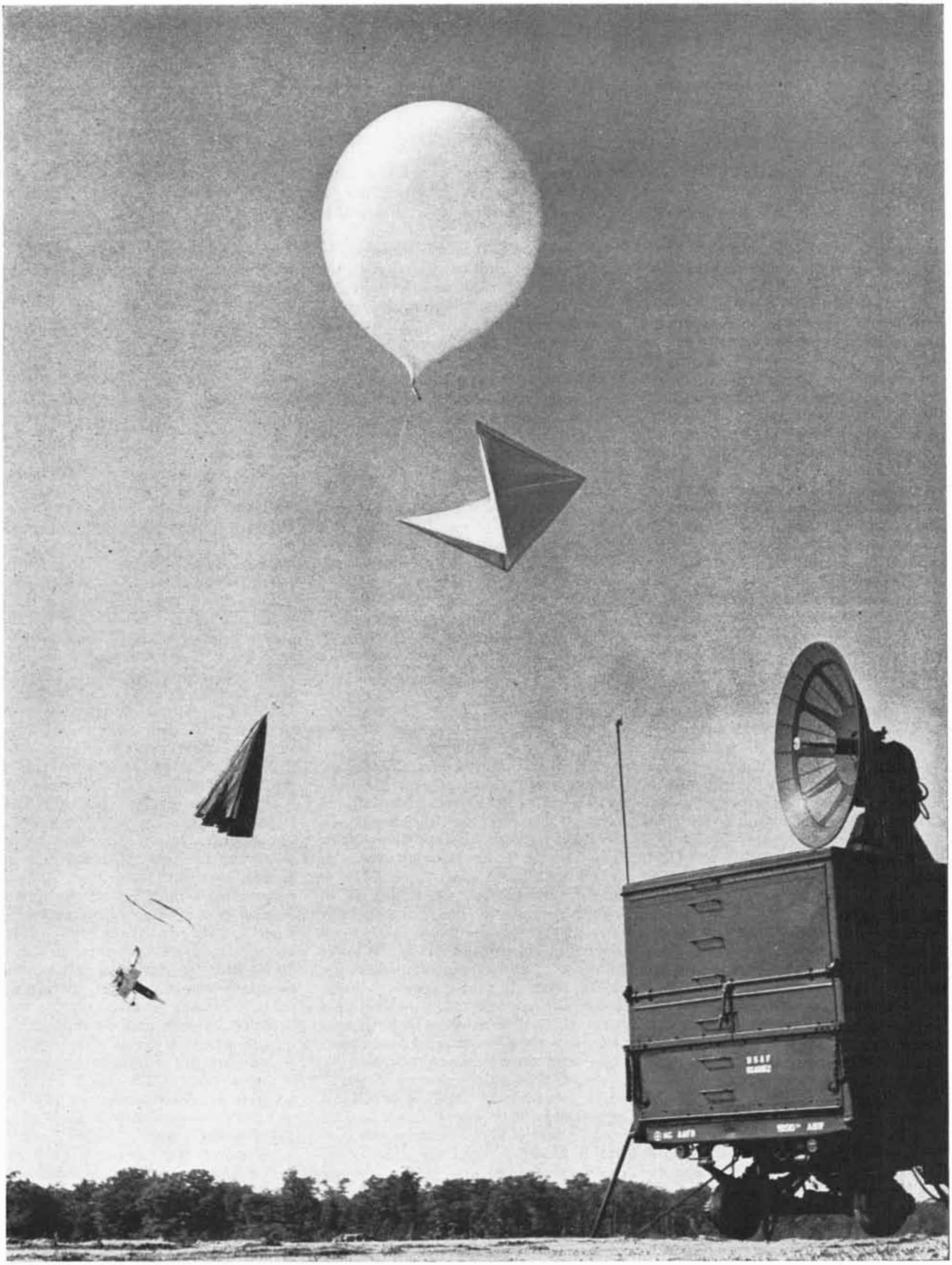
Another logical approach is to look for chemicals which will inhibit the process of detoxification. One such chemical is piperonyl cyclonene, commonly used as a synergist to amplify the toxicity of the natural pyrethrin insecticides. Hoskins and Perry found that it will also increase the toxicity of DDT to resistant flies, and were able to demonstrate that this chemical works by inhibiting the detoxification process. W. T. Summerford and his co-workers of the U. S. Public Health Service then made the equally interesting observation that DMC, a DDT analogue useful against mites, was even more effective than piperonyl cyclonene as a DDT synergist for resistant flies. March and his co-workers have tested hundreds of other DDT analogues and have found several that increase the effectiveness of DDT against resistant flies 100 or more times. These materials, three of which are shown on page 23, do not completely restore the potency of DDT against resistant flies. Interestingly enough the combination of DDT and a synergist has proved to be no more effective against non-resistant flies than DDT alone. A similar search is being made for synergists for lindane, and some progress is being made. Field tests have already demonstrated that synergists hold more than academic interest. Combinations of one part of synergist with five parts of DDT as a residual application have given from four to eight weeks of very satisfactory fly control in localities where very high DDT-resistance existed.

ADMITTEDLY fundamental investigation into the biochemistry and genetics of insect resistance to insecticides has not yet shown us much in the way of practical results. Such work is not calculated to yield immediate solutions. In the long run, however, it is certain that without increase in our knowledge of these fundamental processes we would be merely fumbling in the dark.

Meanwhile we can expect to see high returns from purely empirical efforts along a number of lines. One largely neglected possibility is the use of two or more insecticides having entirely different modes of action, applied either in combination or in alternate treatments. Such applications are entirely feasible, and it seems logical that they would retard the development of resistance. Then there is evidence that insects are not able to develop resistance against certain insecticides. For example, oil sprays have been used for 30 years or more for the control of San Jose and California red scale without any indication of tolerance. As mentioned earlier in this article, laboratory studies have indicated that the housefly does not readily develop resistance to parathion. This material and related organic phosphorus insecticides are already showing much promise in the field control of resistant flies and mosquitoes. Other insecticides against which resistance is difficult to develop will doubtless be discovered.

Finally, it ought to be observed, time is on our side. The large majority of our important agricultural insect pests breed one to three generations a year. Since it apparently takes from 20 to 40 generations of intensive selection by an insecticide to develop a high level of resistance, such pests as the codling moth and the corn borer may require from 10 to 20 years to make our present chemicals obsolete. Thus, though the more universal nuisance of the fast-breeding housefly and mosquito might suggest otherwise, the synthetic organic insecticides still constitute a net gain in insect control. The normal rate of progress in development of new insecticides should continue to keep us ahead of the insects' amazing capacity to circumvent them. It can be predicted with confidence that we shall not have to resign ourselves again to sticky paper and fly swatters.

Robert L. Metcalf is an entomologist in the University of California at Riverside, Calif.



SOUNDING BALLOON is used to probe the upper atmosphere. Radar (*lower right*) follows course of balloon (*top*) by echo returned from the reflector hanging below it. This gives altitude and wind-velocity information. Radiosonde on parachute (*left*) sends temperature, pressure and humidity data throughout flight.

THE JET STREAM

Meteorologists have recently discovered that from 10,000 to 40,000 feet above the surface of the earth there are strange rivers of air that can travel as fast as 300 miles per hour

by Jerome Namias

When B-29s first began to raid Japan during World War II, the crews of the bombers came back with a story that meteorologists found hard to believe. The pilots reported that in some bombing runs at 20,000 to 30,000 feet their ground speed was almost zero—the planes were virtually standing still. And when they turned down-wind after their bombs were away, their ground speed was about twice the air speed indicated by their instruments. These reports were subsequently confirmed, and when high-altitude weather studies in other parts of the world disclosed winds of 200 to 300 miles per hour at around 30,000 feet, it became clear that the bombers had encountered a previously unsuspected and spectacular meteorological phenomenon—the jet stream.

We now know that between 10,000 and 40,000 feet above the surface of the earth there are narrow filaments of air moving at high speed for thousands of miles. These strange winds attain their highest velocities between 30,000 and 40,000 feet, and they move in a general westerly direction. Often the individual jet streams connect with each other to form a great river of rushing air which girdles the hemisphere in a meandering course between the Arctic Circle and the Tropic of Cancer.

The tremendous extent of the jet streams meant that we could not learn of their existence until high-altitude wind measurements were made, not only regularly, but also over the entire Northern Hemisphere. In the early 1940s the U. S. Weather Bureau's Extended Forecast Section made a start toward hemispheric weather charts for the upper air. It was the wartime military need for weather information, however, that finally brought into being a network of hemisphere-wide probing stations complete enough to give a fairly accurate picture of the circulation aloft. This picture soon revealed the narrow, high-speed jets. The discovery fascinated meteorologists, and the jet stream became the object of intensive research. A group at the University of Chicago, under the distinguished Swedish-American meteorologist C. G. Rossby, took up the first full-scale attack on the problem in 1946. Since then many others have studied it; we now have a reasonably complete description of the phenomenon, although its origin is still obscure.

The jet stream, it must be understood, is not an occasional atmospheric freak but an ever-present, though varying, component of the general circulation of the atmosphere. Let us briefly consider this circulation. The great wind systems are caused by the fact that the earth receives more heat in equatorial regions than at the poles. Winds are nature's attempt to distribute the heat more uniformly and thus prevent impossible accumulations or deficits. Because the sun's elevation changes during the year, the character of the atmospheric circulation also changes seasonally; and because of the uneven distribution of land and water over the globe, the wind systems vary regionally in a longitudinal as well as latitudinal sense.

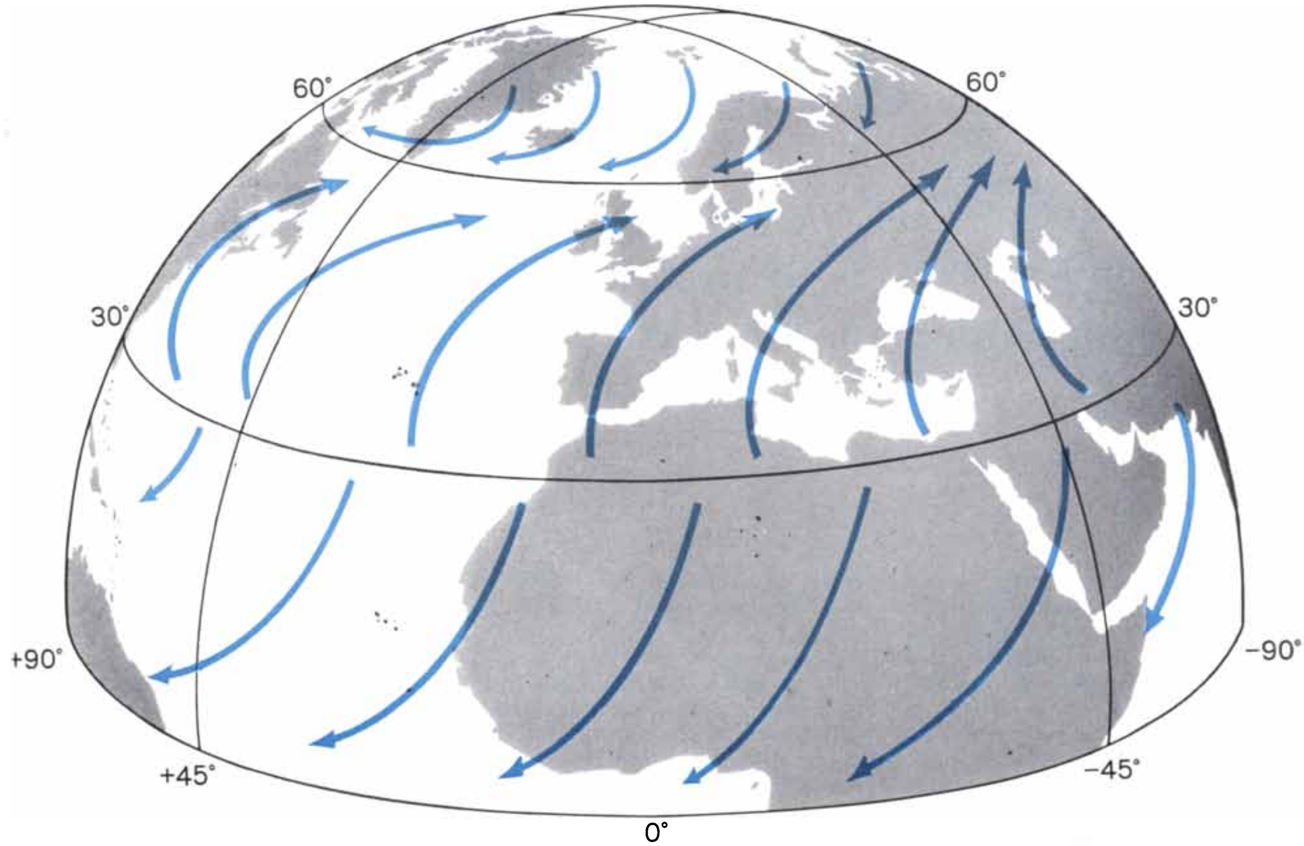
On the average, however, the winds fall into quite regular patterns. Those at the surface of the earth are shown in the diagram at the top of the next page. Here we find the three great average wind systems: the northeast trades blowing from the subtropics toward the Equator, the prevailing westerlies of middle latitudes, and the polar easterlies. Between the westerlies and the trades are the horse latitudes, which received their name from the fact that old-time sailing ships, becalmed for days in these waters, often had to throw horses overboard to reduce ballast.

As we move upward from the surface of the earth the picture changes radically. In the diagram at the top of page 29 is a schematic portrayal of the typical winds of the Northern Hemisphere at a level of about 40,000 feet. Here we find that most of the air-flow is from a westerly direction with speeds increasing from the pole southward until they reach a maximum at around 30 degrees North, and then declining rapidly to a region where weak easterly winds may be encountered. It is the zone of strongest winds which is the jet stream. This stream is thus a vital part of the circumpolar vortex—the great whirl of west winds around the pole. It is interesting to note that the belt of strongest winds at these high levels lies directly over the calmest belt at the surfaces, the horse latitudes.

Averages of wind-flow for different elevations and different seasons show that in general the peak strength of the westerlies, the jet stream, is usually reached at about 40,000 feet. It is found just below the base of the stratosphere both in winter and summer, and hence varies somewhat in height. The jet moves with the seasons, however. It shifts from about 25 degrees North latitude in winter to about 45 degrees North in summer, and in so doing falls off to less than half its wintertime speed.

Corresponding data for the Southern Hemisphere are not yet available in such completeness. F. Loewe and U. Radok of Australia and V. W. Hutchings of New Zealand, however, have found that a quite similar wind pattern prevails in their sector of the hemisphere. The similarity includes a poleward migration and weakening of the jet stream in summer.

The jet stream does not move at the same speed over all its length. For example, its chart for January on page 31 shows that during the winter the highest speeds are generally found off the Asiatic coast, not far from the area where the B-29 bombing crews encountered their extreme winds. Another strong wintertime jet is frequently found over southeastern U. S., and still another



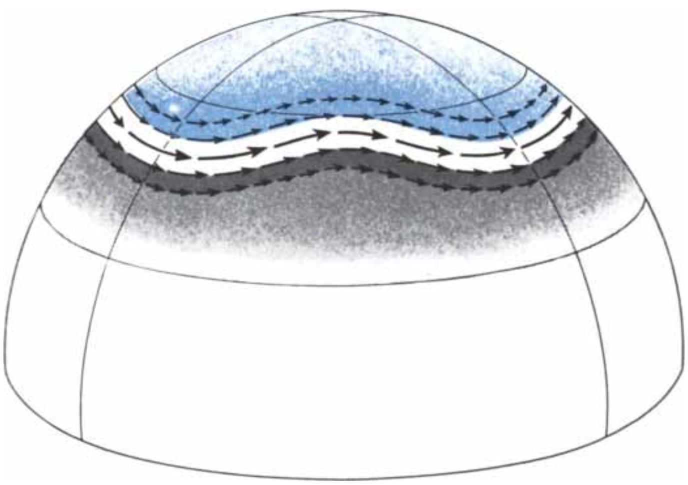
SURFACE WINDS of the Northern Hemisphere usually follow the pattern diagrammed above. North of the equator are the trade winds, then the mid-latitude prevailing westerlies and finally the polar east winds.

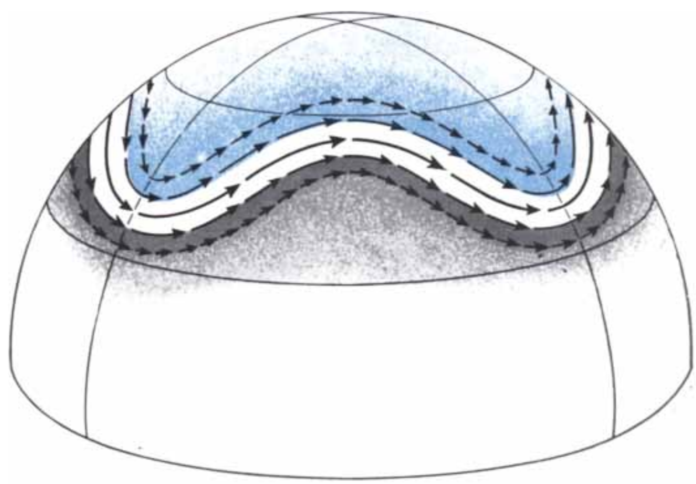
appears to run from North Africa to the Indian Ocean. In the summertime corresponding charts show a northward migration and weakening of the jet axes, and the regional differences are less marked than in winter.

THE conditions we have described at 40,000 feet hold, in general, down to about 10,000 feet. The average wind-flow is fairly constant in direction, but slows up with decreasing altitude. At 10,000 feet the winds move only a third or a fourth as fast as they do at 40,000 feet.

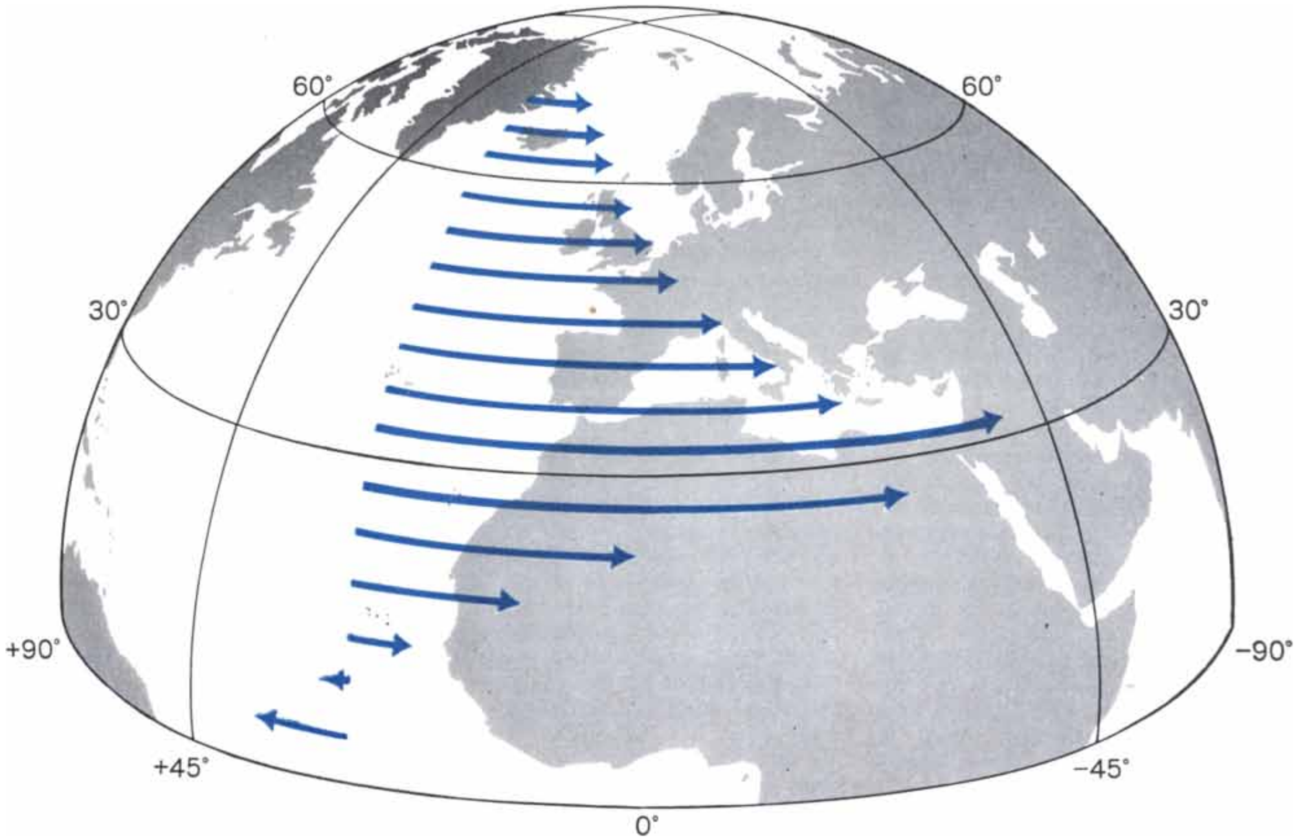
Aside from seasonal variations in the circulation of the upper air, there are large irregular variations, so that the conditions prevailing for a day, a week or even a month can be quite out of the ordinary. It is these irregular variations that cause anomalous periods in the weather. In broad outline the major non-seasonal changes take the form of great expansions and contractions of the circumpolar vortex, during which the jet radically changes form and position. The periods when this happens, called index cycles, often last from four to six weeks. A typical cycle is shown in the diagrams that run across the bottom of these two pages.

In the first stage the jet stream lies well to the north of its normal position and has undulations of fairly small amplitude; the strong west winds imprison the cold polar air masses to the north, and the temperate latitudes are bathed in relatively mild air from the oceans.





DISTURBANCE in the behavior of the jet stream brings periods of unusual weather. The typical sequence of change, called an index cycle, is shown in the series of diagrams above. The undulating river of air goes into

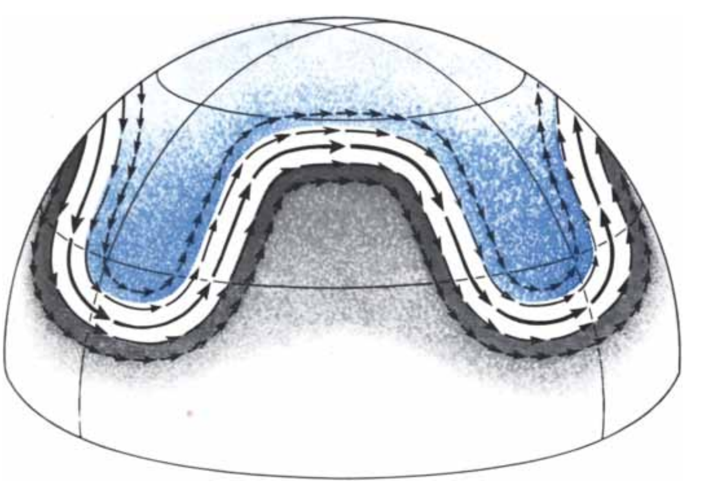


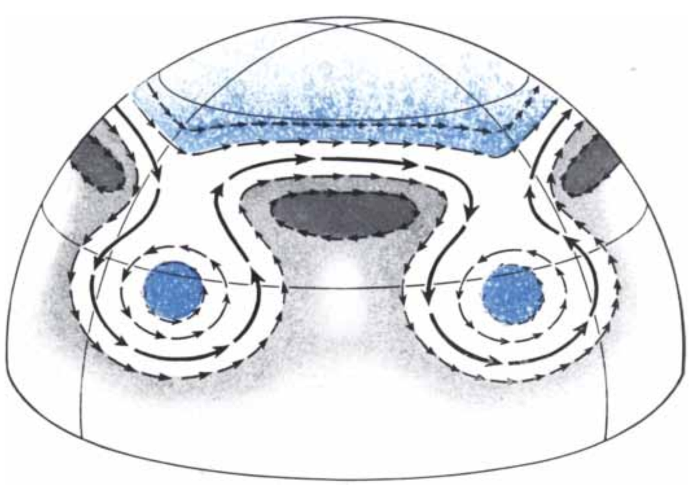
HIGH-ALTITUDE WINDS move in a different pattern. At 40,000 feet westerlies cover most of hemisphere, their speeds increasing from the pole southward until they reach a maximum at about 30 degrees North latitude.

Then, in the second stage, the amplitude of the waves increases and the mean latitude of the jet stream moves south. There are corresponding intrusions of polar air southward and tropical air northward. Next there is a further increase in amplitude of the jet, accompanied by strong north-south movements of polar and tropical air masses, causing great longitudinal temperature contrasts. The mean position of the jet has moved further toward the Equator. Finally, in the fourth stage of the cycle, the waves in the jet have increased their amplitude so much that pools of polar and tropical air are cut off. Now come the periods of "topsy-turvy weather" when Alaska may be warmer than Florida. In this final stage an initially wave-like pattern of westerlies has been transformed into a cellular pattern. Each of the stages may last about a week, with smaller superimposed daily fluctuations. The last stage often persists longer.

The great convolutions of the jet stream represent nature's principal method of exchanging air between polar and tropical latitudes. Were it not for this exchange the equatorial regions would become increasingly and impossibly hot.

Turning from the broad behavior of the jet stream to its detailed structure, we find that it is far from homogeneous. Eric Palmèn, a Finnish meteorologist who has made the most complete analyses, has shown that horizontally across the jet and vertically through it are large and abrupt vari-





increasingly large oscillations. North of this stream lies the cold mass of polar air (*blue*), which the oscillations gradually carry into latitudes farther south. Finally the waves break loose leaving cells of cold air in the south.

ations in wind speed. For example, a change of 100 m.p.h. across a distance of 150 miles is not uncommon, nor is a 100-m.p.h. increase from 20,000 to 30,000 feet. Studying summertime jets over North America, Rossby has found them to consist of "elongated, slowly progressive and nearly parallel streaks of high wind separated from each other by belts of much weaker air motion." As more detailed studies are made with the help of finer-grained networks of observations the picture may prove even more complex. Indeed, some meteorologists feel that present equipment is too coarse to probe the very refined structure of the jet.

Meteorological elements other than wind speed are also spectacularly distributed in the jet stream. Horizontally across it at levels from 10,000 to 40,000 feet the temperature changes very rapidly from unseasonably warm to abnormally cold. The boundary between the lower atmosphere and the stratosphere, called the tropopause, which normally slopes from about 60,000 feet over the Equator to 30,000 feet over the pole, may, in the neighborhood of a strong jet stream, abruptly change its elevation by this much within a distance of a few hundred miles. In these cases the tropopause is said to be fractured or discontinuous.

SUCH are the facts. When we turn to ask for an explanation of them, we find that meteorology cannot yet tell us much. Two theories have been proposed, one by Rossby and the other by two U. S. Weather Bureau meteorologists, P. F. Clapp and myself. Rossby's theory is the more elegant in that it is built on a more rigid mathematical and physical framework. It explains the jet stream as the result of large-scale horizontal mixing processes brought about by the cyclones and anticyclones of the middle latitudes. Since mixing occurs only in temperate latitudes, where cyclones and anticyclones are active, and not in tropical and subtropical latitudes, a boundary to the mixing zone is established. Rossby shows mathematically that at this boundary the speed of the west wind must reach a maximum and then fall off abruptly. Some observations of the way in which winds vary with latitude are in good agreement with Rossby's calculations.

Our theory is mainly descriptive and qualitative, but to many practicing forecasters it seems more useful. It contends that the jet stream is due to the confluence of vast streams of equatorial and polar air to great heights. These streams are brought together by different patterns of flow in high and low latitudes, the patterns being determined in part by mountains, land and water boundaries and so on. When these warm and cold air masses are brought side by side, the resulting pressure differences set up a strong circulation of air which may develop into the strength of a jet. Thus the jet is looked upon as a zone in which the prevailing westerlies aloft are brought to peak strength by a localization of temperature contrast through a deep layer. The location of the principal average jets of winter along and off the coastlines of Asia and North America, where cold continental air often flows next to warm oceanic air, would seem to lend support to this theory.

Neither theory, however, accounts for all the facts; neither is complete enough for detailed weather prediction. This is unfortunate because a thorough understanding of the jet stream would have great utility, particularly in aviation and in long-range weather forecasting. With aircraft flying ever faster and higher it becomes increasingly important to know accurately the conditions of the atmosphere up to about 50,000 feet. Tail or head winds, for example, may be critical factors in jet-plane flight because of the limited fuel supply of these craft. If a flier could ride a jet stream going his way he would extend his cruising range enormously. But with present facilities we cannot even find the jet stream in many parts of the world. It is so narrow that only a dense network of upper air soundings can be depended upon to spot it. Naturally it is impossible to forecast where a jet stream is going to be if the forecaster is not aware of its existence. Fortunately over many important areas, for example North America and Europe, observations are sufficiently dense to detect the jets. When we do find them we can usually forecast their behavior in a general way for periods about a day in advance. The North Atlantic is now covered by a sufficient number of weather ships to allow reasonably good estimates, but many large areas of the Pacific are still meteorological no-man's lands.

ALSO limiting the usefulness of jet streams in aviation is the unpredictable presence of isolated areas of severe turbulence. Pilots of the British European Airways who have flown in these currents report that with no warning their planes are suddenly subjected to a series of short, sharp, hammering blows. The turbulent regions usually are between 50 to 100 miles wide and about 3,000 feet thick. To escape such a buffeting the pilot must climb or descend, or travel cross-wind, but in doing so he naturally loses much of the power of the jet stream.

It is not only aviators who are affected by the violent and unpredictable behavior of the jet stream. All of us on the surface of the earth feel its influence, albeit less directly. The great Polar Front, which separates the tropical from the polar air masses in the lower layers of the atmosphere, generally intersects the earth's surface a few hundred miles south of the upper jet. Since the Polar Front is intimately associated with the weather, particularly storms and rainfall, the jet stream is an important element in these phenomena.

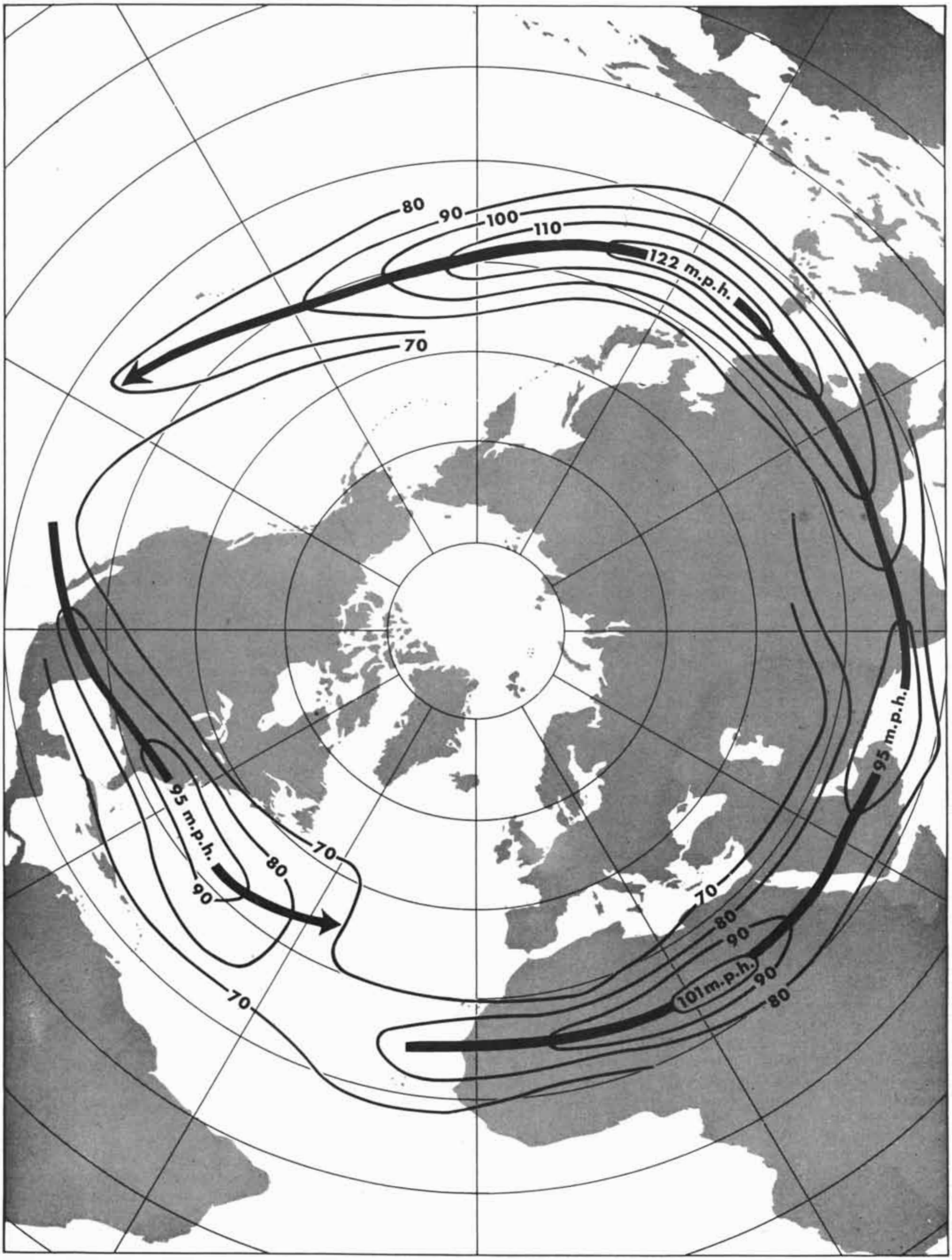
Just what part it plays is difficult to say, since the Polar Front, jet stream and storms are so intertwined that the question of cause and effect is highly controversial. Cyclones frequently intensify after running along below a jet stream, and rainfall is likely to be concentrated below the jet. But whether the rainfall can be attributed to the action of the jet independent of the Polar Front and of the movement of the cyclone below is doubtful. The jet stream is frequently associated with the birth and later intensification of cyclones. Weather forecasters are on the watch for this, but they also know that a strengthening cyclone may modify the location and structure of the jet stream appreciably. We have here one of the "feedback" mechanisms which are so useful in technology but are often disconcerting in meteorology. In a general way, however, the jet streams may be considered to steer cyclones (storms) and anticyclones (fair weather areas) across the weather map.

The jets also put in motion those vast air masses whose transit across the continent brings sustained warm or cold spells. A particular pattern of the jet stream may sometimes persist, with brief interruptions, for weeks on end. When this happens we get long spells of abnormal weather such as may bring on droughts or floods.

What makes jet streams repeat their performance during a particular month and what causes their often striking differences in behavior from one month to the corresponding month of the following year are questions that remain unanswered. Some meteorologists think the solution is in variations of solar radiation, possibly associated with sunspots. Others believe that variable ocean temperatures, particularly in the Gulf Stream and the Japan Current, are responsible. Still others say simply that an "anomalous" atmosphere always contains the seeds of new and eternally different states.

Fortunately there is usually some regularity in the evolving jet-stream complex, especially when its behavior is averaged over a week or more. Thus the long-range forecaster can utilize jet streams even though he is ignorant of their basic causes. Obviously, however, his predictions must be far from perfect until he knows what these causes are.

Jerome Namias is Chief of the Extended Forecast Section of the U. S. Weather Bureau.



JET-STREAM CHART for the month of January shows average wind positions and speeds between 35,000 and 45,000 feet during the month. Two main jets are to be seen, one starting off the west coast of North Africa and extending two-thirds of the way around the Northern Hemisphere to a point in the Pacific below Alaska, the other running from Lower California across Mexico and the southern U. S. and ending in mid-Atlantic Ocean.

The Diphtheria Toxin

The substance secreted by the diphtheria bacillus is one of the most potent poisons known: one milligram of it is enough to kill 1,000 tons of guinea pig. How does it work?

by A. M. Pappenheimer, Jr.

ALTHOUGH we take it for granted, it is strange that organisms so small that they are invisible to the naked eye can cause fatal disease in an animal as large as man. Indeed, this is one of the reasons why more than two centuries elapsed between the time when Anton van Leeuwenhoek described the "little animalcules" that he had seen through his microscope, and the independent and simultaneous demonstrations by Louis Pasteur and Robert Koch that anthrax in man and animals was caused by rod-shaped microscopic bacteria. That discovery was made in 1877; before another decade had passed the causative bacteria for most of the common infectious diseases had been found.

Then how is it that these microscopic forms of life are capable of causing disease? To the present day this question remains unanswered in the case of anthrax and many other bacterial infections; but in 1888 Emile Roux, Pasteur's former assistant, showed that bacteria-free filtrates from cultures of the diphtheria bacillus contained a poisonous substance which he called the diphtheria toxin. The injection of this toxin into laboratory animals caused delayed death with exactly the same symptoms as those caused by infection with living diphtheria bacilli. Soon other bacterial toxins were discovered. Lockjaw, or tetanus, is caused by a toxin released from tetanus bacilli growing in deep wounds. Botulism, a rare but fatal form of food poisoning, is caused by the ingestion of botulinus toxin, a product of the soil bacillus *Clostridium botulinum*.

Within recent years these three bacterial toxins have been isolated as highly purified proteins. In fact, both tetanus and botulinus toxins have been reduced to handsome crystals. They are the most potent poisons known. A single milligram of crystalline tetanus or botulinus toxin is enough to kill over 1,000 tons of guinea pig; it may be also calculated that only 20 million molecules of botulinus toxin suffice to kill a 20-gram mouse.

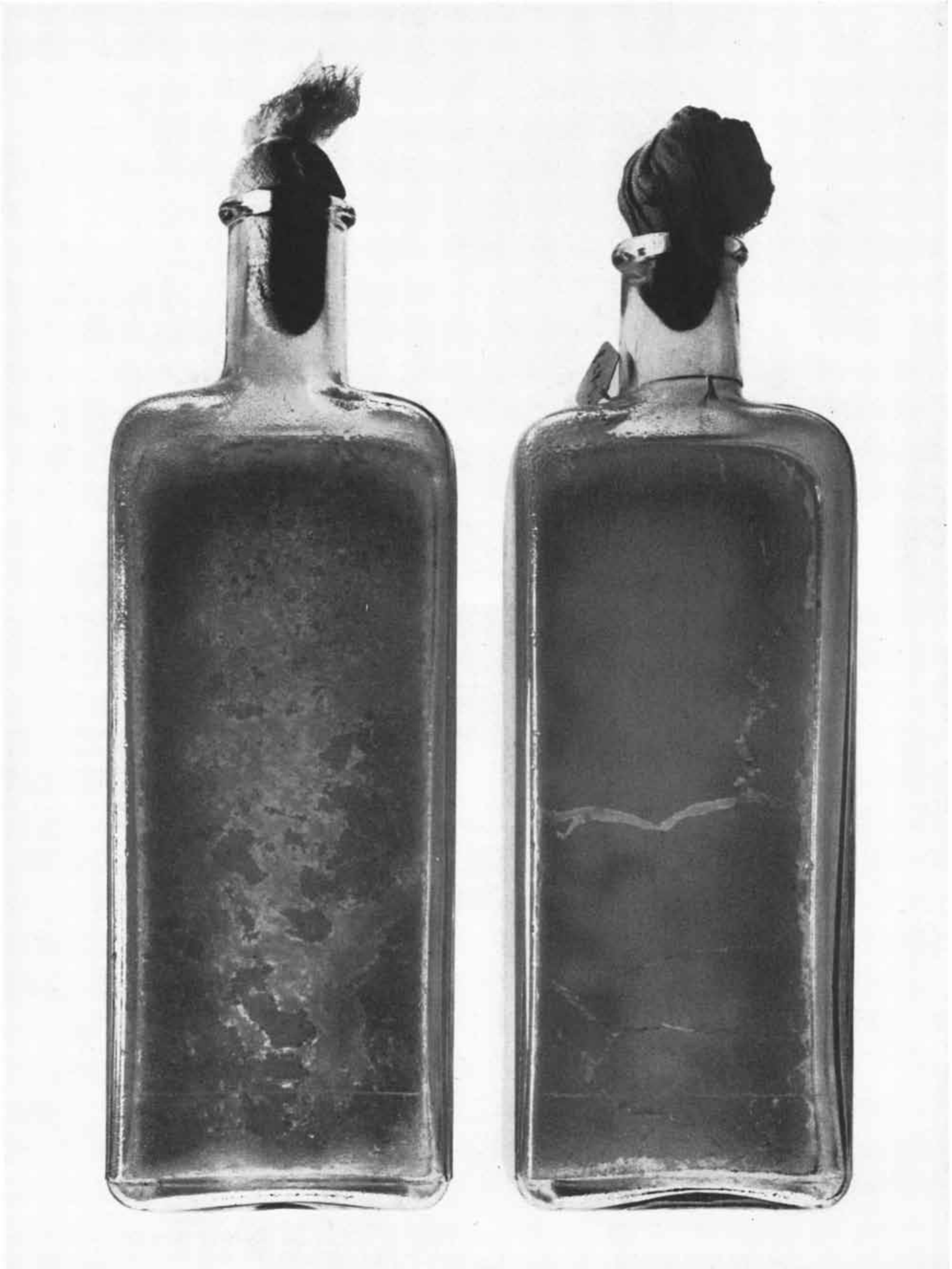
IT IS CLEAR that diphtheria, tetanus and botulinus bacilli cause disease because they produce such powerful toxins. But how do these toxins injure the tissues of higher animals? Chemical analysis has failed to answer the question. All three toxins are unstable proteins composed of the same amino acids found in the normal tissue proteins of the host itself. In the case of the Type A botulinus toxin, a complete amino-acid analysis has revealed no unusual chemical groupings that might provide a clue as to why it is toxic. Perhaps the toxins inhibit essential enzymes, those remarkable catalysts which speed the chemical reactions of life. This seems unlikely; enormous doses of diphtheria, tetanus and botulinus toxin can be added to sliced or homogenized tissues from a susceptible animal without any discernible effect upon their metabolism, at least within any reasonable period of time. Perhaps the toxins are themselves enzymes which destroy some substance essential to metabolism, or which catalyze the formation of poisons.

It is unlikely that any single explanation holds for all the toxins; the mode of action of each will probably have to be worked out separately. As an example *Clostridium welchii*, an organism that can cause a fatal wound infection, secretes a toxic enzyme which destroys cells by breaking down lecithin, an essential constituent of the cell surface. On the other hand, diphtheria, tetanus and botulinus toxins show no enzymatic action when tested, and would appear to act in some other way.

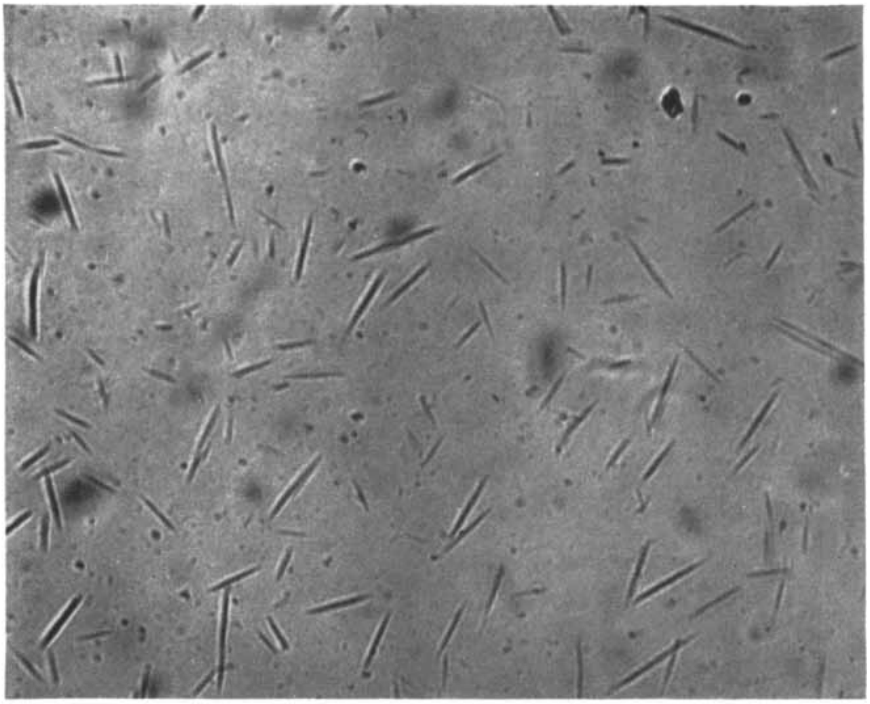
The diphtheria toxin is a colorless protein that decomposes when a solution of it is heated. The molecular weight of the protein is 70,000, *i.e.*, each of its molecules weighs as much as 70,000 hydrogen atoms. If .0000001 gram of this potent substance is injected beneath the skin of a guinea pig, the animal dies in four to five days. The tetanus and botulinus toxins injure only nerve tissue; the diphtheria toxin, at least in the case of birds and mammals, attacks almost any kind of cell. Thus only about .00000000005 gram injected into the skin of a guinea pig, a rabbit or a susceptible human being is enough to kill a visible area of cells. It may be calculated that only a few molecules per cell, perhaps only one or two, are required to kill skin tissue.

A few minutes after it is injected the diphtheria toxin enters into an irreversible combination with the cells. Animals may be protected from the toxin by the previous administration of small amounts of specific antitoxic serum, but within a few minutes after the toxin has been injected, no amount of antitoxin will reverse its action. In spite of their relatively large size, the toxin molecules can apparently penetrate the cell wall; the antitoxin molecules cannot. Although the toxin seems to combine with the cells immediately, many hours pass before any symptoms appear. The problem that particularly concerns us is to find out what happens during the interval between the fixation of toxin by the cells and the appearance of symptoms 18 to 20 hours later. A clue has been found in certain facts relating to the production of the toxin by the diphtheria bacillus, and to its role in the metabolism of that organism.

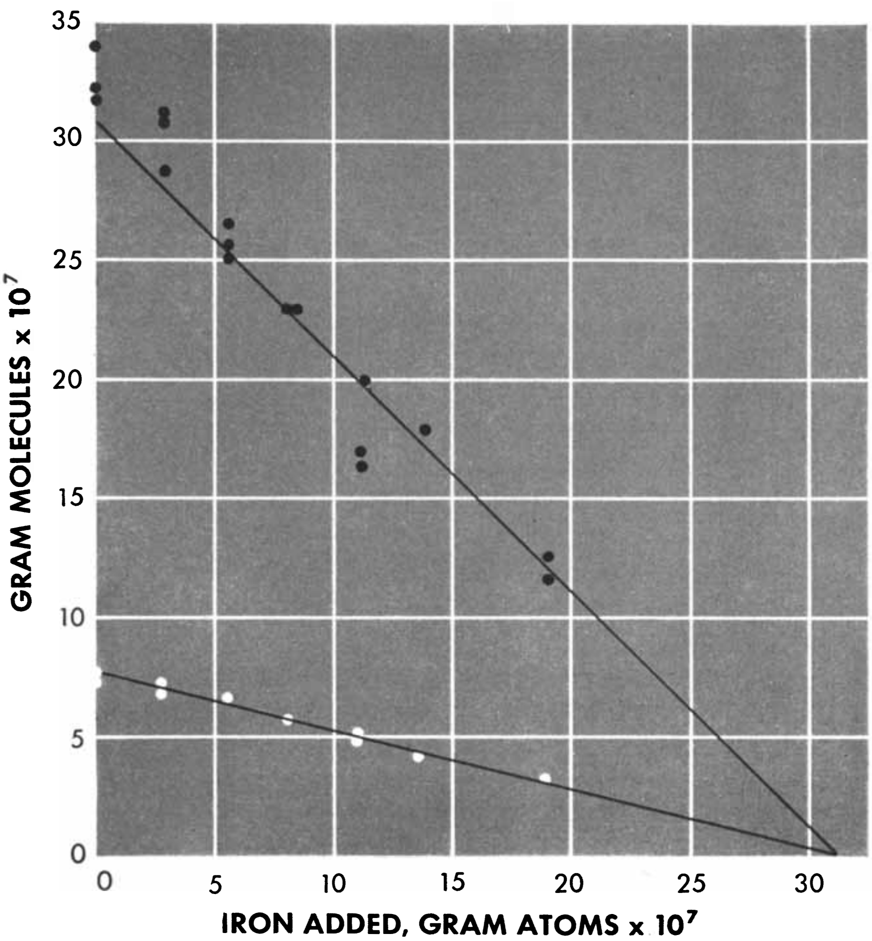
WHEN the diphtheria toxin is treated with dilute formalin in a slightly alkaline solution, it is no longer toxic. The harmless product, diphtheria toxoid, is an excellent immunizing agent, and its injection into man or animals results in the production of a circulating antitoxin that specifically neutralizes the toxin and prevents the disease. Now that the immunization of children during the first year of life has become almost universal practice in this country and Europe, large amounts of toxin are produced commercially, and methods for its production have been intensively



DIPHTHERIA BACILLI are grown in bottles. Because they require large quantities of oxygen, they grow in a thin layer, or pellicle, on the surface of a nutrient medium. This photograph is a top view of two culture bottles lying on their sides. In the bottle at right the pellicle is intact; in the bottle at left some of it has fallen.



BOTULINUS TOXIN was crystallized by Adolph Abrams, Gerson Kegeles and George A. Hottle. The crystals are enlarged 500 diameters in this photograph, which was first published in *The Journal of Biological Chemistry.*



EFFECT OF IRON on the diphtheria bacillus is shown by these two curves. The top curve represents the production of coproporphyrin; the bottom curve, the production of toxin. Both decrease with the addition of iron.

studied. Until recently, however, the efficient production of the toxin was more a mysterious art than a rational technique. To be sure, many of the factors were understood. It was recognized early that some strains of the diphtheria bacillus were better toxin producers than others; today almost every laboratory in the world uses a high toxin-producing strain called P.W. 8, isolated by William Park more than 50 years ago. It was also known that the toxin is produced only in the presence of abundant oxygen; the organisms were therefore grown as a pellicle, or veil, on the surface of a shallow culture medium. But there was no agreement as to what constituted a suitable medium until the effect of iron in toxin production was comprehended.

Some years ago the Connaught Laboratories in Toronto described a medium composed of pig stomachs digested by their own enzymes; it gave these laboratories the highest yields of toxin ever reported up to that time. When other laboratories tried to repeat the Toronto procedure, they obtained a luxuriant growth of bacteria but almost no toxin. Eventually an explanation was found. The Toronto medium was made up with tap water, and Toronto tap water is exceptionally hard because of its high calcium content. The calcium in the water and the phosphate in the pig stomach-digest formed a precipitate which bore away most of the iron in the water. Thus it was learned that minute traces of iron will inhibit the production of diphtheria toxin. Indeed, the production of toxin is so sensitive to iron that traces of the element in the chemicals used to prepare the culture medium, in filter paper and even in the glass culture vessels may markedly affect the yield.

NOW it happens that the toxin is not the only substance whose production by the diphtheria bacillus is determined by the iron content of the culture medium. If a culture of bacilli is filtered, the filtrate contains not only toxin but also a pink pigment called coproporphyrin, the production of which is similarly inhibited by iron. It was the relationship between iron, coproporphyrin and toxin which furnished an insight into the nature of diphtheria toxin and its probable mode of action. Organisms that require oxygen to live burn sugar and other carbohydrates by transferring their hydrogen to oxygen and forming water. In most of these organisms the oxygen is transferred by a chain of iron-containing enzymes known as cytochromes. When light is passed through a solution of these enzymes in the spectroscope, each member of the chain differs from the preceding one in the position of its characteristic two-banded spectrum. The cytochromes are protein pigments which, like their close relative hemoglobin, owe their intense red color and their catalytic properties to the presence of heme, a complex salt of iron. A precursor to the formation of heme is coproporphyrin, the pigment found in cultures of the diphtheria bacillus.

Traces of iron are required for the growth of all living cells. When iron is gradually added to a culture of P.W. 8 diphtheria bacilli, their number, their toxin and their coproporphyrin production increase in strict proportion to one another until a point is reached where the culture medium contains .1 part of iron per million of water. If iron is added beyond that point, the number of bacteria continues to increase, though at a diminished rate, but the yield of toxin and coproporphyrin falls. Finally, when the iron content of the medium reaches .6 parts per million, only negligible amounts of these substances appear in the filtrate.

Once the point of maximum toxin production has been reached, every additional four atoms of iron prevents four molecules of coproporphyrin and one of toxin from appearing in the culture. This ratio of iron to pigment to protein corresponds almost exactly to their proportion in hemoglobin, cytochrome *c* and many other heme-containing proteins; it suggests that the toxin is in some way related to an enzyme that takes part in the oxidation of carbohydrates by the bacteria.

We also know that *all* of the iron added to the medium is taken up by the bacterial cells and is distributed among the various iron-containing enzymes. By far the greatest part of the iron, however, is found in cytochrome *b*. Indeed, diphtheria bacilli grown in the presence of excess iron are the richest known source of this particular enzyme. From the intensity of its characteristic spectrum it may be estimated that the amount of cytochrome *b* which appears inside the bacterial cells after the addition of iron to the medium corresponds closely to the amounts of toxin and coproporphyrin which *fail* to appear in the culture filtrate. This fact suggests that, just as coproporphyrin is probably the precursor of the heme portion of diphtherial cytochrome *b*, so the toxin may be the precursor of the protein portion of this same enzyme.

IF diphtheria toxin is related to the protein portion of diphtherial cytochrome *b*, it seems logical to go one step further and consider the possibility that the toxin may interfere in some way with the normal functioning of the cytochrome system in the tissues of susceptible animals. We know from experiment that even large amounts of toxin added to homogenized tissues have no direct effect on their cytochrome activity. Moreover, diphtherial cytochrome *b* is not identical with that of higher animals: its bands are shifted slightly toward the blue region of the spectrum, and it is more readily oxidized by atmospheric oxygen than is the corresponding cytochrome of animals.

But perhaps the toxin is taken up at the site of cytochrome formation in the host because of its similarity to the protein of the mammalian enzyme. Because its configuration is not identical, the molecules of the toxin cannot replace those of the host protein entirely; therefore it is possible that they act by irreversibly blocking the formation of cytochromes in the tissues of the host. Such a mechanism would not only account for the incredibly high toxicity of only a few molecules per cell; it might also explain the prolonged delay before the symptoms of disease appear. For if the toxin prevents the formation of a cytochrome component, then its effect on the cells of the host would not become apparent immediately. Sooner or later, however, the cytochrome content would fall below a critical level because the toxin had interfered with its manufacture. The theory has an additional virtue: it can be put to experimental test.

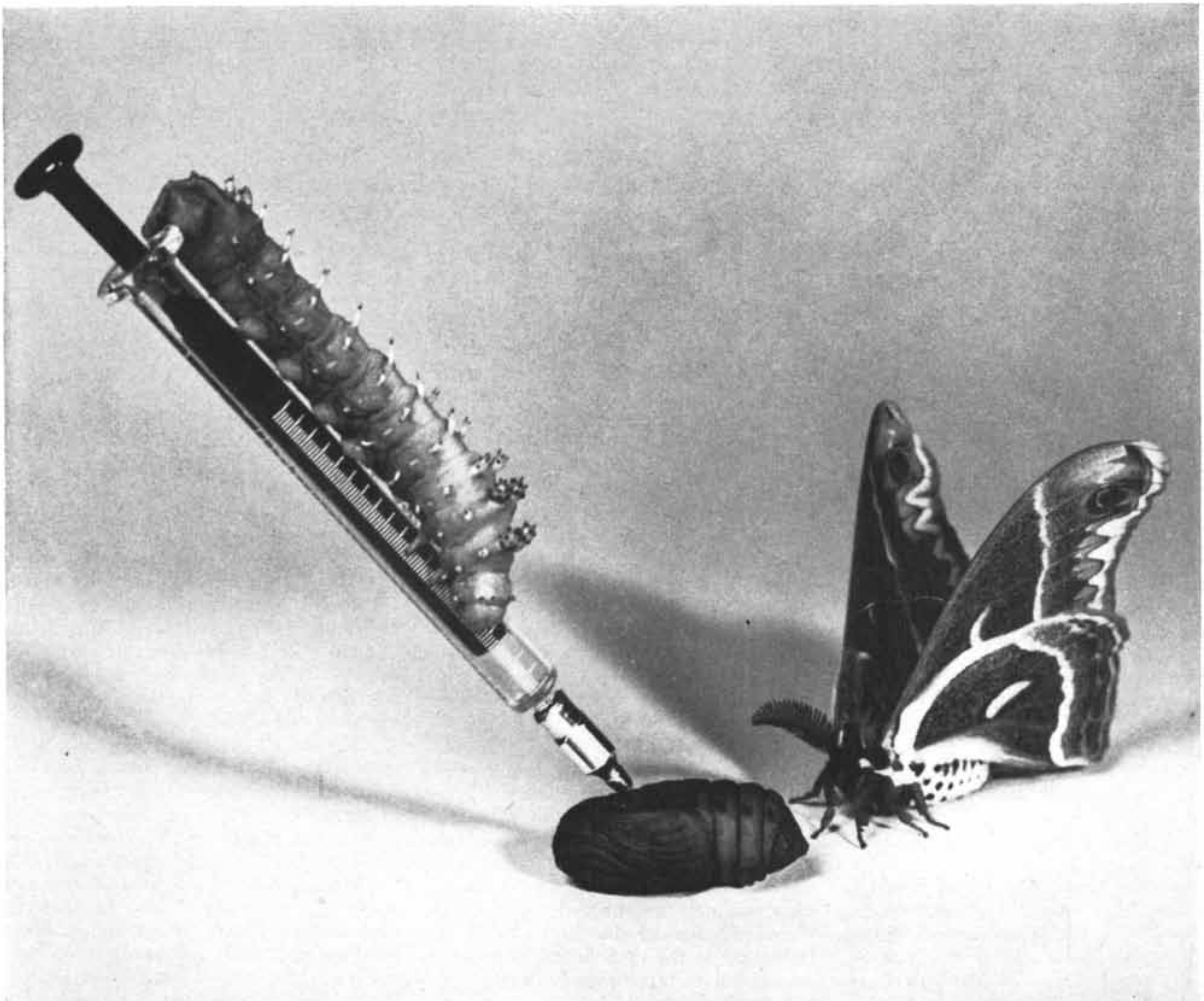
GUINEA PIGS and rabbits are the laboratory animals generally used to study the effects of diphtheria intoxication. Pigeons are also highly sensitive, and, because the breast muscle of pigeons is rich in cytochromes, these birds might seem to merit attention. None of these animals has proved suitable for the verification of the theory. A slight reduction in the cytochrome *b* activity in relation to other cytochromes of intoxicated pigeon and guinea pig muscle has consistently been observed, but the changes have been too small to be convincing. One great difficulty with experiments of this kind is that we do not really know what proportion of the cells is affected by the toxin. Thus it is probable that the total destruction of 20 to 30 per cent of its cells will damage a given tissue such as muscle beyond repair. Yet if the toxin fails to gain access to the remaining cells, the metabolic activity per unit weight of tissue may deviate only slightly from the normal.

Therefore an experimental animal was sought in which the blocking of the cytochrome synthesis might produce effects which were more sharply defined. Fortunately an animal was found that satisfied these requirements. Surprisingly it was an insect: the Cecropia silkworm. As this insect goes through its life history from caterpillar to pupa to magnificent moth, there are large and predictable variations in its cytochrome content. If the diphtheria toxin does indeed act by preventing the formation of cytochrome, we might expect the action of the toxin on Cecropia to differ during the several chapters of its life history.

In April, 1950, SCIENTIFIC AMERICAN published an article in which the Harvard University biologist Carroll M. Williams described some of his experiments on Cecropia. At that time Williams had demonstrated how hormones controlled the metamorphosis of the insect. More recently he and his students have shown that this metamorphosis is associated with remarkable variations in metabolism. Thus the abundant musculature of the caterpillar, rich in cytochrome, largely disappears at the time of pupation. During the dormant state that follows, the small amount of cytochrome which remains is mostly concentrated in a group of muscles which control the movements of the pupal abdomen. Then, with the onset of adult development, a renewed and vigorous formation of all the cytochromes occurs and continues until the adult moth emerges.

THE diphtheria experiments with Cecropia consist essentially in measuring the relative resistance of the insect to toxin at the various steps in its metamorphosis. The results have been striking. The dormant pupa, which contains but little cytochrome, will survive the injection of 70 micrograms of toxin for more than four weeks. This is 100 to 1,000 times the dose of toxin necessary to cause the death in one to two weeks of the caterpillar or the developing adult, both of which depend upon a high cytochrome activity for their survival. The correlation may be carried even further. About a week after a few micrograms of toxin are administered to the pupa, the animal loses its capacity for abdominal movement. This paralysis can be equated with the fact that the abdominal muscles are almost the only tissue in the dormant insect which still retains high cytochrome activity. Pupae that are no longer capable of movement due to the action of the toxin showed almost complete dissolution of their abdominal muscles. The pupal heart often continued its rhythmic beat for several weeks thereafter, a resistance of the heart muscle readily explained by the finding that spectral bands corresponding to cytochromes *a*, *b* and *c* are completely absent in this tissue. Still more dramatic is the effect of toxin on the developing Cecropia adult. Although death may not come for days, the development of the insect is brought to a stop within a matter of hours.

All of these facts seem most readily interpreted if we assume that diphtheria toxin acts, not by inhibiting any particular cytochrome component already formed, but by preventing the synthesis of new cytochrome. In the case of the maturing adult, where further development depends upon the continued formation of cytochrome, the effect of the toxin is immediate. On the other hand, several days must pass before its effect



CECROPIA SILKWORM was used to study the effect of the diphtheria toxin on animals. This group picture shows Cecropia at three stages of its life history. At left is the caterpillar; in center, the pupa; at right, the moth. The picture was made by Frank White in the laboratory of Carroll M. Williams of Harvard University.

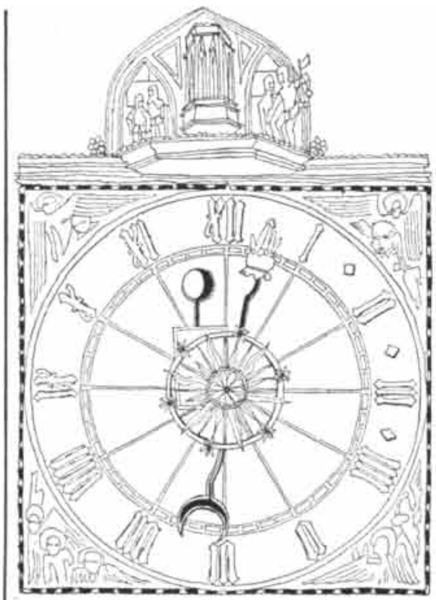
is felt in pupal abdominal muscle. Since the tissue contains a complete and functioning chain of cytochromes, further synthesis is required only to maintain the level of a system already formed.

The action of diphtheria toxin on Cecropia is, so far as we now know, peculiar to that substance. Other bacterial toxins, those of tetanus and Streptococcus, for example, produce no effect on the insect, even when large doses are injected. Williams has found that developing Cecropia are resistant to a large number of drugs and poisons. Even more significant, of the many substances he has tested, only those which are known inhibitors of the cytochrome system act in a manner similar to diphtheria toxin. Potassium cyanide and carbon monoxide under pressure inhibit the cytochrome system by combining with cytochrome a_3. These two poisons duplicate the action of diphtheria toxin to the extent of blocking adult development and paralyzing the abdominal muscles of dormant pupae. However, the actions of cyanide and of carbon monoxide are reversible, and adult development is resumed promptly upon removal of the inhibitor. Moreover, their action on tissues already containing the cytochrome system, such as the abdominal muscle of Cecropia, is immediate rather than delayed, as in the case of toxin.

DESPITE the absence of formal proof, it is reasonable to conclude that diphtheria toxin is injurious because it interferes with the normal functioning of the cytochrome system in the tissues of the host. Its action is not direct; it seems likely that it acts by blocking the synthesis of one or more cytochrome components. We have seen how the theory would provide a reasonable explanation for the extreme toxicity of the toxin, and for its delayed action. The theory does not explain why some animals, such as the rat, are resistant to this action. For the time being we must content ourselves with assuming that for reasons unknown rat cells are impermeable to the large toxin molecules. Still other questions remain to be answered. We do not know just which cytochrome components are involved, although cytochrome *b* is obviously suspected. We have yet to determine at what stage cytochrome synthesis is blocked. It would appear that the penetration of only one or two molecules of toxin per cell produces a lethal effect. It is believed that enzyme synthesis is controlled by those particles which govern the hereditary characteristics of the cell—the genes. Is it possible that diphtheria toxin enters into an irreversible combination with a gene controlling cytochrome synthesis, and so brings about a specific lethal mutation of the susceptible cell?

A. M. Pappenheimer, Jr., is professor of microbiology at the New York University College of Medicine.

SCIENCE AND



Good News from Mexico

FOR several years an epidemic of foot-and-mouth disease in Mexico has kept the U. S.-Mexican border closed to traffic in animals and disquieted the U. S. cattle-raising industry. Last month U. S. Secretary of Agriculture Charles F. Brannan and President Miguel Alemán of Mexico jointly announced the good news that the disease has been wiped out in Mexico and that all quarantines have been lifted.

The contagious infection was stopped by a fourfold program carried out by a U. S.-Mexican eradication commission: all infected areas were quarantined; all sick animals and all those known to have been exposed were killed; all susceptible animals in areas near the centers of infection were inspected; polluted premises were disinfected, and the land was tested with "guinea pig" animals before new stock was brought in. Between 1948 and 1950 all healthy stock was vaccinated. Some 8,000 workers were employed in the campaign; the U. S. contributed $125 million. At the height of the outbreak 640 inspectors patrolled the border day and night in jeeps, airplanes and on horseback to see that no Mexican cattle or meat crossed into the U. S.

To prevent a repetition of the threat the two countries have set up a permanent joint commission which will inspect suspected cases and act quickly to wipe out local infections. The U. S. Department of Agriculture has just begun work on a $10 million laboratory for the study of foot-and-mouth disease and other animal ailments. It is to be located on Plum Island.

Nerve Gases

NERVE gases, an unpleasant subject about which rumor has had much to say ever since World War II, are not mere rumor; they exist and are under active military study. The British Ministry of Supply has just confirmed that fact in the *British Medical Journal,* with a description of the gases' deadly properties.

The substances in question (no names or chemical formulas are given) are liquids with boiling points from 150 to 250 degrees Centigrade, a volatility about like that of kerosene. According to the British account, two or three drops of one of these liquids on the skin will kill a person within half an hour; a drop in the eye or a tiny amount of the vapor inhaled kills within a few minutes. The substances penetrate any ordinary clothing. And in the most chilling tradition of science fiction, they destroy insidiously without warning, for they do not attack tissue and are undetectable by any of the senses.

The poisons act by inhibiting the action of cholinesterase—the enzyme that helps translate the electric nerve impulses into the chemistry of muscle activity. The result is complete paralysis of all voluntary and involuntary muscles. Symptoms of the attack are copious salivation, slowing of the heart, constriction of the pupils, headache, nausea, diarrhea, vomiting and muscular weakness. The muscles of respiration are weakened or paralyzed; death comes from asphyxiation.

The account says that artificial respiration and atropine in massive and repeated doses are the indicated treatment for poisoning by these gases.

Fluoridation

THE well-known controlled experiment in fluoridation of the water supply in Newburgh, N. Y., is now eight years old, and last month the New York State Health Commissioner reported on the results to date. The rate of tooth decay among the children in Newburgh has been reduced 47 per cent since the city began to put fluorine in its water in 1944, while in nearby Kingston, the comparative control, there has been no change. Newburgh children who have drunk treated water since birth have two-thirds fewer cavities than children of comparable ages had before the experiment started. There are twice as many children in Newburgh as in Kingston who have no decay whatever in their baby teeth. The Commissioner added that careful examinations since the beginning of the study "reveal absolutely no harmful effects from drinking fluoridated water."

On the basis of results such as these,

more and more local governments are installing fluoridation systems. As of last month 7,585,000 people in 413 U. S. communities were drinking treated water.

But Jack E. McKee, a California Institute of Technology sanitary engineer, suggests in the Caltech journal *Engineering and Science* that nationwide fluoridation would be impracticable—too costly, inconvenient for large cities and impossible in terms of the available supply of fluorine. He proposes that children be supplied with fluorine in their milk rather than in the general water supply. He has been adding fluorine to his own family's bottled milk. The cost is infinitesimal—about five-millionths of a cent per quart. If dairies offered both treated and untreated milk the medication could be a matter of individual choice. Moreover, in this form fluorine could reach the 35 per cent of U. S. families who have no community water supply.

New Uranium Plant

THE Atomic Energy Commission last month announced that its new gaseous diffusion plant will be built in Pike County, Ohio, about 60 miles south of Columbus. This $1.2 billion facility will be the third uranium-separation installation in the U. S. The whole construction is expected to take about four years, although it will be put into operation piecemeal as portions of it are finished. The Union Carbide and Carbon Corporation, which runs the existing U-235 separation plants at Oak Ridge, Tenn., and Paducah, Ky., will help in the construction of the new plant and in training personnel, but will not operate it. The corporation explains that the AEC wants to bring more industrial companies into the field of atomic energy.

The Long View

"THE Phoenicians, who cut down the cedars on the slopes of Lebanon, . . . stand condemned before history for having irresponsibly and selfishly robbed future generations." Will men 2,000 years hence pass the same judgment on the nations of the 20th century for despoiling the earth of uranium? The Austrian physicist Hans Thirring, who has made a specialty of writing on atomic energy, raised this question in last month's *Bulletin of the Atomic Scientists.*

From published estimates of the reserves of workable uranium deposits, and on the assumption that nuclear fuel will eventually furnish 10 per cent of the world's power needs, Thirring calculates that readily available uranium supplies will last a few hundred years, leaving little for the "subsequent millions of centuries" when man will probably have learned to do "much more exciting things with atomic energy."

Thirring argues that instead of turning immediately to atomic power we should exploit the tremendous unused reserves of water power and the inexhaustible energy of the winds, the tides and the sun. The capital costs of such plants would be no greater than for nuclear power plants, he believes, and their operating cost would be practically nil.

Analysis by Neutrons

A POWERFUL new technique for detecting and measuring minute traces of impurities in materials has been announced by the Oak Ridge National Laboratory. With it the Laboratory is testing samples for producers of foods, drugs, metals and other products in which a high degree of purity is important.

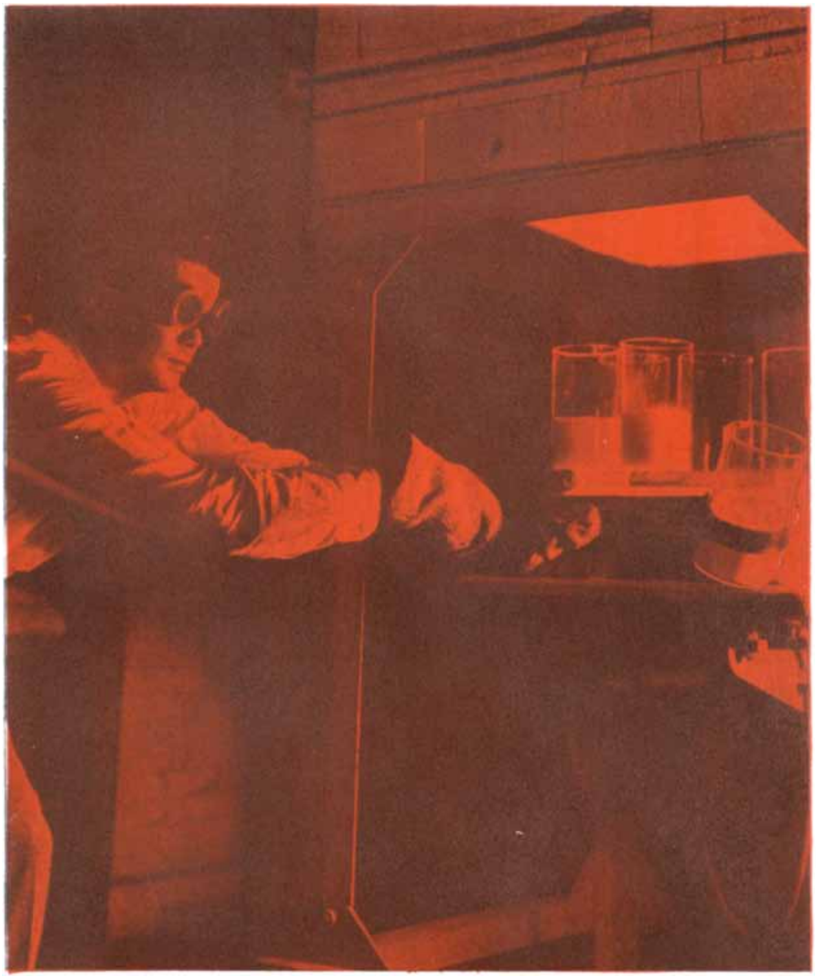
The Laboratory irradiates the sample with neutrons in a uranium pile. The substances in the sample can then be identified and measured by the radiation and decay characteristics of their radioactive isotopes. The sensitive detection instruments can measure, with an accuracy within 10 per cent, less than a billionth of an ounce of material in a sample.

Coal Battery

BURNING coal to make steam to drive a turbine to run a generator to produce electricity is an inefficient way to use the energy stored in coal: it yields only about 35 per cent of the coal's potential energy, even in the best-designed power plant. Fuel engineers have been trying for many years to find a more efficient process. Researchers of the Pittsburgh Consolidation Coal Co. now think they are on the track of such a development.

Their method generates electricity in a "fuel cell" something like the cell in a common storage battery. It consists of two iron plates separated by a complex conducting substance imbedded in ceramic. Coal gas is passed over one of the plates and removes oxygen from the plate. At the same time air is blown over the other plate, giving up oxygen to it. Oxygen ions travel from the second plate through the conductor to the first, producing an electric current.

Both the fuel cell and the method of gasification (heating coal with steam) have been known for some time. What is new is their combination to yield very high efficiency. Everett Gorin, the



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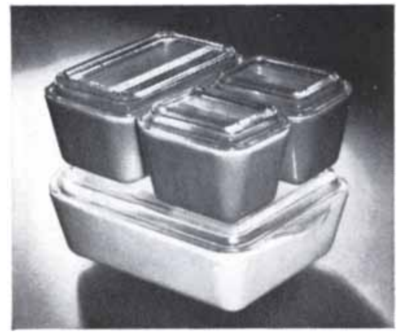

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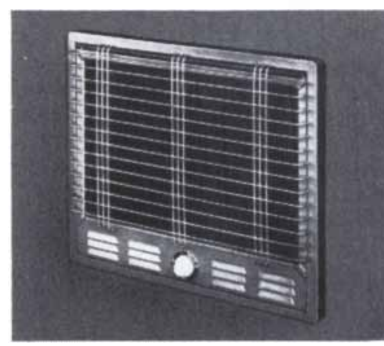

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engineer who developed the process, conceived the idea of putting the fuel cell inside the gasification chamber, so that the heat yielded by the reaction in the cell is used to gasify the coal. Hot exhaust gases also make the steam for the gasification chamber. In this way efficiencies as high as 80 per cent are attained. The chief factors limiting efficiency are heat losses through imperfect insulation and the necessity of running the fuel cell and the gasification chamber at the same temperature, which is not the optimum for either.

A single fuel cell produces current at less than one volt, but combinations in series, as in any other battery, would provide higher voltages. A pair of plates about two and a half inches square will deliver two amperes. Since the output is direct current, which cannot be economically transmitted over any distance, the new generator will probably be used first in electrochemical plants requiring large direct-current supplies. If the operating efficiencies live up to expectations, it may pay to convert the low-voltage direct current into the more generally useful alternating current by a motor-generator combination.

Gorin estimates that commercial development of the process is several years away, as further experiments are needed to establish that the high cost of installation and problems of operation and maintenance will not offset the gain in efficiency.

How to Arrest a Frog

THE University of Illinois zoologist S. Meryl Rose has lately been growing tadpoles without a nervous system, tadpoles without a heart and tadpoles without blood. His odd results support a theory he has formed as to the brake that stops cell differentiation in a growing embryo and allows it to become an adult animal.

Rose believes that development of an animal's organs takes place in stages: after a given type of tissue has been formed its manufacture ceases, and the next cells to differentiate are channeled in another direction, forming a different tissue. What causes the halt in the manufacture of each tissue? According to Rose's theory, it is the accumulation of a substance that inhibits the making of that particular tissue. If his idea is correct, every fully developed organ should contain the substance which stopped its growth. Rose tested this by adding a bit of adult frog brain tissue to a culture with a growing embryo at the stage when it would ordinarily begin to form nerve tissue. The embryo grew into a tadpole, but it had no nervous system; the formation of nerve tissue was inhibited, as Rose had expected. In the same way he stopped the formation of embryonic hearts in tadpoles by putting adult heart tissue in

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the culture, and produced bloodless tadpoles by introducing a few drops of adult blood.

Chloromycetin with a Caveat

THE U. S. Food and Drug Administration decided last month to permit continued distribution of chloromycetin, in spite of recent reports of blood disorders resulting from its use. A committee of the National Research Council, which the FDA had asked to evaluate the evidence, suggested that a warning of the potential danger of the drug be given on the label and that it "not be used indiscriminately or for minor infections." The FDA has followed these suggestions in new labeling requirements.

The Commissioner of Food and Drugs explained: "The Administration has weighed the value of the drug against its capabilities for causing harm and has decided that it should continue to be available for . . . those serious and sometimes fatal diseases in which its use is necessary."

Hope for the Crane

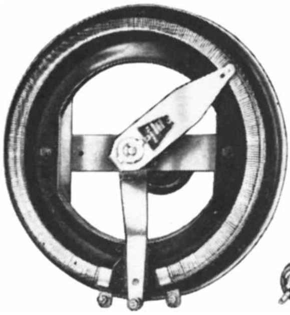
THE whooping crane is the rarest, one of the most picturesque and one of the most mysterious of American birds. It stands five feet high, and its cry can be heard for two miles. It has slowly been vanishing, and ornithologists do not know why. Although they have anxiously guarded the whooping cranes' winter home in the Texas coastal marshes for years, only about 30 of the giant waterfowl are left.

For 50 years naturalists have been hunting for the birds' summer nesting place in the North, hoping to save the birds from extinction by protecting their young. This summer they found their first clue. Robert Smith and Everett Sutton of the U. S. Fish and Wildlife Service, searching the Arctic acre by acre in a small amphibian plane, spotted two cranes in the marshes north of the western end of Great Slave Lake in northern Canada. Plans are now being laid to send a ground party into the area next summer to look for their nesting grounds.

Russian Births

THE Russian population pattern, which under the Czars followed the high birth and death rates of Oriental nations, has swung since 1917 toward the low birth and death rates of Western Europe and North America. So states Robert C. Cook, acting director of the Population Reference Bureau, Inc., on the basis of detective work and some informed guesses.

The 1952 population of the U.S.S.R. is estimated at 207 million. In 1935 Stalin announced that the annual in-



crease was three million. In 1951 Lavrenti P. Beria, a member of the Soviet Politburo, said in a speech that improved living conditions had cut the death rate to half of what it was in 1940, but the annual population increase remained at three million. Cook reasons that the birth rate must therefore be falling even faster than the death rate.

A number of factors could account for the fall in the birth and growth rate. Up to the First World War the major population movement in Europe was from east to west; today Soviet development of its Eastern territories has largely reversed that trend. Industrialization has raised the percentage of urban workers, and city people are less prolific than farmers. Finally, the last war made deep inroads into the male population, and these losses are still reflected in the disproportionate number of women in the population.

Whatever the reasons the Soviet government is undoubtedly disturbed by the falling birth rate, and no official figures on the subject can be obtained. The liberal marriage and divorce laws, the easy access to contraceptives and abortion, the disdain for family traditions that prevailed in Russia in the mid-1920s have been changed. The emphasis now is on secure marriage and large families. Bonuses, tax reductions and other benefits are conferred on prolific parents. Soviet economists violently challenge Malthusian views on population and the food supply. Nonetheless, the birth and death rates in Russia apparently are coming more and more to resemble those of the countries to the west.

Manly Art

TO keep prizefighters operative round by round, their seconds often resort to emergency treatment. The therapeutic regimen may include: daubing at wounds with the dirty towel that the second carries draped around his neck; sealing the edges of torn skin with carpenter's glue, and rubbing adrenalin into open cuts to stop bleeding, sometimes using enough to affect the fighter's pulse, blood pressure and respiratory rate. These practices were deplored by physicians attending a recent medical symposium sponsored by the New York State Athletic Commission. The symposium concluded that national medical standards should be established for the ring, and that ringside doctors should have the authority to protect injured boxers against the ministrations of their handlers.

A Pennsylvania Athletic Commissioner sounded, however, a note of caution about medical standards. "You must know who you are dealing with—they are rough and tough," said John ("Ox") Da Grosa. Requiring too much

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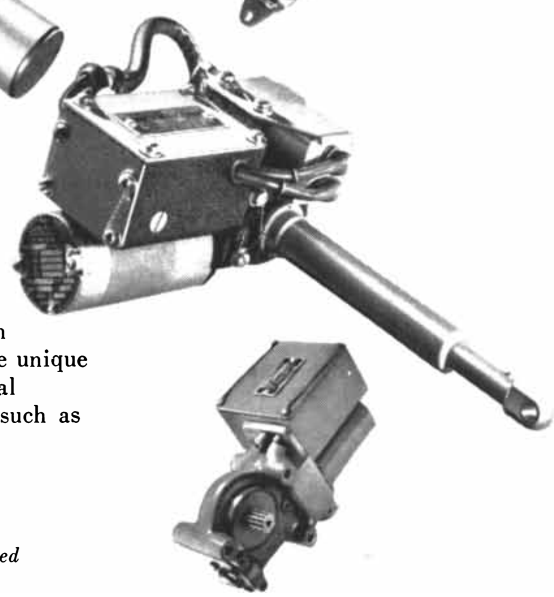

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expensive equipment and too many medical tests might force young fighters to become "slaves to the moneylenders and managers." Their indebtedness might then tempt the boxers to agree to a "tank job."

That repeated blows to the head, or what the late W. O. McGeehan used to call the Manly Art of Modified Murder, may permanently hurt a fighter was once again emphasized last month in *The Journal of the American Medical Association.* A new Colorado law requires that every professional boxer be examined by electroencephalogram at least once a year, and after every knockout. The two doctors who made the examinations, reviewing the first year's results, reported that of 24 boxers tested, nine showed abnormal brain waves. Those who had at some time been knocked out showed the more severe disturbances. One young fighter, who appeared perfectly healthy after suffering a knockout, exhibited severe and persistent abnormalities on his electroencephalograms. He was barred from boxing on the basis of the tests.

Antibiotics for Plants

U. S. farmers, who are now feeding antibiotics to their chickens and hogs, may soon be plowing the drugs into the soil as well. Plant chemists of Chas. Pfizer & Co. last month announced the news that antibiotics promote the growth of plants as they do of animals.

Louis G. Nickel, a Pfizer chemist, made this discovery in experiments with pieces of plant tissue grown in test tubes. He found that the plants' growth was stimulated by bacitracin, terramycin, streptomycin, penicillin and thiolutin (an antibiotic too toxic for human use). Nickel then tested the drugs in soil plots with growing plants, using terramycin and penicillin in a solution of one ounce of antibiotic to 7,000 gallons of water. Corn grown in soil treated with terramycin weighed twice as much as control plants, dry weight. Penicillin-treated soil produced radishes three times as heavy as normal.

If these results can be achieved on the farm, Pfizer workers believe the way is open to greatly increased crop yields at a reasonable cost. As a plant food the drugs will not need to be purified but can be applied in crude form as they come from the fermentation vats.

Nickel believes that the drugs may help plant growth by killing retarding bacteria in the soil. The theory that antibiotics assist growth in animals by killing certain bacteria in the intestines has just received some support in work by an English biologist, M. E. Coates. Addressing the British Association for the Advancement of Science at its Belfast meeting last month, she reported that antibiotics had little effect on the growth of chicks raised under sterile conditions.

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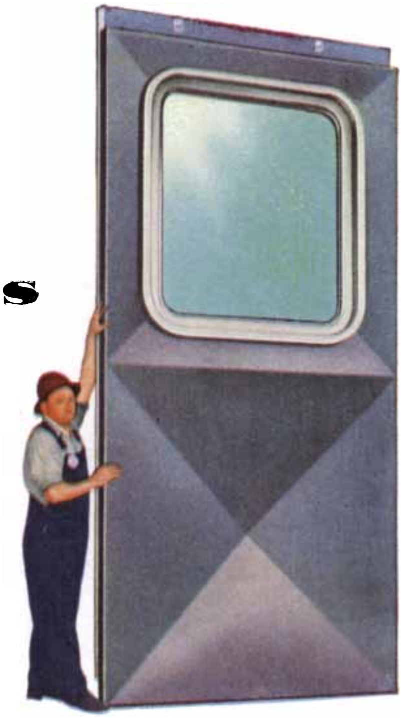

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Meanwhile, other Alcoa engineers proved aluminum for applications inside the building: an aluminum combination acoustical ceiling and radiant heating and cooling systems . . . ductwork . . . wire, bus and conduit.

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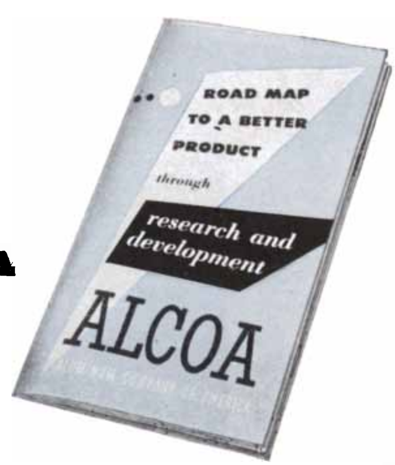

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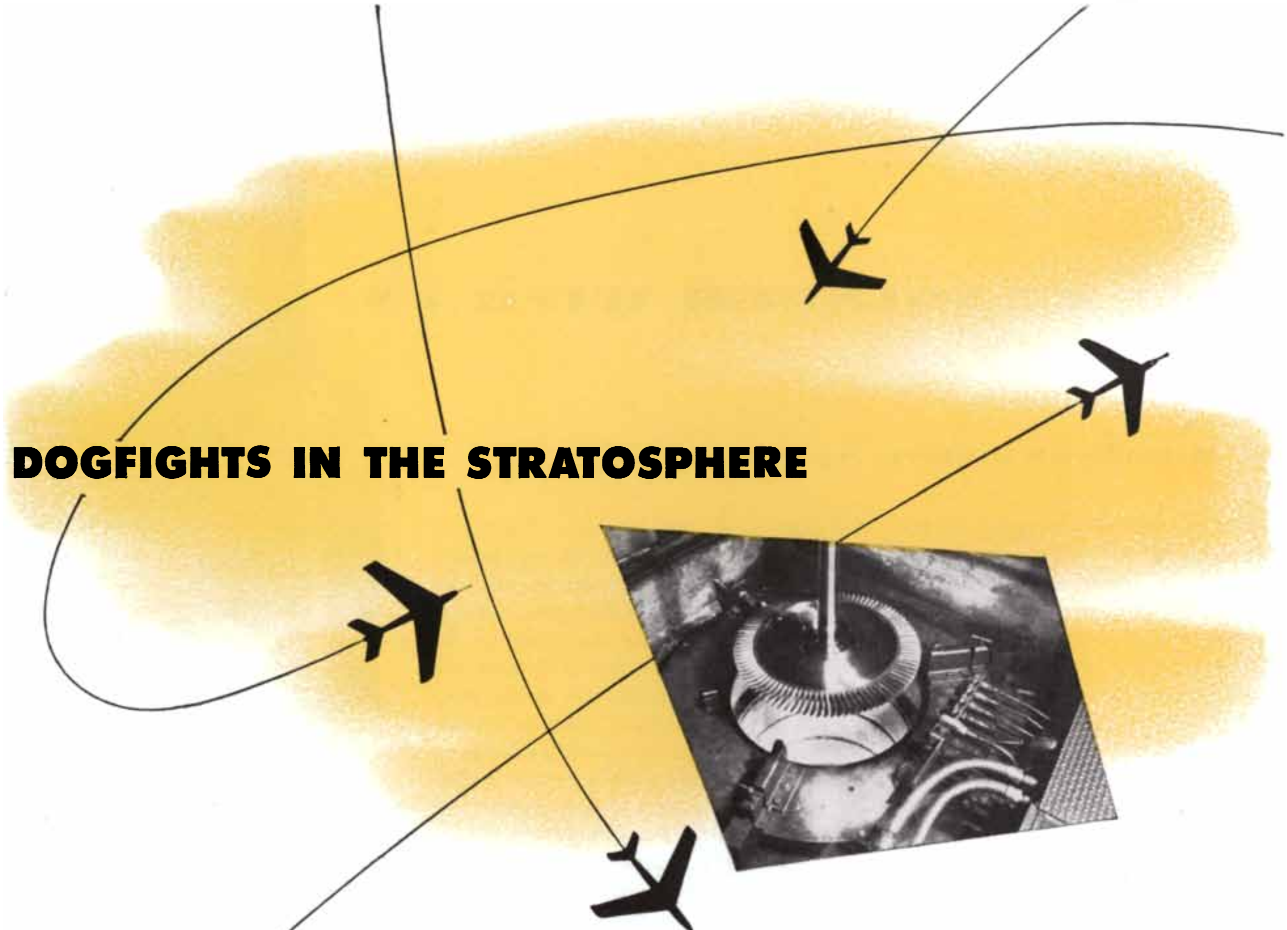

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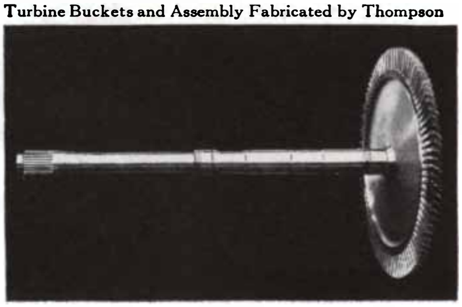

JET DIVISION

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THE ORIGIN OF THE EARTH

The emergence of the theory that the solar system coagulated from a vast cloud of dust has led to a new inquiry into the chemical history of our planet

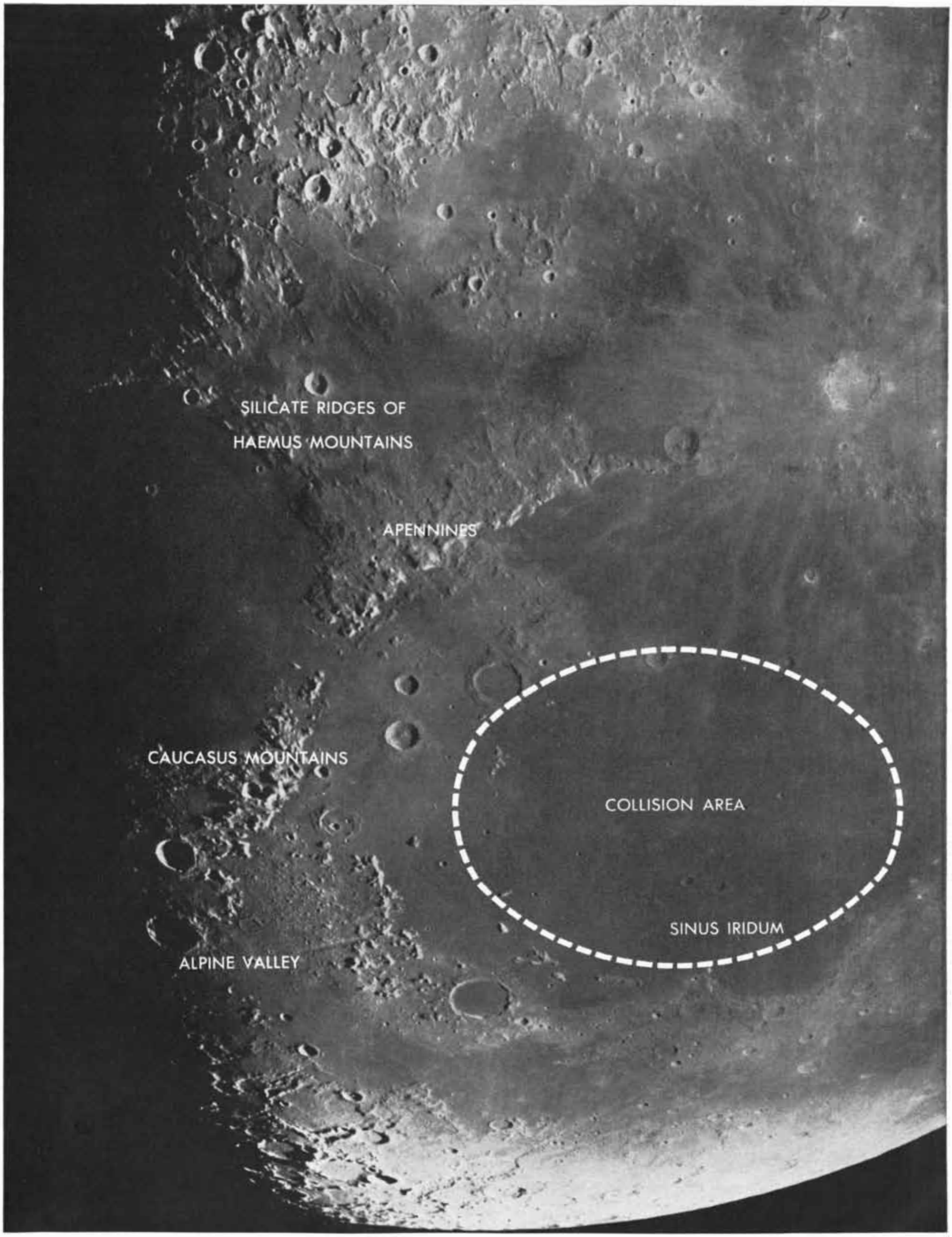
by Harold C. Urey

IT IS PROBABLE that as soon as man acquired a large brain and the mind that goes with it he began to speculate on how far the earth extended, on what held it up, on the nature of the sun and moon and stars, and on the origin of all these things. He embodied his speculations in religious writings, of which the first chapter of *Genesis* is a poetic and beautiful example. For centuries these writings have been part of our culture, so that many of us do not realize that some of the ancient peoples had very definite ideas about the earth and the solar system which are quite acceptable today.

Aristarchus of the Aegean island of Samos first suggested that the earth and the other planets moved about the sun—an idea that was rejected by astronomers until Copernicus proposed it again 2,000 years later. The Greeks knew the shape and the approximate size of the earth, and the cause of eclipses of the sun. After Copernicus the Danish astronomer Tycho Brahe watched the motions of the planet Mars from his observatory on the Baltic island of Hveen; as a result Johannes Kepler was able to show that Mars and the earth and the other planets move in ellipses about the sun. Then the great Isaac Newton proposed his universal law of gravitation and laws of motion, and from these it was possible to derive an exact description of the entire solar system. This occupied the minds of some of the greatest scientists and mathematicians in the centuries that followed.

Unfortunately it is a far more difficult problem to describe the origin of the solar system than the motion of its parts. The materials that we find in the earth and the sun must originally have been in a rather different condition. An understanding of the process by which these materials were assembled requires the knowledge of many new concepts of science such as the molecular theory of gases, thermodynamics, radioactivity and quantum theory. It is not surprising

GREAT FURROW (*right center*) on the surface of the moon must have been made by a tough metallic object. The author believes that this was a fragment of a large body that crashed into the moon from the right.



MARE IMBRIUM, a large circular plain near the northern edge of the moon, was probably made by the fall of a body about 60 miles in diameter. This planetesimal apparently ploughed in through Sinus Iridum and spread out in a collision area outlined by relatively small, iceberg-like masses. The rocky silicates of the planetesimal splashed out in the region of the Haemus and the Apennine Mountains. The Alpine Valley, which is the same formation that appears on the preceding page, may have been made by a metallic object.

that little progress was made along these lines until the 20th century.

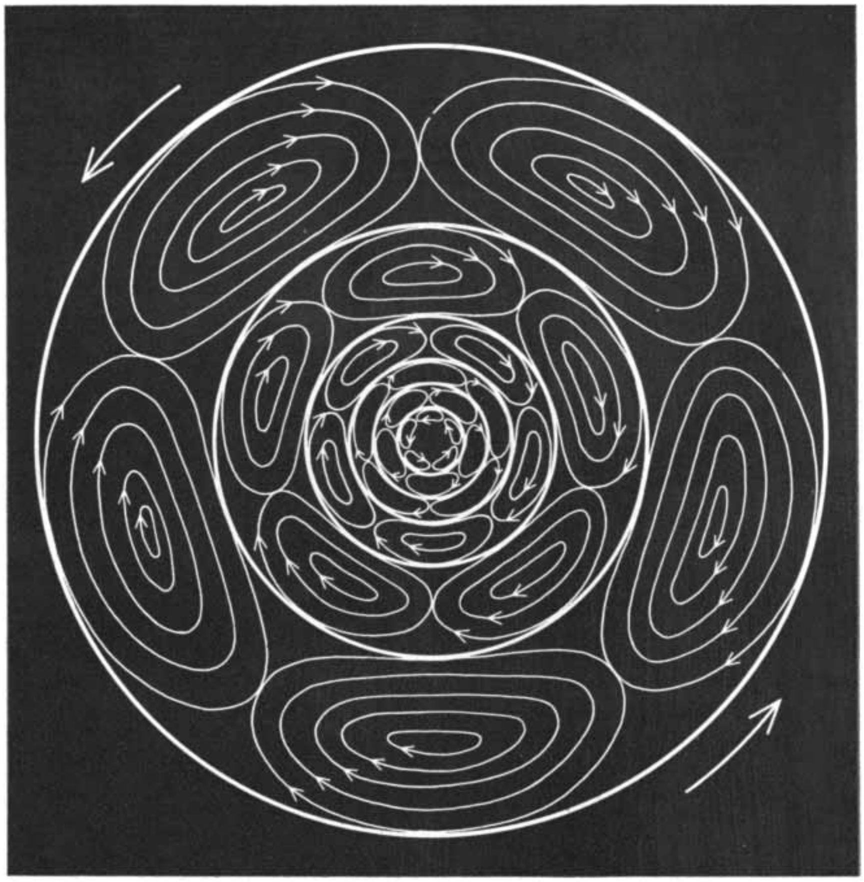
The Earlier Theories

It is widely assumed by well-informed people that the moon came out of the earth, presumably from what is now the Pacific Ocean. This was proposed about 60 years ago by Sir George Darwin. The notion was considered in detail by F. R. Moulton, who concluded that it was not possible. In 1917 it was again considered by Harold Jeffreys, who thought that his analysis indicated the possibility that the moon had been removed from a completely molten earth by tides. In 1931, however, Jeffreys reviewed the subject and concluded that this could not have happened; since then most astronomers have agreed with him.

But although Moulton and Jeffreys showed the improbability of the origin of the moon from the earth, they proposed theories for the origin of the solar system involving the removal of the earth and the other planets from the sun. Together with James Jeans and T. C. Chamberlin they proposed that another star passed near or collided with the sun, and that the loose material resulting from this cosmic encounter later coagulated into planets. This idea of the origin of the solar system has been widely held right up to the present.

The evidence gathered by our great telescopes now tells us that most of the stars in the heavens are pairs or triplets or quadruplets. We have determined the masses of multiple stars by means of Newton's laws of motion and his universal law of gravitation; we have also studied the velocities of these stars by significant changes in their spectra and by actually measuring the motions of nearby examples. We find that the two stars of a pair seldom have exactly the same mass, and that the ratio of the mass of one star to that of the other varies considerably. Gerard P. Kuiper of the University of Chicago concludes that the number of pairs of stars is entirely independent of the ratios of their masses; that is, there is very little probability that one ratio of masses would occur more often than another. In fact, it would appear that there is about as much chance of finding a pair of stars in which one has one-thousandth the mass of the other as there is of finding a pair in which one is 999 thousandths as massive as the other.

Of course it would be very difficult to see a double star in which the secondary was only a thousandth as large as the primary, particularly if the second emitted no light. The sun and Jupiter, the largest of the planets, might be viewed as such a double star: Jupiter weighs about a thousandth as much as the sun, and it shines only by reflected sunlight. Even from the nearest star Jupiter would be invisible. There is much evidence, however, that a double star such as the sun and Jupiter should occur as a regular event in our galaxy, and the same considerations would seem to indicate that there may be as many as a hundred million solar systems within it. Solar systems are almost certainly commonplace, and not the special things that one might expect from the collision of two stars.



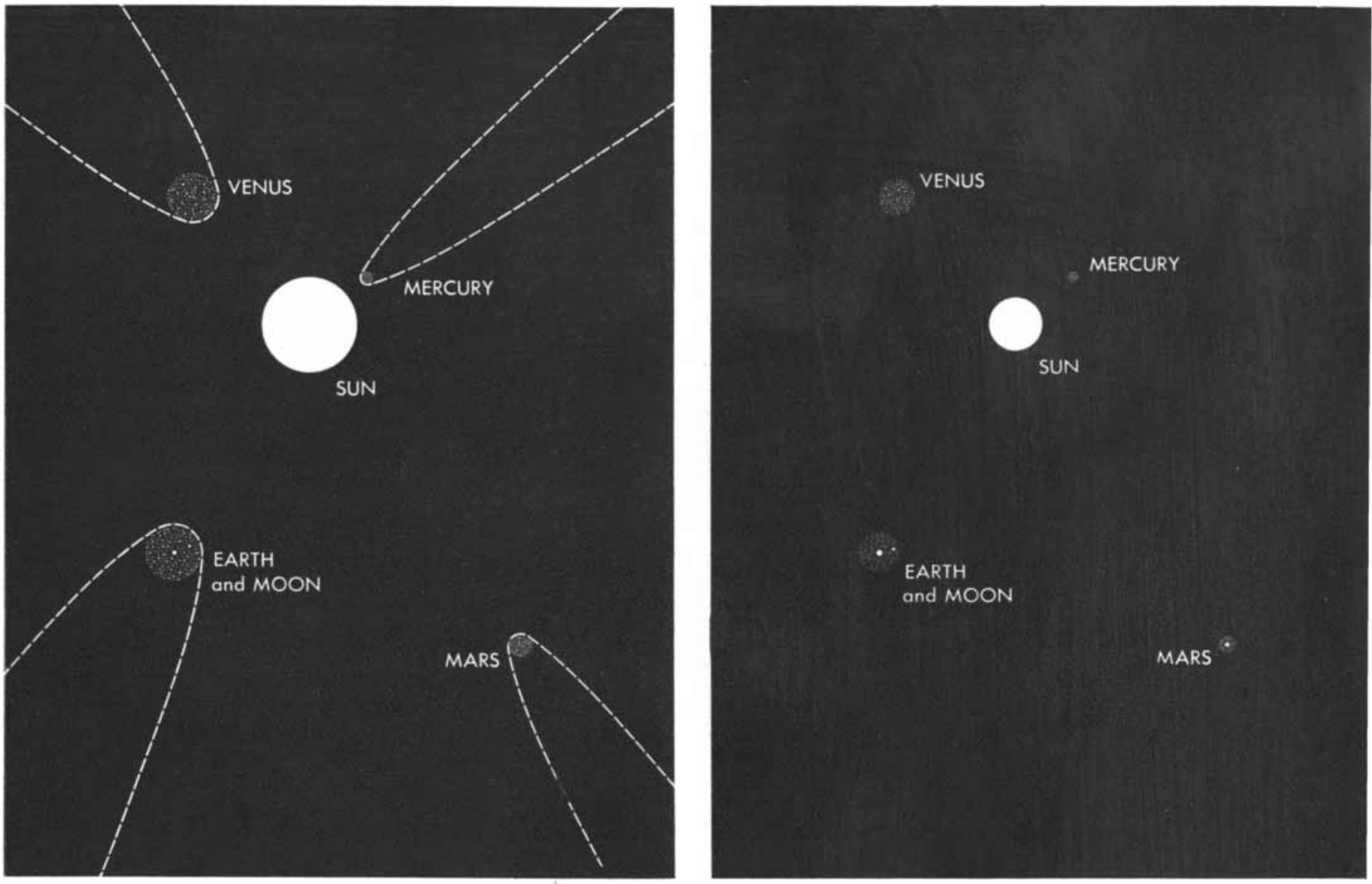
CLOUD OF DUST **from which the solar system evolved may have developed this intricate pattern of turbulence, suggested by the German physicist C. F. von Weizsäcker. The dust in each eddy gradually coagulated.**

The Dust Cloud Hypothesis

Many years ago E. E. Barnard of the Yerkes Observatory observed certain black spots in front of the great diffuse nebulae that occur throughout our galaxy. Bart J. Bok of Harvard University has investigated these opaque globules of dust and gas; they have about the mass of the sun and about the dimensions of the space between the sun and the nearest star. Lyman Spitzer, Jr., of Princeton University has shown that if large masses of dust and gas exist in space, they should be pushed together by the light of neighboring stars. Eventually, when the dust particles are sufficiently compressed, gravity should collapse the whole mass, and the pressure and temperature in its interior should be enough to start the thermonuclear reaction of a star.

It would seem reasonable to believe that if a star such as the sun resulted from a process of this kind, there might be enough material left over to make a solar system. And if the process was more complex we might even end up with two stars instead of one. Or again we might have triple stars or quadruple stars. Theories along this line are more plausible to us today than the hypothesis that the planets were in some way removed from the sun after its formation had been completed. In my opinion the older hypotheses were unsatisfactory because they attempted to account for the origin of the planets without accounting for the origin of the sun. When we try to specify how the sun was formed, we immediately find ways in which the material that now comprises the planets may have remained outside of it.

One piece of evidence that must be included in any theory about the origin of the solar system consists in our observation of the angular momentum that resides in the spinning sun and the planets that travel around it. The angular momentum of a planet is equal to its mass times its velocity times its distance from the sun. Jupiter possesses the largest fraction of the angular momentum in the solar system; only about two per cent resides in the sun. Another fact that must



EVOLUTION OF THE EARTH and the planets Mercury, Venus and Mars is depicted in this series of schematic drawings. In the first drawing the primordial dust cloud has coagulated into protoplanets composed of planetesimals. The gases that have coagulated with the planetesimals are driven away (*dotted lines*) by the pressure of light from the sun. In the second drawing the gas has been completely removed from the proto-

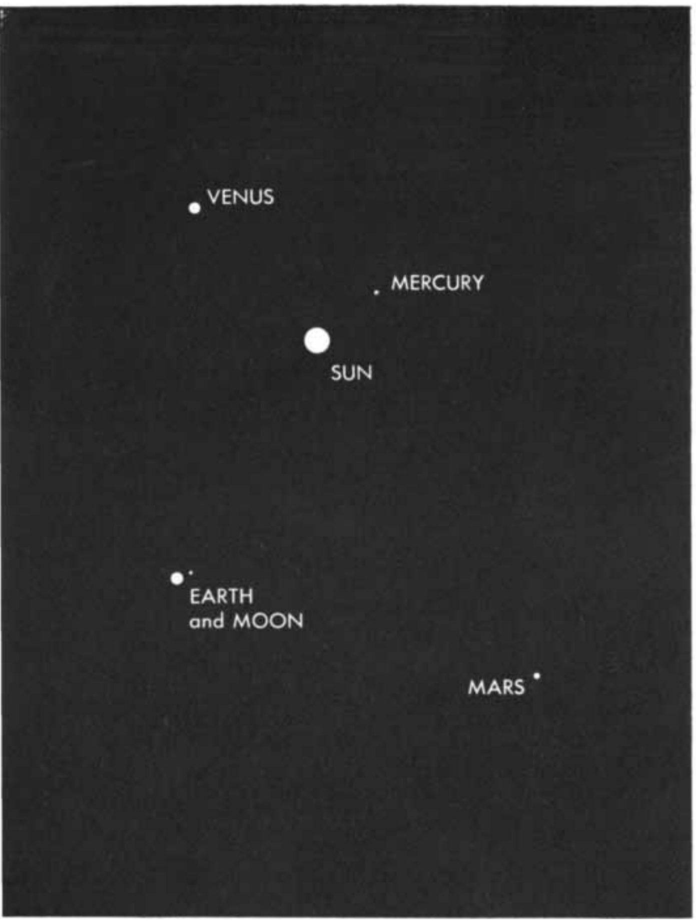
be encompassed by any theory is the so-called Titus-Bode law, which points out in a simple mathematical way how the distances of the planets from the sun vary: the inner planets are closer together and the outer ones are farther apart. This is only an approximate law which does not hold very well, and perhaps more emphasis has been put upon it than it deserves. In my own study of the problem I have looked for other evidence regarding the origin of the solar system.

Some 15 years ago Henry Norris Russell of Princeton and Donald H. Menzel of Harvard pointed out that there was a very curious relationship between the proportions of the elements in the atmosphere of the earth and the atmospheres of the stars, including the sun. It is particularly noteworthy that neon, the gas that we use in electric signs, is very rare in the atmosphere of the earth but is comparatively abundant in the stars. Russell and Menzel concluded that neon, which forms no chemical compounds, escaped from the earth during a hot early period in its history, together with all of the water and other volatile materials that constituted its atmosphere at that time. The present atmosphere and oceans, they proposed, have been produced by the escape of nitrogen, carbon and water from the interior of the earth. The German physicist C. F. von Weizsäcker similarly suggested that the argon of the air has resulted mostly from the decay of radioactive potassium during geologic time, and has escaped from the interior of the earth. F. W. Aston of Cambridge University also pointed out that the other inert gases, krypton and xenon, were virtually missing from the earth.

The Chemical Approach

My own studies in the origin of the earth started with such thoughts about the loss of volatile chemical elements from the earth's surface. Exactly how did these elements escape from the earth, and when? I came to the conclusion that it was impossible that they were evaporated from a completely formed earth; the evaporation must have occurred at some earlier time in the earth's history. Once the earth was formed its gravitational field was much too strong for volatile gases to escape into space. But if these gases escaped from the earth at an earlier stage, what is the origin of those that we find on the earth today? Water, for example, would have tended to escape with neon, yet now it forms oceans. The answer seems to be that the chemical properties of water are such that it does not enter into volatile combinations at low temperatures. Thus if the earth had been even cooler than it is today, it might have retained some water in its interior that could have emerged later. But meteorites contain graphite and iron carbide, which require high temperatures for their formation. If the earth and the other planets were cool, how did these chemical combinations come about?

Indeed, what was the process by which the earth and other planets were formed? None of us was there at the time, and any suggestions that I may make can hardly be considered as certainly true. The most that can be done is to outline a possible course of events which does not contradict physical laws and observed facts. For the present we cannot deduce by rigorous mathematical methods the exact history that began with a globule of dust. And if we cannot



planets. In the third drawing the planetesimals have formed the planets. The relative sizes of the sun and planets and the distances between them have been distorted for purposes of diagrammatic clarity.

do this, we cannot rigorously include or exclude the various steps that have been proposed to account for the evolution of the planets. However, we may be able to show which steps are probable and which improbable.

Kuiper believes that the original mass of dust and gas became differentiated into one portion that formed the sun and others that eventually became the planets. The precursors of the so-called terrestrial planets—Mercury, Venus, the earth and Mars—lost their gases. The giant planets Jupiter and Saturn retained the gases, even most of their exceedingly volatile hydrogen and helium. Uranus and Neptune lost much of their hydrogen, helium, methane and neon, but retained water and ammonia and less volatile materials. All this checks with the present densities of the planets.

It seems reasonably certain that water and ammonia and hydrocarbons such as methane condensed in solid or liquid form in parts of these protoplanets. The dust must have coagulated in vast snowstorms that extended over regions as great as those between the planets of today. After a time substantial objects consisting of water, ammonia, hydrocarbons and iron or iron oxide were formed. Some of these planetesimals must have been as big as the moon; indeed, the moon may have originated in this way. The accumulation of a body as large as the moon would have generated enough heat to evaporate its volatile substances, but a smaller body would have held them. Most of the smaller bodies doubtless fell into the larger; Deimos and Phobos, the two tiny moons of Mars, may be the survivors of such small bodies.

Massive chunks of iron must also have been formed. On the moon there is a huge plain called Mare Imbrium; it is encircled by mountains gashed by several long grooves. It would seem that the whole formation was created by the fall of a body perhaps 60 miles in diameter; this has been suggested by Robert S. Dietz of the U. S. Naval Electronics Laboratory, and by Ralph B. Baldwin, the author of a book entitled *The Face of the Moon.* The grooves must have been cut by fragments of some very strong material, presumably an alloy of iron and nickel, that were imbedded in this body. Of course large objects of iron still float through interplanetary space; occasionally one of them crashes into the earth as a meteorite.

How were such metallic objects made from the fine material of the primordial dust cloud? In addition to dust the planetesimals contained large amounts of gas, mostly hydrogen. I suggest that the compression of the gases in a contracting planetesimal generated high temperatures that melted silicates, the compounds that today form much of the earth's rocky crust. The same high temperatures, in the presence of hydrogen, reduced iron oxide to iron. The molten iron sank through the silicates and accumulated in large pools.

It now seems that the meteorites were once part of a minor planet that traveled around the sun between the orbits of Mars and Jupiter. The pools of iron that formed in this body may have been a few yards thick. In the case of the object that was responsible for Mare Imbrium and its surrounding grooves, the depth of the pools must have been several miles. If the temperature of such a planetesimal had been high enough, its silicates would have evaporated, leaving it rich in metallic iron. The object must eventually have cooled off, for otherwise its nickel-iron fragments could scarcely have been hard enough to plow 50-mile grooves on the surface of the moon.

It was at this stage that the planetesimals lost their gases; Kuiper believes that they were probably driven off by the pressure of light from the sun. This left the iron-rich bodies that are today the earth and the other planets. The whole process bequeathed a few meaningful fossils to the modern solar system: the meteorites and the surface of the moon, and perhaps the moons of Mars.

The Moment of Inertia

Recently we have redetermined the density of the various planets and the moon. The densities of some, calculated at low pressures, are as follows: Mercury, 5; Venus, 4.4; the earth, 4.4; Mars, 3.96, and the moon, 3.31. The variation is most plausibly explained by a difference in the iron content of these bodies. And this in turn is most plausibly explained by a difference in the amount of silicate that had evaporated from them. Obviously a planet that had lost much of its silicate would have proportionately more iron than one that had lost less.

It is assumed by practically everyone that the earth was completely molten when it was formed, and that the iron sank to the center of the earth at that time. This idea, like the conception of an earth torn out of the sun, and a moon torn out of the earth, almost has the validity of folklore. Was the earth really liquid in the beginning? N. L. Bowen and other geologists at the Rancho Santa Fe Conference of the National Academy of Sciences in January, 1950, did not think so. They argued that if the earth had been liquid we should expect to find less iron and more silica in its outer parts.

There is other evidence. Mars, which should resemble the earth in some respects, contains about 30 per cent of iron and nickel by weight, and yet we have learned by astronomical means that the chemical composition of Mars is nearly uniform throughout. If this is the case, Mars could never have been molten. The scars on the face of the moon indicate that at the terminal stages of its formation metallic nickel-iron was falling on its surface. The same nickel-iron must have fallen on the earth, but there it would have been vaporized by the energy of its fall into a much larger body. Even so, if the earth had not been molten at the time, some of the nickel-iron might still be found in its outer mantle.

If there is iron in the mantle of the earth, it may be sifting toward the center of the earth; and if it is moving toward the center of the earth, it will change the moment of inertia of the earth. The moment of inertia may be defined as the sum of the mass at each point in the earth multiplied by the square of the distance to the axis of rotation, and added up for the whole earth. If iron were flowing toward the interior of the earth, this quantity should decrease. It is a requirement of mechanics that if the moment of inertia of a rotating body decreases, its speed of rotation must increase. Finally if the speed of the earth's rotation is increasing, our days should slowly be getting shorter.

Now we know that our unit of time is changing; but it is getting longer, not shorter. That is, the earth is not speeding up but is slowing down. Very precise astronomical measurements, some of them dating back to the observation of eclipses 2,500 years ago, indicate that the day is increasing in length by about one- or two-thousandths of a second per day per century. It has been thought that the lengthening of the day was due to the friction of the tides caused by the sun and the moon. But if we attempt to predict changes in the apparent position of the moon on the basis of this effect alone, we find that our calculations do not agree with the observations at all. If on the other hand we assume that iron is sinking to the core of the earth, the changing moment of inertia would also influence the length of the day. Indeed, calculations made on the basis of both the tides and the changing moment of inertia do agree with the observations.

In order to make the calculations agree we must postulate a flow of 50,000 tons of iron from the mantle to the core of the earth every second. Staggering though this flow may seem, it would take 500 million years to form the metallic core of the earth. Some calculations indicate that it may have taken as long as two billion years. The important thing is that the order of magnitude approaches that of the age of the earth, which is generally given as two to three billion years. If this reasoning is correct, the earth was made initially with some iron in its exterior parts, and it could not have been completely molten.

To complicate matters Walter H. Munk and Roger Revelle of the Scripps Institution of Oceanography have shown that the moment of inertia of the earth is probably decreasing because water is slowly being transferred from the oceans to the ice caps of Greenland and Antarctica, and that this process can account for the lengthening of the day without assuming that iron is moving to the center of the earth, at least not so rapidly as I have calculated. In view of the ar-

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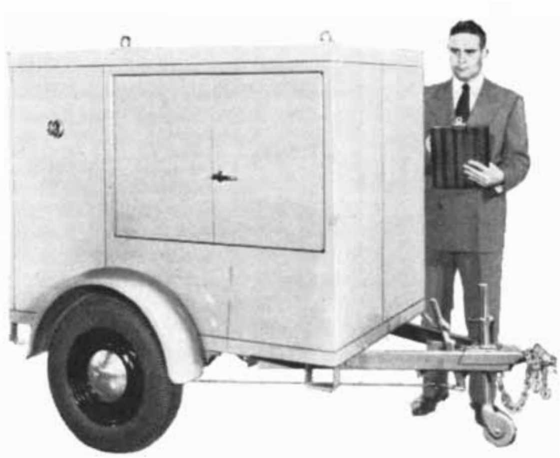

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gument of Munk and Revelle we really have no evidence for the flow of iron to the center of the earth. However, we have little evidence to the contrary. New observations are needed.

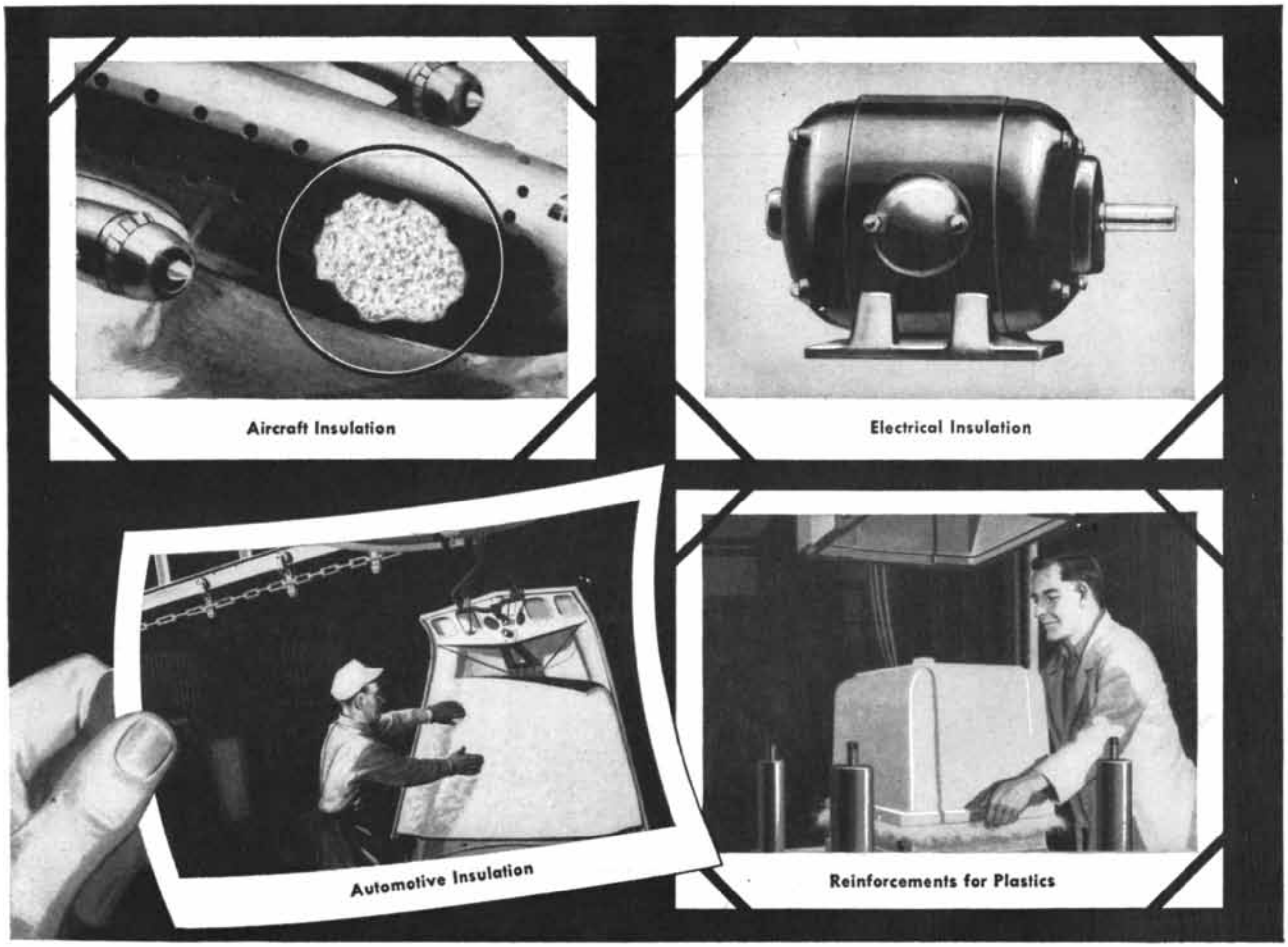
The Last Stages

Let us briefly retell what the course of events may have been. A vast cloud of dust and gas in an empty region of our galaxy was compressed by starlight. Later gravitational forces accelerated the accumulation process. In some way which is not yet clear the sun was formed, and produced light and heat much as it does today. Around the sun wheeled a cloud of dust and gas which broke up into turbulent eddies and formed protoplanets, one for each of the planets and probably one for each of the larger asteroids between Mars and Jupiter. At this stage in the process the accumulation of large planetesimals took place through the condensation of water and ammonia. Among these was a rather large planetesimal which made up the main body of the moon; there was also a larger one that eventually formed the earth. The temperature of the planetesimals at first was low, but later rose high enough to melt iron. In the low-temperature stage water accumulated in these objects, and at the high-temperature stage carbon was captured as graphite and iron carbide. Now the gases escaped, and the planetesimals combined by collision.

So, perhaps, the earth was formed!

But what has happened since then? Many things, of course, among them the evolution of the earth's atmosphere. At the time of its completion as a solid body, the earth very likely had an atmosphere of water vapor, nitrogen, methane, some hydrogen and small amounts of other gases. J. H. J. Poole of the University of Dublin has made the fundamental suggestion that the escape of hydrogen from the earth led to its oxidizing atmosphere. The hydrogen of methane (CH_4) and ammonia (NH_3) might slowly have escaped, leaving nitrogen, carbon dioxide, water and free oxygen. I believe this took place, but many other molecules containing hydrogen, carbon, nitrogen and oxygen must have appeared before free oxygen. Finally life evolved, and photosynthesis, that basic process by which plants convert carbon dioxide and water into foodstuffs and oxygen. Then began the development of the oxidizing atmosphere as we know it today. And the physical and chemical evolution of the earth and its atmosphere is continuing even now.

Harold C. Urey is professor of chemistry in the Institute for Nuclear Studies at the University of Chicago.


Aircraft Insulation
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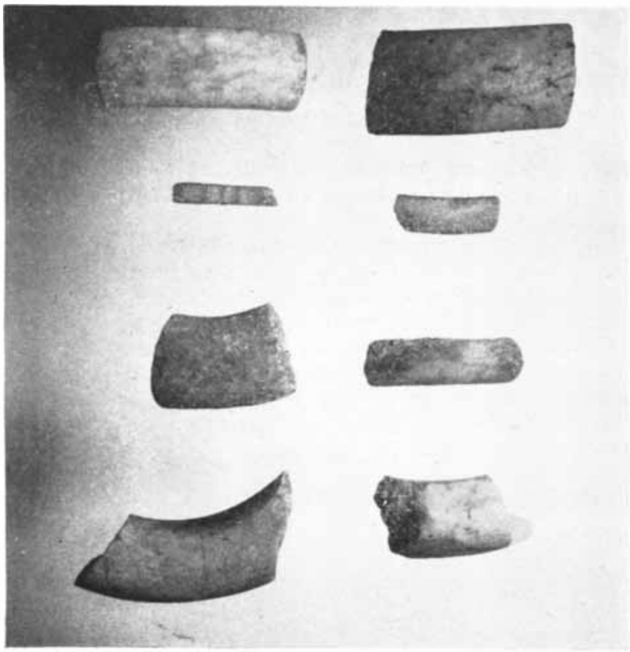
Reinforcements for Plastics

MASONRY excavated at Jarmo had provided the foundation for houses made of *touf*, or pressed mud. These remains are in one of Jarmo's upper architectural levels. Earlier houses had been built without foundations.



BRACELETS worn by the people of Jarmo were made of stone. Numerous fragments of these have been found.

TOOLS were also made of stone. Shown here are several stone axes and adzes found at the site of the village.

From Cave to Village

An account of a recent expedition to Iraq which sought the remains of a prehistoric revolution in the life of man: the birth of agriculture and animal husbandry

by Robert J. Braidwood

THUS FAR in human history there have been two principal economic revolutions. One is the Industrial Revolution, which began 175 years ago and which, to judge by the stresses of our period, is still far from complete. The other is the food-producing revolution—the invention of agriculture and animal husbandry—which began in prehistoric times. Although there is no contemporary written record of this earlier revolution, its material remains may be read by the prehistoric archaeologist. This article is concerned with some meaningful remains of the food-producing revolution uncovered by a recent expedition of the Oriental Institute of the University of Chicago to the Near East.

For 500,000 years before the food-producing revolution small groups of men lived mostly in caves. They were obliged to spend almost all of their time in the quest for food; they hunted, fished and gathered a few edible wild plants. After the revolution larger groups of men lived in villages. Tilling the soil and tending the animals gave them enough food, and thus enough leisure, to develop specialized skills. It is easiest for the archaeologist to comprehend the economic and technological features of such a profound development, but it must have embraced all the other aspects of culture: social, political, religious, moral and esthetic. To say that the economic and technological aspects came before the others would be rather like asking the conundrum: "Which came first, the chicken or the egg?"

WHERE did the food-producing revolution occur? There is overwhelming evidence that the first experiments in food production and village life were made in the Near East. Similar experiments in China and India surely came later, and quite possibly were due to Near Eastern influence. The beginnings of food production in the New World were independent, but still later.

The Near East also appears to have been the natural habitat of the plants and animals that were later domesticated to provide the basis for the agriculture and animal husbandry of the western Old World. One might assume that these species grew, as did the earliest civilizations, on the classic plains of the Tigris and the Euphrates and the Nile—the region that the great historian James H. Breasted called "The Fertile Crescent." Actually it now seems that they and the first villages were native to the hills that flank this region. These hilly grasslands were independent of irrigation; in them the winter rains of any normal year assure a spring crop even today. Thus it would appear that as the revolution progressed the basic food plants and animals were brought to the Fertile Crescent from the hills.

But exactly when and how did the food-producing revolution come about? In 1947, when we began to organize our expedition at the Oriental Institute, we held the following view of Near Eastern prehistory. The remains of preagricultural cave dwellers had been found in Palestine and Egypt, and to a lesser extent in Syria, Lebanon and Iraq. The latest of these cultures, the Natufian of Palestine, differed from the others only in that its people had domesticated the dog and devised a flint sickle, apparently for the collection of a wild food plant. Then there was an abrupt break in the historical sequence. The next remains are those of villages in full flower: established settlements with architecture, pottery and weaving—a vastly larger Sears, Roebuck catalogue than that of the cave dwellers.

In Iraq, for example, the latest remnants of the preagricultural people had been found in the cave of Zarzi; they were represented by tools of chipped flint. Next came the village materials of Hassuna, whose people first camped around hearths in the open and later built mud houses, made several different kinds of pottery and altogether lived a full peasant existence. After Hassuna followed an uninterrupted succession of excavated cultural materials, in which were presently seen the settlement of the Mesopotamian plain, the building of towns and temples, the invention of writing and the founding of city-states. Between the cave of Zarzi and the village of Hassuna there was clearly a large gap in culture and time. In this gap occurred the food-producing revolution.

We chose to seek evidence of the revolution in Iraq, where the sequence of villages after the gap had been thoroughly worked out, where the world's earliest civilization later developed and where the Government Directorate-General of Antiquities was cordial and cooperative. Early in 1947 Dr. Naji-al-Asil, the Director-General, had sent us a list of promising sites, and in the fall of that year three of us departed for Iraq. From March to May of 1948 we excavated the remains of a village south of the great modern oil-producing town of Kirkuk. These remains resembled those of Hassuna, but we were unable to find anything more primitive. In May and June we spent a month digging at another site that had been listed by the Director-General. This was Qalat Jarmo, 30 miles east of Kirkuk in the Kurdish hills. Our test soundings showed that Jarmo was surely part of what we were after.

A large-scale prehistoric excavation is expensive, and its financing is not easy. It took us two years to get back to Iraq. We reopened our excavation at Jarmo in the fall of 1950, and, with the exception of time lost to winter rains, continued to dig until the spring of 1951.

THE village of Jarmo lay on the crest of a hill overlooking a deep *wadi,* or gully. It covered an area of at least three acres. It was inhabited for a moderately long time; the debris of its life is 25 feet deep. When we dug into the debris, we discovered that it was made up of perhaps 12 different levels, each represented by a change in architecture.

The people of Jarmo lived in houses made of what the modern Iraqi calls *touf*: pressed mud. At any one time there

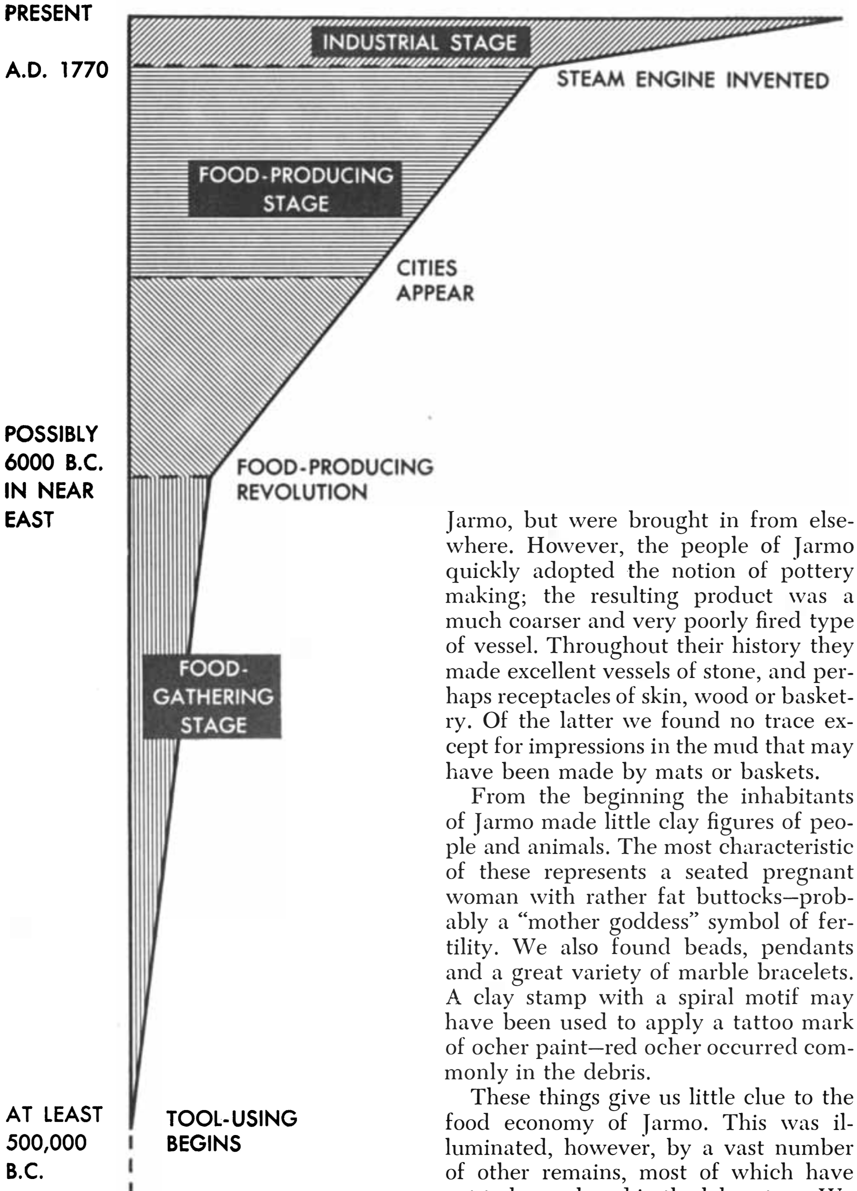


CHART shows place of the food-producing revolution in human history.

were about 30 of these structures, sheltering perhaps 200 people. In the uppermost levels of the debris the touf walls rested on foundations of stone. The houses had mud floors, often packed over a layer of reeds. Each house was equipped with an oven; in one case we found a fairly intact oven vault, with its fire door opening into an adjoining room. Another feature of the houses, especially those in the lower levels of the debris, was a basin that was baked into the floor; this was apparently used as a permanent receptacle.

In the five uppermost levels of Jarmo we found portable pottery vessels. The earliest fragments of pottery are few in number, but have painted and burnished exteriors. Their advanced workmanship suggests that they were not made at Jarmo, but were brought in from elsewhere. However, the people of Jarmo quickly adopted the notion of pottery making; the resulting product was a much coarser and very poorly fired type of vessel. Throughout their history they made excellent vessels of stone, and perhaps receptacles of skin, wood or basketry. Of the latter we found no trace except for impressions in the mud that may have been made by mats or baskets.

From the beginning the inhabitants of Jarmo made little clay figures of people and animals. The most characteristic of these represents a seated pregnant woman with rather fat buttocks—probably a "mother goddess" symbol of fertility. We also found beads, pendants and a great variety of marble bracelets. A clay stamp with a spiral motif may have been used to apply a tattoo mark of ocher paint—red ocher occurred commonly in the debris.

These things give us little clue to the food economy of Jarmo. This was illuminated, however, by a vast number of other remains, most of which have yet to be analyzed in the laboratory. We found weights for digging sticks, hoe-like celts, flint sickle-blades and a wide variety of milling stones. Bone was abundantly employed in the manufacture of hafts, awls, needles, blades and spoons. We also discovered several pits that were probably used for the storage of grain. Perhaps the most important evidence of all was animal bones and the impressions left in the mud by cereal grains.

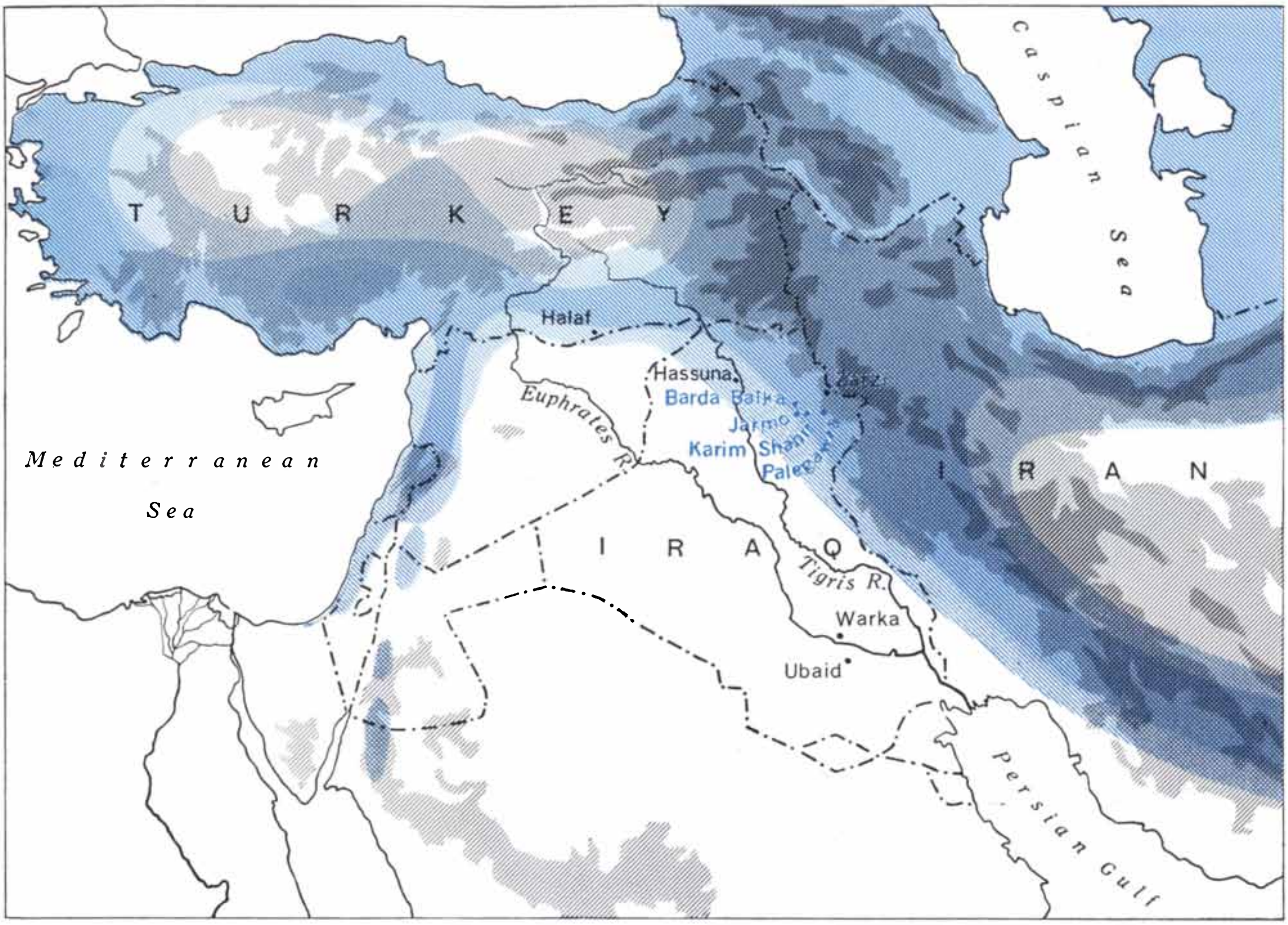
One of our collaborators, Hans Helbaek of the Danish National Museum, has already shown that the people of Jarmo grew at least two varieties of wheat and a legume. Fredrik Barth of the University of Oslo, who was with us in the field, classified the bones of pigs, cattle, dogs, sheeplike goats and a relative of the horse, as well as those of wild animals. Barth found that the proportion of sheep-goat bones was very high, and that the teeth of these animals indicated that almost all of them had been yearlings—a selection that does not suggest hunting.

All of these things indicate that Jarmo is the earliest village site yet uncovered in the Near East. One of our keenest hopes was to determine its actual age by means of the radiocarbon method, in which organic substances such as charcoal, shell or burnt bone can be dated by their radioactivity. Even in 1948 we had brought snail shells from Jarmo to the Institute of Nuclear Studies at the University of Chicago, where Willard Libby and his associates developed the radiocarbon method. To these shells Libby's laboratory assigned an age of 4757 B.C. ± 320 years. Libby was reluctant to accept this as a firm date because shell is less reliable than charcoal for radiocarbon purposes. During the past summer, however, he has run tests on two samples of charcoal from Jarmo, one taken from exactly the same site as the shell. The ages of these charcoal samples are 4654 B.C. ± 330 years and 4743 B.C. ± 360 years. In other words, the shell and charcoal dates corroborate one another with a surprising degree of accuracy. This not only suggests the validity of shell dates, but also leaves little doubt that Jarmo began to flourish around 4750 B.C.

Our own date for Jarmo, reckoned by fitting its remains into the accepted "relative" chronology of Near Eastern archaeology, had been 6000 B.C. We suspect that as the possibility for errors is reduced in the still experimental radiocarbon instrumental procedure, and as more samples from the Near East are tested, it will be necessary to bring the whole sequence of Near Eastern prehistoric dates forward in time.

On behalf of the American Schools of Oriental Research we began in March of 1951 to explore the region around Jarmo for even earlier settlements. We first selected Karim Shahir, a two-acre site on a hill two miles up the wadi that runs past Jarmo. Karim Shahir has only one archaeological level; architecturally it consists only of an incomprehensible scatter of stones, each about the size of a human fist. These had been definitely carried to the site, but we could make no architectural sense of them. There was no trace of either stone or pottery vessels. We did find a storage pit, fragments of stone mills and a fair number of chipped and ground stone-hoes—all of which suggest an incipient agriculture.

At Karim Shahir we gathered a great many of the tiny stone blades that the archaeologist calls microliths. We had also found microliths at Jarmo, but there was an important distinction between those of the two sites. All of the Karim Shahir microliths were made of flint; some of those at Jarmo were of the volcanic glass obsidian. The lack of obsid-



MAP of the Near East shows the location of the sites described in this article. Lighter gray shading denotes land higher than 3,000 feet; darker gray shading, land higher than 6,000 feet. Blue shading indicates rainfall.

ECONOMY	HISTORICAL CHARACTERISTICS	PERIOD IN IRAQ
		2000 B.C.
↑ FOOD-PRODUCING	*Civilization:* Fully efficient food production, cities, formal political state, formal laws, formal projects and works, classes and hierarchies, writing, monumentality in art.	AKKADIAN EARLY DYNASTIC
		3000 B.C.
	Era of Incipient Urbanization: New social and political aspects of culture crystallize.	PROTO-LITERATE
	Era of Established Peasant Efficiency: Market towns, temples, expansion into river valleys.	WARKA UBAID
	Era of Primary Peasant Efficiency: Permanent villages, pottery, metal, weaving.	HALAF HASSUNA
	Incipient Agriculture and Animal Domestication.	JARMO KARIM SHAHIR PALEGAWRA
FOOD-GATHERING ↓	*Era of Cave-dwelling Hunters, Fishermen and Food-collectors:* Cultural unit probably small mobile band.	ZARZI BARDA BALKA

DIAGRAM locates the sites shown on the map at the top of this page in time and in cultural development. The names of the sites excavated by the expedition, and the historical gap that is filled by them, are in blue.

ian at Karim Shahir is an example of the difference between the two settlements. The closest known sources of obsidian are several hundred miles away in Turkey; it must have been imported to Jarmo. Thus Jarmo represents a new era in which trade has begun. Karim Shahir is only on the verge of that era.

In every way Karim Shahir seems to represent the cultural stage just before Jarmo: a time when men were probably making their first experiments with agriculture and animal domestication—as well as with that most significant consequence of deliberate food production, village life. We purposely do not call Karim Shahir a village; the deposit there was very thin and it is possible that its population was only seasonal.

From Karim Shahir we extended our exploration in time by investigating the cave of Palegawra, some 15 miles east of Jarmo. Judging by the bones we found in the cave, its occupants were successful hunters of wild horses, deer, goats, gazelles, sheep and pigs. They made long stone blades and minute microlithic tools which must have been mounted, perhaps as harpoons or arrow points. But we found no evidence of agriculture or animal husbandry.

Finally we inspected one still earlier site called Barda Balka. Here the remains indicated men who made flint and limestone hand-axes, pebble-tools and scrapers. They lived a catch-as-catch-can existence, along with extinct elephants and rhinoceroses, in a landscape that must have been very different from the now almost treeless countryside. Although Barda Balka shed no light on our central problem, it provided an archaeological and geological check point for the early cave materials of Iraq.

AS OF NOW the account cannot be any more complete than this. It is clear, however, that we have bracketed the gap in knowledge between the terminal cave-stage and the established village stage in Iraq. Our work adds four new phases to the known sequence of prehistory in a "nuclear" area of cultural activity, but I do not suspect that we have completely closed the gap. Nevertheless, when the reports are all in and the full story can be written, there will be a new understanding of a range of time and of cultural activities which were of vast consequence to human history. The people of Jarmo were adjusting themselves to a completely new way of life, just as we are adjusting ourselves to the consequences of such things as the steam engine. What they learned about living in a revolution may be of more than academic interest to us in our troubled times.

Robert J. Braidwood is associate professor in the Oriental Institute and the Department of Anthropology at the University of Chicago.

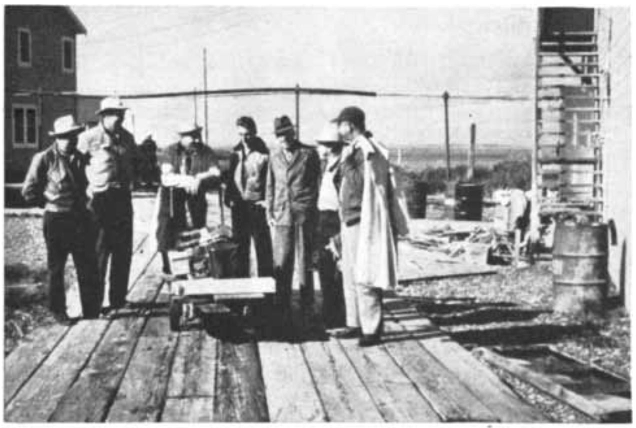
WHALE CARDIOGRAM

In the summer some scientists seek adventure: the Boston cardiologist Paul White and his friends traveled to Alaska and first recorded the heartbeat of a large aquatic mammal

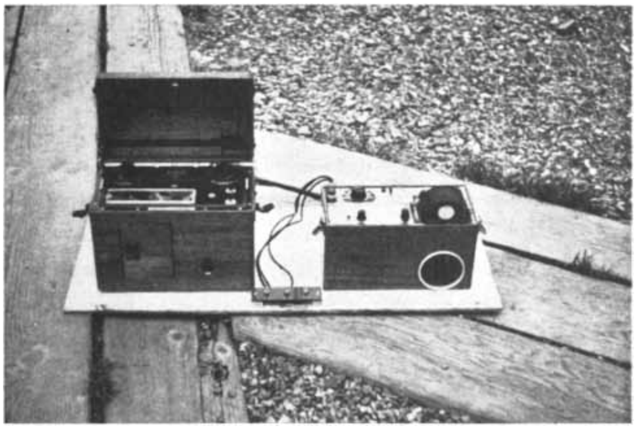
FOR at least 30 years Paul Dudley White, a Boston cardiologist and chief consultant to the National Heart Institute, has nourished an unusual ambition: he has wanted to analyze the heartbeat of a whale. Last August he achieved this feat. In an open boat off the coast of Alaska he and his associates made a five-minute electrocardiogram of a 14-foot, 2,500-pound beluga whale. It is the latest addition to his collection of similar records for animals ranging from mice and hummingbirds through the primates to the elephant. Dr. White notes that his whale was a rather small one, but now that his group has developed a technique for taking electrocardiograms of these aquatic mammals, he plans to pursue a larger specimen.

Dr. White's interest in the hearts of whales and other animals stems from his study of the relation between size and pulse rate in the human heart. It is his belief that in both man and animals the larger the heart, the slower the pulse rate. His evidence to date would seem to confirm this hypothesis. The tiny heart of the hummingbird beats about 1,000 times a minute; the heart of a mouse, perhaps 300 times a minute; the heart of a man, 68 to 72 times a minute. In 1936 Dr. White and his associates made an electrocardiogram of an elephant by inducing it to step on damp pads containing the electrocardiograph leads; the pulse rate of the animal was 35 to 40 a minute.

With Dr. White on his Alaskan expedition were Robert L. King, a Seattle heart specialist who is president-elect of the American Heart Association, and James L. Jenks, Jr., president of the Sanborn Company, which manufactures medical testing apparatus. Their equip-



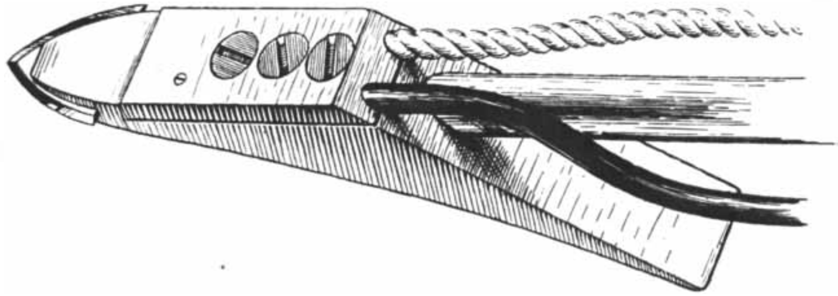
GROUP PICTURE was made before the cardiogram cruise. Dr. King is at right; Dr. White, third from right.



TWO ELECTROCARDIOGRAPHS were used. At left is a direct-writing model; at right, a photographic type.

SKIFF from which the cardiogram was made was 20 feet long. The electrocardiographs were mounted in bottom.

PILOT of the boat was Joe Clark of the Alaska Packers Association. Here he is about to harpoon the whale.

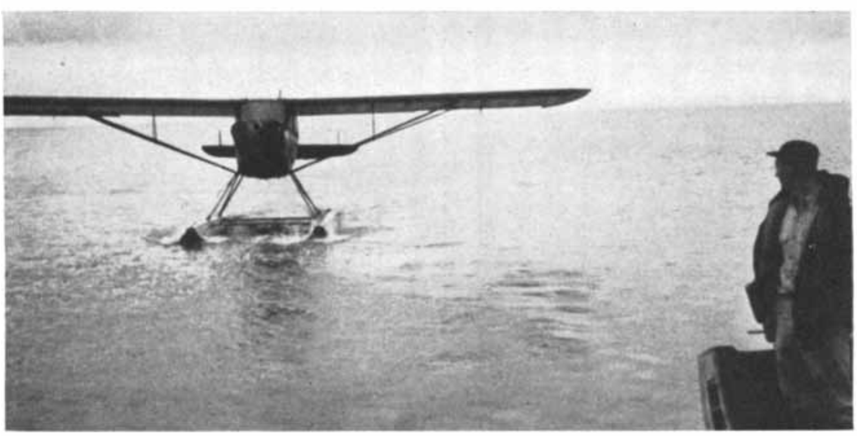


HARPOON was made especially as an electrocardiogram lead. The head is at the left; behind it are nylon rope (*top*) and wire connection (*bottom*).

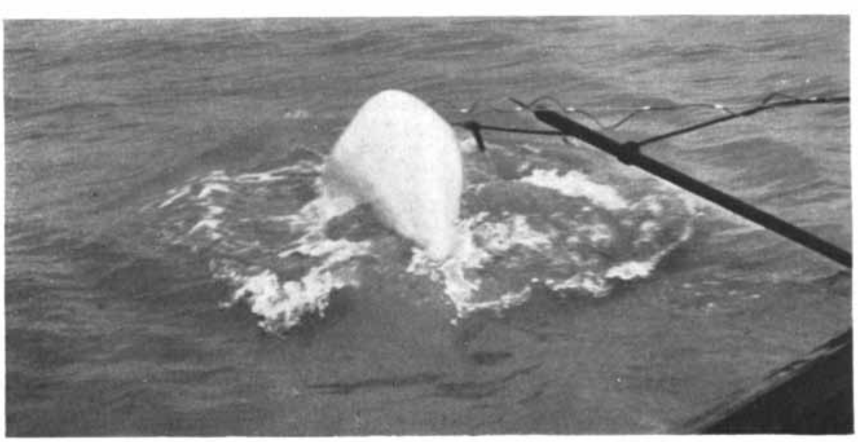
ment consisted of two standard portable electrocardiographs, which were mounted under a tarpaulin in the bottom of a 20-foot whaleboat. The leads of the electrocardiograph were two special brass-headed harpoons; attached to each of them was a connecting cable and a nylon rope. Assisting the investigators were Jeff Davis and Joe Clark, two expert whalers of the Alaska Packers Association.

The party put out from the Aleut village of Clark's Point into the choppy waters of Bristol Bay, off the southwestern coast of Alaska. On their first attempt they harpooned a whale, but were unable to get an electrocardiogram. When they returned, they discovered that a wire to one of the harpoon leads had broken. Their second attempt was successful. When one of the white belugas was sighted, Clark maneuvered the boat close to it and Davis threw a conventional whaling harpoon. This merely captured the whale; the electrocardiograph harpoons were then thrust into it.

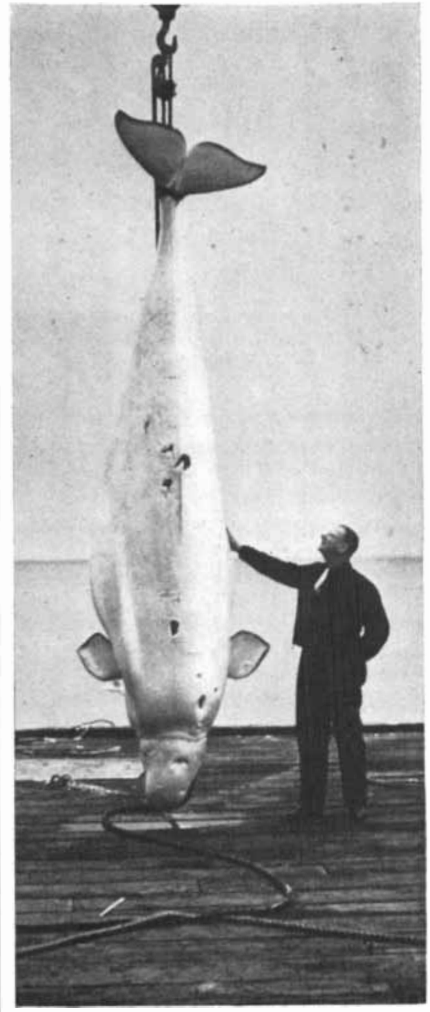
The whale thrashed violently around the bay, towing the boat behind it. While the other occupants of the boat



FLOAT PLANE was employed to spot schools of beluga whales for the expedition, which set forth from Clark's Point on Alaska's Bristol Bay.



WHALE tows electrocardiograph boat trailing rope and wire. The animal was harpooned once to hold it, then twice more to make the cardiogram.



WHALE is inspected by Jenks, who operated the two electrocardiographs. The holes in the carcass were made by the harpoons and by rifle shots that finally dispatched the animal. The whale was then presented to the natives of Clark's Point for meat.

clung to its gunwales, Jenks crouched under the tarpaulin with his electrocardiographs. After a wild ride he emerged and announced that they had made a successful tracing of the whale's heartbeat. The whale was then killed by rifle fire and taken ashore.

The electrocardiogram showed that the pulse rate of the whale was 20 per minute. This was appreciably slower than the heartbeat of the elephant that Dr. White had studied, but curiously the heart of the whale was smaller than that of the elephant. This would seem to upset Dr. White's hypothesis, but the discrepancy had been anticipated. Laurence Irving, a U. S. Public Health Service physiologist in Anchorage, Alaska, had already discovered that when diving mammals such as the porpoise are submerged, they have a heartbeat slower than that of land animals of comparable size. Now Dr. White would like to make the cardiogram of the largest of all animals: the blue whale.

Alchemy and Alchemists

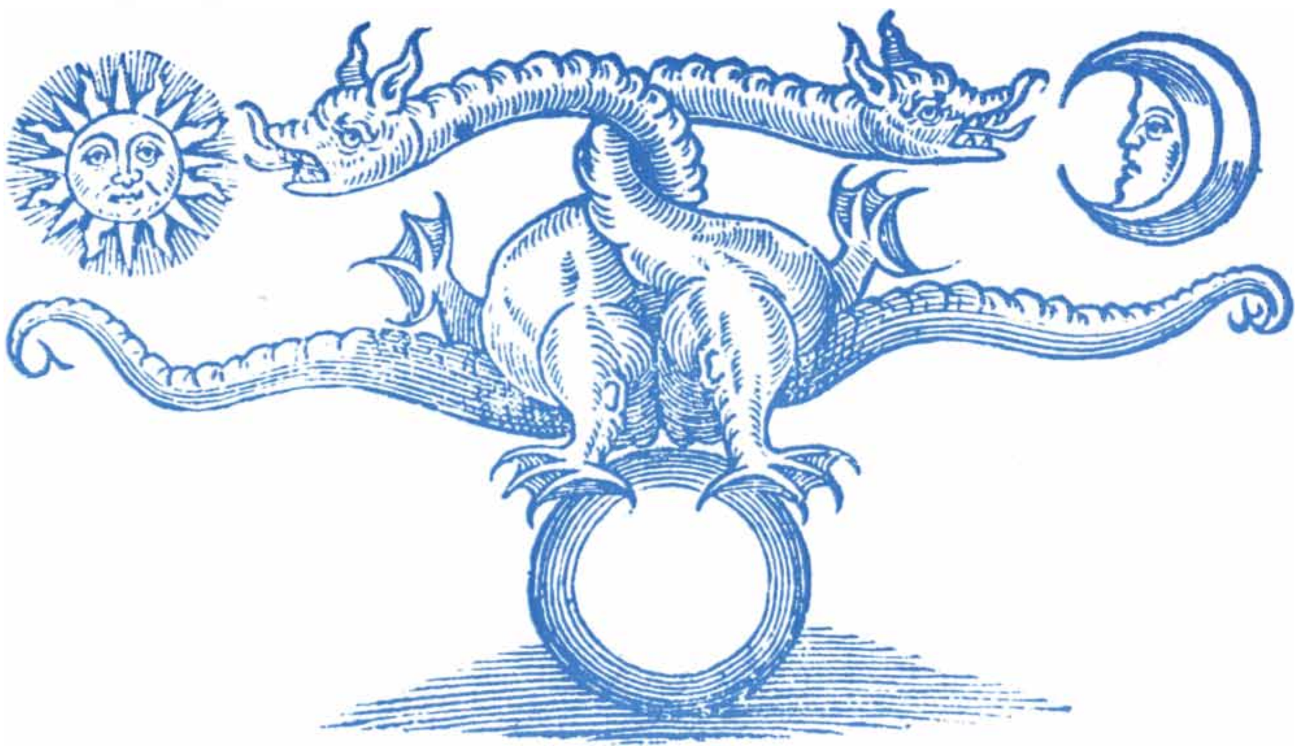
To the disreputable discipline of ancient and medieval times modern chemistry owes its name, its occasionally esoteric symbolism and some of its principal attitudes

by John Read

THE FATHER of the astronomer was the astrologer, the father of the surgeon was the barber and the father of the chemist was the alchemist. In our eyes these prescientific practitioners have a somewhat disreputable air; it may not be in the best taste to remind the modern professions of their dubious forebears. But the increasing specialization of science has produced an increasing need for the broad perspectives history affords, and one does not go back very far in the history of most sciences before coming upon the prescientific era. In the case of alchemy, moreover, it appears that there was more depth to the antique discipline than is generally supposed.

Alchemy is often identified—as in Chaucer's *The Canon Yeoman's Tale* and Ben Jonson's play *The Alchemist*—with questionable attempts to transmute the base metals, such as tin and lead, into their noble relatives silver and gold. Such an assessment of alchemy is superficial. A 19th-century French scholar named Albert Poisson saw much deeper when he wrote that scholasticism, theology and astrology, with their infinite subtleties, ambiguities and complications, were but child's play in comparison with alchemy. In its fullest sense alchemy was a philosophical system containing a complex and mobile core of rudimentary science and elaborated with astrology, religion, mysticism, magic, theosophy and many other constituents. Alchemy dealt not only with the mysteries of matter but also with those of creation and life; it sought to harmonize the human individual with the universe surrounding him. On the material plane it sought to perfect base metals into gold; on the spiritual plane it sought to perfect man himself. Aristotle held that Nature strives toward perfection, and alchemy sought to hasten the attainment of this goal. Alchemy endured for more than 1,000 years; it is not surprising that its conceptions pervaded the thought, art and imagery of the Middle Ages.

Alchemy's birthplace is not known. Its origin is often ascribed to Egypt, or Khem, the land of dark soil, the Biblical Land of Ham. Hence this "art of the dark land" was designated as *al khem* in its passage through Islam, and reached the Western world under the name of alchemy. The medieval



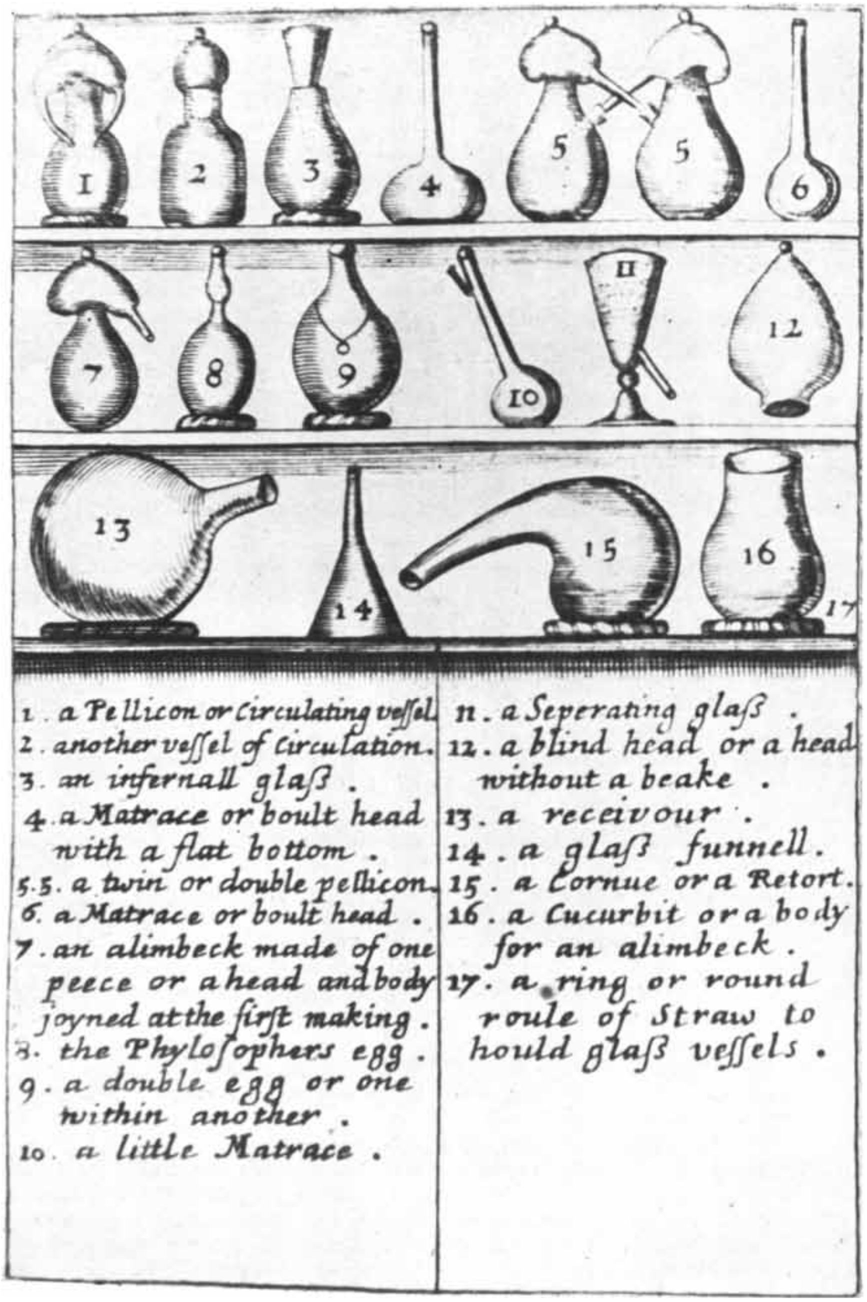
EMBLEM of the sulfur-mercury theory appears in the 17th-century English work *Theatrum Chemicum Britannicum*. The dragon pointing toward the sun symbolizes sulfur; the dragon pointing toward the moon, mercury.

alchemists often called themselves "Sons of Hermes," in allusion to their patron Hermes Trismegistos, or Hermes the Thrice-Great. The Greek Hermes was related in turn to the Egyptian god Thoth, a deified representation of the intellect. In Hermes the alchemical fraternity recognized not only the father of the so-called Hermetic Art but also the author of the Emerald Table. This famous creed set forth the true doctrine of alchemy in a series of 13 cryptic precepts. The fourth of these refers to the Philosopher's Stone in the words: "Its father is the Sun, its mother the Moon; the Wind carries it in its belly, its nurse is the Earth." Cryptic expression of this sort was one outstanding characteristic of alchemical literature; symbolic representation was another. Chemistry inherited some of the cabalistic nature of its parent and even today makes use of a wide range of symbols incomprehensible to the layman.

THE PROOF that alchemy was invented by the Egyptians, or by any Western people, is not conclusive. Indeed, considerable evidence has been produced for an Eastern birthplace—possibly in Chaldea, more likely in China. Alchemy had close links with astrology; and in Chaldea the sun, moon and planets were associated with individual metals, as well as with specific organs of the human body and with human destinies. As early as the fifth century B.C., alchemical ideas were prevalent in China, particularly in the religious and philosophical system of Taoism. In the second century after Christ Wei Po-Yang, sometimes called the father of Chinese alchemy, wrote the first Chinese treatise on the subject. In it he described the preparation of an *Elixir Vitae*, which he termed "the pill of immortality."

Whatever their true source may have been, it is clear enough that the early alchemical conceptions prevailing in ancient Egypt, Babylonia, Assyria, India and China were integrated in the Greek philosophy of the Alexandrian age. This better-defined body of lore then moved on to Islam, largely by way of Syria and Persia. In the 12th century it began to percolate into western Europe, chiefly through Spain.

Although enmeshed in a bewildering variety of subsidiary conceptions, the fundamental principles of alchemy can nevertheless be singled out. First, all kinds of matter are traced by the alchemist to a common origin. Second, these multifarious species were produced by evolutionary processes. Third, and consequent upon the foregoing, all species of matter possess one permanent soul which is housed in a variety of temporary bodies. Since these bodies are transitory, they can be changed or transmuted, thus allowing matter to

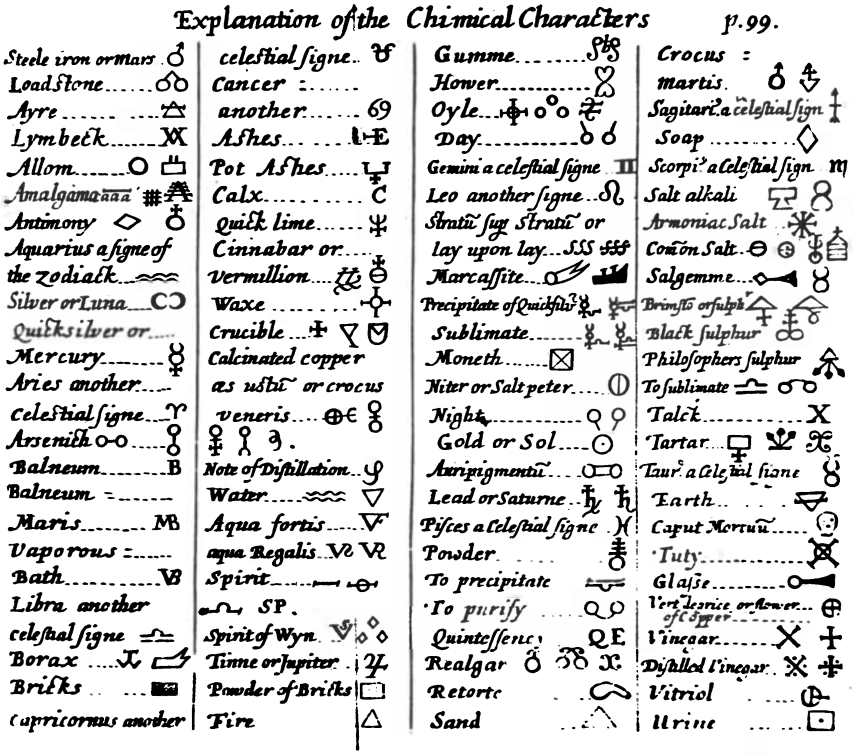


VESSELS of the alchemist resemble some in the modern chemical laboratory. These appear in the 17th-century *A Compleat Body of Chymistry*.

pass from one state to another. This view of the ultimate constitution of matter does not differ essentially from the one held by modern physical science. Transmutation is no longer regarded as a necromancer's vision. In the present century "modern alchemy," as Lord Rutherford termed it, has effected many transmutations of elements.

In addition to affirming the unity of matter alchemy proclaimed the existence in Nature of a transmuting agent of fabulous power. This agent, which alchemists strove to acquire by the correct practice of their art, became known as the Philosopher's Stone. The base nature of metals like tin and lead was often regarded as a disease which could be cured by means of the Stone. From the postulate of the unity of all things it followed that the medicine of the metals should also function as the medicine of man. In this way the Stone came to be looked upon as a universal remedy for human ills, under some such name as the *Elixir Vitae*.

THE OLDEST theory of physical science—that of the Four Qualities and Four Elements—was closely associated with alchemical conceptions. Although usually ascribed to Aristotle, it was entertained long before his time in both Egypt and India. The theory



SYMBOLS of the alchemist are reflected in the similar usages of modern chemistry. These also appear in *A Compleat Body of Chymistry.*

designated earth, water, air and fire as the four elements of the material world and arranged them, with the four qualities of cold, wet, hot and dry, in the scheme shown in the diagram at the top of page 76.

The diagram expresses the belief that each element is an embodiment of two qualities taken from a set composed of two pairs of contraries. Water is wet and cold. When its coldness is replaced by heat, this element undergoes a change into "air," which is wet and hot. Thus the possibility of transmutation is implicit in the theory. In modern terms liquid water passes into gaseous water (steam) when heated. Similarly three of these elements may be held to represent the solid, liquid and gaseous states of matter, while the fourth (fire) represents energy.

At bottom the theory rests upon a primitive mode of thinking sometimes known as the Doctrine of the Two Contraries. In alchemy the opposed elements, or contraries, fire and water, assumed a role of the first importance in the sulphur-mercury theory of the constitution of metals, which seems to have arisen during the Islamic period of alchemy, about the 9th century after Christ. "Sulphur" is here essentially the quality of combustibility, and "mercury" that of metallicity, fusibility or liquidity. These two principles were believed to come into contact in the bowels of the earth and, depending upon their degree of purity, to produce base or noble metals. Sulphur and mercury of superfine quality would yield the Philosopher's Stone, a substance so much purer than ordinary gold that a few grains of it could change a large amount of base metal into gold of ordinary purity. It was held that the alchemist in his laboratory should be able to imitate, or even surpass, Nature in this refining process.

The two principles, often called "sophic sulphur" and "sophic mercury," enjoyed great eminence in alchemical expression and symbolism, and assumed a bewildering number of guises. They were called Sol and Luna, sun and moon, Osiris and Isis, king and queen, brother and sister, masculine and feminine, active and passive, giver and receiver, fixed and volatile, toad and eagle, wingless lion and winged lioness and so on in almost endless variety.

A NOTION that prevailed among the adepts of alchemy was that chemical processes could be applied to ordinary gold and silver so as to extract their "seeds," otherwise sophic sulphur and sophic mercury. Through the conjunction of these seeds, often shown as occurring in a menstruum (solvent), such as the Hermetic Stream or the Bath of the Philosophers, it was supposed that the Philosopher's Stone could be achieved. This union was symbolized sometimes as a marriage, sometimes by a representation of the Hermetic Androgyne, Rebis or Two-Thing, and in many other ways. The final stages in the so-called Great Work, leading to the synthesis of the Stone, were carried out in the sealed Vase of Hermes, or Philosopher's Egg. The successful achievement of this Grand Magisterium was marked by the appearance in the Vase, during its heating in the alchemical furnace, or athanor, of a sequence of colors ending in red. As Thomas Norton of Bristol wrote in 1477, "Red is last in work of *Alkimy.*"

These fundamental alchemical conceptions were elaborated in many ways. Sometimes they were linked with Biblical episodes; often they referred freely to classical mythology. An alchemical manuscript in the collection of the Chemistry Department of the University of St. Andrews has a colored illustration depicting the birth of Eve from Adam's rib, with the Serpent as an interested and sardonic spectator. This is essentially a form of the Hermetic Androgyne, the liquid menstruum being represented by the Serpent and the pool of water in the foreground of the picture. As a simple example of the adaptation of classical mythology in the service of alchemy, Apollo and Artemis (Sol and Luna, or sulphur and mercury) are sometimes shown in the arms of Leto, their mother, confronted by the Serpent (menstruum) sent by the jealous Juno to terrorize them. Count Michael Maier, serving at the 17th-century court of the Emperor Rudolph II, "the German Hermes," was one of many alchemists who held seriously that the whole body of classical mythology had been designed expressly as an allegorical medium for concealing the cherished truths of alchemy.

There are many subsidiary alchemical conceptions, of which one interesting example is the Saturnine mysticism. This intricate discipline includes the idea of a rebirth or renewal of life, succeeding a stage of the Great Work known as *putrefactio,* or death. The "seeds" of metals, like seeds of plants (as was wrongly supposed in medieval times), had to die and putrefy before they could be revivified and ennobled. Thus the dissolution of gold in *aqua regia* might be expressed as the death of the king and represented in an appropriate symbolic design; the subsequent recovery of the gold could then be depicted as the resurrection of the king. Similarly lead could be "killed" or "mortified" by what we should now call oxidation; it could then be revivified by reducing the resulting oxide.

THE TERM alchemist, as used in Europe of the Middle Ages and later, embraced many types of men having a real or professed knowledge of alchemical tenets and practice. They ranged from the most unscrupulous charlatans to the purest religious mystics. Simon Forman (1552-1611), the original of Subtle in *The Alchemist,* was a typical quack. He assumed the title of alchemist merely to impress his clients, mostly credulous society ladies in search of

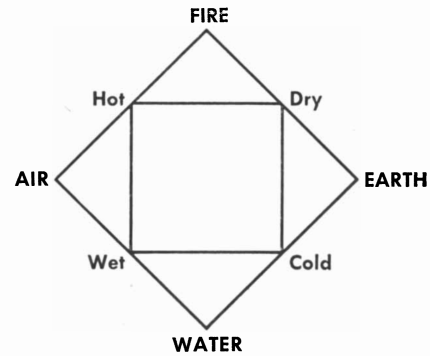
charms, love-philters, spells and enchantments. In another group were the pathetic "puffers" or bellows-blowers. These men were for the most part simple practitioners, ignorant of the esoteric principles and tenets that the adepts of alchemy concealed so elaborately in their cryptic writings and pictorial symbolism. A confirmed puffer was almost certain to dissipate his possessions in pursuit of gold.

A more rewarding career as a professed goldmaker was enjoyed by Michael Sendivogius, the "noble Pole," who is said to have carried out a dramatic transmutation before the Emperor Rudolph II at Prague in 1604. The Emperor commemorated the episode by affixing to the wall of the room where it took place a marble tablet, bearing in Latin the inscription: "Now let someone else attempt this which Sendivogius the Pole has done!"

In addition to the purists among the alchemical adepts, many of whom devoted their lives to solitary reflection on the cryptic writings of their predecessors, there were men like Agricola, Libavius and Glauber who delighted in the discovery of new substances and processes. Others like Roger Bacon and Albertus Magnus, in an earlier era, operated on the higher plane of scholastic philosophy. Finally the religious mystics viewed alchemy as "the divine Art," and they thought transmutation important only as a material proof of their theology.

Once alchemy had penetrated to the countries of western Europe this structure of elaborate mystification crystallized and held sway over men's minds century after century, unanimated by new ideas or fresh goals. Then Paracelsus early in the 16th century gave it a new trend by diverting the efforts of its followers from attempted goldmaking to the preparation of chemical remedies for human ailments. Paracelsus, a propagandist and reformer, tried to follow Luther's example in religion and emancipate science and medicine from the trammels of authority. His efforts inaugurated a period of medico-chemistry and from that time on the old alchemy gradually declined, although the 17th century witnessed a revived interest in goldmaking and alchemical mysticism. Paracelsus modified alchemical theory by propounding his system of the *tria prima*, or three principles. These were named "sulphur," "mercury," and "salt." Materially they represented inflammability, metallicity and fixity; mystically they denoted the soul, spirit and body of man.

In 1661, 120 years after Paracelsus' death, Robert Boyle published his *Skeptical Chymist*, wherein he put forward the modern idea of a chemical element and struck a fatal blow at both the theory of the Four Elements and of the *tria prima*. But alchemy was deeply entrenched and died slowly. Modern chemistry did not really emerge for another 100 years. During this Indian summer of alchemy the new Theory of Phlogiston held the stage while the four elements and the three principles hovered like uneasy ghosts behind the scenes. Phlogiston, a principle of inflammability thought to be present in all combustible bodies, was essentially a revival of sophic sulphur and claimed noble descent from the Sun-god of the primitive religions. The fires of Phlogiston were finally put out by the discovery, in the second half of the 18th century, of the true composition of the ancient "elements" air and water and of the real nature of combustion. These events ushered in the era of modern chemistry.



ALCHEMICAL THEORY of Four Qualities and Four Elements was presented in the form of a diagram.

ALCHEMY has been a dead science for at least 200 years, but modern chemistry owes much more to it than its name and its esoteric symbolism. Baron Justus von Liebig, the 19th-century German chemist, held that without the idea of the Philosopher's Stone, acting powerfully and constantly on the minds and faculties of men, "chemistry would not now stand in its present perfection. . . . In order to know that the Philosopher's Stone did not really exist, it was indispensable that every substance accessible . . . should be observed and examined . . . it is precisely in this that we perceive the almost miraculous influence of the idea." Francis Bacon gave a shrewd summary of alchemy's contributions to science in his *De Augmentis Scientiarum*: "Alchemy may be compared to the man who told his sons that he had left them gold buried somewhere in his vineyard; where they by digging found no gold, but by turning up the mould about the roots of the vines, procured a plentiful vintage. So the search and endeavours to make gold have brought many useful inventions and instructive experiments to light."

John Read is professor of chemistry at the University of St. Andrews and a Fellow of the Royal Society.

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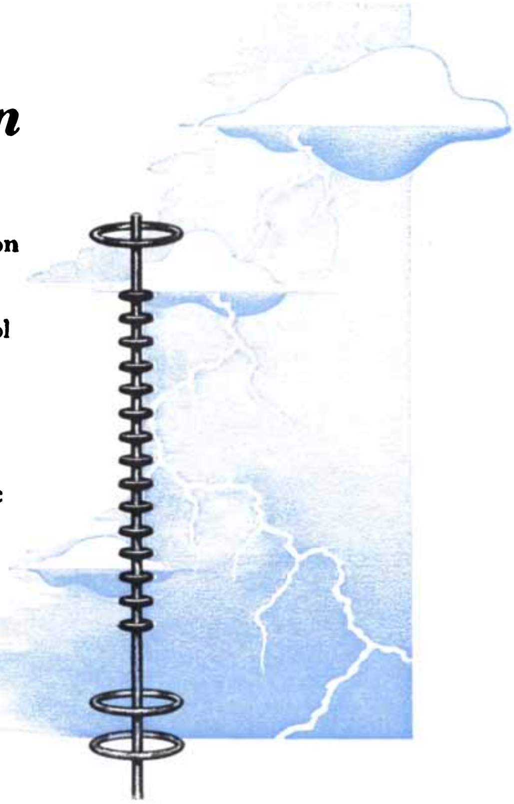

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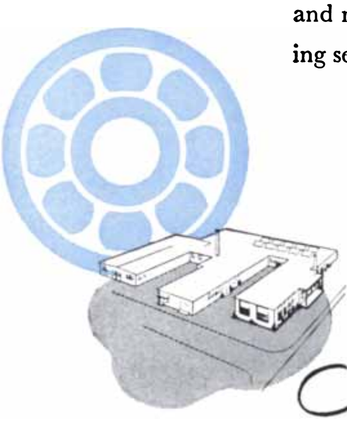

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The Rise of Water in Plants

How do tall trees elevate water to their highest leaves? An early investigator made some surprisingly perceptive guesses, but it took two centuries to corroborate them

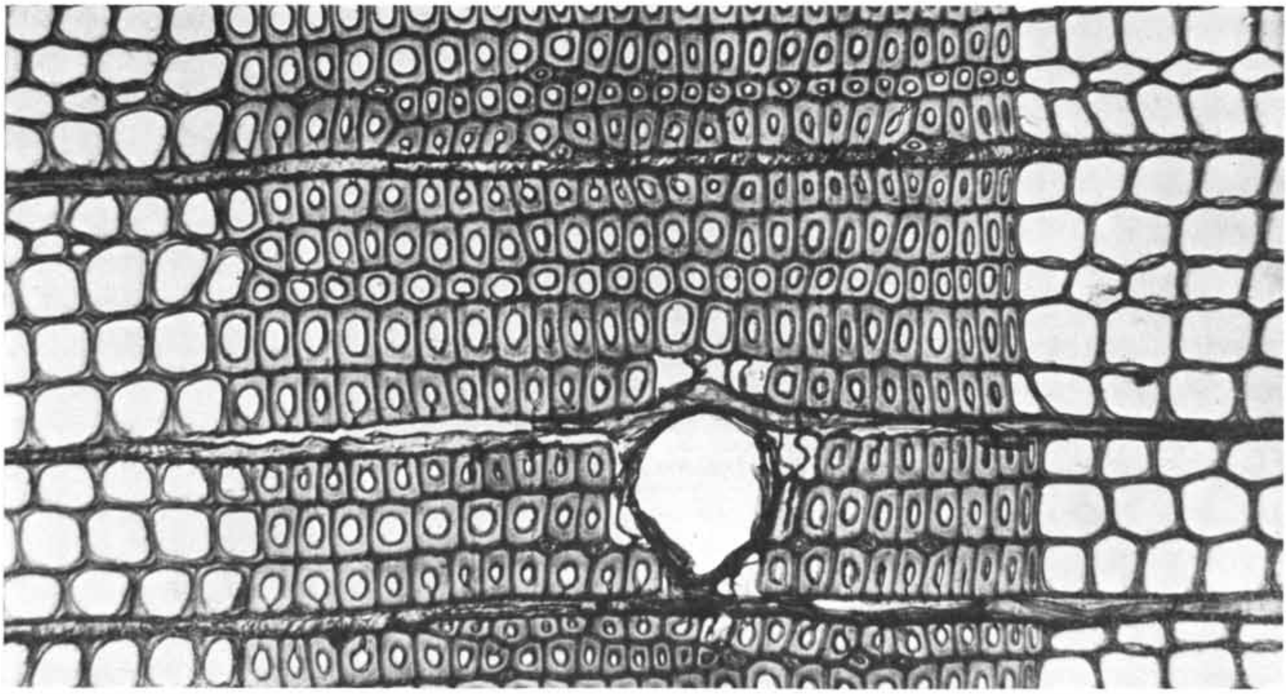
by Victor A. Greulach

THE giant redwood trees of California are very tall, but the Douglas firs of the Pacific Northwest are even taller; some of the firs have been known to reach a height of 400 feet. To reach the highest leaves of such a tree, water must rise from roots beneath the ground, a vertical distance of approximately 450 feet. How does the tree force its sap to this great height? Botanists have been puzzling over the problem for more than 200 years; even today we do not know the complete story of how water travels upward through plants.

Many wrong explanations have been proposed, and have enjoyed more or less wide acceptance. Yet as early as 1727 what we now believe to be the true account had been suggested. That was the year when Stephen Hales, a versatile English clergyman and scientist, published his *Vegetable Staticks.* In this historic work Hales laid the foundation for the science of plant physiology. A good portion of the book concerns his experiments on the rise of water in plants. Hales' methods and conclusions are surprisingly modern. Of the two mechanisms that are now thought to account for the phenomenon, he did considerable work on one, and at least hinted at the other.

What are the facts that a successful theory must explain? First, it must account for the origin of rather large forces. Merely to raise water 450 feet requires a pressure or tension of about 210 pounds per square inch. Friction between the water and the walls of the tubes which conduct it may call for almost as much force again, making the total 420 pounds per square inch.

Second, the theory must account for the speed of ascent and the volume of flow of water in plants. In some hard-



TRACHEIDS running through the wood of a shortleaf pine are revealed in cross section by this photomicrograph. At left and right are the thin-walled tracheids of spring wood; in center, the thick-walled tracheids of summer wood. This difference in tracheids is responsible for the annual rings. The large clear circle is a resin duct.

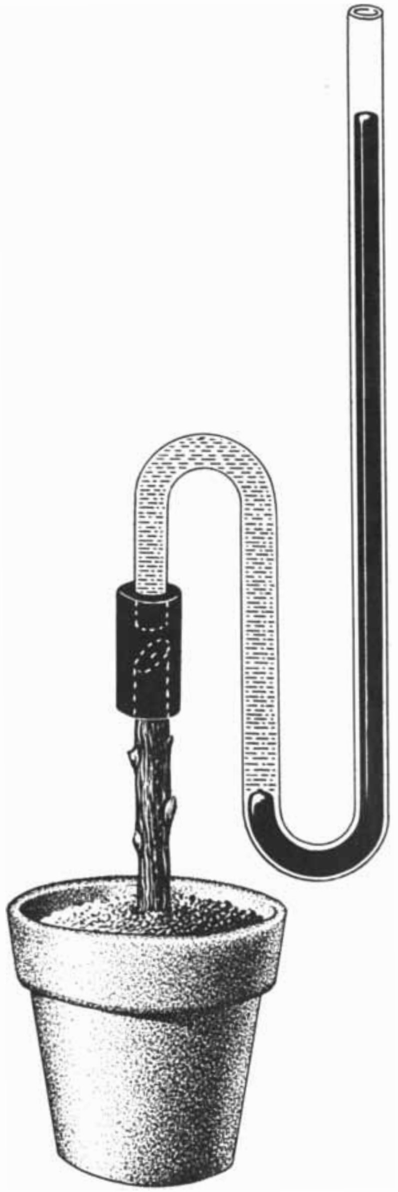
wood trees it rises at the rate of almost 150 feet per hour. A date-palm tree in a desert oasis may need to raise as much as 100 gallons of water a day to make up its losses from transpiration (evaporation, mostly from the leaves).

Finally the explanation must fit the facts of plant anatomy and physiology. The upward flow of water in plants takes place in the xylem, or woody tissue. Throughout the xylem are many dead cells consisting only of cell walls and a central cavity. It is through these cavities that water passes. In trees of the pine family the water-conducting cells are called tracheids. They have spindle-shaped bodies as long as 3/16 inch and up to .0012 inch in diameter. In hardwood trees there are few tracheids; most of the water is carried through vessels that consist of chains of tubular cells whose end walls have dissolved away. These vessels may be more than three feet long and up to .015 inch in diameter.

THE problem is to find the mechanism that forces the liquid up through these inert pipes. Probably most laymen, and even the authors of some biology textbooks, would answer that the water moves up by capillary action. Even in the thinnest tracheids, however, capillary rise could amount to no more than five feet, while in the larger vessels the limit would be two or three inches. Some students have pointed to minute tubes which exist in the walls of vessels and tracheids, claiming that capillary rise might take place in them. But we know that water moves through the cavities and not the walls, because plugging the cavities cuts off all flow.

There have been several so-called vital theories which hold that the living tissue in the xylem surrounding the vessels or tracheids acts in some way to force the water up. But plants whose stems, and even roots, have been killed may continue to absorb and conduct water for several days. The point was proved on a heroic scale by a German botanist named Eduard Strasburger. He cut off a 70-foot oak tree close to the ground, immersed the end of the trunk in a vat of picric acid to kill its living cells, then dipped it in water and found that the water still moved to the top of the tree.

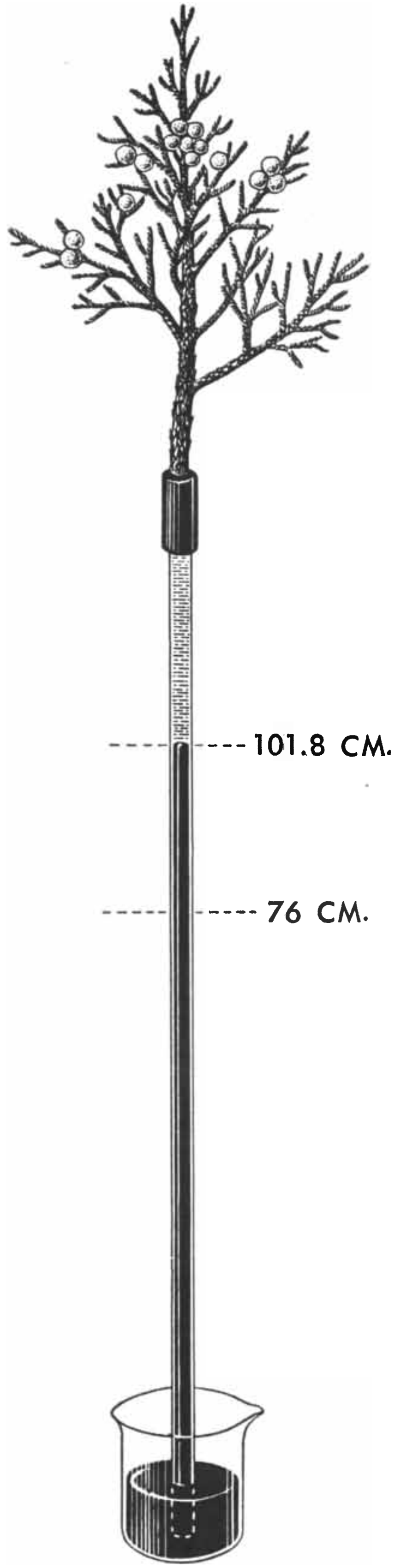
A more satisfactory explanation, in that it probably does account for the rise of water in some plants some of the time, is the root-pressure theory, originating in the work of Hales. He found that plant roots sometimes develop pressure due to their osmotic absorption of water from the soil, and suggested that this pressure accounted for the rise of liquid in the stem. Root pressure cannot, however, be the full answer, as Hales himself recognized. The greatest values of this pressure are far too small to raise water to the tops of tall trees; moreover some plants develop no root pressure at all. Finally this mechanism could not elevate water nearly as fast as the sap sometimes rises in trees.



ROOT PRESSURE is demonstrated by fastening a mercury manometer to a cut stem. When water is forced up through the stem by the roots, the mercury rises in the tube at right.

The only theory that seems to meet all the requirements was proposed in 1895 by H. H. Dixon, an Irish plant physiologist, and his co-worker J. Joly. It is variously called the cohesion theory, the transpiration stream, the transpiration-cohesion-tension theory and the Dixon theory. We shall add still another name—shoot tension—which is probably more accurately descriptive and which is comparable to the term root pressure.

The theory turns on an often-overlooked quality of water itself—its cohesion. If water is enclosed in a thin,



SHOOT TENSION is proved by joining a cedar twig to a tube filled with water (*top*) and mercury (*bottom*). Atmospheric pressure will hold the mercury at 76 centimeters; the twig will lift it to 101.8 centimeters.

air-tight tube, and does not contain too much dissolved gas, it has great tensile strength. Under the proper conditions such a column of water can withstand a pull of 5,000 pounds per square inch. Plant sap does not have quite as much cohesion as water, but its tensile strength has been measured at 3,000 pounds per square inch. Such a pull could theoretically lift a column of sap to a height of 6,500 feet, surely enough to account for the rise of sap in the tallest trees.

THE sap, then, is capable of being pulled up. What pulls it? The force comes not from high pressure below, but low pressure above—the low diffusion pressure of water in the cells of leaves and other living parts of the shoot. As water is lost from the leaf cells by transpiration, or is used up in photosynthesis, digestion or growth, a water deficit is created in these cells. The resulting drop in their diffusion pressure causes the water to move inward from the liquid in the xylem by osmosis, and thus the entire water column, which is continuous from the leaves down to the roots, is pulled up. This in turn increases the difference in diffusion pressure between the root water in the tissues and the soil water, and water diffuses rapidly into the roots.

The tensions developed in the living cells of the shoot are more than adequate to pull water to the tops of even the tallest trees. Furthermore, the walls of the vessels and the tracheids have been found to be strong enough to prevent their collapse when the water in them is under tension, and they also appear to be sufficiently air-tight. The pressure differential between water in leaf cells and water in the soil is usually from 300 to 400 pounds per square inch, and may be even more. It is possible that the maximum shoot tension developed by trees of a particular species is an important factor in determining the maximum height to which these trees can grow. Shoot tension also accounts for the most rapid rate of water movement known in plants. In fact, the water is pulled up just as quickly as it is lost or used, provided the soil contains an adequate supply.

There are no basic theoretical objections to shoot tension as the mechanism of water-rise in plants, but it is rather difficult to understand how it can operate so efficiently. Why do the water columns not break as the tree sways in the wind? Why does cutting off a branch, even a large one, not disrupt the system? We cannot yet answer such questions, but they do not seem serious enough to undermine the theory.

In addition, we have considerable direct evidence that shoot tension is actually operating in plants. If a vessel in a stem is laid bare and punctured with a fine needle, the water column in it snaps apart, as would be expected

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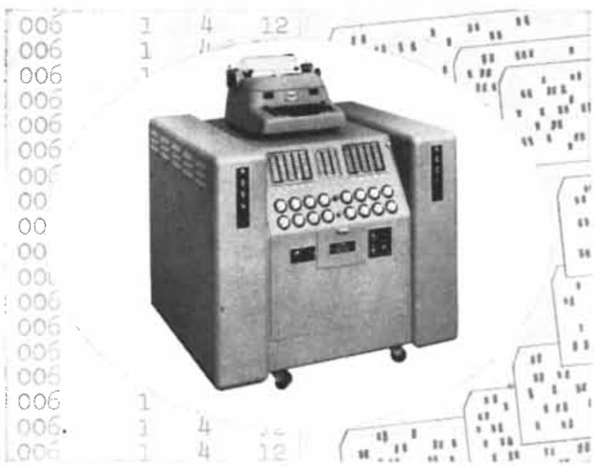

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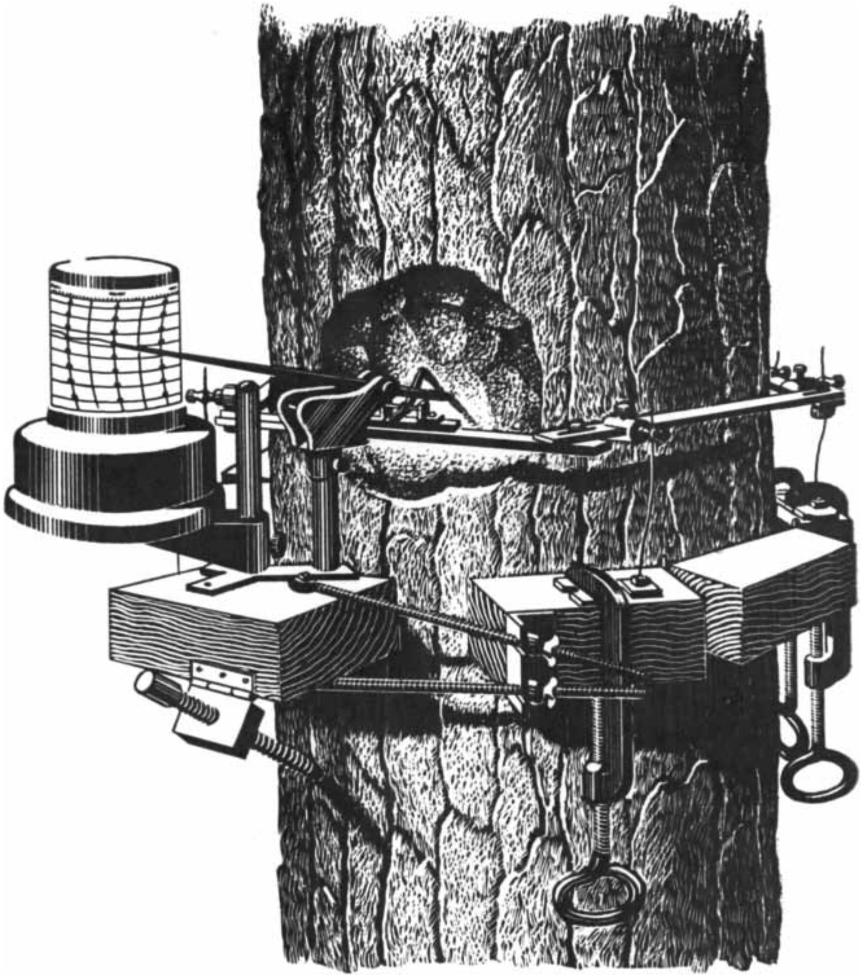

DENDROGRAPH showed that the trunk of a tree is slightly smaller during the day than at night. Because water in the trunk would be under greater tension during the day, this supported the theory of shoot tension.

if the water were under tension instead of under pressure. H. F. Thut of Eastern Illinois State College has demonstrated tension in another way. He attached tree branches to long glass tubes filled with air-free water and immersed in containers of mercury (*see diagram on page 80*). The tension created by the branches raised the mercury as high as 40 inches, or about 10 inches higher than it could be forced by the pressure of the atmosphere. This was equivalent to a water-rise of about 46 feet. Still another experiment was performed by D. T. MacDougal of the Carnegie Institution of Washington. He reasoned that, if water ascends in trees by shoot tension, the trunks should be slightly smaller in diameter during the day, when the water is under greater tension and is moving most rapidly, than at night. The inward pull on the walls of each vessel should add up to an appreciable decrease in diameter of the trunk as a whole. MacDougal designed an extremely sensitive device known as a dendrograph, which by a system of magnifying levers could record minute changes in the diameter of the tree trunks. He found that the trunks of trees are indeed somewhat thinner during the day.

ALL this seems to add up to the fact that shoot tension accounts for the ascent of water in most plants most of the time, although root pressure apparently provides the motive force in some plants some of the time. Now let us turn back some 200 years to Hales and his *Vegetable Staticks*. After extensive accounts of his careful experiments on root pressure he concludes: "These last experiments all show, that although the capillary sap-vessels imbibe moisture plentifully; yet they have little power to protrude it farther, without the assistance of the perspiring leaves, which do greatly promote its progress." Hales can be excused for believing that perspiration (transpiration) is required, for even today botanists assume that it is a component of the shoot-tension mechanism. Actually any use of water will provide the necessary water deficit.

Victor A. Greulach is professor of botany at the University of North Carolina.

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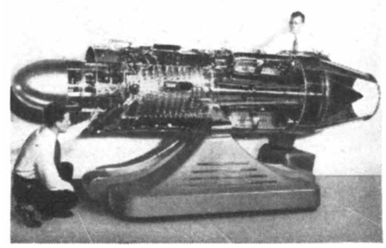

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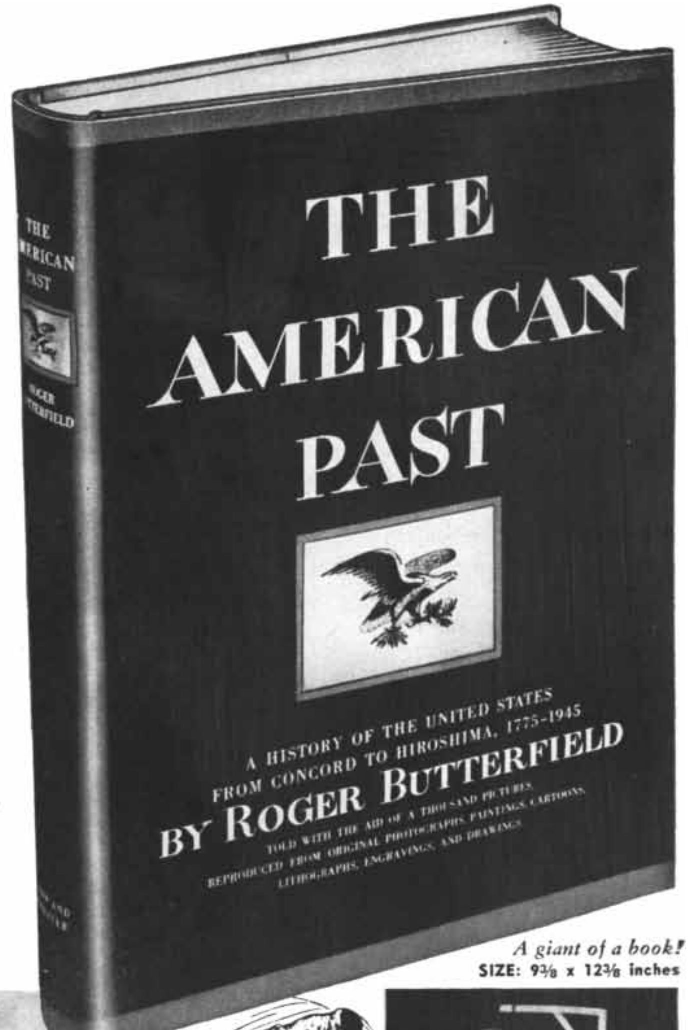

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BOOKS

An account of the origin and development of the most influential invention: writing

by James R. Newman

A Study of Writing, by I. J. Gelb. University of Chicago Press ($5.00).

THE history of invention may be defined as a branch of knowledge dealing only with trivial events. This is not to say that all inventions are trivial, but rather that almost nothing is known about those which have contributed most to man's development. Obvious examples are the wheel, the sail and the art of writing. "Writing," says Professor Gelb, "like money, or the wireless, or the steam engine, was not invented by one man in one certain place in one particular period. Its history and prehistory are as long as the history of civilization itself." Dr. Gelb, an Assyriologist at the Oriental Institute of the University of Chicago, has undertaken a broad survey. His work covers the earliest stages of writing, in which meaning is conveyed by pictures (semasiography), as well as the later stages, in which writing becomes the vehicle of language, the "graphic counterpart of speech" (phonography). The subject is complex; not only because a large number of tributaries flow, after long and winding journeys, into the main stream, but because the attempt to trace these feeders to their origins, to catch even a glimpse of their sources, is soon frustrated by the mists of prehistory.

The forerunners of writing are many and varied. All over the world, and dating from earliest Paleolithic times, are to be found traces of man's imaginative powers and his urge to express himself. These include crude rock-drawings and -carvings in North America, graceful rock-paintings in Southern Rhodesia, the magnificent cave-paintings of animals in France and Spain. It is often impossible to say why the pictures were drawn; at other times their purpose is self-evident. They may represent magic, religious or esthetic impulses; they may commemorate an important personal or group experience—the success of the hunter, a military victory; they may be geometric designs of unknown purport, developed schematically from earlier picture-forms (*e.g.*, the transition of the so-called "hallelujah man"—a man in a praying posture with hands raised—into simple linear designs); they may convey a clear message, as for example a New Mexico rock-drawing which, placed near a precipitous trail, depicts a horse tumbling over on its rider, while a mountain goat climbs serenely. "Identifying-mnemonic" pictures are used to chronicle the important events of successive seasons, to enter a census of tribal population, to identify an artisan, to prepare a roster of proper names, to record songs, feasts, ceremonial scenes and, last but not least, proverbs. The Ewe tribesmen of Togo, in Africa, have an assortment of sayings which Polonius would have envied. The picture of a thread following a needle is the equivalent of "Like father like son"; a man pointing at his chest (meaning "mine") and another man holding in his left hand the object found, signifies the opposite of "finders-keepers"; the proverb "The world is like a baobab tree . . . so great that it is impossible to embrace it, is expressed by the picture of a man trying in vain to stretch his arms between the tree and the world (symbolized by a circle)"; and finally a proverb for military planners, "Two opponents cannot last"—because sooner or later one of them must retreat—is portrayed by two men armed with bows and arrows.

The Aztec and Maya systems, while not reaching the word-syllabic level of writing, mark a distinct advance over their North American and African counterparts. The symbols are often of striking beauty, and they show considerable progress by both peoples in the "systematization of the formal aspect of writing." Each system contains examples of phonetization. The Mayas attained exceptional proficiency in mathematical and astronomical notation. "The Central American method of writing numbers and things counted as, for example, in the writing of '5 men' by means of the number '5' and the sign for 'man,' is identical with that of the Oriental writings and is totally different from the childish and primitive method employed in the North, where the expression '5 men' would have to be written by means of five separate pictures of man." The Maya hieroglyphs are in no sense held to be a "real writing," matching the Egyptian hieroglyphs. A proper assessment of Maya writing, however, must wait upon a complete decipherment of its symbols.

In Dr. Gelb's view the Sumerians, that fabled people of Mesopotamia who for at least 1,500 years dominated the culture of the Near East, took the first step toward a "fully developed writing." Gelb distinguishes no less than seven systems of phonographic writing—in which conventional marks correspond to linguistic elements—originating in the Orient (roughly defined as the land mass extending from the eastern shores of the Mediterranean to the Western Pacific). These include the proto-Elamite, the proto-Indic, the Chinese, the Egyptian, the Cretan, the Hittite and the Sumerian. The Sumerian "is the oldest (*circa* 3100 B.C.) and the only one in which ample illustration is available for reconstruction of the earliest stages." We are cautioned, however, against flatly proclaiming the Sumerians the "inventors" of Mesopotamian writing, not only because of Gelb's general aversion to the loose use of this word, but because it is thought that an unknown ethnic group (the "X-element") inhabiting Mesopotamia alongside, or even before, the Sumerians may have been responsible "for first introducing what became known later as Sumerian writing."

The symbols of this writing are little strokes incised on clay with a stylus. The natural pressure applied by the scribe to one corner of the stylus gave the strokes a wedge-like appearance; whence the name cuneiform (from the Latin *cuneus*, meaning "wedge"). Cuneiform evolved from an earlier pictographic stage of Mesopotamian writing, examples of which occur on several thousand tablets recently discovered at Uruk (Biblical Erech) in the southern part of the Tigris-Euphrates Valley. Uruk writing is logographic; that is, it consists of separate word-signs for numerals, objects and personal names. In primitive logography the sign is simply a picture of the object it denotes: a picture of a sheep is the word "sheep"; of the sun, the word "sun." In time the sign comes to represent not only the object it depicts but words with which the object is associated; thus the word-sign for sun may also stand for "bright," "white," "day"; a picture of a woman and a mountain for "slave girl"—a "combination derived from the fact that slave girls were normally brought to Babylonia from the surrounding mountains." The limitations of this method are easily seen. It cannot express parts of speech and grammatical forms, it is imprecise and, as vocabulary and the demands on writing increase, it becomes enormously cumbersome. Perhaps its most obvious shortcoming is in rendering personal names. A common Sumerian name of the type Enlil-Has-Given-Life is hard to draw. When, as often happened in larger communities, several persons had the same name, the pictographic method had to be elaborated prodigiously to assure identification. Apparently it was the need for a more economical and precise representation of proper names, in connection with the growth of the Sumerian city-states and the attendant problems of administration and public economy, that led finally to the phonetization of writing.

Phonetization makes use of the rebus principle. Thus a word-sign which is hard to draw is replaced by a sign easy to draw and expressing a word similar in sound. In a "full phonetic transfer" the sign or signs impart the sound completely: a drawing of bended knees = kneel = Neil (the name); bended knees + the sun = kneel + sun = Neilson. In a partial transfer only part of the sound is conveyed by the sign: a picture of two women facing each other + a picture of a cord = discord. (The same word, fully transferred, could be conveyed by two signs, one representing a disk, the other a cord.)

The principle of phonetization spread rapidly. "With it entire new horizons were opened to the expression of all linguistic forms, no matter how abstract, by means of written symbols." Forms were standardized so that they could be learned more easily and so that everyone would draw the signs more or less the same way; a definite correspondence was established between signs, words and meanings; signs came to be associated with specific syllabic values; the order of the signs gradually was made to conform to the order of the spoken language; various measures were adopted—phonetic indicators (special marks) for example—to convey ideas by the smallest possible number of signs. The principle of economy, it should be pointed out, effectively reduced the syllabary but led to omissions and ambiguities, some of which have kept modern scholars busy. The Mesopotamian system ignores many syllables and does not distinguish between voiced, voiceless and emphatic consonants in signs ending in a consonant. The sign for the sound "ig," to cite an example, also has the value "ik" and "iq," just as the sign for "tag" can stand for "tak" and "taq." In some of the older systems the quality of the consonant in signs beginning with a consonant is not distinguished: "ga," for instance, may also have the value of "ka" and "qa."

Throughout its history Egyptian was a word-syllabic writing. A full phonetic system appeared early, "perhaps under the Sumerian influence," after a brief period of mixed writing using descriptive-representational devices and conventional logograms. Hieroglyphics were the formal symbols, used chiefly for "public display purposes"; for everyday practical life the Egyptians developed two forms of cursive writing, the hieratic and the demotic. It was the special characteristic of Egyptian writing—as of the Semitic writings descended from the Egyptian—that vowels were not indicated in the syllabic signs. The Egyptian syllabary has about 24 signs, each with an initial consonant plus a vowel (to be added by the reader according to context), and about 80 signs, each with two consonants plus implied vowels. The sign m^x may take the value m^a, m^i, m^e, m^u, etc.; the sign $t^x m^x$ may denote $t^a m^a$, $t^i m^i$, $t^e m^e$, $t^u m^u$, $t^a m^i$, $t^e m^i$, and so on. It is not too difficult, especially with the help of a few auxiliary marks, to read writing without vowels, whether in the Semitic or the Indo-European languages: 'n rdng ths sntnc y wll fnd tht ths prncpl hlds 'vn fr 'nglsh.

Gelb differs from the majority of Egyptologists in considering Egyptian writing to be syllabic rather than consonantal, the signs representing syllables (with the vowels left undetermined) and not consonants. This point is essential to Gelb's entire theory. He believes that the evolution of writing is controlled by an inflexible principle, "attested in dozens of various systems": historically the logographic form is followed by the syllabic, and only then is the way open for consonantal writing. There is no more escape from this sequence than from the evolutionary sequences of biology. It would have been impossible, says Gelb, for the Egyptians to short-cut their way to a consonantal system without passing through a syllabic phase. In truth their writing never emerged from the syllabic phase, and it was not until thousands of years later that the higher stage of abstraction was attained in the Greek alphabet.

Among other systems discussed by Gelb is the Chinese, which emerges as a fully developed phonetic system about 1300 B.C., during the Shang Dynasty. It has undergone changes in its long history, but in inner structure "the oldest inscriptions hardly differ from those of recent times." The Chinese have an enormous number of word-signs and do not have a full syllabary, but their writing also makes use of phonetization whenever necessary, as in rendering foreign words and names. "Jesus" is written as *Yeh-su*; "French" as *Fa-lan-hsi*; "telephone," with a marvelous ear for the comic, as *tê-li-fêng*, or *tê-lu-fung*. The Chinese like to abbreviate: thus *Ying* for "English"; *Lo* for "Roosevelt" (besides *Lo-ssu-fu*). In spelling foreign names the individual sign may stand not only for syllabic values but is "frequently so chosen as to convey a meaning either inherent in the name borne by the person or otherwise thought to be characteristic of him." The name "Stuart" can be written *Ssu-t'u* by means of two phonetic signs which also stand for a Chinese word for an official corresponding to a steward; the name "Woodbridge" is written *Wu-pan-chiao*, where *Wu* is the surname and *pan-chiao* means actually "wood-bridge."

Rebus writing, for all its advantages over earlier methods, is inadequate to meet the demands of extensive practical use. Unless conventions are established to equate identical syllables of various words with identical signs, the rebus system simply collapses because of ambiguity induced by ingenuity. Take the word "mandate." In rebus style it can be conveyed by pictures of a man plus a palm date, a man plus a palm tree, a man plus a boy-and-girl combination, a man plus a calendar. Clearly this will not do where speed and accuracy in reading are required. Even an elaborate convention of syllabic signs, in which every syllable is assigned an invariable symbol, falls far short of the efficiency of an alphabetic system of writing, however inconsistent the spelling of its individual words.

Alphabetic writing, in which a single sign stands for one or more sounds, consonant or vowel, stems from the Greeks. The date assigned to its development is around 1000 B.C. The Greeks of course built on earlier achievements; the derivation of their signs from a Semitic prototype "can be established without great difficulty." Indeed, the symbols of their alphabet correspond "almost exactly" to those found in Semitic writings. Compare *alpha*, *beta*, *gamma*, *delta* and so on, with *'aleph*, *beth*, *gimel*, *daleth*, having the respective meanings "ox," "house," "camel" and "door." (Phoenician, according to Gelb, is the particular Semitic language from which the Greek signs can "theoretically" be derived.) I remarked earlier that neither Egyptian nor Semitic writings had signs for vowels. Strictly this is true, but as regards the Semitic the statement may be misleading. A number of auxiliary signs—known as *matres lectionis*, "mothers of reading"—did occur in Semitic systems, signs expressing so-called "weak consonants" and intended to facilitate the correct reading of the vowel in the preceding syllable. (Example: the sign i^i in $D^a w^i \underset{\frown}{i}^i d(^i)$ = "David" in Old Hebrew, has as its sole purpose to make sure that the preceding syllable w^i will be read as *wi* and not *wa*, *we*, *wu* or *wo*.) What the Greeks did—and this may be regarded as their distinctive and most significant achievement—was to convert these auxiliary signs, used by the early Semites "only in an irregular and sporadic fashion," into a methodical feature of their written language whereby all vowels appear wherever they are expected and all words can immediately be read, not merely interpreted. The Semitic *'aleph* sign, "expressing a soft breathing—something like the sign between *w* and *e* in 'however'—was changed to the vowel *a* of *alpha*; Semitic *he* to Greek *e* of *epsilon*; Semitic *waw*, used in older periods of Greek for the consonant *w* (*digamma*), also developed the value *u* of *upsilon*; Semitic *iodh* became in Greek the vowel *i* (*iota*); and finally the emphatic sound *'aiin* of the Semites was converted into the vowel *o* (*omicron*)." Besides giving "vocalic values" to certain Semitic syllabic signs in which the vowel quantity was imperfectly and unsystematically expressed, the Greeks broke down the remaining syllables (by the process of "reduction," for which there are numerous precedents in the history of writing) into their separate consonants and vowels. (To illustrate: if in the written form $t^i i^i$, the second sign is interpreted as the vowel *i* "to help in the correct reading of the first sign which theoretically can be read as *ta, ti, te, tu* or *to*, then the value of the first sign must be reduced from a syllable to a simple consonant.") Thus was created a full vocalic system and an alphabet, the "last important step in the history of writing"; for since the Greek period "nothing new has happened in the inner structural development of writing . . . and generally speaking we write consonants and vowels in the same way as the ancient Greeks did."

It must not be thought that the Greeks made their alphabet in a sudden burst of inspiration. They took off, as we have seen, from a point well along the road to their destination, and while the earliest extant Greek inscriptions display the full range of vowel-signs, it seems clear that the development must have been gradual. Cultural diffusion, it may be added, led to the payment by the Greeks of the debt owed to the Semites: in course of time the alphabetic method was absorbed in Semitic writings.

Professor Gelb rounds off his analysis of the evolution of writing in chapters dealing with modern writing among primitive societies, with the single or multiple origin of writing, with the relation of writing to speech, art and religion, and with the future of writing. His main ideas are unfailingly provocative, and even the sidelights are instructive as well as entertaining. The writing of the Cherokee nation was "invented" by a half-breed named George Guess, or Sequoya, who made up a system of syllabary signs based on the signs in his English book, which, however, he could not read. To the sign *H*, for example, he gave the value "mi," to the sign A, that of "go," and so on. His determination was rewarded, for the books and newspapers of the Cherokees were published in the writing he created. Gelb considers it not impossible that writing derives from a single cultural source. The arguments in favor of monogenesis are, he says, "neither stronger nor weaker than those adduced in favor of the dependency of Greek astronomy on Babylonian prototypes"; but his presentation of the case impresses me, a general reader, as both thin and contrived.

The book offers a very sensible appraisal of the importance of the advent of writing. A few eminent historians, philosophers and anthropologists have been all but overcome when faced with the task of describing the magnitude of this intellectual achievement; Dr. Gelb keeps his balance and enlarges our understanding. He does not deny that writing is a parent of civilization, but he stresses the fact that the appearance of writing was accompanied in the ancient world by simultaneous advances in government, the arts, commerce, industry, transportation, agriculture, domestication of animals and so on. The time was ripe for growth: one cannot explain the phenomenon and therefore one falls back upon this lame phrase. Nonetheless it conveys an important trend. Geographic, social and economic circumstances "created a complex of conditions which could not function properly without writing . . . in other words, writing exists only in a civilization and a civilization cannot exist without writing."

The conservativeness and the idiosyncrasies of writing are the subject of penetrating as well as amusing comment. Difficult and obsolete forms of writing have often been maintained, Gelb suggests, to protect the vested interests of a special caste, religious or political. Whatever impedes the general use of writing, and reading, contributes to the preservation of the existing social order. Examples of the application of this principle are scarcely confined to ancient Egypt, Babylonia or China. Tradition alone prevents us from accepting "ain't," or "no good" for "not good." The words "debt" and "doubt" got their unpronounced *b* from scribes bemused by the Latin antecedents of these words: *debitum* and *dubitum*. Similar silliness sprinkles the words of other languages. Lawrence of Arabia, when asked by his publisher to spell his foreign words and names more uniformly, is said to have replied: "I spell my names anyhow, to show what rot the systems are." A more logical reaction was that of the foreigner whose name sounded like "Fish" in English, and who decided to revenge himself on our spelling practices by writing his name "Ghotiugh," *i.e.*, Gh=f, as in tough; o=i, as in women, ti=sh, as in station; ugh is silent, as in dough.

A Study of Writing is a richly informative and well-written book, scholarly but not pedantic. Experts in various fields will, one suspects, eagerly pounce on Professor Gelb's classification of language systems, philological interpretations, theories of the evolution of writing, readings of prehistoric evidence, evaluation of the causes of social development and kindred matters. His ideas will challenge prevailing beliefs, and that is good: not the least merit of his study is its bold and positive pronouncements on controversial questions. Gelb is learned but not timid, thoughtful and disinterested without affecting the conventionally required air of academic modesty. He is not afraid to be wrong and to be found out. His book, finally, has many excellent illustrations, useful charts, a bibliography and an indispensable glossary.

MAN AND HIS GODS, by Homer W. Smith. Little, Brown and Company ($5.00). Homer Smith is a well-known physiologist and the author of a delightful natural history book, *Kamongo*, published 20 years ago. The present volume is an ambitious, and in many respects admirable, account of man's ideas about where he fits into the scheme of things, his fear of death, his search for immortality, the origins and the development of his religious and mystical systems, their effect upon his way of living and upon human history as a whole. Dr. Smith commits himself to rationalism in the 19th-century tradition, a noble philosophy which today falls increasingly into disfavor. His book is an impressive and unqualified indictment of man's faiths and creeds nourished by fear; it has the merit and some of the defects of the best of such grand-scale polemics. As a catalogue of faith-derived insanities, cruelties, depravities and superstitions; of the evils men have done to each other and to themselves in the name of their God; of the power and profit derived from organized religion by its professionals; as a record, in short, of what A. E. Taylor once described as the world's "ample stupidity," this is a brilliant book. It is less satisfactory, indeed in some respects surprisingly old-fashioned, in its analysis of the causes of animism and irrationalism, and superficial in its treatment of philosophy and science. The book attempts too much: a history of, among others, rationalism, superstition, theology, scriptures, philosophy, evolutionary theory, the Church, the beliefs and practices of primitive and ancient societies, the sex habits of the Greeks, the idea of progress—to which is added a 15,000-word autobiography including a lengthy and somewhat unaccountable recital of the author's difficulties in getting his work published—makes a considerable bundle. But it is a bundle worth unwrapping, full of many excellent things which one hopes may be widely shared.

GEOMETRY AND THE IMAGINATION, by D. Hilbert and S. Cohn-Vossen. Chelsea Publishing Company ($5.00). An able translation of the notable German work, *Anschauliche Geometrie* presenting the facts and problems of modern geometry "in large brush-strokes" and stressing the "visual intuitive aspects" for the benefit of those interested in the great advances of this major branch of mathematics but unable to cope with its increasingly formidable abstractness. Anyone who would like to see proof of the fact that a sphere with a hole can always be bent (no matter how small the hole), learn the theorems about Klein's bottle—a bottle with no edges, no inside and no outside—and meet other strange creatures of modern geometry will be delighted with Hilbert and Cohn-Vossen's book. It is not a primer, but it does bring very difficult matters into range and it conducts a fascinating tour of the 20th-century mathematical zoo.

THE SCIENTIFIC PAPERS OF JAMES CLERK MAXWELL, edited by W. D. Niven. Dover Publications, Inc. ($10.00). An unabridged edition of this famous collection of Maxwell's published research papers, lectures, addresses, essays, reviews, biographical memoirs and short treatises. It includes his outstanding contributions to the *Transactions* or *Proceedings* of the Royal Societies of London and Edinburgh on various mathematical and physical problems: the theory of compound colors, a dynamical theory of the electromagnetic field, the dynamical theory of gases and so on. This volume is a visit with one of the greatest minds of the 19th century, and to turn its pages is an exciting intellectual experience even for the reader who does not have the mathematical equipment necessary to grasp their full meaning. The publishers have greatly reduced the bulk of the book in this new edition, but the type of its 1,400 pages is perfectly legible and the diagrams are clear. It is a real boon to students of science to have this now very scarce set made available in one volume at a fair price.

THE EXPLORATION OF SPACE, by Arthur C. Clarke. Harper and Brothers ($3.50). About a year ago Mr. Clarke, who is chairman of the British Interplanetary Society, published a little book, much superior to some of the long-winded tomes on the subject, summarizing current knowledge of the problems of rocket travel to the moon and more distant places. The book attracted slight attention, probably because it used simple mathematics, frightening to readers and reviewers alike in this scientific age. The present volume, while readable and interesting, is inferior to its predecessor. It is hastily written, eschews all equations and is a book-club selection. Clarke deals with the construction of rockets, the problem of escaping the earth's gravitational clutch, the experiences of a future moon traveler, the possibility of visiting other planets, the building of

What GENERAL ELECTRIC People Are Saying

T. M. BERRY
J. P. HANNA

General Engineering Laboratory

FERROMAGNETOGRAPHY: The graphic arts have always managed to keep abreast of the needs of business and industry; that is, until the high-speed electronic computing machine came along. Many of the problems of business, particularly in the field of accounting, involve not only the processing of large amounts of information but also the output of relatively large amounts of printed matter showing the results. Digital computer techniques could be adapted to the solution of such problems only if faster printing techniques could be developed to keep pace with electronic computations.

This leads us to General Electric's development of "ferromagnetography," a new and basic principle in printing. This is a method through which the printed and written text and pictures are reproduced by: (1) forming magnetic images on thin sheets of permanent-magnetic material; (2) making these images visible by the deposition of tiny ferromagnetic particles; (3) transferring these particles to a medium such as paper. These steps are analogous to plate-making, inking, and printing in the graphic arts.

A permanent-magnetic stylus (the magnetic field of which is concentrated at the point) can be used for writing and drawing magnetic images. Suppose, instead, you use a permanent-magnetic rod, whose tip or pole is shaped like an alphabetical or numerical character. Then, by placing the tip of the rod on a magnetic sheet, an invisible magnetic image of the character is formed. Because the sheet is permanently magnetized, this image remains after the rod is removed.

Magnetic materials with current-carrying coils about them (electromagnets) can be used in place of the permanent magnets to make images. If the current is varied, the strength of the magnetic image also varies. In this way you can vary the magnetic field from zero through maximum to zero in a few millionths of a second. Therefore, magnetic images can be formed at rates up to tens of thousands per second. Here we have the basis for high-speed printing.

If you bring a suspension of iron particles into contact with the magnetized portion of the sheet, they form a figure, being held by the force of magnetic attraction. The field strength of the magnetic image determines the number of these iron particles attracted.

Transfer of this image to paper or other media is a tricky process. One way is by the use of an adhesive or bonding agent. In other words, the adhesive force between the particles and the paper is greater than the magnetic attraction between the particles and the image. Or, instead of removing the particles, you can use the magnetic sheet as the printer uses his press; that is, coat the particles with printing ink and run off copies.

In particular, ferromagnetography promises to fill the need for printing large amounts of statistical data at high speeds, because its "line-at-a-time" technique is capable of printing several thousand lines per minute.

G-E Review
July, 1952

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W. R. G. BAKER

Electronics Division

ELECTRONICS—PROMISE AND REALITY: We are surrounded by evidence that the electronic evolution, if you wish to call it that, is well under way.

First to feel the greatest effect will be the continuous process, unchanging product factory. Next, I believe, or even concurrently, will be the industries with long run mass production of a relatively few products. Third, I believe will be the job lot plant, with electronic devices even here taking over the monotonous repetitive jobs.

Perhaps equally as important as electronic controls will be the increased use of electronic communication and the integration of communications with both production and distribution.

Again, as in electronic controls, we have many of the bits and pieces that can make up an integrated electronic business system. We have closed circuit industrial television, microwave and facsimile for transmission of business information, electronic memory devices and computers, telemetering for reading gages at long distances, electronic business machines.

Broadly, this is the promise that electronics holds for us. It offers us a means to increase productivity and therefore our standard of living. It offers us quicker and better methods of communications in all areas of industry, commerce, education and entertainment. It offers us a way of making better use of our skills. It offers us a way of bolstering our defenses against aggression.

These promises will not turn into reality automatically and without effort on our part.

They call for investment on our part not only of capital funds but of human resources. We must make it possible for greater numbers of young men and women to receive the education and the training that will permit them to participate in this more highly technical civilization and to contribute to its continued growth. We must continue to invest in research, to broaden the basic knowledge on which we can build a stronger economy. The true return on the investment will be measured in the advancement of civilization.

Meeting, The Robert Morris Assoc'ts
Syracuse, New York
May 14, 1952

space stations. His book survives its illustrator, R. A. Smith, whose creations are strikingly garish and implausible even in the literature of "astronautics."

AUTOMATIC AND MANUAL CONTROL, edited by A. Tustin. Academic Press Inc. ($10.00). Papers contributed to the Conference on Automatic Control organized by the Department of Scientific and Industrial Research and held at Cranford (England) in July, 1951. A reference book for engineers, students and other specialists on the subject. Professor Tustin is the author of the article entitled "Feedback" in the September issue of SCIENTIFIC AMERICAN.

ONE LITTLE BOY, by Dorothy W. Baruch. Julian Press, Inc. ($3.50). A psychiatric success story beginning with the first interview of an asthmatic, learning-blocked child and including not only a detailed, graphic and moving account of his cure but also a description of treatment of the mother and father in personal interviews and group sessions. Mrs. Baruch explains how current problems of family living have their roots in old but unresolved difficulties between the mother and the father, and how the child's gradual acceptance of himself depends on his parents' abilities to look at, and accept, their own lives. The book shows what a skilled and sensitive therapist can do to free a child from the destructive and incapacitating forces around and within him. The author writes in a direct style that is admirably free of specialized terms.

ESSAY IN PHYSICS, by Herbert L. Samuel. Harcourt, Brace & Company ($3.00). Amidst the demands of a long and distinguished career in politics and government administration, Viscount Samuel has never relinquished an active interest in philosophy and science and has turned out a number of uncommonly literate books embodying his beliefs. In this volume he takes issue with some of the modern concepts of physics, including the fundamental theories of causal relationships, which, he feels, because of their probabilistic basis fail to meet the requirements of a consistent and comprehensive interpretation of physical relations. In other words, there is a gap between the picture of the world presented by mathematical physics and what the mind demands for a satisfactory understanding of what is actually happening. "The space-time continuum has every qualification to enable it to account for the physical phenomena of the universe and only one disqualification—that it does not exist." Lord Samuel's proposals to remedy the defect seem only to add to the confusion; nevertheless this is a most readable book. It is, as another reviewer has remarked, "a gallant little book" some of whose penetrating criticisms (the subject of comment in an interesting letter from Dr. Einstein, attached as an appendix) are as unanswerable as the dilemmas of physical theory to which they are pointed.

BIOLUMINESCENCE, by E. Newton Harvey. Academic Press Inc. ($13.00). A massive reference monograph dealing with the striking phenomenon of bioluminescence, defined as "the production of light without heat by living things." Dr. Harvey, noted for his researches in this field, has gathered information on the great number of "totally unrelated and diverse organisms," plants and animals, which have this strange ability (from comb jellies, marine worms, sea spiders, squids, starfish and fireflies to bacteria, smuts, rusts and mushrooms); on the enzyme kinetics of the process; on the relation of bioluminescence to fundamental biophysical and biochemical problems. Harvey's book is a considerable scientific achievement. It is well written, and its descriptions of strange species and discussion of some of the experimental work conducted in this branch of biology are certain to interest even the casual reader. One learns, for example, that a series of beautifully ingenious and imaginative laboratory investigations demonstrated that luminous bacteria (*Bacterium phosphorescens*) exhibit a light-production efficiency of one per cent, which is about the same as that of the ordinary incandescent lamp calculated from the energy of coal used in generating current.

OXFORD JUNIOR ENCYCLOPAEDIA, VOL. VII, INDUSTRY AND COMMERCE; edited by Laura E. Salt and Geoffrey Boumphrey. Oxford University Press ($8.50). The new installment of this excellent British reference work embraces topics from Accountancy through Zinc Mining. The project continues to maintain its standards of a clear, simple, attractively written text, comprehensive and authoritative coverage, and an abundance of meaningful, vivid illustrations. The plates, in this volume at least, are of uneven quality.

THE ATMOSPHERES OF THE EARTH AND PLANETS, edited by Gerard P. Kuiper. University of Chicago Press ($8.50). Revised edition of a symposium on planetary atmospheres first issued in 1948, a number of the contributions having been brought up to date or rewritten. The topics include light-scattering in the atmospheres of the earth and planets, the upper atmosphere studied from rockets, spectra of the night sky and aurora, rare gases and the formation of the earth's atmosphere, the origin of planetary atmospheres. A book for meteorologists, high-atmosphere specialists and astronomers.

THE AMATEUR SCIENTIST

On the culture of plants without soil, and the behavior of the telescope-maker's pitch

Conducted by Albert G. Ingalls

GARDENING probably claims the interest of more enthusiasts than all other avocations combined. Whether the plot comprises acres of winding paths and formal beds or only a bit of potted soil on the ledge of an apartment window, those who do the tilling share a common love of things that grow. Whether the gardener senses it or not he is a confirmed experimentalist, everlastingly testing nutrient, location, lighting and variety. To the extent that his efforts are guided by observation, analysis and test, the gardener is also an amateur scientist.

Nat E. Mankin of Chicago, a railroad freight-expediter for a nationwide transportation concern, is an extreme example of the casual gardener turned amateur botanist. His work in the field of soilless gardening, or hydroponics, during the past 20 years has attracted wide attention in both professional and lay circles. His experimental techniques rank with those of the best professionals. Despite the impressiveness of his accomplishments Mankin's two decades of off-hour fun have cost him little in terms of time and money—no more than other city dwellers spend maintaining a few potted plants. "A few seeds and $10 worth of chemicals," he says, "will keep you going a lifetime."

Experiments with growing plants in liquid solutions, according to Mankin, date back to the days of the Roman Empire, when plants were grown in jars and vessels to which fertilizer was added from time to time. History does not indicate what objective prompted the experiments of the Romans, nor how their scientific studies, if any, came out. But in view of the complex chemistry of organic fertilizers and the wide variation of their quality, it is safe to assume this early work lacked any form of experimental control. The first recorded attempt at a controlled study appears to have been made in 1699 by an English botanist named Woodward. He grew spearmint in water containing an extract of soil. Although he observed that without aeration plants continuously immersed in a solution soon turn yellow and die, Woodward did not achieve true hydroponic culture because he, and everyone else, had insufficient knowledge of chemistry.

The credit for pioneering hydroponics, in the modern meaning of the term, goes to the French chemist Jean Boussingault, whose work in South America during the early decades of the 19th century proved that plants could be grown in sand, charcoal, quartz and other inert materials to which inorganic solutions were added. His studies proved that plants cannot assimilate free nitrogen from the atmosphere, and he first evaluated the role of manures. In recognition of these and related contributions, he was invited to occupy the chair of chemistry at Lyons, moving later to that of agricultural chemistry in Paris.

Boussingault's methods were quickly taken up independently by two German workers, A. Knop and Julius von Sachs, the latter a botanist at the University of Würzburg. They first focused attention on the fact that growing plants operate the world's largest chemical industry, and that with the proper control plants are powerful tools for determining how nature converts the simple chemicals of the atmosphere into complex food substances. The controlled techniques of Knop and Sachs for studying the irregularities affecting soil-grown crops have survived nearly a century of use; their basic formulas for nutrient solutions still serve as the starting point for most hydroponic research.

Despite its long history hydroponics did not become a popular branch of amateur science until 1929. In that year William F. Gericke, a plant physiologist at the University of California, developed a special technique for applying hydroponics to commercial crop production. The transition from laboratory tool to business enterprise was attended by widespread publicity. Soon seed stores from coast to coast were sending customers from their counters laden with packages of mineral salts.

"The successful growth of a robust crop," says Mankin, "is based on the balanced supply of two classes of nutrients: the major fertilizing elements which supply most of the plant's food requirements, nitrogen, potassium, calcium, phosphorus and sulfur; and the minor trace elements such as iron, manganese, boron, zinc and copper. Minute amounts of these trace elements, along with vitamin B_1, play a decisive role in maintaining the health of plants.

"The precise function of all the trace elements is not known—one of the things that attracts both professional and amateur botanists to the hydroponic technique. Without iron no green coloring forms in the plant. In the absence of boron no seeds develop. Deficiencies in other trace elements cause plants to be stunted, lacking in color or malformed. In contrast, a well-balanced diet of major and minor elements makes it possible to grow plants more luxuriant than almost any that can be grown in soil. By soilless culture a single tomato plant of the Marglobe variety, for example, can be grown to a height of 25 feet and made to bear 20 pounds of perfect tomatoes. So effective is the technique that the Army Air Force maintained soilless gardens on Ascension Island, in British Guiana and on Iwo Jima during World War II for the large-scale production of food crops. A number of commercial enterprises with personnel quartered in the Tropics and arid parts of the world operate similar installations."

Soilless culture takes one of three forms, according to the means of mechanically supporting the plants: sand, gravel or water. Each of the three techniques has certain advantages and disadvantages, but all share the common distinction of giving the experimenter more control of the plant's nutrition than is possible with soil.

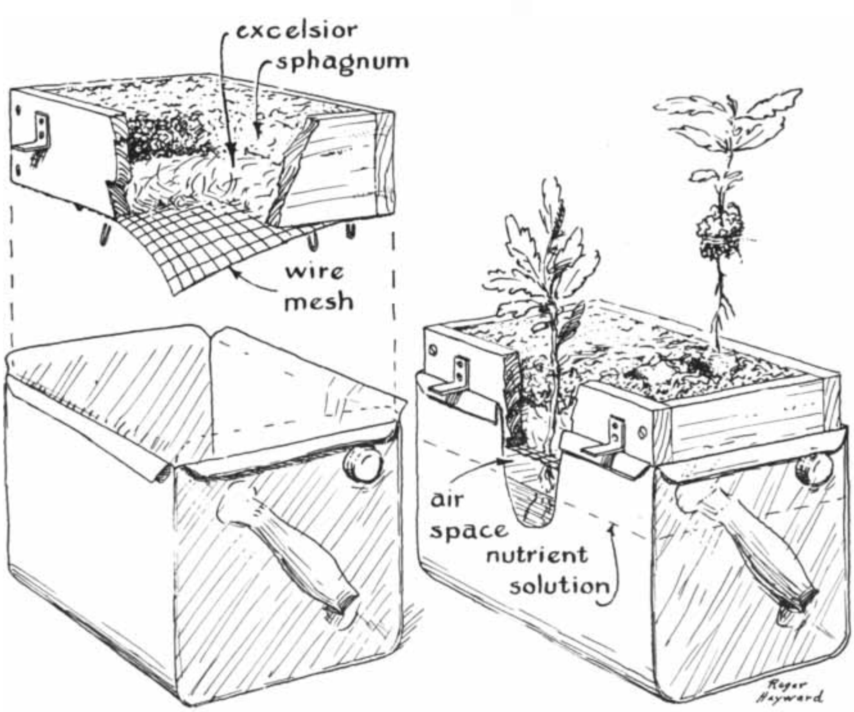
Sand culture, developed for commercial purposes by New Jersey and Rhode Island agricultural experiment stations during the 1920s, is perhaps the simplest of the three methods. Mankin recommends it highly for the beginner. "Seeds planted in a sand-filled flowerpot," he explains, "are kept moistened with nutrient solution until they mature as full-grown plants. Like the soil of the conventional garden, the sand must have drainage, and it should be flushed with pure water about once a week to remove excess mineral salts. This technique is also known as 'slop' culture. Its advantage lies in the fact that fresh air is brought into contact with the root system daily when the application of the nutrient solution drives stale air from the sand. The beginner may expect gratifying results from sand culture, at least equal to those he can achieve with a good quality of topsoil. The principal disadvantage of sand culture lies in the fact that the nutrients in a solution tend to crystallize on the grains of sand. This obviously alters the concentration of the nutrients, and deprives the experimenter of precise chemical control over his culture. The variation in nutrients may seem slight when considered in absolute terms of grams or ounces, yet it is sufficient to induce astonishing changes in a plant's metabolism. The presence or absence of one part of vitamin B_1 in a billion can make the difference between a healthy plant and one that is seriously ill. Another disadvantage of the method is that many common sands contain soluble minerals that contaminate the nutrient solution or radically alter the concentration of its trace elements. Sand need not contain much ferrous sulfate to alter the concentration of a nutrient solution calling for one part of iron per million."

For commercial soilless culture gravel has several practical advantages over sand or water. Chief among these is the relative ease and speed with which solutions may be pumped into and out of gravel-filled growing-tanks. The medium may consist of any coarse-grained, chemically inert solid, ranging from stream gravel to crushed granite and coal cinders. As with sand culture the medium tends to introduce variations in the nutrient solution. Gravel culture is less exacting than water culture, but if the experimenter fully exploits its conveniences it requires almost as much equipment. Mankin urges the beginner to master the sand technique, and then to shift directly to water.

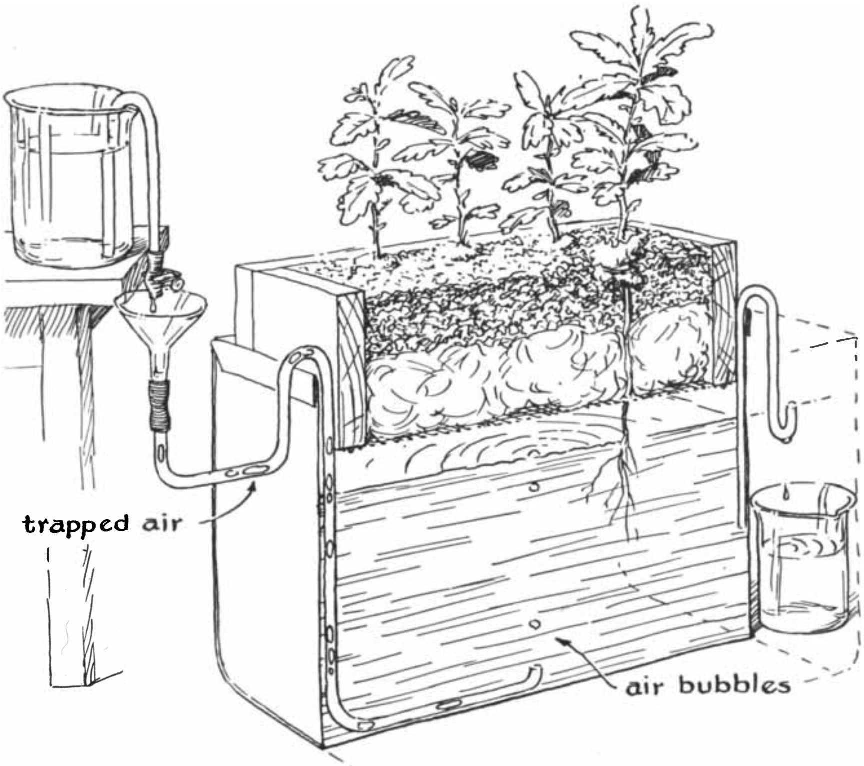
"If the amateur is reasonably handy with tools," writes Mankin, "he can build his own growing-tank for experimenting with water culture or 'pure' hydroponics. A common five-gallon can of the type found at filling stations can with little labor be converted into a serviceable tank. The side of the can is removed, and its four corners are cut to a depth of about half an inch. Then, with the aid of pliers, the metal strips are bent outward along an even line and folded back against the sides of the can. It is then easy to flatten them with a mallet or hammer, producing a rounded edge for the tank. After tightening its screw-cap the tank is painted inside and out with an asphalt paint or emulsion. The paint must be of petroleum origin; others are toxic. Allow the asphalt a few days to dry.

"The completed tank is then fitted with a growing-tray. This is made of conventional one- by four-inch stock of pine, fir, spruce or white cedar. Redwood is toxic to most plants. The tray should be fitted to drop easily into the tank. The corners may be joined with corrugated fasteners, but for necessary rigidity and strength they should be reinforced with wood screws.

"The bottom of the tray is covered with either a fine-mesh chicken wire or a hardware cloth of heavy gauge: 1/2- to 3/4-inch mesh. The mesh is attached to the tray by staples, and is supported by two or three narrow widths of metal strip spaced evenly across the bottom.



A home-made tank for the culture of plants in water



The continuous-flow method of aerating a water-culture tank

The netting must also receive a protective coat of asphalt. The tray is suspended in the tank by means of four metal angle-braces extending from its upper edge at each corner. Finally the netting is covered with an inch or so of shredded excelsior and, over this, enough sphagnum moss, glass wool, dried hay or even coarse sawdust to fill the tray to its top. Make sure that no shreds of this litter extend through the mesh or over the sides. Toxic materials such as redwood sawdust should be avoided.

"For introductory work it is advisable that the amateur use young transplants whose roots have been gently washed free of soil. Tomatoes take readily to pure hydroponic culture, and hence they are good plants with which to gain experience. A hole is made through the litter to receive the plant; a sharpened stick will serve as a suitable tool. The plant is inserted through the litter so that about an inch of stalk separates the root system from the mesh. The plant is then secured in position by packing the hole with moss or other litter. Be careful not to injure the plant by applying heavy pressure, but close the hole completely. The solution must be kept in the dark to avoid the growth of algae.

"The root system must be supplied with oxygen; thus some means of aerating the solution must be provided. A piece of glass tubing closed at one end with a porous ceramic plug may be inserted through the litter so the plug rests against the bottom of the tank. This is coupled to an air pump through a length of rubber hose. Complete aeration rigs, including an electrically driven air pump, can be purchased for a few dollars in stores specializing in the needs of tropical fish, or the experimenter can do the job with a bicycle tire-pump. The aerator must run for at least 15 minutes twice a day. Another scheme that works well uses the so-called 'continuous flow' method of aeration. Solution drips continually from an elevated container into the center of a narrow-necked funnel. A length of tubing leads from the spout of the funnel to the bottom of the tank. Bubbles trapped between successive drops are carried into the tank, which must also be equipped with an overflow siphon.

"Two alternatives are available with respect to preparing the nutrient solutions. Seed stores market a number of packaged plant foods under such brand names as Hyponex, Gilbert's Nutrient Formulas, New Plant Life and a number of others. Simple directions on the package explain how to make up the solution. The use of these preparations obviously limits the extent to which the amateur can manipulate the growth process. In contrast, solutions prepared from basic formulas encourage experiment and enable the advanced worker to vary the plant's nutritional intake at will. Unlike conventional gardening, water culture enables the experimenter to manufacture any variety of 'soil' he desires.

"Enough solution should be prepared to fill the tank to within an inch and a half of the bottom of the tray. This air space between the top of the solution and the tray is important. From it the hairs near the top of the root system take up oxygen.

"All ingredients for a basic plant food are available through most drugstores. Just as no universal diet exists for all animals, no one formula meets the nutritional requirements of all plants. But plant physiologists in a number of universities and agricultural experiment stations have developed suitable nutrients for groups of common plants.

"The following formula will give good results with most common garden vegetables and household flowers:

Major elements

Compound	*Grams per gallon*
Magnesium sulfate	1.04
Monocalcium phosphate	0.54
Potassium nitrate	2.20
Calcium sulfate	3.04
Potassium chloride	1.60

Minor elements

Compound	*Grams per gallon*
Ferrous sulfate	.01
Manganese sulfate	.004
Boric acid	.0056
Copper sulfate	.0004
Zinc sulfate	.0004
Thiamine chloride	trace

"Other simple formulas that can be compounded by the amateur and modified to compensate for variations in the worker's local climate or to meet special research objectives may be procured from the New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J. Ask for Bulletin No. 636, March, 1948, entitled *Methods of Growing Plants in Solution and Sand Cultures,* by J. W. Shive and W. R. Robbins.

"All solutions must be adjusted for *p*H, or acidity. Most common vegetables and flowers prefer a slightly acid solution, their tolerance extending from *p*H 5 to 6 on a scale calibrated from 0 (extremely acid) to 14 (extremely alkaline). On this scale 7 represents a neutral solution. The experimenter must procure a kit for making *p*H tests. These are available through most seed stores. Although these kits take a variety of forms, most employ chemically treated paper, the color of which changes when it is dipped into a nutrient solution. The test paper is then matched against a varicolored chart calibrated in *p*H. The *p*H of the nutrient solution may then be adjusted to the correct range by adding minute amounts of sulfuric acid or potassium hydroxide. If the solution is too acid, potassium hydroxide is added; if it is too alkaline, acid is used."

Similar tests, described in handbooks on chemistry, enable the advanced amateur to maintain a close check on the concentration of all the minerals in the nutrient solution. Although these tests are useful, the most powerful indicator is the plant itself. By continuously observing and recording changes in the size, color, rate of growth and general health of the plant, its body, root system and leaves, the amateur learns to detect hunger signs that lead to refined growing techniques. By varying the proportion and amounts of the minerals, ideal foods can be developed for each species of plant in relation to its local ecology. The role of each element can be observed, and thus the art as well as the science of hydroponics can be mastered.

EVERY amateur astronomer who has polished a disk of glass on a pitch lap to make a telescope mirror knows that pitch slowly flows. Though pitch is a solid at ordinary temperatures, it is classed by science as a liquid with a viscosity many billions of times greater than that of water. The term viscosity has several meanings: to most people it suggests stickiness; to the physicist it means a resistance to flow arising from internal fluid friction.

It is a strange fact that the writers of instruction books on telescope making have not explained why a pitch lap does its work. They only tell how. Thus it has remained for a ringside observer to state it. In a recent article the experimental physicist John Strong writes: "The viscous nature of the pitch prevents quick changes in the polishing surface so that the polishing pressures are greatest and the polishing action is greatest on areas of the work where the glass surface is relatively high."

After a single reading this sentence may seem to be no more than a simple statement of the obvious, yet it is an almost unique expression of a rather subtle process. Amateur telescope makers are often dissatisfied with the empirical; then they seek the underlying reasons for the phenomena of their art. The following discussion should not be confused with others that treat with the nature of the process that polishes glass; it has solely to do with the behavior of the pitch.

The sentence by Strong deals with the viscosity of pitch, but pitch is also elastic. Some optical workers would challenge this statement. Lively arguments have occurred between those who say, like John M. Pierce, "Pitch is certainly elastic, otherwise it would be no good for non-spherical surfaces such as paraboloids," and others who answer, "Liquid yes, and viscous yes, but elastic no—not so long as the indentation of my thumbnail remains in a lap." One advanced amateur optical worker comments: "The elastic recovery of pitch is new to me." When asked whether the same substance could be both viscous and elastic, a professional optical worker replied simply, "No." The question was submitted to Strong. "Is there a restoring force (elasticity) in pitch?" He answered, "Yes." He was also asked: "How can pitch be viscous and elastic too?" His answer was, "See the bouncing putty." True enough, silicone putty is viscous, elastic and visco-elastic. A ball of it will bounce, but when left on a table for a few hours the same ball will flow under the force of gravity into a pancake.

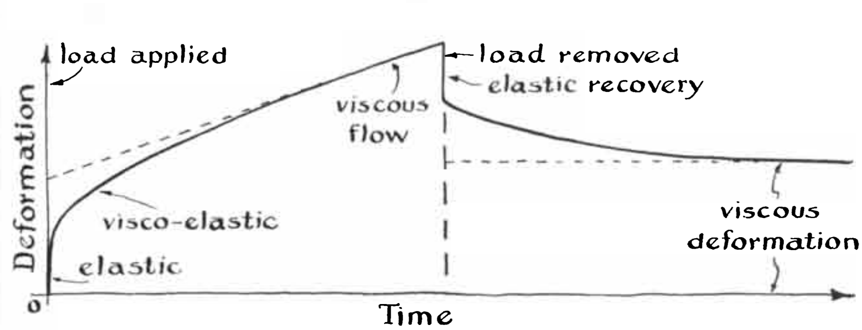
Possibly amateur optical workers, including the writer, should keep up to date with the sciences that touch upon their hobby. To attempt a remedy, the discipline of rheology was frontally attacked in the hope of finding an unequivocal answer about pitch. Rheology is the science of the deformation and flow of matter: gaseous, liquid and solid. The prefix "rheo" means flow, as in rheostat or diarrhea. Rheology deals with elasticity, viscosity, plastic flow, creep and other phenomena in liquids and resinous materials, of which pitch is an example, and in metals and other forms of matter, including crystals.

There is no elementary book on rheology, no "Rheology for Everybody." Its books, such as R. Houwink's *Elasticity, Plasticity and the Structure of Matter*, are elementary only to the physicist. To others they seem to begin in the middle. My investigation of the subject resembled a dog's attack on a porcupine. I did, however, find one simple demonstration that should convince anyone. Twist a length of pitch into a spiral. Release one end and the pitch untwists a little. The addition of a pointer may be needed to reveal this elastic effect. A curve was also found in E. N. da C. Andrade's *Viscosity and Plasticity* that describes the flow and recovery of "a pitch-like substance." Would it be safe to assume that this was also the curve for the actual pitch that is used by the optical worker? Even if so, would not the attempt of a non-rheologist to write an interpretation of it be brash, considering that rheology is slippery even for the rheologist? A brief inquiry sent to the Hercules Powder Company of Wilmington, Del., the largest manufacturer of naval-stores products, brought a fortunate answer. The following letter was written for the amateur telescope maker with pitch in his hair by W. H. Markwood, a research supervisor at the Hercules Experiment Station and a vice-president of The Society of Rheology.

"As an interested reader of 'The Amateur Scientist' I am pleased at the opportunity to tell you about the rheological behavior of pine pitch during the polishing of optical surfaces. To begin with, materials of this sort are both elastic and viscous. However, one may not say that they have only one elasticity and/or one viscosity even at only one temperature. They are also influenced by how fast one makes them flow, that is, how hard they are pushed. Let us confine ourselves to the region between room temperature and the softening point (both wood and gum rosins 'melt' at about 180 degrees Fahrenheit). In this range, if a resinous material is pressed very gently it flows in the manner of a very thick oil, and stays put when the force is removed. It acts as though it were viscous only. On the other hand, if a great force is suddenly applied, it appears to react like an entirely elastic crystal. The applied force may bounce back or the 'crystal' may shatter.

"For intermediate forces and intermediate rates of force-application it seems to behave in three ways. There appear to be (1) a purely elastic component like a time-independent ideal spring, (2) an elastic component that will slowly recover after force removal and (3) a non-recoverable, viscous component. The middle one is sometimes called creep or visco-elasticity or elasto-viscosity or recoverable elasticity or retarded elasticity. The ideal spring part deforms instantly in direct proportion to the force applied, while the viscous part deforms, that is, flows, at a *rate* that is proportional to the force. However, the visco-elastic deformation is dependent not only on how much force but on how fast it is applied. This idea of 'parts' can be confusing. A thing is a thing and not three things. This 'thing' has what might be called a multi-behavioristic attitude.

"Let's examine the curve you traced from Andrade's *Viscosity and Plasticity*. The curve was intended to illustrate the above. If the ordinate represents deformation under a *constant* load, if the ab-



How pitch behaves when loaded and unloaded scissa is time and if the maximum on the plot is the time at which the load was suddenly removed, all the 'parts' described above are illustrated. At first a sudden, elastic jump occurs, deformation then slows down and becomes a combination of visco-elastic and viscous distortion for a while (curved part), then straightens out into 'pure' viscous flow. When the load is removed, an elastic rebound takes place that is equal to the initial jump; then a slow, time-dependent, retarded-elastic recovery appears; finally the material stops recovering and it is seen that a 'set' has taken place that is permanent and represents the viscous deformation only.

"One can go further and visualize models to describe phenomenologically this 'multi-behavior.' Let the purely elastic part be represented by an ideal spring, the purely viscous part by an oil-filled dashpot, and the visco-elastic part by a spring whose action is damped by a dashpot connected rigidly parallel to it. If these are added together the situation shown in the enclosed drawing [*next page*] obtains.

"Suppose one suspends this model vertically and hangs a weight on it. At the instant the weight is released the top spring stretches until the elastic modulus times the deformation of the spring just balances the weight. At this point (still zero time) the second spring begins to stretch, but its motion is damped by the dashpot, which first carries all the load, gradually transferring it to the spring until *its* elastic modulus times *its* strains also balances the effect of the weight, when its motion stops. However, the piston in the viscosity dashpot has also been moving and will continue to move linearly with time so long as the weight is applied. If the weight is now removed, the elasticity spring will snap back to its original position in zero time; the visco-elastic spring will try to do the same but will again be retarded by the 'oil flow' in its dashpot and will arrive back at its initial position in exactly the time it took to stretch. In the meantime the whole viscosity dashpot will go along for the ride; that is, its piston will not change position relative to its cup. This use of a model is a pretty crude but somewhat useful conception in a physical sense. It is often employed by the rheologist. Furthermore, the concept is easily handled mathematically.

"Looking again at the model, it is easy to visualize that if you pull on it fast enough and let it go fast enough only the elastic spring will stretch and recover. If you pull on it very, very slowly the viscosity dashpot will move before either spring can stretch without recovering in an infinitely short time as deformation proceeds—which brings us back to paragraph four.

"If the constant load we picked had been a different one, the behavior *pattern* would have been the same, but the

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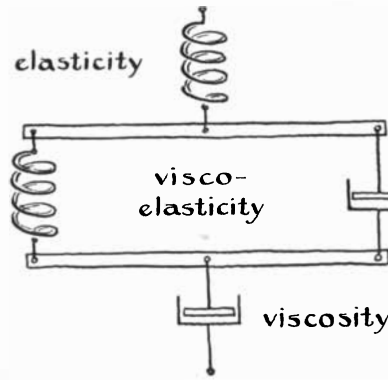

A model for pitch behavior

relaxation time would have been different. There is not just one but a whole spectrum of them, corresponding to spectra of elasticities and viscosities.

"I believe that if you'll warm some pitch, press on it hard, remove the load and watch, you'll see some small, slow recovery, indicating visco-elasticity. If you strike it rapidly and lightly, no change in shape will be seen. If you press on it very slowly and remove the load, no recovery will occur. Of course, its own mass will make it flow also; which can be seen if it is either warm enough or if you wait long enough."

Now that Markwood has assured us that pitch really is elastic as well as viscous, it is interesting to note that the great 19th-century English astronomer Sir John Herschel suspected the same thing from his optical shop experience. It is probable that he heard it from his famous telescope-making father William Herschel. John Herschel also believed that if pitch were not elastic, a mirror could not be parabolized on it. The following quotation from the younger Herschel's book *The Telescope,* published in 1861, concerning the polishing and parabolization of speculum-metal mirrors on a pitch lap, contains crystal-clear proof that both facts were known to him a century ago. For some reason they have not been restated in recent books on the art. Herschel wrote:

"When the metal is reduced by grinding to a perfectly true and even surface, free from the smallest perceptible scratch, it will be found reflective enough to afford an image of a star, or of a distant white object, sufficiently distinct to try whether its focal length is correct; and if it be so, the process of polishing may be commenced, the object of which is not merely to communicate a brilliantly reflective surface, but at the same time a truly parabolic form. If the material of the tool on which this operation is performed were perfectly hard and non-elastic, it is evident that this would be impracticable, since none but a spherical form could arise from any amount of friction on such a material once supposed spherical; and even if parabolic it could not communicate that form to a more yielding body worked upon it. . . . Happily, however, there exists a material which, with sufficient hardness to offer a considerable resistance to momentary pressure, is yet yielding enough to accommodate its form to that pressure when prolonged, and at the same time sufficiently elastic to recover it if quickly relieved; that substance is pitch, whose properties, in this respect, were at once taken advantage of by Newton, with that sagacity which distinguished all his proceedings, as the fitting material for a polisher."

Herschel, who so clearly understood the rheological behavior of pitch, was mistaken about Newton, who did not understand it. As is well known, Newton was unable to parabolize the two-inch spherical mirrors he made for the first reflecting telescopes in 1668 and 1671, and his description of their polishing, in *Opticks,* shows why. He used a pitch lap "as thin as a groat," so thin that its elasticity was too insignificant to be effective; a groat was thinner than a well-worn dime. The probable explanation is that Herschel wrote without referring to *Opticks.*

Most optical workers buy their pitch retail and cannot trace it through trade channels to its origin. Some use mineral pitch but many dislike it. Most of the pitch used in optical work is pine pitch. Asked about pine pitch Markwood replies: "Pitch is a general term applied to many natural and proprietary mixtures. There are two sources of such materials which, with other products, are commonly called naval stores. The first is from the living pine tree. When the tree is wounded by scoring it near the base, an oleoresin exudes which is a mixture of turpentine and rosin. These are separated by distilling out the turpentine.

"The second source is the stumps and heartwood of large virgin pine trees. By far the largest method of processing this wood is to grind it, extract it with a hydrocarbon solvent and distill out the oils to give a residue called wood rosin. Much of the rosin produced in this manner is refined by the use of selective solvents or adsorbents to give pale-colored rosin.

"Another method of processing pine-stump wood is to destructively distill it in retorts, using the technique employed for producing charcoal from hardwood. Pine-tar oil is volatilized from the wood. Most of the volatile material is removed from the product, leaving pine pitch. It softens at a lower temperature than rosin and contains less acidic material. Many of the commercial pitches sold under various names are obtained by this retort process. The compounded pitches are probably made either by modification of these materials or from rosin or related materials by plasticizing them with pine oils or other softeners to obtain the softening point desired."

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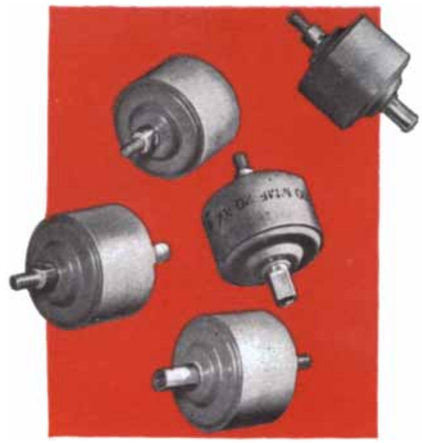

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Colors are custom-tailored, too

There's nothing like a colorful new dress, made just for herself, to brighten up a lady's life. And there's nothing like custom-tailored colors to brighten up the life of fabrics.

Vat dyes, produced by Cyanamid's Calco Chemical Division, are specially made to meet the varied dyeing demands of all types of fabrics—cotton, linen, rayon, the new synthetics, and mixtures of all. Aristocrats of color, these vat dyes are known as *fast* colors because they fight off the onslaughts of sun, sea water, washing, perspiration, bleaches—hold fast under the most extreme of service conditions. You see them everywhere and in many types of garments . . . in mother's colorful housedresses and favorite fashions, in baby's bright T-shirts, in brother's sturdy corduroys, in dad's shirts and socks and in many fabrics for use by our armed forces.

Developing and producing better dyes for every purpose is one way in which Cyanamid chemistry helps to make everyday living not only more colorful but more economical.

AMERICAN *Cyanamid* COMPANY

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Dyes for the textile industry—one of Cyanamid's many services