# SCIENTIFIC AMERICAN


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July 1953

# *Things are different—up there!*

## You would be amazed at the tricks nature plays in the stratosphere

As aviation progress has carried man farther into the upper air, he has found that nature has many tricks up her sleeve in the stratosphere. Many things that worked well on the ground wouldn't do as well, or failed completely, in the space beyond the clouds. Things are truly different up there.

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# LETTERS

Sirs:

I have read with great enjoyment the interesting and informative article by Gérard de Vaucouleurs on Mars in the May *Scientific American.* However, as a lover of the planet Venus I should like to point out that this planet has a better right than Mars to be considered, next to the Moon, our closest neighbor in the solar system.

As the orbits of Venus and the Earth lie in nearly the same plane, a good approximation to the average closest distance of approach can be obtained by substracting the mean distance between the Sun and Venus from the mean distance between the Sun and the Earth. That is, 93 million miles minus 67.2 million miles leaves about 26 million miles. At every inferior conjugation the Earth and Venus would be roughly this distance apart, whereas Mars never can get closer than 34 million miles.

If one should take into account certain asteroids such as Eros, which can come nearly as close as 14 million miles, or Hermes, which approached closer than one million miles, or Adonis, Apollo, Albert, Amor or Icarus, Mars would seem a relatively distant body.

STEPHEN H. FORBES

Moylan, Pa.

Sirs:

It was with great interest that I read the article on low-speed aerodynamics in "The Amateur Scientist" of *Scientific American* for April. We here at the Aero-

**Scientific American**, June, 1953, Vol. 188, No. 6. Published monthly by Scientific American, Inc., 2 West 45th Street, New York 36, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

**Editorial correspondence** should be addressed to The Editors, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

**Advertising correspondence** should be addressed to Martin M. Davidson, Advertising Manager, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y.

**Subscription correspondence** should be addressed to Circulation Manager, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y.

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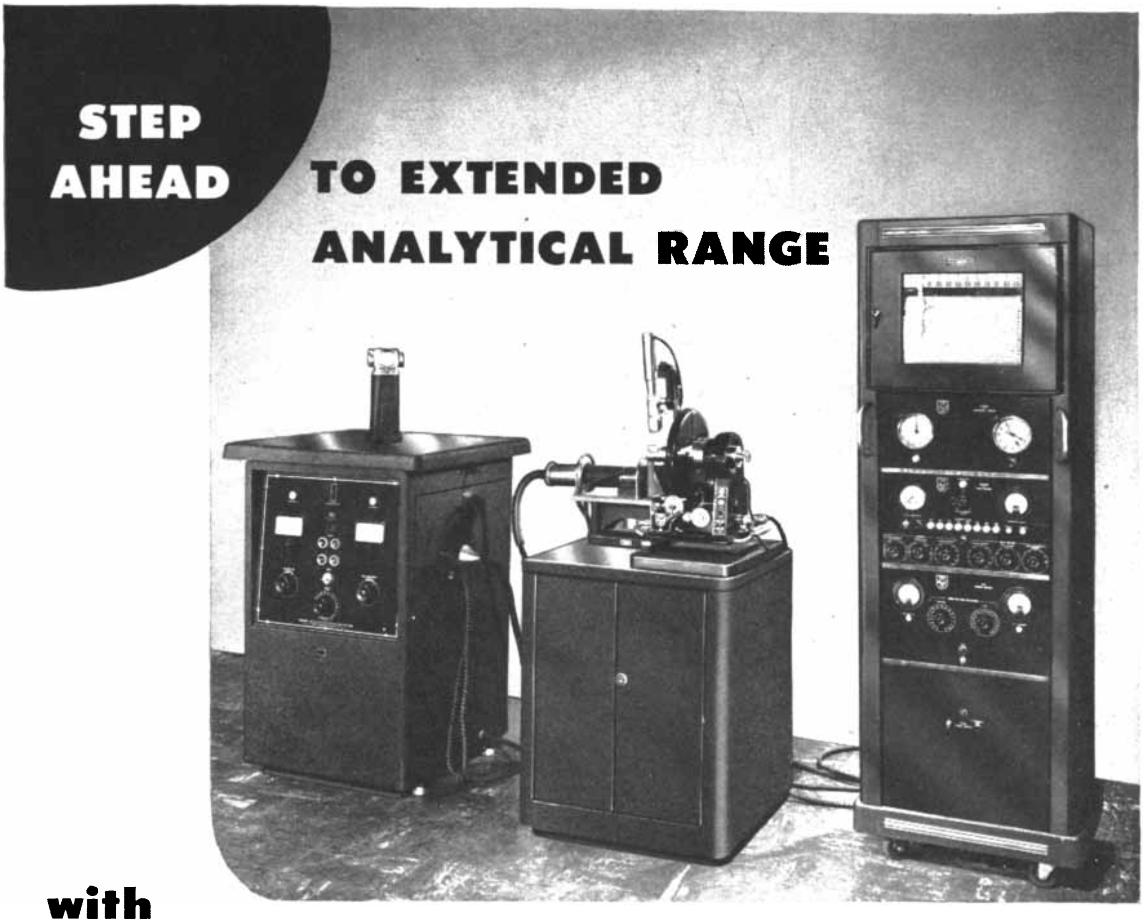

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In Canada: Rogers Majestic Electronics Ltd., 11-19 Brentcliffe Road, Leaside, Toronto 17, Ontario physics Department of Mississippi State College recently had the pleasure of having as our guest Professor Ichiro Tani of the University of Tokyo. While here, Professor Tani showed us the results of experiments which he performed just after the last war when "aeronautical aerodynamics" was forbidden to scientists in his country. Among these experiments were some concerning the curving of baseballs. His tests were made both in wind tunnels using smoke to detect the flow directions and also with pitched balls whose path, velocity and rotational speed were recorded with strobo-flash cameras.

Dr. Alexander Lippisch, the father of the delta-wing aircraft, also a recent visitor to this campus, has developed some striking techniques for utilizing smoke in low turbulence tunnels to picture the flow patterns around his models. Dr. Lippisch also published some years ago in *Air Trails* a series of articles on the aerodynamics of model airplanes.

At the present time our department is engaged in a low-speed flight-research program sponsored by the Office of Naval Research. Many other colleges and institutions throughout the country are engaged also in this program. Our work here is mainly concerned with controlling the laminar and turbulent boundary layers for the purpose of both low drag and high lift.

I agree that there is a tendency in modern aerodynamics to neglect the low-speed range in favor of the perhaps more glamorous high-speed flight. There can be no doubt that a thorough understanding of the basic mechanism of flow at low speeds will benefit technology at all speed ranges. And since, as you have shown in your article, the tools necessary to conduct such research are simple, cheap and readily available there exists a wonderful opportunity for the amateur to make some substantial contributions in this interesting field.

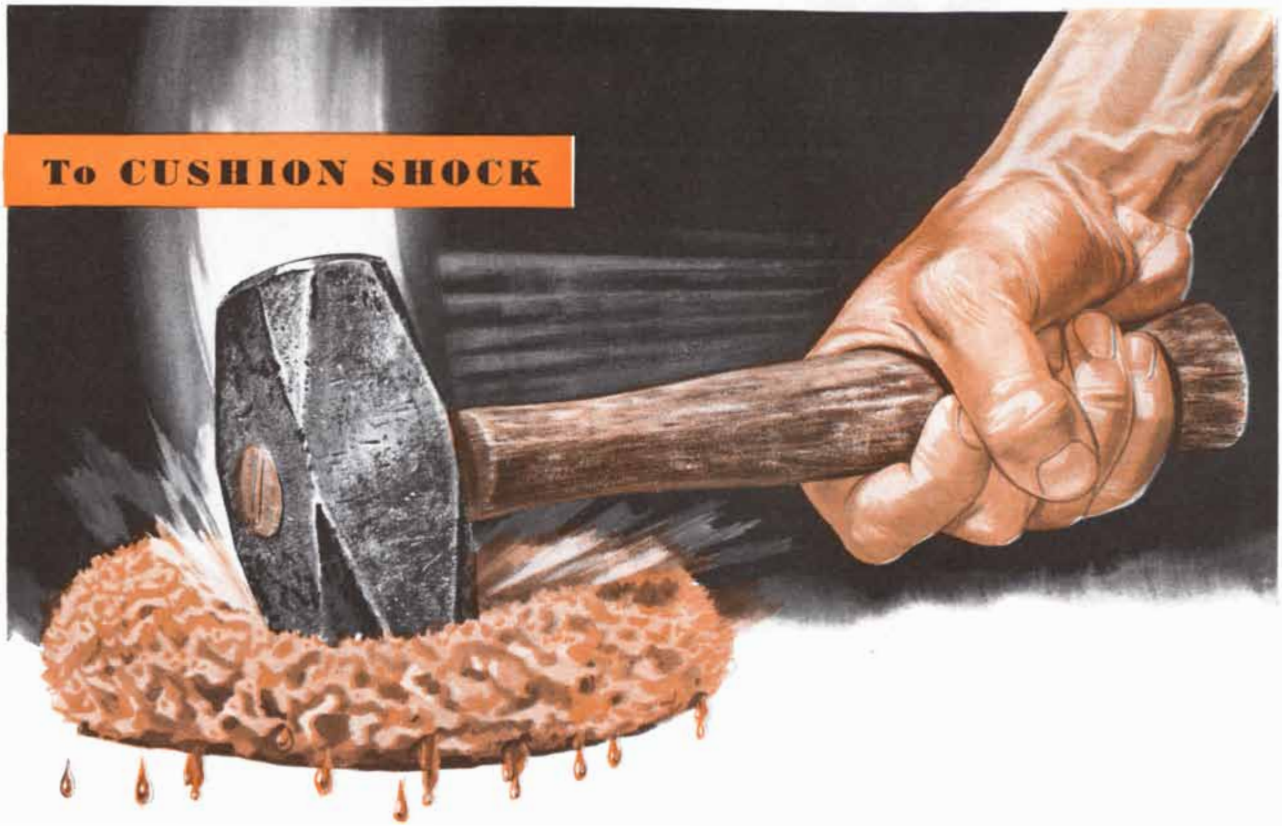
JOSEPH J. CORNISH

Mississippi State College
State College, Miss.

Sirs:

I have read the stimulating article by Albert I. Lansing in the April issue of your magazine. In this excellent piece of work, Dr. Lansing found that the survival time and size of the offspring of consecutive generations of young rotifer females were superior to those of old females. Inasmuch as he worked with a genetically homogeneous population and thought that he had kept the environmental conditions entirely constant, he drew the conclusion that this had to be explained by the presence of at least one substance responsible for "aging" and perhaps also for variations in growth.

I wonder whether Dr. Lansing's re-

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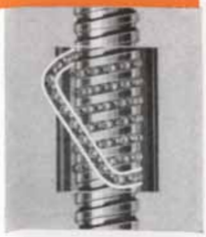

sults could not be interpreted differently. We have been interested in the aging of rats. As is well known, subsequent litters of a rat usually show deterioration in that the litter size and the weight of the young are smaller and the numbers of stillborn are larger among the fourth or fifth litters than those of previous litters. This can be explained by damages brought about by environmental influences (deficiencies, infections, etc.) which affect the whole rat and particularly the uterus so that the ovum eventually finds an inadequate environment for its development.

In my opinion a similar interpretation could be given to Dr. Lansing's results. It is quite possible that the environmental conditions selected by him damaged the uterus of his older females sufficiently to bring about unfavorable results. The offspring of young females, on the other hand, are constantly favored by excellent intra-uterine conditions; this selection may lead to improved offspring.

Such an interpretation would make unnecessary the assumption of a special aging substance. The whole present evidence makes it more plausible that death occurs as a consequence of disease caused by external influences rather than by a substance the unavoidable formation of which leads to suicide.


HANS KAUNITZ, M. D.

College of Physicians and Surgeons
Columbia University
New York, N. Y.


Sirs:

Dr. Kaunitz would have an excellent point if the rotifer were viviparous; it is not. The egg is laid in the medium, and embryonic life is entirely outside the maternal body. In addition, the fact that the aging effect is reversible (in my papers but not in the *Scientific American* article) rules out genic changes and environmental influences as listed by Dr. Kaunitz.


ALBERT I. LANSING

School of Medicine
Washington University
St. Louis, Mo.


ERRATUM

In the SCIENTIFIC AMERICAN department "Science and the Citizen" for May, a computing machine manufactured by the International Business Machines Corporation was described as having a weight of 10,000 tons. The weight of the machine is 22,000 pounds.

# 50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JULY, 1903: "Sir William Crookes, in an address before the Congress of Applied Chemistry in Berlin, discussed the phenomenon of radioactivity and its significance in our present theory of matter. 'The existence of electrical atoms or electrons, the constitution of Röntgen rays and their passage through opaque bodies, the emanations from uranium, the dissociation of the elements—all these isolated hypotheses are now focused and welded into one harmonious theory by the discovery of radium. Indulging in a "Scientific Use of the Imagination," and pushing the hypothesis of the electronic constitution of matter to what I consider its logical limit, we may be, in fact, witnessing a spontaneous dissociation of radium—and we begin to doubt the permanent stability of matter. The chemical atom may be actually suffering a catabolic transformation; but at so slow a rate that supposing a million atoms fly off every second, it would take a century for weight to diminish by one milligramme. Our views today of the constitution of matter may appear satisfactory to us, but how will it be at the close of the twentieth century? Are we not incessantly learning the lesson that our researches have only a provisional value? A hundred years hence shall we acquiesce in the resolution of the material universe into a swarm of rushing electrons?' "

"Santos-Dumont's new airship, the No. 9, has been tried in the neighborhood of Paris with considerable success. The tests thus far made may be considered as experiments with the new egg-shaped forms of balloon before building a larger airship on the same plan. The vessel is the smallest airship ever built. Its gas capacity is only 340 cubic yards. The new No. 9 is not intended to make any great speed, as the balloon body is of egg-shaped form and travels with the large end foremost. This construction makes it steadier than the pointed form. Hence the balloon is not as likely to pitch. The experimental No. 9 having proved so successful, the new No. 10, which is to be the largest airship yet built, and which will carry ten persons, will be constructed on the same lines."

"Our English contemporary, *Nature*, in a recent article, makes a statistical

comparison of the provision for university education in Great Britain and the United States, in which some truly remarkable results are shown. It seems that in the United Kingdom, with a population of 41,000,000, there are 25,500 university or university college students, or say six to each 10,000 inhabitants, while in the United States, with 76,000,000 inhabitants, there are 97,100 students, or 12.77 for each 10,000 inhabitants. The amount donated by private individuals for higher education in the period from 1871 to 1901 was eight times greater in the United States than that given for similar purposes in Great Britain; while, to say nothing of the income from state land grants, the amount provided by the state for higher education in the United States is six times as much as the government grants for the same purpose in Great Britain."

"Perhaps in no other country in the world is the work of the investigator in fields of scientific inquiry so little appreciated at its true worth as in the United States. If Americans seem cold, other nations on the contrary seem more than warm in their praise of scientific work. Not the least striking example of the heights to which the enthusiasm of a warmhearted race may soar in its appreciation of one of its members, is afforded by the greeting accorded to Marconi on the occasion of his recent visit to Rome. What American scientist or inventor was ever welcomed at a railway station by a deputation of city authorities and by a multitude of cheering countrymen? Not only the students of the colleges shouted an Italian welcome to him, but little school children seemed carried away by the popular fervor, and added their voices to the outburst of their elders. Not even a heavy downpour of rain could check the Italian ardor."

"Mme. Curie, having obtained about a decigramme of pure radium chloride by fractional crystallization of radiferous barium chloride, has endeavored to determine the atomic weight of radium. The results of her experiments show that the atomic weight is 225, with a probable uncertainty of not more than one unit, radium being considered a bivalent element."

SCIENTIFIC AMERICAN

JULY, 1853: "A terrible riot occurred on June 22nd at the residence of Dr. George A. Wheeler, of New York, caused by the finding of some human bones on the premises. A mob of 3,000 collected, armed with clubs, axes and stones. Dr. Wheeler's store and dwelling were at-

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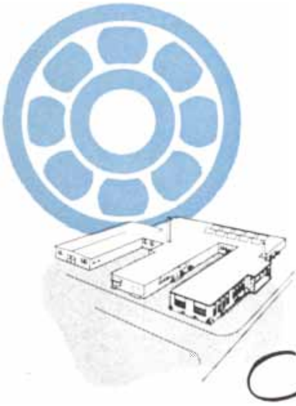

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tacked, the inmates driven out, and the premises completely gutted. Not one of the mob who had his arm or leg broken, but would run or get carried to a doctor to get it set, and how could he do this unless he was acquainted with the anatomy of the human body?"

"Gail Borden, Jr., to whom was granted a Council Medal at the World's Fair of 1851 for his celebrated meat biscuit, has taken measures to secure a patent for some exceedingly valuable improvements in preparing and concentrating sweet milk in such a manner that incipient decomposition is completely prevented. We have kept a quantity of this milk for three months, and although it has stood in a tolerably warm place, it is as sweet today as when we first received it."

"A number of gentlemen are making arrangements for the purpose of setting in operation a Metropolitan Telegraph for communication with all parts of New York City. The present idea is to establish in the upper part of the town ten offices, and wires connecting with the office in Wall St. They will transmit brief messages for a very small sum, and must necessarily do a large business. In fact, it is not improbable that the telegraph may be so extended as to do nearly all the real business correspondence between uptown and downtown. The post office is too slow, and we want such a telegraph."

"Professor Faraday of London, the celebrated electrician, has been experimenting on table-turning, 'not,' he says, 'that it was necessary on my own account, for my conclusions respecting its nature were soon arrived at, and are not changed.' Assuming that the tables were moved by a quasi-involuntary muscular action of the operator, Faraday's first point was to prevent the mind's having any undue influence over the effects produced. The point was to determine the place and source of motion, that is to say, whether the table moved the hand or the hand the table. To ascertain this, indicators were constructed. As soon as the index is placed within view, and the operator perceives that it tells truly whether he is pressing downwards only, or obliquely, then all effects of table-turning cease, even though the operator perseveres till he becomes weary and worn out."

"We have in our possession a photographic likeness of the Moon, painted by herself in the reflecting telescope at Cambridge, Mass. The artist was Mr. Whipple of Boston, whose fame is coextensive with our country. He has lately made great improvements in taking lunar photographic pictures by daguerreotyping them on glass prepared for that purpose."

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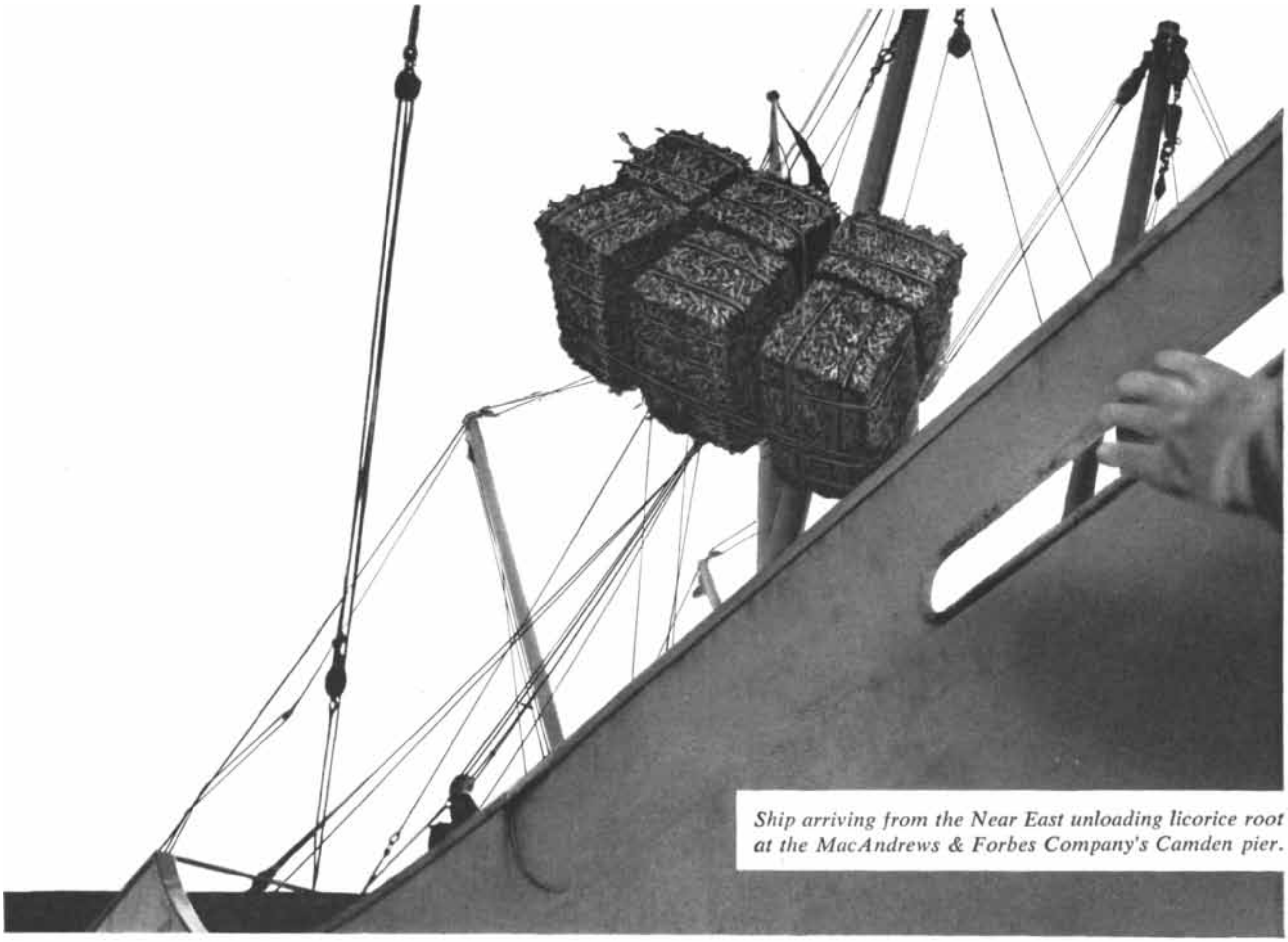
# THE AUTHORS

WILLIAM McD. HAMMON ("Gamma Globulin in Polio") directed the field tests which established the effectiveness of gamma globulin for short-term immunization against poliomyelitis. He is professor and head of the Department of Epidemiology and Microbiology of the Graduate School of Public Health at the University of Pittsburgh. He was born in Columbus, Ohio, in 1904. After high school Hammon decided to be a missionary and entered the Pittsburgh Bible Institute, where he studied "a little of everything—theology, agriculture, printing, mechanics, the building trades." He took a course in tropical medicine at the Belgian School of Tropical Medicine in Brussels, and then spent four years with his wife in the African Congo, building a mission, running an industrial school and operating a dispensary. In 1930 Hammon decided to go into full-time medical work and returned to the States to get an M.D. at the Harvard Medical School and a degree at the Harvard School of Public Health, where, under the direction of Hans Zinsser, he began to do virus research. He spent 10 years on the faculty of the University of California and transferred to his present position in 1950. He has specialized in work on virus diseases that attack the nervous system.

LAWRENCE P. LESSING ("Hydrazine") is a member of the Board of Editors of SCIENTIFIC AMERICAN. His background was briefly outlined in the May issue.

HAL FOSTER ("Radar and the Weather") recently joined the U. S. Weather Bureau as its first and, so far, only radar meteorologist. He is now at work on the West Coast on the study of cloud-seeding that he mentions in his article. He learned the new art of radar meteorology by practicing it for four years with the Weather Radar Research Project at the Massachusetts Institute of Technology. Born in 1920, Foster went no further than high school in his formal civilian education, but in the Air Force, which he joined in 1939, he attended weather schools. After serving in the Pacific Theater from 1943 to 1945, he was assigned to the Weather Bureau-Army-Navy Central in Washington to make analyses of upper-air charts for the U. S. He left the service in 1948 as a warrant officer and went to work on the M.I.T. project, remaining there until he took his present post last year.

PAUL C. MANGELSDORF ("Wheat"), one of the leading workers in the U. S. on the genetics of crop



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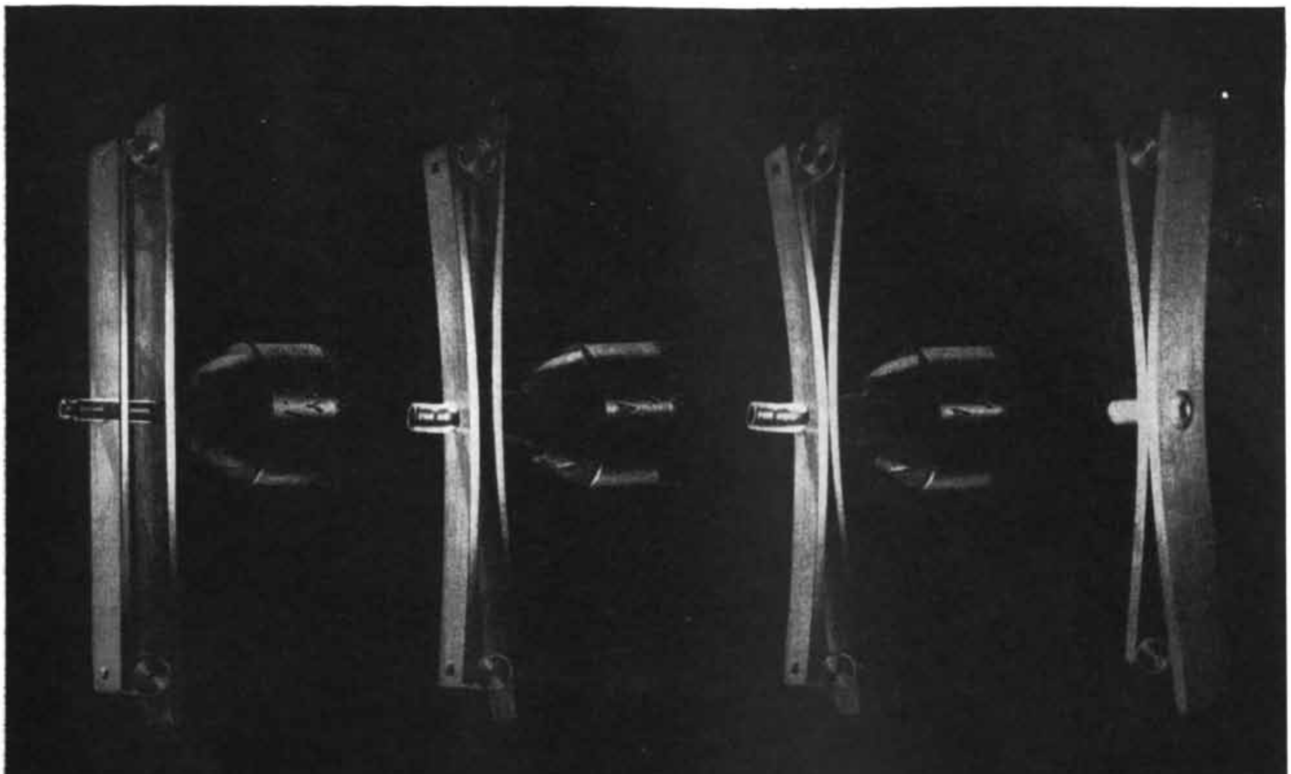
plants, dates his interest in cultivated plants from childhood. His father was a Kansas florist and seedsman. Young Mangelsdorf studied wheat- and corn-breeding at Kansas State College and after graduation in 1921 went to the Connecticut Agricultural Experiment Station as an assistant geneticist. He worked there under Donald M. Jones and took graduate work at Harvard under Edward M. East—these two played major parts in the development of hybrid corn. From 1926 to 1940 Mangelsdorf was agronomist at the Texas Agricultural Experiment Station, where he produced hybrid corn strains for the Texas climate and developed new varieties of wheat, oats and barley. He went to Harvard in 1940 and is now professor of botany and director of the Harvard Botanical Museum. Since 1941 Mangelsdorf has been Consultant for Agriculture with the Rockefeller Foundation, helping underdeveloped countries produce more corn and wheat. He has written two other articles for SCIENTIFIC AMERICAN, "The Mystery of Corn," in July, 1950, and "Hybrid Corn," in August, 1951.

HANS KALMUS ("More on the Language of the Bees") takes up the story where August Krogh left it in his article, "The Language of the Bees," in our August, 1948, issue. A geneticist who holds degrees in zoology and medicine, Kalmus is especially interested in the genetics of sense perception, on which he wrote in the May, 1952, issue of this magazine. He was born in Prague and taught at the German University there until 1939, when he took refuge from the Nazis in Great Britain. He is now a lecturer in the Department of Biometry, Eugenics and Genetics at the University of London. During the war he did experiments on high-pressure physiology in a study of the problems of escape from submarines. He has written three books, one of which, *Genetics*, is published in the English Penguin series. Kalmus is a founding member of the International Society for the Exploration of Biological Rhythms. In his leisure hours, he says, he used to be a "keen sprinter" and still enjoys skiing, hiking and mountain climbing.

JAMES R. NEWMAN, who edited and wrote the introduction for Leonhard Euler's memoir on the Koenigsberg Bridges in this issue, is a member of our Board of Editors and conductor of the Books department. He was born a doctor's son in New York City in 1907, graduated from the Columbia Law School in 1929 and later developed a love for mathematics and science. He practiced law, served the Government in many capacities during World War II, as special assistant to the Undersecretary of War and chief intelligence officer of the U. S. Embassy in London, and after



Clinching power of Monel Pop Rivet is tested against two thick (.090" gauge) strips of hardened 24ST aluminum alloy held apart by metal bearings. Note head of steel mandrel (left) projecting from inside hollow rivet.

Strips begin to pull together as hand tool (collet at right) draws mandrel head back through blind end of rivet. Radical expansion caused by swallowed mandrel head shows why rivet requires tough, ductile metal.

Pop Rivet clinches down strips with increasing power until high strength steel mandrel breaks under 1800 pound force exerted by patented hand tool. Mandrel strength depends on rivet diameter, from 7/64 to 3/16-inch.

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What they needed was a metal strong enough to clinch tightly and *stay* tight . . . ductile enough to "upset" and form a head properly . . . resistant enough to give the back of its hand to corrosives.

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the war was counsel to the Senate Committee on Atomic Energy and helped draft the Atomic Energy Act. On the side he did a great deal of writing; the well-known book *Mathematics and the Imagination*, which he wrote with Edward Kasner in 1940, is still popular. He held a Guggenheim Fellowship in 1946 and 1947. Newman now devotes all his time to writing and editing. His recent books include *The Tools of War* and *The Control of Atomic Energy*, the latter with Byron Miller. An able chess player, he recently defeated a former champion of the Manhattan Chess Club in three successive games.

KNUT and BODIL SCHMIDT-NIELSEN ("The Desert Rat") have collaborated in investigating the physiology of desert mammals. Knut was born in Trondheim, Norway, in 1915 and educated at the universities of Oslo and Copenhagen. At Copenhagen he studied with August Krogh, Nobel laureate in physiology and medicine, and received a doctorate of philosophy in 1946. While at Copenhagen he married his mentor's daughter Bodil. She was born in Copenhagen in 1918, holds a dental degree and Ph.D., and has done much work in general physiology. The Schmidt-Nielsens came to the U. S. in 1946 and have successively been on the faculties of Swarthmore College, Stanford University and the University of Cincinnati. They are now at Duke University, Knut as professor of zoology and Bodil as an assistant professor. Both members of this husband-and-wife team hold Guggenheim Fellowships for a study of water metabolism in camels.

LOREN C. EISELEY ("Is Man Alone in Space?") is chairman of the Department of Anthropology at the University of Pennsylvania and curator of early man in the University Museum. Born in Lincoln, Neb., in 1907, he attended the University of Nebraska, took his doctorate at the University of Pennsylvania and developed a wide range of interests, from general biology to cosmology. In anthropology he has specialized in archaeological studies of man in the New World and has done extensive field research in the western U. S. and Mexico. Eiseley also is a prolific writer, both in and outside his professional field. He was one of the editors of a recent Wenner-Gren Foundation publication entitled *An Appraisal of Anthropology Today*. His short stories and verse have appeared in popular magazines. He has contributed two previous articles to SCIENTIFIC AMERICAN, "Antiquity of Modern Man" in July, 1948, and "Is Man Here to Stay?" in November, 1950. This year Eiseley is on leave from the University of Pennsylvania on a grant from the Wenner-Gren Foundation "for the purpose of doing some writing."

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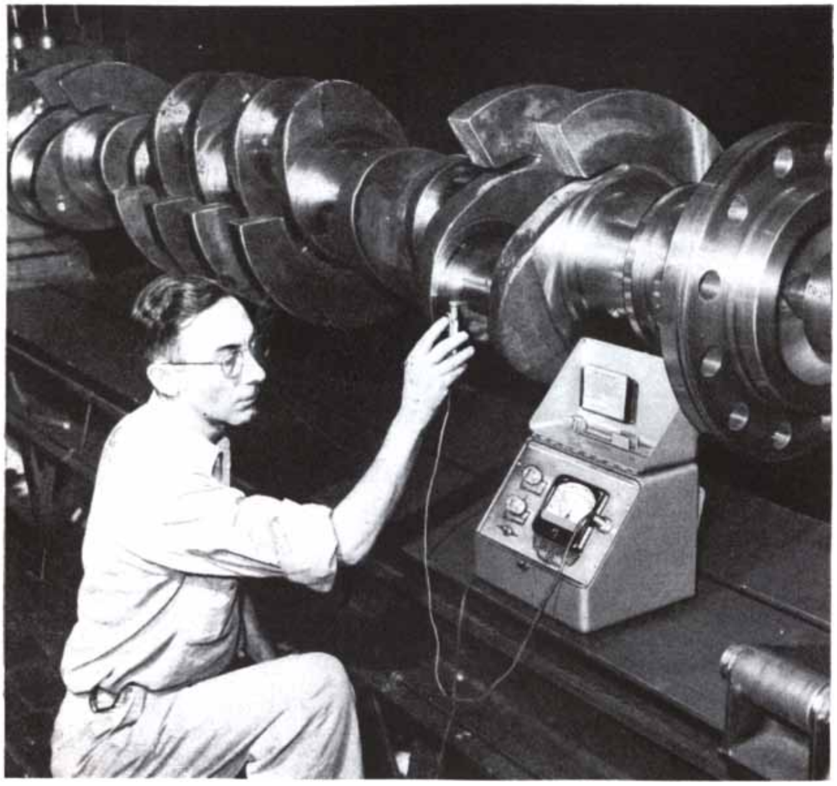






### THE COVER

The painting on the cover shows several plant species associated with the evolution of modern wheat (*see page 50*). Tied with a blue ribbon at the upper left are *Aegilops squarrosa* (*left*), a wild grass, and einkorn (*right*), the first cultivated wheat. Each of these species has seven chromosomes. Together with a piece of bread in the center of the painting are two heads of wild emmer, the immediate ancestor of the second oldest cultivated wheat, which has 14 chromosomes. At the lower right is a head of common wheat, which has 21 chromosomes. These specimens are from the Economic Herbarium of Oakes Ames in the Harvard Botanical Museum.

### THE ILLUSTRATIONS

Cover painting by Stanley Meltzoff

| Page | Source |
|---|---|
| 26 | David E. Scherman (*top*), Harvard University (*bottom*) |
| 27 | David E. Scherman |
| 28 | Sara Love |
| 29 | National Foundation for Infantile Paralysis |
| 30-31 | Irving Geis |
| 32 | U. S. Rubber Company |
| 33 | Irving Geis |
| 35-38 | U. S. Army Signal Corps |
| 51 | Ewing Galloway |
| 52-53 | Rudolph Freund |
| 54-55 | Sara Love |
| 56 | Rudolph Freund |
| 57 | U. S. Department of Agriculture |
| 58 | Rudolph Freund |
| 60 | Zachary from Black Star |
| 61-64 | Bunji Tagawa |
| 66 | James Egleson |
| 67-68 | New York Public Library |
| 69 | James Egleson |
| 73 | Courtesy Knut and Bodil Schmidt-Nielsen |
| 74-76 | Sara Love |
| 80-84 | Eric Mose |
| 89-90 | Yerkes Observatory |
| 95 | Courtesy Theodore Kazimiroff |
| 96 | Mount Wilson and Palomar Observatories |
| 98 | John Tremblay |

# DESIGNING WITH ALUMINUM

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

NO. 3

## ELECTRICAL CHARACTERISTICS

**HIGH CONDUCTIVITY-WEIGHT RATIO OF ALUMINUM ALLOYS USEFUL IN VARIED ELECTRICAL APPLICATIONS**

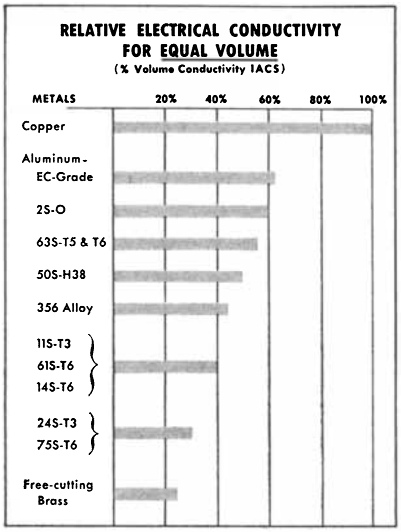
USEFULNESS of a material for electrical applications depends substantially on such considerations as cost, availability, strength, weight, workability, and permanence as well as upon the electrical properties themselves. Aluminum ranks well in all factors, and as a result finds many electrical uses besides those in the field of power transmission and distribution, where it occupies a commanding position.

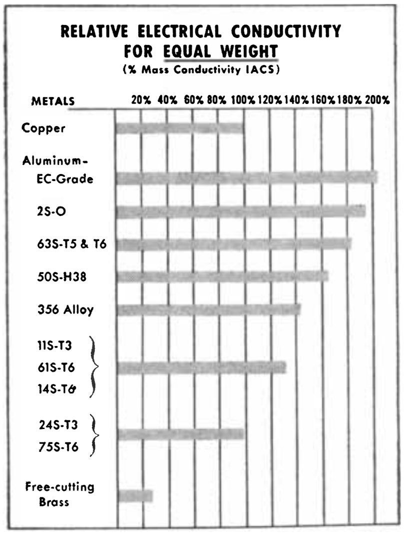
Per pound and per dollar, aluminum can deliver more electrical energy than any other material. Aluminum of EC (Electrical Conductor) grade, hard drawn (H19 temper), has a minimum conductivity of 60.97% of the International Annealed Copper Standard on the basis of *equal volume,* but its conductivity is *204% for equal weight.* In wire and cable design, volume conductivity is the factor commonly used. But in other electrical applications the mass conductivity may be more important.

## Aluminum alloys also have good conductivity

The values above apply to metal of 99.45% minimum purity. But it is worth noting that practically all aluminum alloys have good electrical conductivity, especially on the basis of *equal weight*—a circumstance which may well be utilized advantageously in the design and manufacture of electrical equipment, fittings and parts having other requirements in addition to electrical conductivity.

Conductivity decreases with the addition of various alloying elements, but to a less degree than might be expected. The accompanying bar charts illustrate the relative conductivity of a number of widely used alloys on both the volume and weight bases. While they do not imply specific recommendations for electrical applications, the charts show graphically that




on a comparative basis most commercial alloys of aluminum possess good electrical properties.

The alloys charted include representative non-heat-treatable and heat-treatable types of wrought and casting alloys, and all standard forms of aluminum mill products—sheet, plate, rod, bar, wire, forging stock, extrusions and casting ingot. Their availabilities are as follows:

| ALLOY | |
|---|---|
| EC | Sheet, plate, wire, conductor, bus bar. |
| 2S | Sheet, plate, rod, wire, forging stock, extrusions. |
| 63S | Extrusions. |
| 50S | Sheet, plate. |
| 356 | Casting ingot. |
| 11S | Rod, bar, wire. |
| 61S | Sheet, plate, rod, wire, forging stock, extrusions. |
| 14S | Sheet, plate, rod, wire, forging stock, extrusions. |
| 24S | Sheet, plate, rod, bar, wire, extrusions. |
| 75S | Sheet, plate, forging stock, extrusions. |

These alloys include a range of tensile strengths up 83,000 psi for 75S-T6, the strongest commercially produced aluminum alloy, which on a *weight* basis has practically equal conductivity with copper. The tensile strengths of several other heat-treatable alloys are also greater than that of hard-drawn copper.

Also, a cable or bus bar of EC aluminum, having a tensile strength of 27,000 psi, will have a total breaking strength in tension close to that of a copper cable or bus of equivalent resistance because of the somewhat greater cross-sectional area required. An aluminum bus will have greater bending strength because of the increased section modulus.

The greater peripheral area of an EC aluminum conductor of equal resistance to a copper conductor means that it will dissipate more heat at a given temperature. This, combined with a lower inherent skin-effect, gives the aluminum conductor a current carrying capacity which varies from

PLEASE TURN TO NEXT PAGE ➡

78% to 84% (depending on size) of the same-size copper conductor.

## Present applications suggest future uses

The progress made in recent years in successful electrical applications of aluminum indicates an accelerating rate of development. Thousands of fractional horsepower motors have been and are being produced with aluminum magnet wire stator windings. Some changes in manufacturing techniques were required, but no serious problems were met in actual practice, including aluminum-to-copper connections where they were required.

Similarly aluminum wire is being used, and giving good performance, in transformer windings and discharge lamp ballasts. Use of aluminum has even made it possible to build larger turbine driven generators than ever before because of its combination of light weight and good conductivity, permitting higher rotor speeds without exceeding safe centrifugal force limits.

Aluminum sheet is standard material today in the manufacture of electric light bulb bases and lamp sockets. The alloys generally used have a volume conductivity of 42% and 35%, respectively. Aluminum in these applications has better conductivity than brass, is more economical and is easily fabricated.

Cast aluminum is regularly used in the rotors of induction motors, with lower costs for both metal and fabrication. An important additional advantage is that cooling fans may be cast integrally with rotor bars and collector rings. Aluminum rod and bar (screw machine stock) are used for battery terminals, and similar applications.

Because it provides a high ratio of area to volume by being rolled to extremely fine gauges, aluminum foil is standard in capacitors. The surface area is generally increased further by etching the foil.

## Connections for aluminum

Different types of connections and different techniques are employed with aluminum. Though not all problems have been solved yet, the important fact is that satisfactory connectors and methods for aluminum-to-aluminum and aluminum-to-copper connections are available and have proved them-

selves in practice. The use of welding to connect aluminum with copper shows much promise and is being exploited increasingly; it appears to perform satisfactorily in service despite the difference in the coefficients of thermal expansion for the two metals and provides excellent joint conductivity.

The oxide coating which forms on the surface of aluminum when exposed to air is insulating in nature and must be removed or penetrated when making a connection. Suitable contact and sealing pastes are available which assist in establishing a good electrical connection while at the same time preventing re-formation of a new oxide film.

(Incidentally, it is possible to take advantage of this oxide coating as an insulator. A thickness of .001″ is capable of withstanding 1000 volts, and the oxide may be built up to as thick as .006″. This property is being used in some current-limiting reactors, where it has been found that with aluminum windings the enameling of alternate layers of strands is unnecessary to provide the insulation needed to reduce skin-effect and eddy-current losses. Being stable when heated, the oxide may provide advantages in some applications over other normally used coverings such as organic coatings.)

## Savings offer strong aluminum inducement

With its characteristics of less weight and substantially lower per pound cost, the savings in metal costs through the use of aluminum present an opportunity for substantial economies. In some cases, it is true, manufacturing costs may rise somewhat until techniques are developed, but seldom enough to wipe out the metal saving. On the other hand, economies in fabrication, handling and shipment will undoubtedly be achieved.

It is important also that the price of aluminum is relatively stable and that expanding aluminum production is steadily increasing its availability.

The broad advantages that aluminum offers in electrical applications are well worth investigating. Services of experienced Kaiser Aluminum engineers are available for consultation and assistance on your design and manufacturing problems. Call the nearest Kaiser Aluminum sales office or write Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

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# SCIENTIFIC AMERICAN

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CONTENTS FOR JULY, 1953 VOL. 189, NO. 1




## ARTICLES



## DEPARTMENTS

SCIENTIFIC AMERICAN

JULY, 1953 VOL. 189, NO. 1

# Gamma Globulin in Polio

*The field trials have most significantly shown that small amounts of antibody are sufficient to prevent the disease, a fact that enhances the prospect of a successful vaccine*

by William McD. Hammon

THE DISCOVERY that gamma globulin can prevent poliomyelitis is only a roadmark on the way to conquest of the disease. Gamma globulin's success is, paradoxically, much less important than its shortcomings, which have been immensely valuable in showing what must be done to control polio, and how this may be accomplished.

To see why gamma globulin is not a final answer to polio we must examine the differences between active and passive immunization. Active immunization means that the body itself plays an active part in creating the immunity. After acquiring the disease in a natural manner or being inoculated with the disease-producing organism or an essential part of it, the body forms its own antibodies, which then stand ready to defeat any new invasion by other members of the same tribe of organisms. Sometimes the vaccine is a living microbe of a comparatively harmless strain; an example is the cowpox virus injected to protect against smallpox. The immunity induced by this kind of vaccination may last many years, possibly even a lifetime. For many diseases there is as yet no safe living vaccine; the organism must be "killed," *i.e.*, inactivated so that it cannot multiply in the body. Such vaccines are used against influenza, encephalitis, typhus, cholera, whooping cough, tetanus and diphtheria. These vaccines must be made of large numbers of organisms, often must be given in a series of injections spaced weeks or months apart, and produce a limited immunity lasting only one year or a few years, depending on the disease and the medium used for the injection.

In passive immunization antibodies themselves, rather than the disease agent, are injected into the body, which plays no role in producing or maintaining immunity. The antibodies are obtained from the blood of human or animal donors. If the serum is from an animal (*e.g.*, diphtheria antitoxin from horses), its effect is transient. The human body destroys these foreign substances in 8 to 10 days, frequently with serum sickness and hives as associated reactions. A subsequent injection of the same serum may lead to a severe or dangerous type of reaction. Hence serum from animals is obviously for emergency use only and is repeated only under exceptional circumstances. Human serum or gamma globulin has none of these reactions and furthermore is slowly excreted by the body. The rate of excretion is measured in half-life, that is, the length of time it takes for half the material to be eliminated. The half-life of gamma globulin is about three weeks in children and two weeks in adults. The larger the dose, the longer the patient will have an effective level of antibody, but at best the immunity given by a single injection lasts for only a few weeks or months.

The one big advantage of passive immunization is its immediate effect. If an infection has already occurred, the serum goes into action immediately upon injection. Thus measles, polio and some other diseases can sometimes be checked even though the injection is given several days after the patient has been infected. Most virus vaccines will not work, however, unless they are injected before or very shortly after infection.

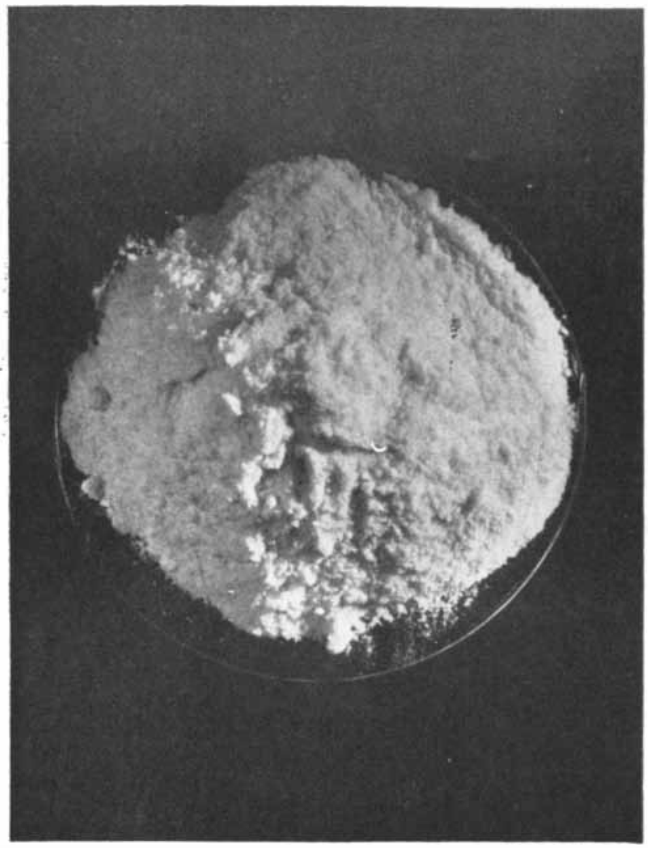
GAMMA GLOBULIN is the fraction of the blood that contains most of the antibodies formed to combat infections. It is removed from the blood plasma by a chemical fractionating process developed by E. J. Cohn of Harvard University. Removal of the gamma globulin does not substantially reduce the effectiveness of the plasma in combatting shock and replacing blood fluid; in fact, in some ways the remaining plasma is better: it can be stored longer and the fractionating process eliminates the jaundice-producing virus which caused so much trouble in World War II.

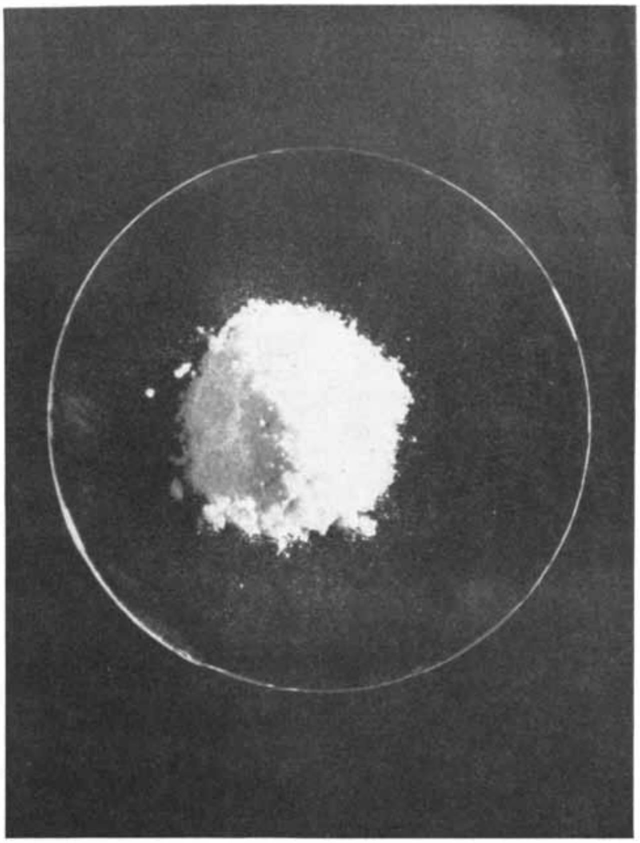
The gamma globulin, extracted as a powder, is diluted to a 16 per cent water-white, slightly opalescent, viscous solution which, with a little preservative, can be kept under refrigeration for many years. For a short period of storage it does not need to be refrigerated.

Let us now consider the use of gam-

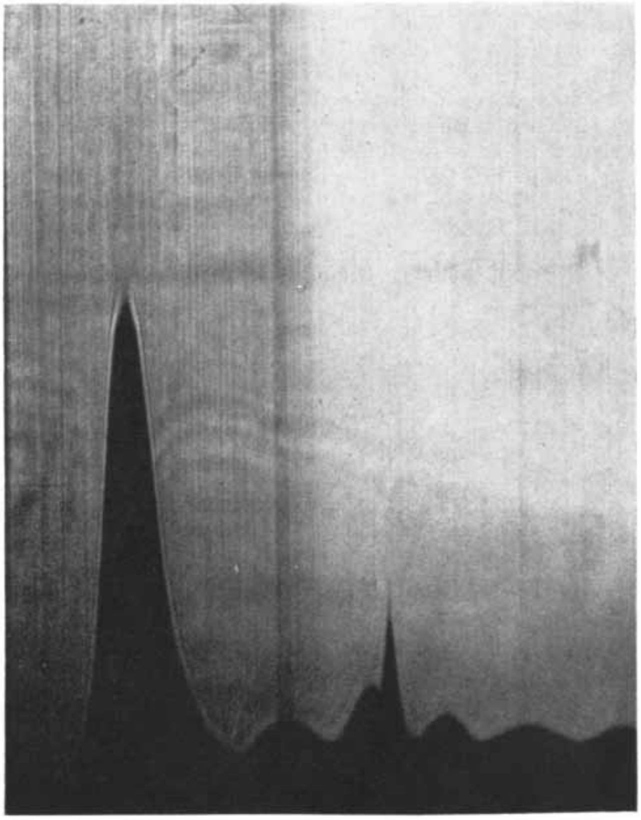
ANNOUNCEMENT

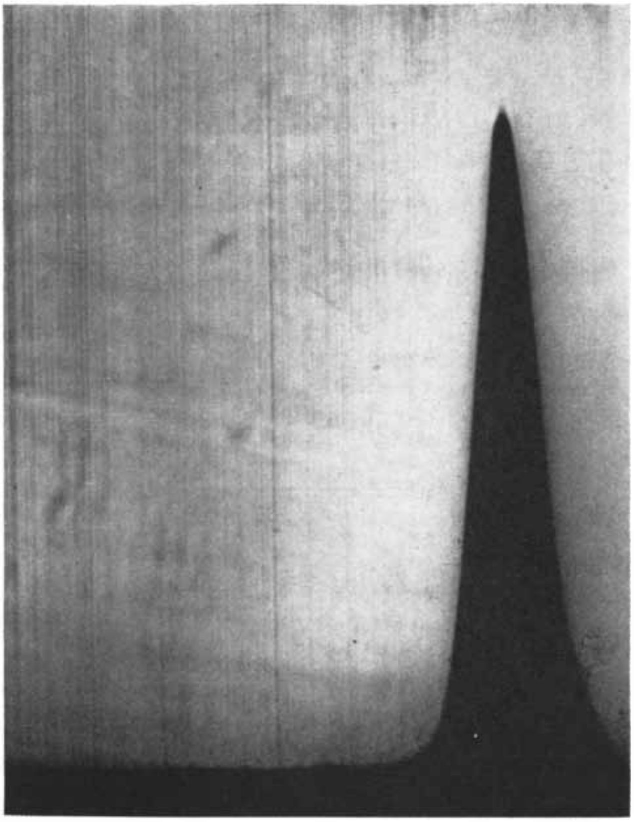
For the past three years SCIENTIFIC AMERICAN has devoted its September issue to a single topic. In 1950 the topic was the history of science during the first 50 years of this century; in 1951 it was the human resources of the U. S.; in 1952, self-regulating machines. This year the September issue will be devoted to fundamental questions of science. It will contain a series of articles by outstanding scientific workers, each of whom will discuss a basic problem in his field of investigation.





**DRIED BLOOD PLASMA** in the watch glass at the left can be fractionated to yield the amount of gamma globulin shown at the right. For clinical purposes the gamma globulin is diluted to a 16 per cent solution.



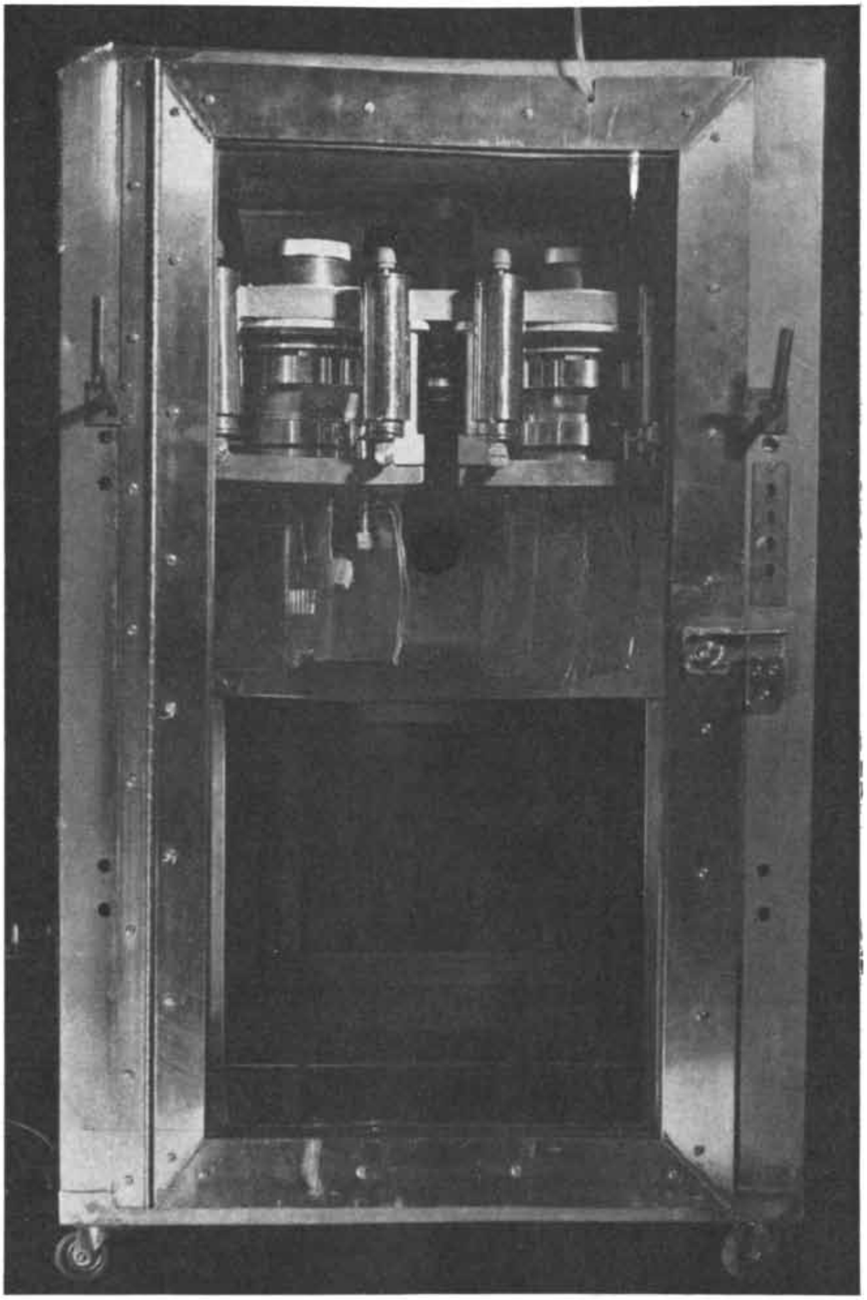


**ELECTROPHORESIS DIAGRAMS** show gamma globulin before and after fractionation. Each peak in the diagram at left is a plasma fraction; gamma globulin is second from right. At right is gamma globulin alone.

ma globulin against polio. Experimenters had known for some time that large amounts of serum from a convalescent monkey could protect another monkey from the disease. Yet serum from a convalescent child frequently had no protective effect on a monkey. Polio researchers, not realizing that the reason for this was the existence of three different types of polio virus which do not produce immunity against each other, were in some doubt as to whether the human body formed polio antibodies. In 1948 the writer and E. C. Roberts at the University of California showed by a series of tests that the human body definitely does produce antibodies following polio infection.

Meanwhile two other groups of scientists—one at the Children's Hospital of Philadelphia under Joseph Stokes, Jr., and the other at the Michigan State Health Department under S. D. Kramer—demonstrated independently that large doses of gamma globulin protected laboratory mice against a strain of polio now known as the Lansing type. Stokes urged that gamma globulin be tested in human patients. He had conducted tests on children in 1932 using whole blood, and the results seemed encouraging. However, nearly all investigators believed, on the basis of the animal experiments, that the gamma globulin dose for human beings would have to be impracticably large—measured in pints.

In 1949 we suggested in a paper before the Academy of Pediatrics in San Francisco that no comparison should be made between a highly artificial direct brain injection of virus into a mouse or monkey and a naturally acquired infection in man. Perhaps a small amount of antibody would prevent polio in man just as it did in measles. Without a human trial one would never know. Almost simultaneously David Bodian at The Johns Hopkins School of Public Health found that antibodies against all three types of polio were present in significant and almost equal amounts in a lot of Red Cross gamma globulin made from a pool of serum from many thousand adult donors. Interest slowly grew, and the National Foundation for Infantile Paralysis arranged for us to present our views to a group of scientists and advisers for discussion. Many of them said, "Why not try it? It might work and no harm would be done." Others said, "It is ridiculous to think it would work better in man than in animals." Still others insisted that many more animal tests should be made.



**BLOOD IS FRACTIONATED** in a new machine developed by E. J. Cohn and his associates at Harvard University, where the photographs on these two pages were made. The machine is placed beside the donor, whose blood fractions are channeled into plastic bags by the centrifuges at the top.

WE WERE encouraged by the Foundation to plan a human field test, which was finally arranged on a pilot scale for the summer of 1951. This was to determine whether medical societies and enough parents would participate in a really large-scale trial. The pilot project was launched with Lewis L. Coriell, director of the Camden Municipal Hospital for Infectious Diseases, as assistant and Stokes as consultant. Utah County, Utah, was selected as the area; it had a serious polio epidemic. We planned to inject 5,000 children, half with gamma globulin, the other half with inert gelatin as control. "Project Lollipop" went off astonishingly well. Physicians brought their own children to be first in line at the public clinics. They and hundreds of laymen volunteered their time. The churches urged parents to participate. In half the time planned, 5,767 children were injected. Six cases of polio developed among these children. Only one of the cases occurred in the group that got gamma globulin, and this child developed the disease five and a half weeks after the injection. The results did not prove very much: purely by chance six tosses of a coin may easily produce just one head or one tail. All the test showed was that we could expect to get the cooperation of physicians and the public in a larger field trial.

There were other favorable developments at about the same time. We succeeded in protecting suckling baby mice against polio with gamma globulin by a new method: giving virus into the abdomen and injecting minute doses of gamma globulin intramuscularly as in man. At the same time Bodian reported that he had found polio virus circulating in the blood of chimpanzees and a species of monkey several days before the animals showed signs of illness. The animals had been infected with special virus strains which produced the disease when given by mouth. He also showed that in these special animals and with these special strains doses of gamma globulin approaching those we had used in Utah offered protection. Dorothy M. Horstmann of the Yale University School of Medicine simultaneously reported virus in the blood in animals under the same special circumstances. They both suggested that if antibodies were present while the virus was circulating in the blood, they might entrap the virus and prevent it from entering the nervous system. This hypothesis is inviting, but much evidence is still required before it can be accepted as the mechanism that regularly occurs in man.

ALL THIS impelled the Foundation to have us go ahead with large trials of gamma globulin. They were carried out in July, 1952, in Harris County, Texas, where 33,137 children received injections in our clinics, and in Woodbury County, Iowa, and contiguous Dakota County, Nebraska, where 15,868 children participated. The latter area had so severe an epidemic and so large a proportion of the children participating that it became obvious we would have to go no further for an adequate answer to the primary problems.

During the next few months teams of physicians and physical therapists carefully followed up all cases of polio that came to their attention in the test areas. As in the first test, none of the attending physicians or parents knew which children had received gamma globulin and which only gelatin. Finally, late in the fall, the Foundation unlocked in its New York office the code that identified the material given to each child so that we could determine what substance had been injected into those children who later developed paralysis. There could be no doubt of the result—gamma globulin had won.

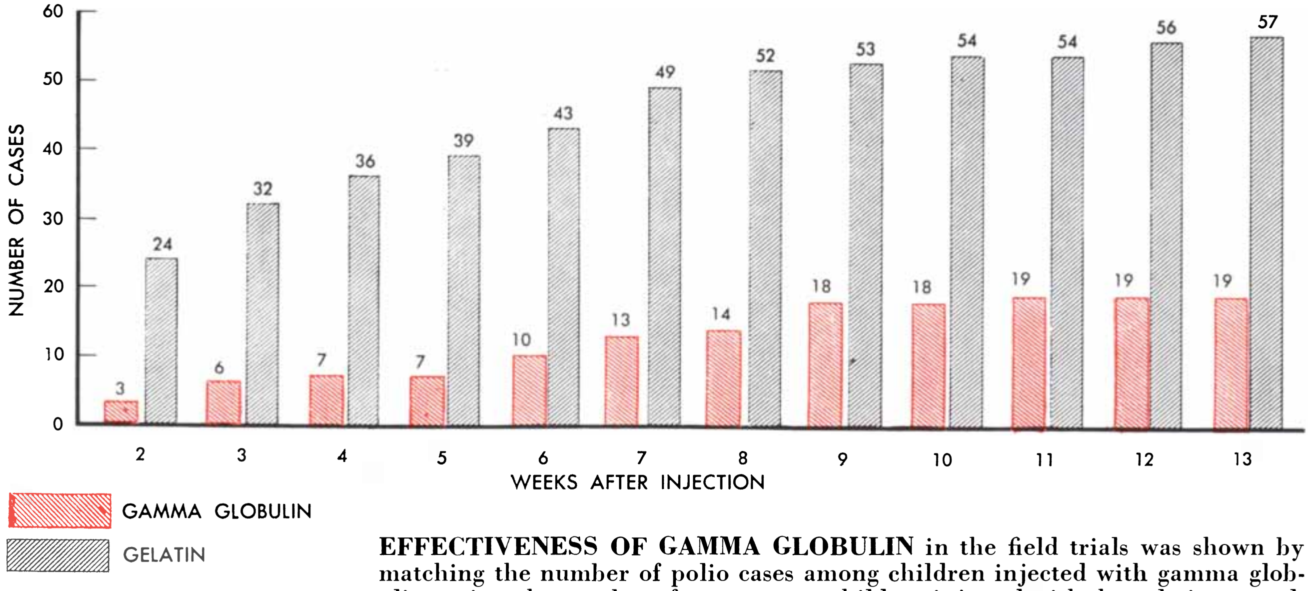
In the first week after injection 12 paralytic cases occurred among those receiving gamma globulin. Their paralysis was so slight that only a careful muscle analysis disclosed it. Within 60 days half of them had completely recovered and none had enough involvement to serve as a handicap. Among the control group given gelatin there were 16 paralytic cases; only one of these recovered completely and several had severe residual involvement.

During the next four weeks seven cases developed in the globulin group and 39 in the non-protected group. By the end of the fifth week the difference began to disappear, and by the ninth week and thereafter equal numbers of cases occurred in both groups.

JUST WHAT does this mean? Is poliomyelitis no longer to be feared? No—emphatically no! Optimism has risen entirely too high. Gamma globulin is only a passive protection, and it is temporary, averaging five to eight weeks with the dosage we used (.14 cubic centimeter per pound of body weight). Moreover, the basic material from which this protection comes is human blood, a limited commodity. Supplies of gamma globulin have been increased, as the armed forces and civil defense have agreed to extraction of the substance from their plasma, and commercial biological manufacturers have begun to process gamma globulin from the blood of professional donors and from human afterbirths, a source otherwise wasted. But there is no possibility that we shall ever have enough of the material to come anywhere near protecting the whole susceptible population against polio.

The use of gamma globulin for general immunization is fantastically spendthrift of a scarce resource. In Iowa and Nebraska, which last year experienced one of the severest epidemics ever to occur in this country, the mass injections gave protection that was needed by only one child in every 250 to 300 injected, and the protection was good for only five to eight weeks. In Texas, where the outbreak was much less severe but more protracted, the protection was needed by only one of every 2,000 children injected. In most areas considered epidemic, mass gamma globulin injections would serve to protect about one child of every 15,000 injected for an average of about six weeks. An average dose for a child (seven cubic centimeters for a child weighing 50 pounds) requires a pint of blood from one adult donor. What does one do if the danger lasts more than five or six weeks—give another injection?

More economical and efficient ways to use gamma globulin probably can be found. For instance, the injections might be given only to vulnerable members of families in which a case is discovered. It is estimated that if any pregnant women in such families, and all persons under 30, were injected as soon as a case in the family was recognized, this would serve to prevent paralytic polio in one out of every 200 to 300 persons

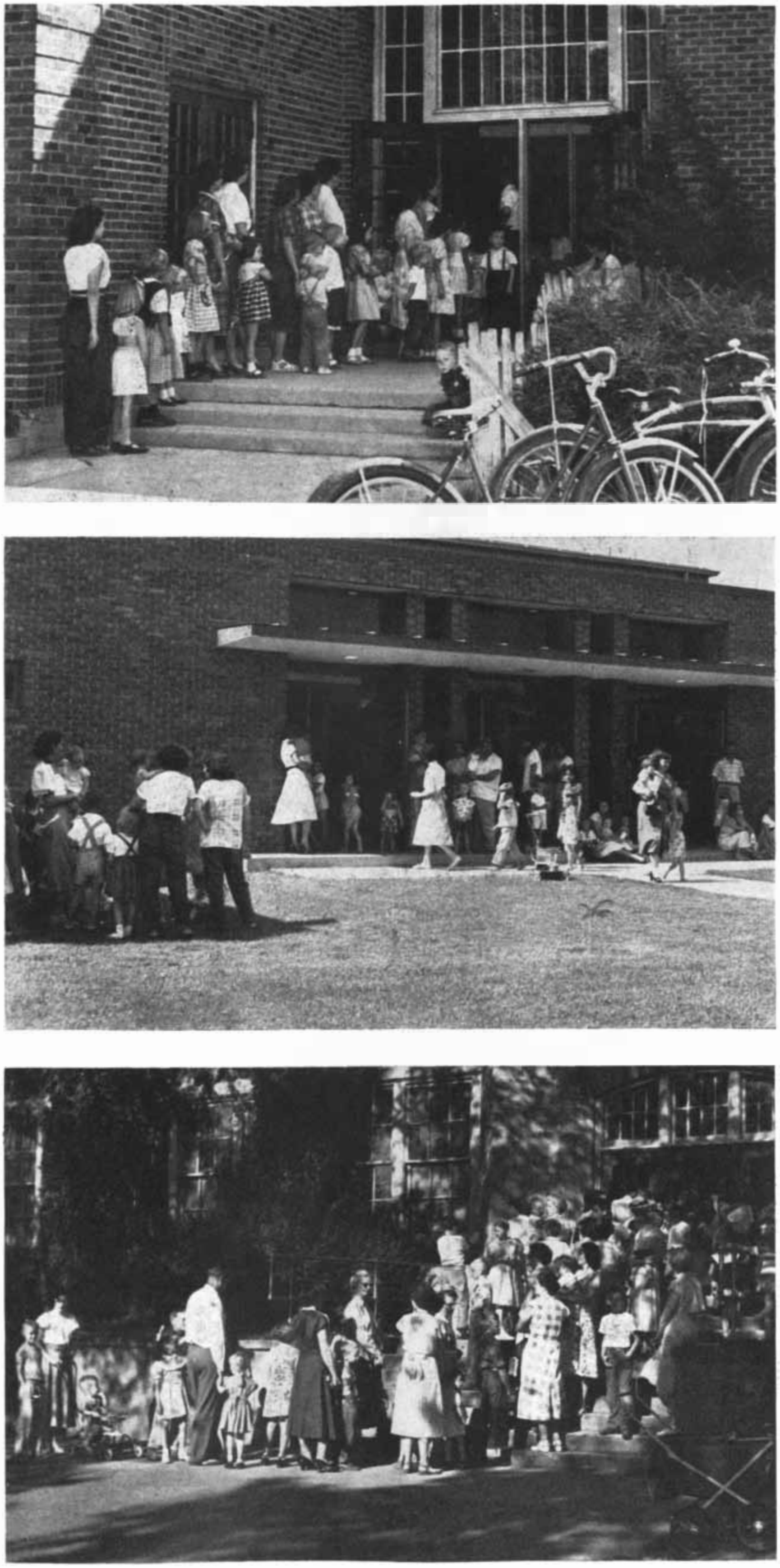



**EFFECTIVENESS OF GAMMA GLOBULIN** in the field trials was shown by matching the number of polio cases among children injected with gamma globulin against the number of cases among children injected with the gelatin control. Each bar represents the total number of cases in its group up to that week.

injected. It might also reduce the severity of the disease in a much larger additional number of cases. Even so, this use of gamma globulin is not nearly as effective as its use against measles, where the source of infection is almost invariably a diagnosed case and the mother knows which of her children have not already had the disease and need protection.

THE MOST important value of the gamma globulin field tests undoubtedly lies in the knowledge they give us regarding what amount of antibody is needed for protection. Formerly it was believed that large amounts had to be present in the blood. This erroneous idea offered what appeared to be an insurmountable barrier for a killed polio vaccine to overcome in order to achieve active immunization. Safe live mutants of all three types of virus were not in view. Now the problem has changed markedly for the better. The antibody level in the blood after present gamma globulin injections cannot even be detected by our available tests. Thus to provide protection we need only produce a vaccine which will stimulate and maintain for a reasonable time a barely detectable amount of antibody against the three types of virus. Perhaps it would suffice to give an injection in infancy and at several intervals thereafter. Yet the problem of waste would remain, because for each hundred who actually needed protection we would have to vaccinate millions who never would have become paralyzed.

Many of the technical difficulties that still stand in the way of producing an effective vaccine seem to be yielding to current research. Two mutants of Type 2 virus are being explored for a living vaccine, while killed vaccines including all three viruses are showing encouraging results. The latter type will probably be available first. However, since the killed virus vaccine is an entirely new biological product and is being produced in tissue from another species of animal, a long period of careful testing for safety will be necessary. This leaves us with only gamma globulin for an indefinite time to come. We must emphasize again that any attempt to achieve a large-scale reduction in the incidence of polio with gamma globulin is bound to be wasteful and disappointing. This infection produces strange paradoxes. In its usual form polio is so much milder than measles that it does not seem to justify the shotgun methods required to control it, for the same agent can be used to much more efficient advantage in measles. Yet polio is far more feared than measles. There is a much greater demand for an agent to control it, and when such an agent is found, it will be used more extensively.



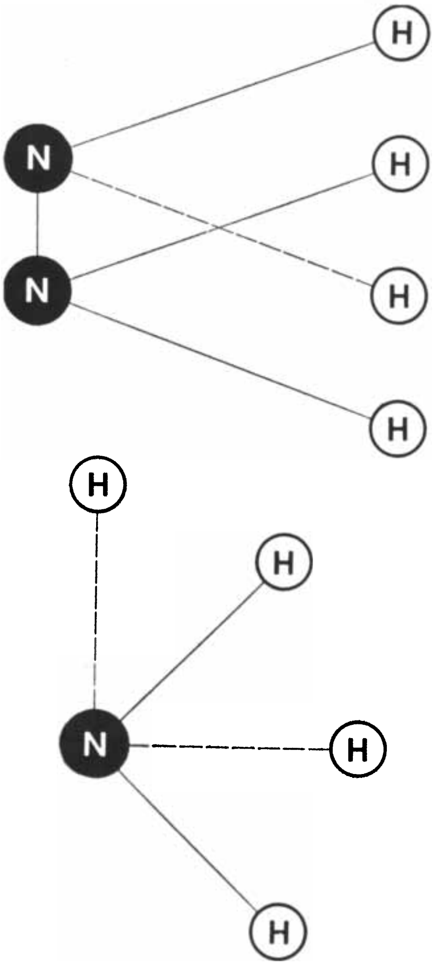
**FIELD TRIALS** were conducted in Utah, Texas and two adjacent counties in Iowa and Nebraska. In these photographs children await injection in Provo, Utah (*top*); in Houston, Texas (*middle*); and in Sioux City, Iowa.

# HYDRAZINE

## This nitrogen compound was propelled out of obscurity in German rocket motors. Its highly reactive molecule, related to ammonia in makeup and origin, is the basis of a new range of chemicals

by Lawrence P. Lessing

HYDRAZINE is an intriguing new material. Indeed, many chemists believe it would be hard to imagine a more reactive and versatile chemical. It is the substance that fueled the first rocket aircraft in history, flown by Germany in the closing days of World War II, and it is a leading candidate to fuel the rockets and guided missiles of the future. It is the important ingredient in a whole spectrum of chemicals developed recently, including tuberculosis drugs, other pharmaceuticals, dyes, detergents, surfactants, antioxidants, agricultural and rubber chemicals, textile and reducing agents, not to mention plastics and synthetic fibers. Hydrazine, in short, is a starting material for an entirely new branch of chemistry.




**THE MOLECULE** of hydrazine is shown in perspective (*top*) and with N-N axis perpendicular to the page.

It is a compound of great energy—a six-atom molecule of two nitrogen atoms and four highly reactive hydrogen atoms which are quick to join with oxygen and other elements in chemical combustion or transformation. The molecule's configuration provides a versatile unit for building other compounds. It is shaped somewhat like a rod-and-ball mobile, the double-linked nitrogen atoms forming a strong axis, with hydrogen pairs swinging off asymmetrically from both ends. While the hydrogen atoms are very active, the nitrogen atoms are so strongly bonded that any reaction violent enough to rip them apart releases large amounts of energy. Hydrazine is about a third more energetic than TNT but is a far smaller molecule: its molecular weight of about 32 is little more than that of two oxygen atoms. Hence it is one of the most concentrated forms of chemical energy known.

Yet the substance does not explode upon simple impact or under friction. In its usual commercial form, hydrazine hydrate, it is no more dangerous than gasoline. In the open air it burns energetically with a blue flame. In a closed space it is more hazardous: hydrazine vapor decomposes with air or water, which it picks up from the atmosphere, into a spontaneously combustible mixture. It is also readily detonated at low temperatures by an electric spark or by contact with traces of certain metals, chiefly copper and iron. Thus hydrazine may be used as an explosive or burned as a fuel. With the proper techniques and precautions it may also be put through slower and more fruitful reactions to yield many products. All this, plus its avidity for oxygen and its similarity to water in physical properties, make it a most unusual chemical.

Hydrazine's primary significance lies in the fact that it is an active inorganic analogue to an organic hydrocarbon. It belongs to a family of chemicals known as the hydronitrogens, which contains some 13 basic compounds, beginning with ammonia. Ammonia, with one nitrogen and three hydrogen atoms, is analogous to the first member of the hydrocarbon series, methane, and hydrazine is an analogue of the second hydrocarbon, ethane. Up to now the hydronitrogens beyond ammonia have not played a very large role in industrial chemistry. In general, the inorganic chemicals are much less reactive and versatile than the organics and have had nothing like the organics' spectacular industrial growth. Elemental nitrogen of course is an inert gas, and even useful ammonia does not have the structure for any great building up of different compounds. But hydrazine is a different affair entirely. It is the first hydronitrogen and one of the few inorganics with a reactivity and with structural possibilities as a building block that can compare with those of the prolific organics. Just as the organic hydrocarbons have given rise to an immense kingdom of chemicals, which has now grown to well over 500,000 compounds, hydrazine promises to be the beginning of a new empire of hydronitrogens.

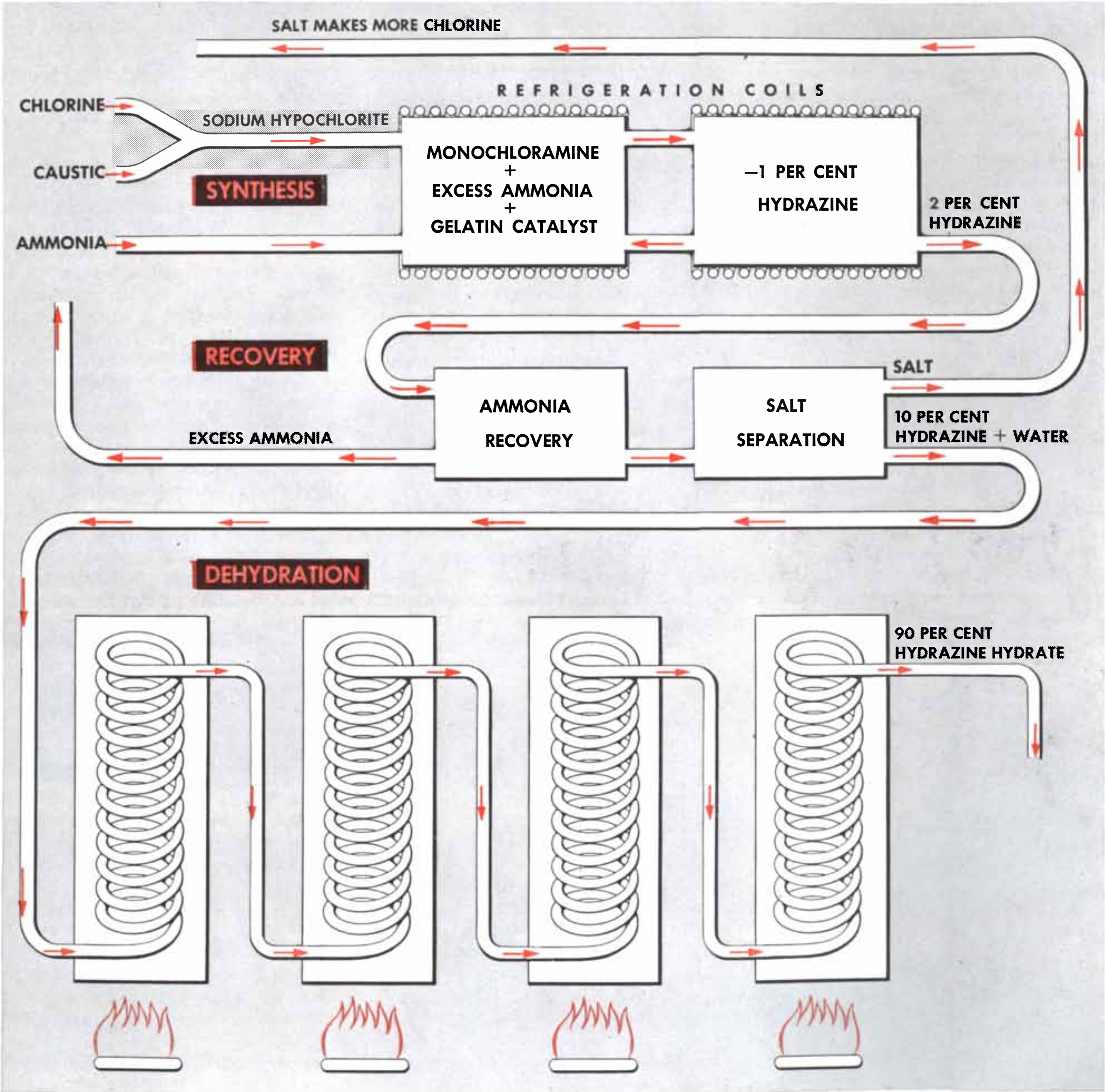
FOR MORE than half a century hydrazine has been an interesting laboratory chemical and little more. It was first identified in a diazo derivative by the German chemist Emil Fischer in 1875. Twelve years later it was isolated by a compatriot, Theodor Curtius. In 1907 Friedrich Raschig hit upon a cumbersome but ingenious method for producing the substance by oxidizing ammonia with sodium hypochlorite. Many chemists played with hydrazine but invariably dropped it because it seemed too difficult and uneconomic to produce.

Theoretically it should be easy to put together two atoms of nitrogen and four of hydrogen. It should also be cheap, for both elements are nearly as free as air.

When the Haber process for fixing nitrogen from air in the form of ammonia scored its revolutionary success 35 years ago, chemists thought it should not be too difficult to synthesize hydrazine and start a great efflorescence of nitrogen chemistry. They tried electric-arc discharge, photochemical techniques and straight chemical methods, but all either yielded too meager an amount of hydrazine or required such huge amounts of power as to be impracticable. The major block is that at the temperature at which hydrazine is formed it rapidly breaks down again.

Today there is still no direct process for the synthesis of hydrazine. But during World War II the Germans began to produce hydrazine by the old Raschig method because they needed a special rocket fuel and cost was no object. Since a rocket must carry its own oxidant as well as fuel, it requires a light fuel of high thermal efficiency and energy content. In addition, the combustion products thrown out of the tail nozzle must be as light as possible for highest velocity, yet of good density for maximum thrust. Thermodynamically the ideal fuel is one rich in hydrogen rather than carbon. The Germans tried many fuel combinations, but found none more powerful than hydrazine. They used two combinations—hydrazine hydrate and methanol (called *C-stoff*) and hydrazine and hydrogen peroxide (*T-stoff*)—to power their rocket fighter planes, the Me-163 and the BP-20, which climbed at the astounding rate of seven miles a minute.

The Raschig process is tricky and costly. The whole first stage of synthesis —in which hypochlorite reacts with ammonia to form chloramine, and chloramine then reacts with excess ammonia to produce small amounts of hydrazine—must be heavily refrigerated in order to cool and hold the hydrazine formed. If the concentrations and temperatures are not just right, and massive excesses of ammonia are not present, the reaction flips over into unwanted products. At




**THE METHOD** used to produce hydrazine is Raschig's synthesis of 1907, one form of which is shown here. Starting upper left, chlorine, caustic and heavy excess of ammonia are put through refrigerated synthesis, then through recovery to get out ammonia and salt, finally through dehydration for a concentrated product.

best the yield is only a 10 per cent solution of hydrazine in water. The water must then be removed, and since hydrazine's boiling point is very close to water's, it takes elaborate condensation equipment and expensive amounts of heat to distill the solution to the required 80 to 85 per cent concentration of hydrazine hydrate. Hydrazine being a touchy compound, explosions were not infrequent in the early days. The cost of hydrazine at the beginning was about $50 a pound. If the Germans had not been determined to have it, there probably would not yet be a hydrazine industry.

AFTER the war the U. S. swiftly began to develop liquid-fuel rockets. The Office of Naval Research took a particular interest, and other military branches also sponsored experimental production and research. Two companies soon undertook to produce hydrazine. During the war a small New Jersey chemical specialties firm, the Fairmount Chemical Company, had supplied small amounts of the chemical to make azides for shell detonators. After the war the Mathieson Chemical Corporation, having sent a team to Germany to study the available data on hydrazine production, set up a broad research program and a semi-production unit at Niagara Falls. It had large sources of ammonia, chlorine and caustic soda (the raw materials) and was getting ready to expand from fertilizers into a broader line of chemicals.

The Fairmount Company recently completed a $150,000 hydrazine plant, quadrupling its production, at Newark, N. J. It is using a variant of the Raschig synthesis, starting with urea instead of ammonia. And last month the Mathieson firm brought into production a new $2.2 million plant at Lake Charles, Louisiana. Its plant is close to large supplies of chlorine and ammonia and to ample natural gas for heating. It employs a modified, continuous Raschig synthesis with many engineering improvements, chiefly in the condensation section. Its output will make Mathieson the largest hydrazine producer in the U. S.

Thus this year for the first time the U. S. will have substantial quantities of hydrazine. The military services have priority on the output, but some of it will be available for other uses. Last year German hydrazine hydrate undersold the domestic product in the U. S. by about 35 per cent, but this spring both Fairmount and Mathieson, with their new plants coming in, cut their prices. Fairmount reduced the price for single-drum quantities by about 40 per cent, and Mathieson nearly halved its bulk prices to about $2.50 a pound by hydrazine content. At $2.50 a pound, tonnage hydrazine represents a notable engineering achievement with the roundabout Raschig process. The Mathieson engineers believe that even with this process further improvements in efficiency will eventually bring the price down to about 50 cents a pound.

Economic and competitive forces are inextricably a part of the development of any chemical. To become useful a chemical must first be available at a reasonable price, otherwise it remains a laboratory curiosity of no wide benefit to the world. Large industrial developments of a product cannot take place without an assured source of it. Not until enough of it gets into industrial laboratories can development even begin. Once it is available, however, the proliferation of products is often amazing.

So far well over 2,000 hydrazine compounds have been made or investigated. The Mathieson chemists have studied more than 800 intermediate and derivative hydrazine compounds. They have discovered a new type of basic hydrazine, and the company is now building a pilot plant for it. During the past year the company has supplied hydrazine to some 300 research organizations, more than 100 of which now have research projects going on the substance. E. I. du Pont de Nemours & Co., Inc., has no fewer than five such projects.

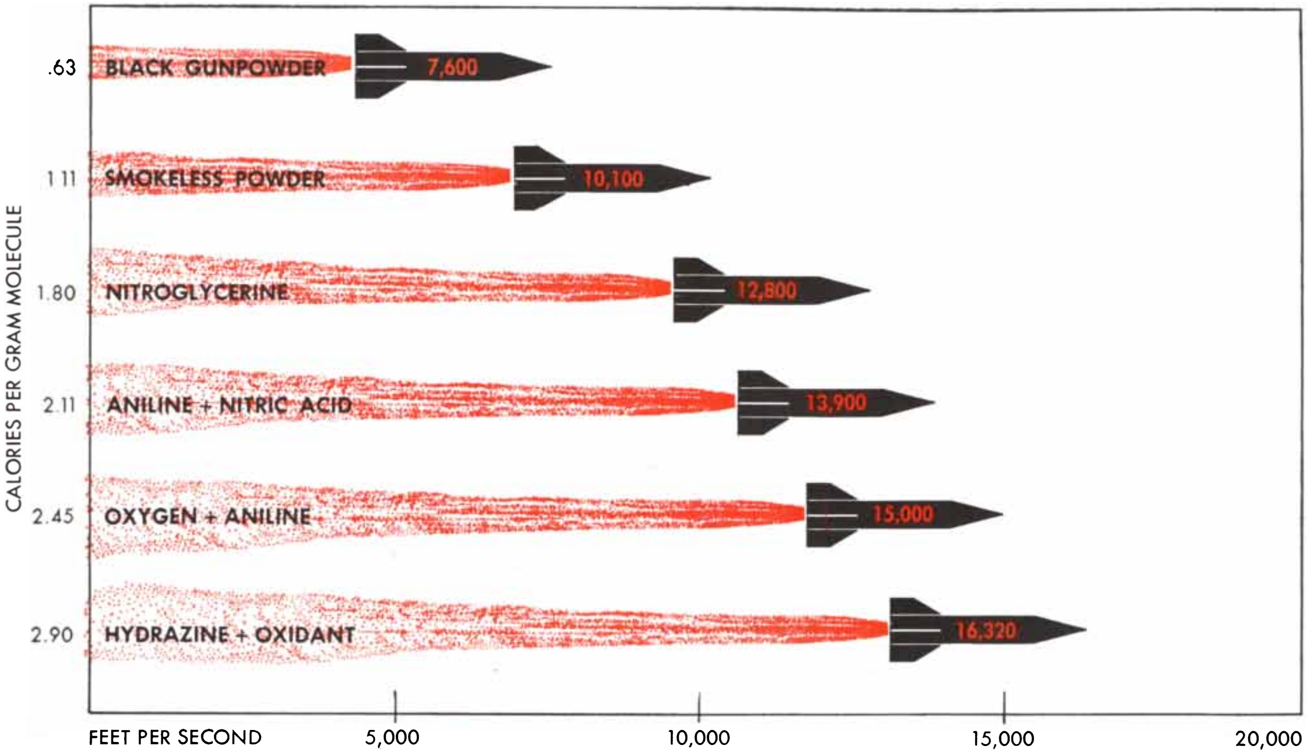
**MALEIC HYDRAZIDE** is a remarkable growth retardant developed from hydrazine. Test-sprayed on parkway grass, it cut mowings from 19 to two.

THE industrial chemist's interest in hydrazine is almost purely structural. Hydrazine's double nitrogen bond, particularly in conjunction with organic compounds, can be used to build up an enormous variety of straight-chain, ring-shaped and cross-linked molecules with new and unusual properties. Hydrazine also can be linked up with itself or with other inorganics, including metals, but these products are either unstable or less versatile than the organic linkages. Thus far the hybrid organic hydrazines have found the most uses, real and potential, and they run the gamut of the chemical industry.

There are, to begin with, the pharmaceuticals. Last year a spate of publicity greeted the trials of isonicotinic acid hydrazide as a treatment for tuberculosis. The new drug (which actually uses only miniscule amounts of hydrazine) has drawbacks, chiefly the fact that it quickly induces resistant strains of the tubercle bacillus. But in conjunction with streptomycin it is a highly useful treatment, and a new group of more powerful hydrazine derivatives which do not develop resistance, called the thiocarbanilides, are now under laboratory test. With more research these hydrazine drugs may yet prove to be, as they have already been hailed by one practitioner, "the greatest chemotherapeutic agents since the sulfa drugs."

Many other hydrazine derivatives are showing promise, less conspicuously but no less dramatically, against disease. One is Apresoline (1-hydrazinophthalazine), which in tests at Vanderbilt University has shown ability to reduce blood pressure in essential and malignant hypertension. There is another large group of new drugs called the nitrofurans, based on hydrazine semicarbazones and furfural, a chemical obtained from oat hulls. One of these, Furacin, is added to poultry feed to combat coccidiosis. The newest, Furadantin, is a broad-spectrum systemic drug which seems especially effective against urinary tract infections. And hydrazine is being employed in the isolation of hormones and in the synthesis of vitamins, new sulfa drugs, histamines, antibiotics and many other complex pharmaceutical compounds.

A second great field for hydrazine is in agricultural chemicals. As its drug action suggests, the substance is toxic, and this toxicity is being built into promising new insecticides and pesticides, now under test by the U. S. Department of Agriculture. From hydrazine has been made a chemical to kill mites—the first such agent that is not toxic to birds that feed




**HYDRAZINE FUELS in combination with oxidizers such as hydrogen peroxide are the most powerful practical rocket propellants known. The chart compares the earliest hydrazine mixtures and other propellants or explosives in heat values per gram molecule and the theoretical jet velocities produced in feet per second.**

on the poisoned mites. Another hydrazine product is a powerful fungicide.

More advanced and revolutionary in effect is the compound maleic hydrazide. This substance was discovered in 1949 by D. L. Schoene and Otto L. Hoffman of the U. S. Rubber Company's Naugatuck Chemical Division, who were searching for a fungicide. They found that maleic hydrazide could retard the growth of many plants without harming them. In proper small amounts and spray mixtures, it apparently halts temporarily the metabolism of the growth tips in certain plants and grasses. It selectively kills some broad-leaved weeds. Maleic hydrazide is rapidly being adopted as a spray to stop the sprouting of onions and potatoes in storage, to prevent the flowering and tasseling of tobacco and hybrid corn, to retard the blossoming of fruit trees until all threat of frost is past and to prevent the re-growth of leaves on defoliated cotton plants until mechanical cotton-pickers can get to them. It may also be a Godsend to those who dislike lawn-mowing. In three seasons of tests on grass plots along the Merritt Parkway in Connecticut, treatment with this chemical has reduced the number of mowings from 19 to 2 per season. Grass control opens a wide field, but one that has had to be approached with caution. This spring the material, under such trade names as Kem-Cut, has been put on the market for householders; it is recommended only for controlling grass along borders and walks. Maleic hydrazide already is the largest single consumer of hydrazine.

As an industrial chemical, hydrazine's most useful properties thus far are its narrow vapor range and its strong reducing action. It is used in reducing compounds to separate rare metals in a pure state from their salts and oxides, and it is the basis of new techniques for thinly plating metals and plastics and for mirroring glass. As an antioxidant, small quantities of it in the water reduce to almost nil the formation of scale on boilers in steam power plants. This use alone could absorb all the present production of hydrazine. A hydrazine monobromide compound with a narrow vapor range has been developed as a soldering flux for copper and brass; the flux vaporizes away at the precise moment when a strong soldering bond is finished, leaving no corrosive residues on the metal. It is now used in soldering all Ford radiators.

Hydrazine's physical structure may well be used to synthesize new nitrogen-ring dyestuffs. Its solvent and cross-linking abilities have given birth to new compounds for softening and vulcanizing rubber. Combined into rod-shaped molecules with nitrogens at one end and fatty acids at the other, it acts as a detergent. It also can be built into powerful wetting agents, crease-resistant coatings for textiles, disinfectants and the like.

Finally, there are its possibilities in plastics and fibers. Until hydrazine is much lower in price, it will not be an attractive raw material for this competitive market. Most of the big plastics producers, however, have hydrazine projects, and all the major synthetic-fiber makers are busy investigating hydrazine in their elongated giant molecules. Hydrazine fits particularly well into the polyamide type of fibers—the nylons and Dacron. It provides more versatile qualities than other raw materials: for instance, a finer denier with more elasticity and strength. It also adds new qualities to straight plastics, such as the ureas. Hydrazine's role probably will be to provide more tailor-made types of plastics and fibers for a wider range of uses.

HYDRAZINE'S potentialities as a rocket fuel—the use which brought the chemical out of obscurity—still lurk in the background. Some of the secret new military projects are said to require fuels that can deliver very high energy for short intervals. Hydrazine is certainly one of those fuels. The military does not have a corner on rockets, however. Recently the speculative logistics of a long-range rocket to the moon has been shifting from atomic power, with its attendant shielding difficulties, back to chemical fuels. There, too, hydrazine has its proponents.

Regardless of such extraordinary employment, hydrazine will soon be able to stand on its own in peaceful chemical development. And what has gone before is only the beginning for this many-faceted molecule.

# Radar and the Weather

*The ability of water drops to reflect radio signals provides a new tool with which meteorologists are extending the scope of their observations, and seeing storms in much finer detail*

by Hal Foster

AMONG the many modern tools with which U. S. meteorologists are attacking the problem of doing something about the weather—tools which range from giant digital computers to nylon stockings (for measuring raindrop sizes)—is an array of more than 100 radar stations spotted around the country. They are being used to locate and follow hurricanes, tornadoes, thunderstorms and other disturbances and to research in detail the anatomy and development of each type of storm. This article reports what radar has accomplished so far in exploring the mysteries of the weather.

The story of how the value of radar for studying storms came to be discovered is well known by now. When military radars entered the very short wavelength (microwave) region of the spectrum during World War II, "weather clutter" began to appear on the radar scopes. This was a nuisance from the standpoint of detecting targets, but it proved to be a discovery of first importance to meteorologists. It was Arthur Bent, a worker in the wartime Radiation Laboratory at the Massachusetts Institute of Technology, who found that radar could detect raindrops and did the pioneer work in applying radar to meteorology.

What radar detects in the atmosphere is precipitation—particles of water in its various forms, such as rain, sleet and snow. The size of particles it will "see" depends, of course, on its wavelength. A radar of 10- to 25-centimeter wavelength will get echoes only from large drops; a 3-centimeter radar will see very small raindrops; a 1-centimeter radar signal will be reflected by the finest rain and by most clouds. The trouble with the very short waves, however, is that they are strongly absorbed by moisture in the air, and they are useless in most rain because too little of the radar beam's energy is reflected back to give an echo on the scope. It is calculated that the ideal compromise for examining storms would be a radar of five or six centimeters. The military radars that have been used up to now are not especially good for weather work. The first radar designed specifically for weather study will soon be placed in operation by the U. S. Air Force Weather Service. Developed after 10 years of engineering and field tests, it is a 3.2-centimeter set with 250 kilowatts of power. This instrument, called the AN/CPS-9, will be stationed at strategic locations throughout the U. S. and will permit a much more thorough investigation of the weather than has been possible heretofore.

WHAT do the echoes from precipitation in the air tell the observer? In the first place, they give the precise location and extent of a storm, since the reflected echoes tell its distance and direction from the radar transmitter. Furthermore, an experienced observer can interpret the character of the storm itself from the picture on the scope. The size of the precipitation particles can be estimated from the strength of the echoed signals; for instance, a single drop of water two millimeters in diameter will return as strong an echo as 4,096 droplets one fourth that size. Thus a thunderstorm, which contains many large drops, will give a much stronger return than a light rain, which is usually composed of relatively small drops. By proper adjustment of the receiver gain the observer can also locate the sections of most intense precipitation within a storm. The echo pattern discloses not only the nature of the precipitation but the stability of the atmosphere. Echoes returned through stable air tend to have fuzzy edges, whereas in turbulent air they tend to be sharp-edged and clearly defined.

What the operator sees on his radar screen depends on how the set is being used and how its echoes are presented. In weather work the two most useful types of presentation are the PPI (Plan Position Indicator) and the RHI (Range Height Indicator). The PPI screen shows a flat map of the circular region above the radar, traced out as the antenna scans the sky in a continuous rotation. The RHI scope shows a vertical slice of the atmosphere along the direction in which the antenna is pointing. On this screen the distance of an echo from the left-hand side of the picture measures the distance of the target, and the height of the echo signal above the base line tells the target's height above the ground.

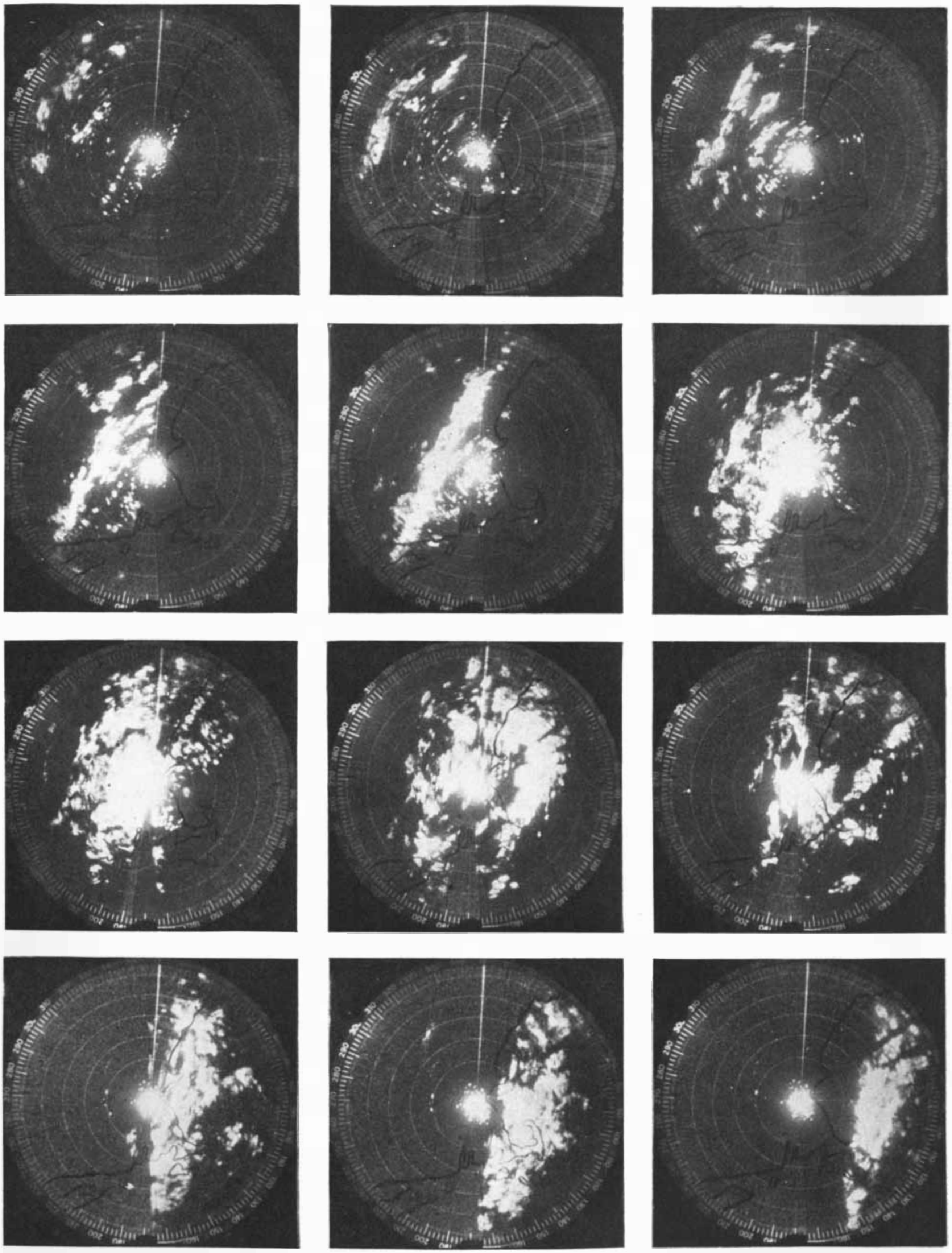
On the radar scope an observer can watch the birth, growth and dissipation of a storm, see snowflakes melt into raindrops high in the air, follow a storm pattern as it moves across country and map air currents, all from his stationary shack.

Radar is especially useful in following a hurricane. To locate exactly the "eye" of a hurricane has always been a difficult matter, and one needs to locate it to determine accurately where the storm is going. Radar can "see" the spiral bands of rain that wind into the center of a hurricane as far as 200 or sometimes even 350 miles away. It tracks the storm's path and the speed with which it is moving. Many power companies and commercial offshore operators along the Gulf Coast now use radar as a standard piece of equipment to guide their operations during the hurricane season.

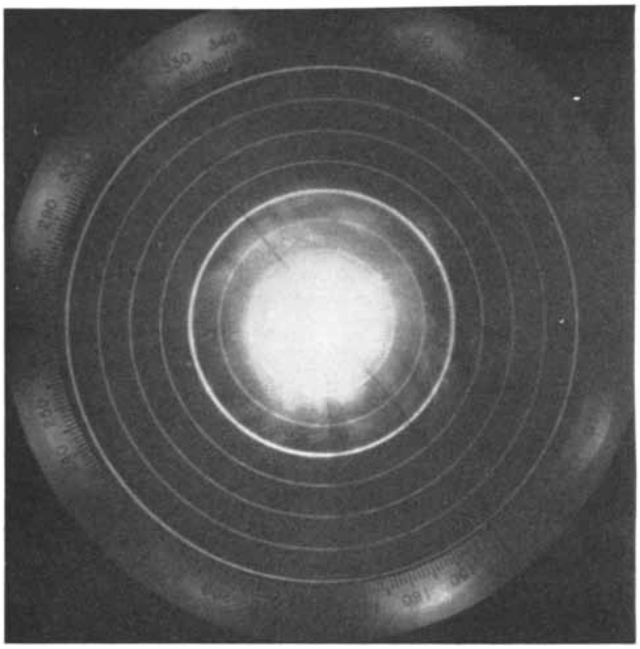
Tornadoes also are tracked by radar. The precipitation pattern of a tornado cannot be distinguished by radar from that of a severe thunderstorm, but when the disturbance is known to be a tornado the radar can track it and warn communities in its path.

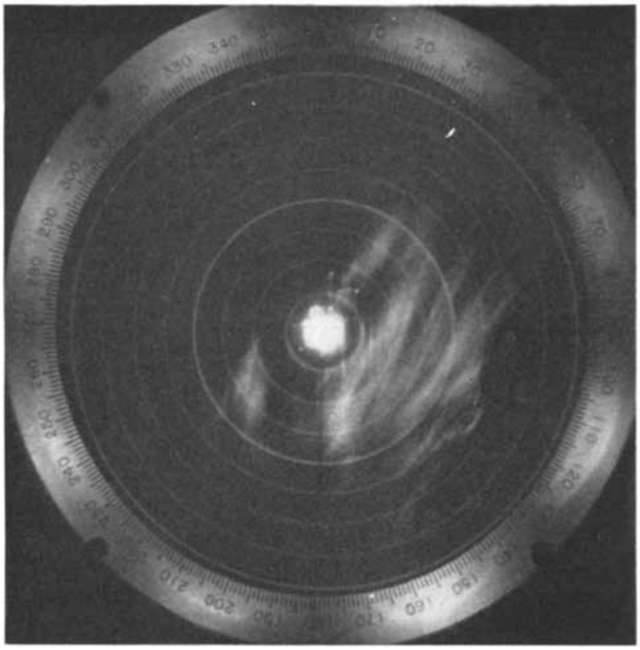
A great deal of engineering effort is now being expended in the development of a lightweight airborne radar set that can be used by aircraft in flight as a means of avoiding thunderstorms, severe icing, turbulence or other dangerous conditions. Such a set can also provide warning against collisions with aircraft or mountains.

Radar has been employed for some time to measure the velocity of the winds aloft. It tracks a kite-like target carried by a balloon drifting with the wind. As the target rises through the atmosphere, its position is recorded by the radar at 30-second or 1-minute intervals. From these records simple calculations give the average wind velocity at various



**THUNDERSTORMS** and heavy rain showers move across the PPI screen as a cold front passes over the set. Concentric range marks are 20 miles apart. The successive pictures (*reading from left to right*) follow the hourly progress of the storm. The photographs in this article were provided by the U.S. Army Signal Corps.





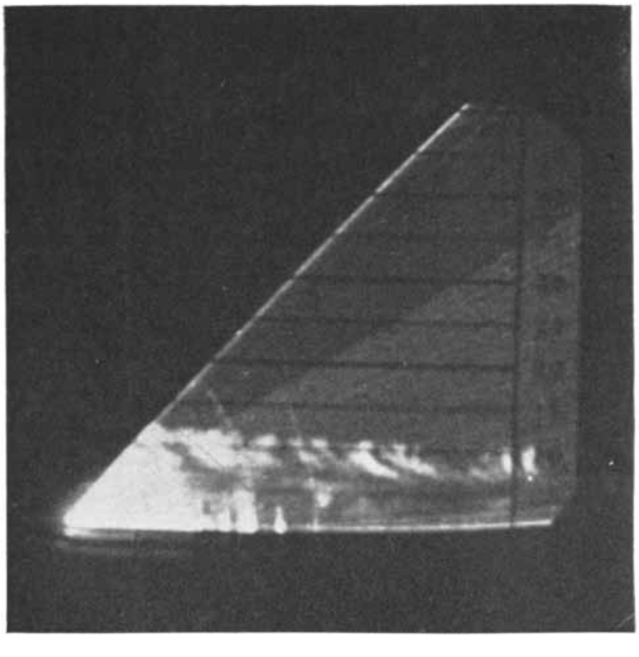
**STABILITY OF THE AIR** can be deduced from the character of the echo. Stable air, in which precipitation tends to be light and steady, gives fuzzy signals like those in the first two photographs. Turbu-

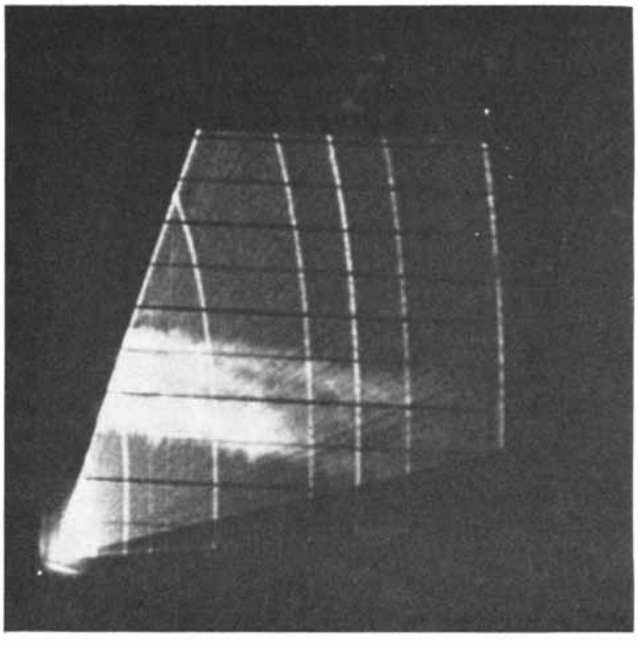
levels in the atmosphere. The measurements can be made day or night, regardless of visibility conditions, and to great altitudes. They are now a routine part of the observations for daily weather forecasting.

WHEN the new meteorological radars are installed throughout the country, we shall have far more complete coverage of weather conditions in the U. S. than we have now. All our knowledge of weather patterns at present comes from local records taken at some 500 weather stations spread across the country. We must interpolate the conditions in the areas between the stations. With a network of radars we shall be able to watch the entire atmosphere over the U. S. and plot the fine-scale details of precipitation patterns. We shall then be able to follow each precipitation cell as it forms, develops and dissipates, and as it moves with the wind fields.

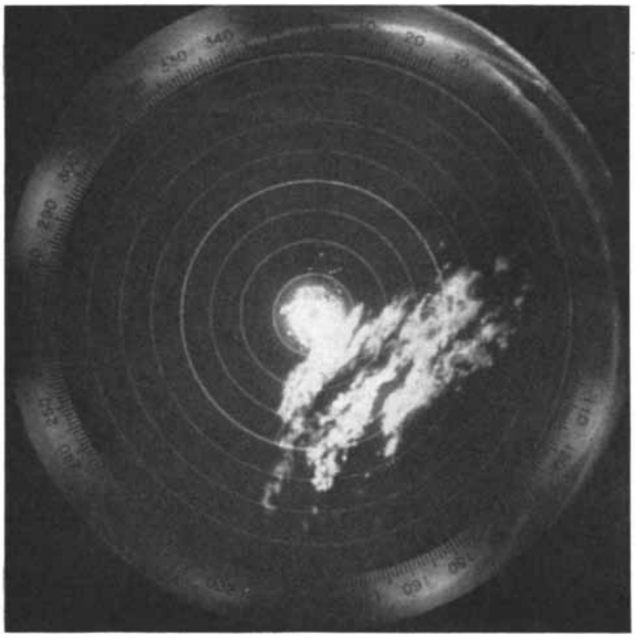
Already radar makes it possible to forecast the weather very accurately for four to six hours ahead. By tracking a rainstorm it allows a precise prediction as to when rain will start and stop in a given locality. These short-term forecasts would be especially useful to pilots approaching an airport, to promoters of sporting events and to housewives trying to decide whether to hang out the laundry. The new radar network may extend such forecasting to 12 or 24 hours.

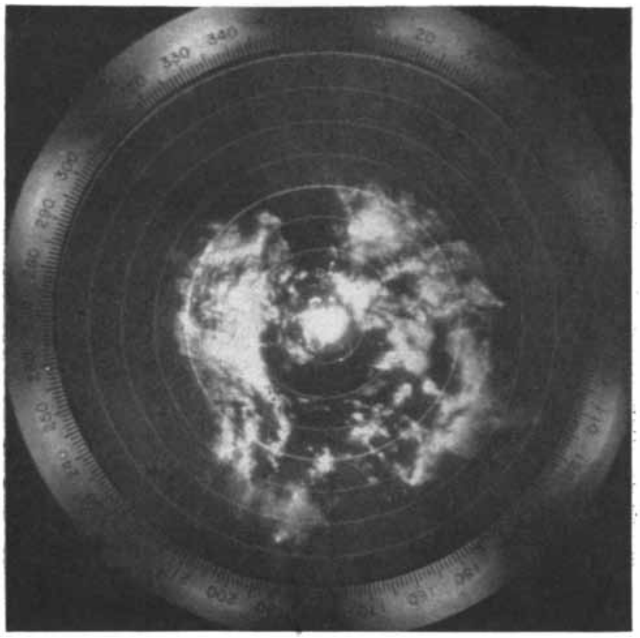
An RHI radar scope often can show the freezing level in the atmosphere. A layer of melting snowflakes just below this level shows up as a bright band on the scope. Thus an airplane pilot can be warned at what altitude he will find icing conditions in a given region. The bright band gives information about the turbulence of the air as well: a narrow band





**RANGE HEIGHT INDICATOR** (RHI) presentation gives a cross-sectional view of storm regions. The distance of any point along the base line from the left tells how far it is from the radar. The vertical distance above





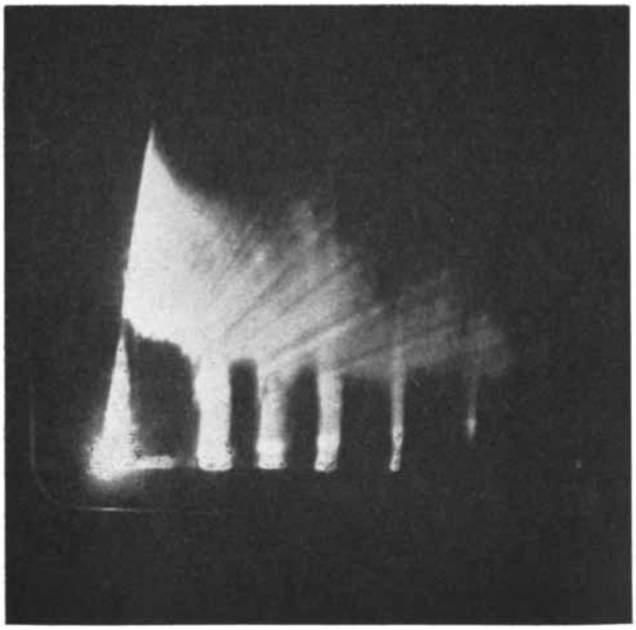
**lent air brings showery storms whose echoes are much more sharply defined, as in the second pair of photographs. The sizes of these storms can be judged from the range rings, which mark off intervals of 25 miles.**

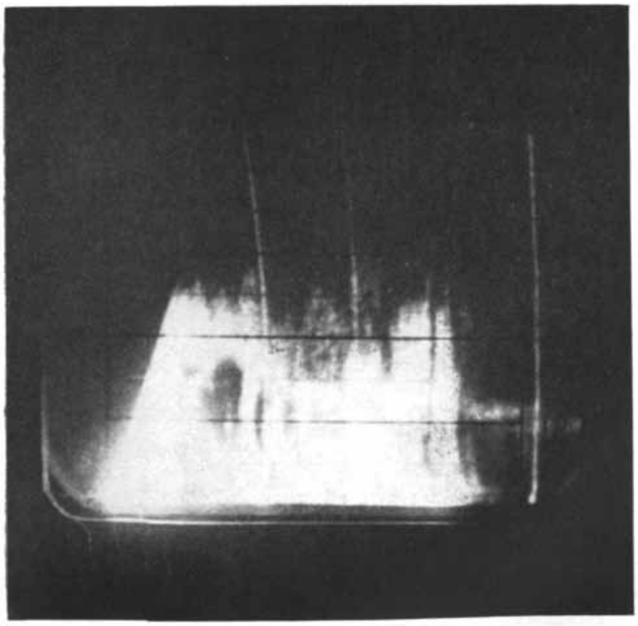
means stable air and a thicker band indicates turbulence.

Examination of precipitation cells with the RHI radar provides a most interesting means of judging wind conditions aloft. When the cell is vertical or nearly so, obviously the wind speed must be about the same at all levels. But when the cell is tilted at an angle to the ground, this is an indication that the wind speed is increasing at a constant rate with altitude. From the degree of tilt of the cell, observers can estimate the wind speeds at various altitudes.

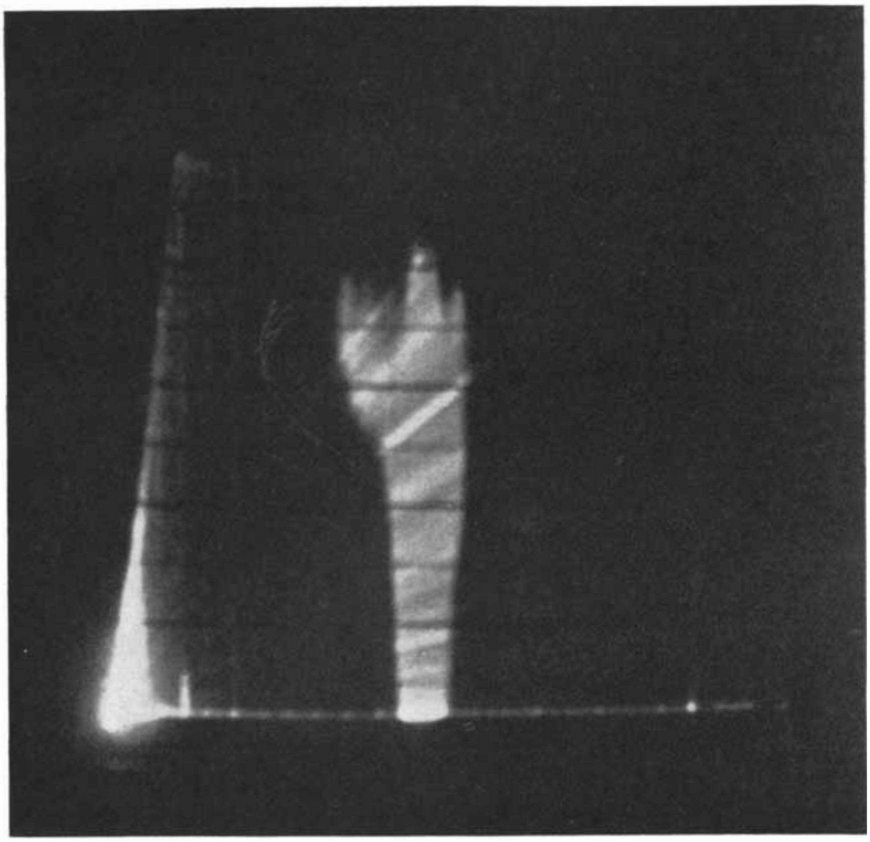
It is in meteorological research, rather than in observing or forecasting, that radar has so far played its main roles. With it cloud physicists have been studying how clouds form, develop and disappear. They have also found that it can measure the total amount of rain that falls on a given area. The radar yardstick for rainfall has been developed by correlating the strength of the echoes from a rainstorm with actual rainfall rates as measured by rain gauges. As a result we have today a means of recording with fair accuracy the total amount of rain that falls on a watershed, and this should be of great value to forecasters in anticipating possible floods. When the system has been developed and put into general use, it should greatly reduce the losses from flash floods. The same system will also measure snowfall, which can be distinguished from rain because it gives a very different echo.

WITH RADAR, meteorologists today are giving intensive study to severe storms. Every hurricane approaching the U. S. is carefully watched by radar throughout its life cycle. Continuous photographs are made of the radar scopes. From these records come de-

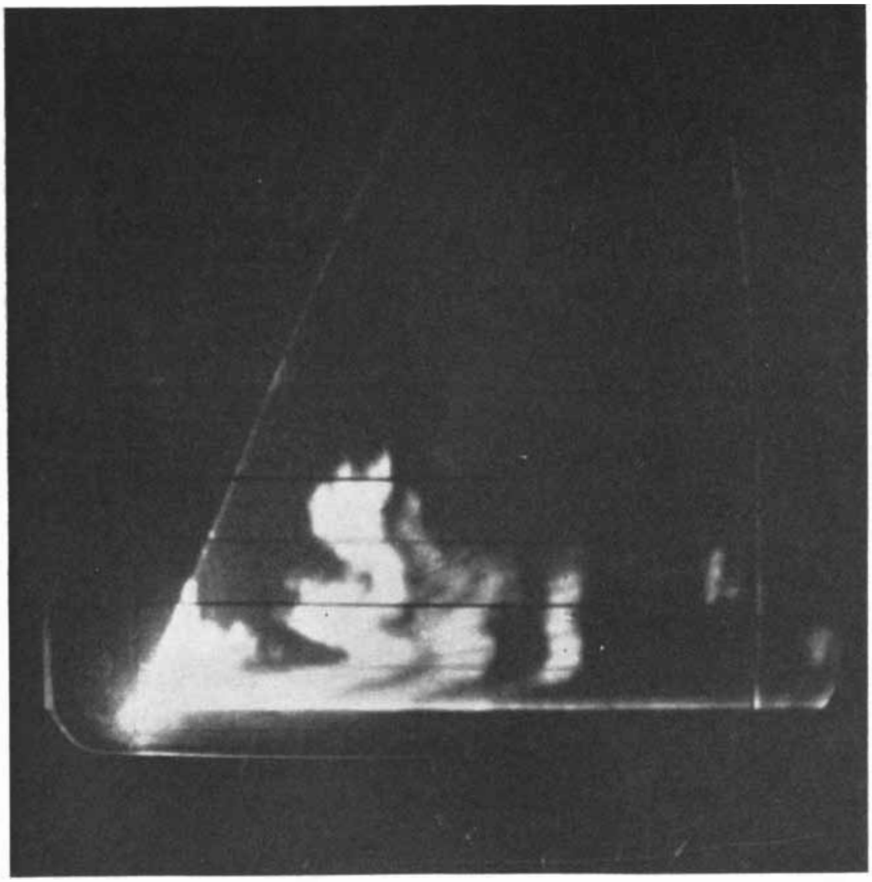




**the base line measures the height of the point above the ground. The horizontal bright band seen in the picture at far right about half an inch above the base indicates icing conditions at a height of about 6,000 feet.**



**THUNDERSTORM** is shown in profile on the RHI scope. The horizontal lines mark 5,000-foot intervals. White dots along base are five miles apart.



**WIND PATTERNS** at various altitudes can be read on the RHI picture from the distortions they produce in the storms which fall through them.

tailed information on the size of the cells, the curvature of the cellular bands and the height, speed and track of the storm. Comparison of each hurricane with its predecessors is adding little by little to our knowledge of the mechanics involved.

Similar studies of tornadoes have shown that these cyclones usually form at the intersection of two lines marking sharp changes in pressure in the atmosphere. They are likely to start in a region of active thunderstorm cells. Tracking these lines with radar promises to help detect tornadoes as soon as they form.

There is still much to learn about the common thunderstorm itself. Here too radar is providing new, detailed information not previously available. It was one of the chief tools used in the very thorough study of thunderstorm structure, the "Thunderstorm Project," directed by Horace R. Byers of the University of Chicago [see "Life of a Thunderstorm," by Roscoe R. Braham, Jr.; SCIENTIFIC AMERICAN, June, 1950]. Much of the data are still in raw form, and researchers will be analyzing them for years. The study has been described in a book entitled *The Thunderstorm*.

A basic problem in meteorology is how a raindrop grows as it falls through the atmosphere. This is what determines whether a rainstorm develops into a light drizzle or a torrential downpour. To follow the progress of falling particles, radar is pointed vertically into a storm and the intensity of the return signal is measured at intervals of one-tenth of a mile or so from the ground up through the top of the echo. The average particle size at any level can be calculated from the strength of the echo. The calculations are checked by sending up airplanes to probe the storm at various heights.

Radar is an ideal tool to study the effects of cloud-seeding. It can trace the cloud structures before and after seeding and show the changes that take place. Radars are now being installed as a major tool in a new Artificial Cloud Nucleation Project of the U. S. Weather Bureau which will soon be in operation on the West Coast.

WITHIN a few years radar has been responsible for more advance in the basic knowledge of the weather than any other instrument or device in the history of meteorology. It has placed a powerful new weapon in the hands of the meteorologist, one that permits a stationary observer to consider the three-dimensional structure of an extremely large volume of the atmosphere and to study the minute changes constantly occurring in the over-all pattern. In the practical realm the infant science of radar meteorology has already made possible advance warning of severe storms, with a large saving of lives and property.

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**a new cellulose acetate sheeting . . . doubling the speed of infrared-sensitive film . . . identifying solids by refractive index . . . checking precision gears**

## Cellulose acetate sheeting

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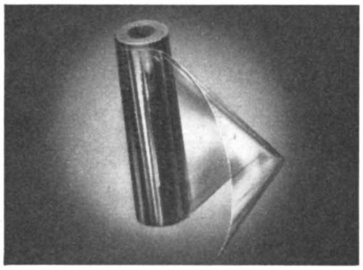


*Kodapak IV Sheet.* Its substance is cast cellulose triacetate, a most durable thermoplastic. It is diaphanous stuff, of the proverbial crystal clarity, but we also make it in matte form. It is an excellent electrical insulator, has higher folding endurance and bursting strength than its predecessors (quantitative data on request). It is readily heat-embossed or drawn. It comes in thicknesses from .001″ to .010″. The thick gauges come in 20″ x 50″ and 25″ x 40″ sheets, and those below .003″ come in sheets of 25″ x 40″, 30″ x 40″, and 40″ x 40″. It is easy to seal by dielectric heating, but if you want to cement it without resorting to special cements, we suggest you first determine whether *Kodapak I Sheet* won't serve your purpose better.

Kodapak Sheet *is supplied by us only in quantities of 200 pounds and over. If you need only a little, we can refer you to a local distributor. Write Eastman Kodak Company, Cellulose Products Sales Division, Rochester 4, N. Y. (The answer, like all correspondence from Kodak, will come in an envelope with a Kodapak window.)*

## Infrared aerial film

The speed of Kodak Infrared Aerographic Film has just been doubled, without adverse effect on sharpness or contrast. To aerial photographers this means that the same exposure they would give Kodak Super-XX Aerographic Film with the customary yellow filter will now suffice for infrared work, such as taking inventory of standing timber with a filter that passes only red and infrared.

We mention this to non-members of the aerial photographic fraternity for two diverse reasons: 1) to call attention to the latest notch of progress in the service which the commercial aerial photographer can render his clients (i.e. better infrared pictures under worse conditions); 2) to remind the earthbound that the fast new infrared film—as well as Kodak Super-XX and Kodak Tri-X—is available for whatever purpose they have in mind in widths of 5¼″, 5½″, 7″, and 9½″ and lengths from 9 to 390 feet.

*If you'd like a list of commercial aerial photographers or if you'd like to find out how to buy aerial film, write to Eastman Kodak Company, Government Sales Division, Rochester 4, N. Y. (No mistake, the division deals with private enterprise too.)*

## Refractive index liquids

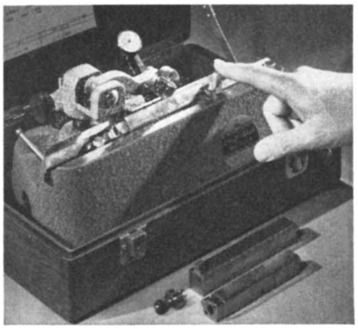
In this day of polarography, x-ray spectrography, infrared spectrophotometry, mass spectrometry, nuclear magnetic resonance, etc., it may be considered primitive (among the excessively sophisticated) to identify a solid compound by immersing it in a liquid of matching refractive index to make it disappear without dissolving. *We* think it is not primitive at all but even elegant, in the scientific sense. On page 214 of the current catalog of Eastman Organic Chemicals there appears a list of 39 organic liquids with their refractive indices, ranging from *Methanol* at $n_D^{20} = 1.3289 \pm .0005$ to *Diiodomethane* at 1.7400. If you order them in lots of 10 or more, we can supply them in 25-cc glass-stoppered bottles. Since most are priced at 60¢ each in this size, you and we can, for as little as $6 plus postage, work out a deal on a set.

*If you don't have a copy of "Eastman Organic Chemicals, List No. 38" from which to make your selection, write Eastman Organic Chemicals Department, Distillation Products Industries, Rochester 3, N. Y.*

## Gear testing

The Kodak Conju-Gage Gear Checker is purely a mechanical device. It has little to do with photography, optics, chemistry, electrons, x-rays, or crystal structure. Its function is to determine how well a gear works. (We got into this sort of thing through building fire-control equipment.)

A gear's job is to transmit angular motion uniformly from one shaft to another. The precision with which it accomplishes this task can



be tested by measuring variations in center distance when the gear is run with a master of known accuracy. There's the rub. If the gear you are interested in must be of the highest obtainable accuracy, what will you use as a master? Naturally, we wouldn't ask the question if we didn't know the answer. It is a Kodak Conju-Gage Worm Section, which resembles a rack and is produced by thread grinding, a process not subject to the accuracy limitations that come into play on a circular gear. The Worm Section and the instrument we build to use it might interest you if you have any gear worries.

*There's more to the gear art than meets the eye of the casual observer. As a gentle introduction to this lore, we can send you "A Practical Approach to Gear Quality" and "The Kodak Conju-Gage Gear Testing Principle." Both are free from Eastman Kodak Company, Special Products Sales Division, Rochester 4, N. Y.*

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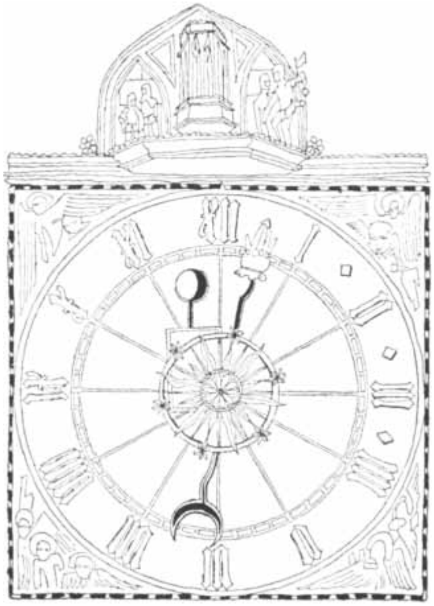

### *Milestone*

THE Atomic Energy Commission last month announced "a milestone in the history of atomic energy." It has succeeded in proving that the breeding of nuclear fuel is possible—a key question for the practicability of atomic power. The Commission's experimental breeder reactor at Arco, Idaho, is now producing at least as much new fuel as it is burning.

The breeder reactor, which was described in the December, 1952, issue of SCIENTIFIC AMERICAN, burns uranium 235 in its core and converts a blanket of non-fissionable U-238 to plutonium. The success of the breeding experiment, about which scientists have been hopeful but by no means certain, means that all the available uranium in nature may be used as nuclear fuel. It should also be possible to breed fissionable material from thorium, but this has not yet actually been accomplished.

Gordon Dean, chairman of the AEC, cautioned in his announcement that the news does not mean "economic power from atomic fuels is here." He pointed out that the chemical process to extract the newly bred fuel is at this stage "one of the most expensive aspects of the atomic energy business," and that breeding is so slow that a reactor may have to operate five or more years before it returns the original fuel investment. The first power reactors may not even use the breeding principle. Nevertheless, Dean declared, we are now at the "crossroads in atomic power policy. . . . The last remaining technical obstacle is to learn how to build atomic power plants so cheaply that the power they produce will be competitive with that from conventional fuels." This job, he indicated, is one that should be shared by private industry in a competitive way.

A start toward private participation has already been made. Four industrial groups have been studying the technical feasibility of building reactors to produce commercial power. A declassified version of their first reports has just been made public by the AEC. All conclude that dual-purpose reactors can be built now and all agree that atomic-electric power can be produced economically in the near future only as a by-product of plutonium.

The four study groups are the Commonwealth Edison Company and Public Service Co. of Northern Illinois, the Dow Chemical Company and Detroit Edison Company, the Monsanto Chemical Company and Union Electric Company and the Pacific Gas & Electric Company and Bechtel Corporation. Under the terms of their research agreements with the AEC, the groups limited their investigation to power-plus-plutonium reactors of a type that "might be built within the next few years." Three of the teams proposed specific designs for such reactors, while the Dow–Detroit Edison study discussed the problem in general terms.

Commonwealth Edison and Public Service suggested two designs. One is a graphite-moderated uranium reactor using helium gas to carry heat from the reactor to the boilers. The companies estimate that an installation to produce 47,000 kilowatts of useful power would cost $40 million. The second proposed design is a uranium reactor using heavy water under pressure as both moderator and coolant. A unit producing 211,500 kilowatts is estimated to cost $118 million (of which $41 million is the cost of the heavy water). The companies believe that the second of these designs has the "best economic possibilities" but the first could be built more quickly and would be subject to fewer engineering uncertainties.

Pacific Gas and Bechtel Corporation also proposed two reactor types. One is a uranium reactor moderated by heavy water and cooled by ordinary water. It would have a net power of 100,600 kilowatts and would cost $41 million. The other is a uranium fast breeder (no moderator) cooled by liquid sodium, estimated to produce 145,300 kilowatts and to cost $51 million.

Monsanto–Union Electric's choice is a uranium and graphite reactor cooled by liquid sodium. They place the unit's output at 554,000 kilowatts and its cost as $61 million.

Dow–Detroit Edison concluded that a fast breeder reactor using liquid fuel and a liquid metal coolant is the most promising line of approach, but did not go into detailed specifications for building one.

All the studies agreed that with present materials and techniques nuclear boilers would have to operate at steam temperatures and pressures substantially lower than in conventional generating systems and would therefore be less efficient. Some of the reports indicate that the cost of the plants should be written off against the plutonium sold rather than the power produced.

### *Smaller Nucleus*

THE nucleus of the atom is some 15 to 20 per cent smaller in diameter and about twice as dense as had been supposed, according to measurements made with a new nuclear yardstick by James Rainwater and Val Fitch of Columbia University.

Their measuring rod was negative mu mesons, produced in Columbia's 385-million-electron-volt cyclotron. When such mesons are aimed at a piece of matter, some are captured by the field of attraction of individual nuclei and begin to revolve around these nuclei in the same manner as planetary electrons. The mesons then lose energy, dropping from one orbit into another until they fall into the nucleus. Each orbital drop is accompanied by a burst of radiation which carries away the lost energy. Since mu mesons are 210 times as heavy as electrons, their corresponding orbits are 210 times closer to the nucleus. The innermost orbit, or "K shell," is so close that a meson in this orbit revolves partly within the fringes of the nucleus itself. The strong forces within the nucleus affect the energy radiated by the meson when it drops into the K orbit. From the measured strength of this effect Rainwater and Fitch calculate the size of the nucleus.

The diameter of a nucleus has been thought to be $1.4$ to $1.5 \times 10^{-13}$ centimeters multiplied by the cube root of the number of protons and neutrons the nucleus contains. The new measurement changes the figure to $1.2 \times 10^{-13}$. Since a 15 per cent reduction of the diameter of a sphere reduces its volume almost by half, the nuclear particles must be crammed into about half the space they had been thought to occupy.

### *Supercritical Boiler*

THE efficiency of a steam turbine depends largely on the temperature and pressure of the steam that runs it. Pressures in common use now are approaching the magic figure of 3,206 pounds per square inch, the "critical" pressure of steam. When water is converted into steam at a pressure above this figure, it does not boil but all of it vaporizes at once. Steam at supercritical pressure has never been used in a commercial boiler. Now the American Gas and Electric Company announces that it is building a power plant which will operate with steam at 4,500 pounds per square inch and a temperature of 1,150 degrees Fahrenheit. This pressure is almost double that of any present steam plant, and the temperature 50 degrees higher.

Operating at supercritical pressure will not only improve efficiency but also eliminate the need for a drum to separate steam from boiling water, the biggest and heaviest single piece of equipment in today's power plants. The boiler of the proposed plant is to be the "once-through" type, described by Philip Sporn, president of American Gas and Electric, as "in effect, a continuous run of tube into which water is pumped at one end and out of which highly superheated steam is delivered at the other.

Most modern power plants employ the "reheat" principle, leading steam back through the boiler for further heating after it has passed part way through the turbine. The new plant will have a double reheat system, with the steam returning to the boiler twice.

"The use of higher pressures, higher temperatures and new ideas in reheat," said Sporn, "will make possible not only new world standards of efficiency in generation of steam-electric power but ultimately will make possible capital reduction by compressing the size of units and bringing about more effective utilization of materials." He predicts that such plants may eventually convert 50 per cent of the energy of coal into electricity—an efficiency half again as high as the best obtained today.

The new plant, with a capacity of 120,000 kilowatts, is expected to cost more than $12 million.

### *Genesis by Lightning*

A NEW way to make organic compounds was reported last month by a young chemist at the University of Chicago. But perhaps "new" is not the right word, for some scientists believe that this method is hundreds of millions of years old; that it is, in fact, the method used by nature herself when she started life on the earth.

The experiment was made to test a theory, championed by the University of Chicago chemist Harold Urey, as to how life began. It suggests that a billion years ago or so the earth's atmosphere consisted of methane, ammonia, hydrogen and water vapor. Under the action of lightning discharges or of ultraviolet radiation, these compounds were split

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into free radicals which recombined in chance ways to form more complex molecules. The new substances were dissolved in the oceans and continued to react with one another, building ever more complicated structures. Eventually a protein molecule, with the magic property of reproducing itself, happened to be put together. The rest was a matter of time.

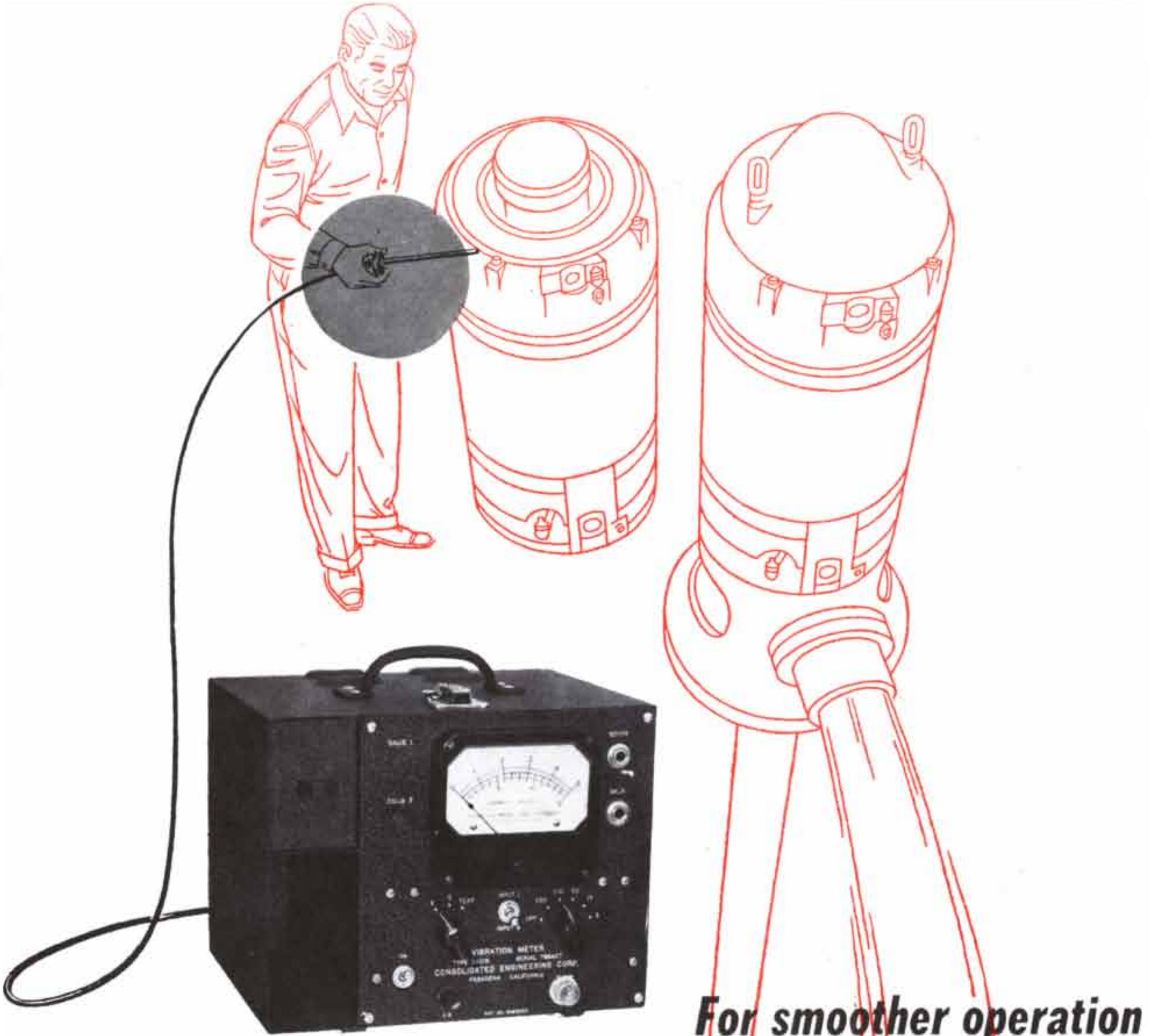
A few months ago Urey put one of his students, Stanley L. Miller, to work to try to reproduce the first steps in the process. Miller assembled a mixture of methane, ammonia and hydrogen over boiling water in an air-tight glass system and circulated the vapor continuously past an electric spark. By the end of a day the mixture turned pink; after a week it was a deep, muddy red. Then Miller analyzed the products by paper chromatography. The results exceeded his and Urey's expectations. The brew contained amino acids—the building blocks of proteins. Miller definitely identified glycine, alpha-alanine and beta-alanine. There were fainter traces of substances which may be aspartic and butyric acids, and still other amino acids may be present in smaller amounts. The substances could not have been made by living organisms in the mixture, because the experiment was run at the temperature of boiling water, and bichloride of mercury was added to prevent contamination during the analysis.

Reporting his results in *Science*, Miller adds that modifications of his procedure might make this a commercially useful method of manufacturing amino acids.

### *The Earth Is a Hothouse*

By adding six billion tons of carbon dioxide to the atmosphere each year, man's industrial activity is slowly warming up the earth. So says Gilbert N. Plass, physicist at The Johns Hopkins University. He told a recent meeting of the American Geophysical Society that he had recalculated the opacity of carbon dioxide to long-wave heat radiation and found it to be much greater than had been thought. This means that carbon dioxide in the air acts like the glass in a greenhouse roof, allowing short-wave heat to come in from the sun and preventing the escape of longer heat waves from the earth.

Plass estimates that at the present rate of industrial activity the amount of atmospheric carbon dioxide will double by the year 2080. That increase would raise the temperature of the earth by about 4 per cent, and the gas will probably trigger a further rise by another process. By blocking the loss of heat from the tops of clouds and reducing the temperature differential between their tops and bottoms, it will weaken the atmospheric convection currents that are



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analytical instruments for science and industry responsible for rainfall. So the climate may become clearer and drier, allowing still more heat from the sun to reach the earth's surface.

Conversely, Plass reasons, a decrease in carbon dioxide in the air would lead to a wetter and cooler climate. He believes that such a decrease may have been responsible for glaciers. In the millions of years of mountain-building that preceded each glacial period, the weathering of new rock may have captured a great deal of the atmosphere's free carbon dioxide and thus have cooled the climate enough to allow glaciation to begin.

### *Human Cancer in Rats*

ONE of the major obstacles to cancer research has been the inability to grow human cancers in laboratory animals. This barrier has now been breached at the Sloan-Kettering Institute for Cancer Research in New York by Helene Wallace Toolan, who has succeeded in transplanting human cancerous tissue into cortisone-treated rats.

Dr. Toolan got onto the new technique through the finding that X-rays seem to lower the rats' natural genetic defense against implantations of foreign tissue, perhaps because X-rays reduce the white blood count. But only half of the irradiated rats successfully grew bits of human tissue, and the growth could not be maintained long. When it was learned that cortisone also caused a severe reduction of white blood cells, Dr. Toolan began using this drug on her rats. She then achieved 90 per cent effective transplants. Moreover, the resulting tumors were bigger and more vigorous than in the X-rayed animals. By repeating the cortisone dose, they could be grown for up to 30 days. Thus far one bit of human cancer about four millimeters square has been transplanted and grown through eight generations in 150 rats.

Sloan-Kettering expects this to speed up cancer research enormously. Experimenters will now be able to try cancer treatments on the transplanted human cancers. By the end of this year Dr. Toolan will have enough human cancer in rats to test all of the some 4,600 substances that Sloan-Kettering examines each year for their possible cancer-inhibiting properties.

### *Antivivisectionists in Retreat*

THE antivivisection movement in the U. S. has been reduced from a national campaign to mere local harassing actions, says the National Society for Medical Research. The Society reports a major change in climate, with the antivivisectionists instead of scientists now on the defensive.

The Society, which has campaigned

for the cause of animal experimentation since 1946, says that the Hearst newspapers have given up the antivivisectionists' cause. Its libel suits on behalf of scientists against the Chicago *Herald-American* were settled out of court early this year. The publisher announced that the paper's editorial policy had changed with the death of William Randolph Hearst. Since then, says the Society, the paper "has been giving . . . animal experimentation . . . a straight play." Another indication of the change in policy was the New York *Journal-American's* virtual silence during the 1952 debate over the Hatch-Metcalf Act, which made animals available for experimentation.

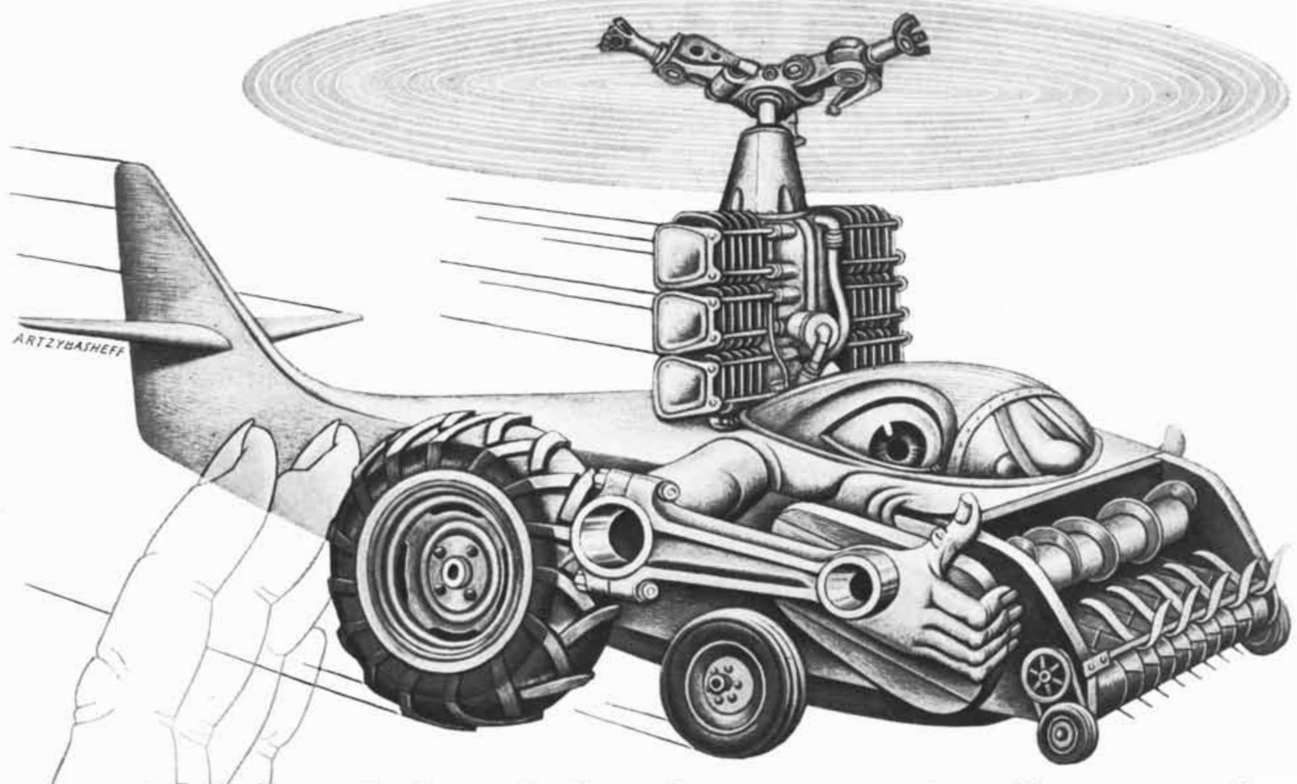
Antivivisectionists are concentrating on making animals difficult for scientists to obtain. The American Humane Association, the national clearing house for local animal welfare groups, is campaigning to defeat legislation which would provide animals for research. But most medical schools are now able to get animals under state or local laws or by working arrangements with humane society pounds. The only places where difficulties remain are Boston, the District of Columbia and Pennsylvania.

### *Soapless Opera*

SYNTHETIC detergents are causing trouble in sewage disposal systems. The first recorded case occurred in a small Pennsylvania town in 1947. On a Friday a large manufacturer passed out samples of his new detergent to almost every home in the community. By the following Monday the local sewage treatment plant was buried beneath a mountain of slimy, sour-smelling foam. As more and more housewives and industries began to use synthetic detergents, more and more plants had to combat foam. It soon appeared that the chemicals had other bad effects on the treatment systems.

The problem was recently reviewed at a meeting of the American Chemical Society and the conclusions were summarized in *Chemical and Engineering News*. In addition to their foaming action, detergents interfere with the operation of settling tanks, because they emulsify the solid particles. They kill many of the bacteria used in biological sewage purification. They promote slime growth in sewer pipes. Their phosphorus salts get into lakes and ponds and encourage rapid multiplication of unwanted algae.

A small share of the difficulties must be laid to the consumers rather than the chemicals. Some of the most popular household detergents need have no foaming action, but because housewives like to see copious suds the manufacturers add a foaming agent. This provides a rich lather not only in the kitchen sink but also in the disposal plant.

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# Wheat

*The grass that bears our daily bread is synonymous with European civilization. What is the basis of its usefulness, and what is the origin of modern wheat?*

by Paul C. Mangelsdorf

WHEAT is the world's most widely cultivated plant. The wheat plants growing on the earth may even outnumber those of any other seed-bearing land species, wild or domesticated. Every month of the year a crop of wheat is maturing somewhere in the world. It is the major crop of the U. S. and Canada and is grown on substantial acreages in almost every country of Latin America, Europe and Asia.

Apparently this grain was one of the earliest plants cultivated by man. Carbonized kernels of wheat were found recently by the University of Chicago archaeologist Robert Braidwood at the 6,700-year-old site of Jarmo in eastern Iraq, the oldest village yet discovered—a village which may have been one of the birthplaces of man's agriculture. Through the courtesy of Dr. Braidwood I have had an opportunity to study some of these ancient kernels and compare them with modern kernels, carbonized to simulate the archaeological specimens. The resemblance between the ancient and modern grains is remarkable. There were two types of kernels in the Jarmo site; one turned out to be almost identical with a wild wheat still growing in the Near East, and the other almost exactly like present-day cultivated wheat of the type called einkorn. Evidently there has been no appreciable change in these wheats in the 7,000 years since Jarmo.

When he domesticated wheat, man laid the foundations of western civilization. No civilization worthy of the name has ever been founded on any agricultural basis other than the cereals. The ancient cultures of Babylonia and Egypt, of Rome and Greece, and later those of northern and western Europe, were all based upon the growing of wheat, barley, rye and oats. Those of India, China and Japan had rice for their basic crop. The pre-Columbian peoples of America—Inca, Maya and Aztec—looked to corn for their daily bread.

What are the reasons for this intimate relation between the cereals and civilization? It may be primarily a question of nutrition. The grain of cereal grasses, a nutlike structure with a thin shell covering the seed, contains not only the embryo of a new plant but also a food supply to nourish it. Cereal grains, like eggs and milk, are foodstuffs designed by nature for the nutrition of the young of the species. They represent a five-in-one food supply which contains carbohydrate, proteins, fats, minerals and vitamins. A whole-grain cereal, if its food values are not destroyed by the over-refinement of modern processing methods, comes closer than any other plant product to providing an adequate diet. Man long ago discovered this fact and learned to exploit it. Guatemalan Indians manage to subsist fairly well on a diet which is 85 per cent corn. In India people sometimes live on almost nothing but rice. Such diets do not meet the approval of modern nutritionists, but they are better than those made up too largely of starchy root crops such as potatoes, sweet potatoes or cassava, or of proteinaceous legumes such as beans, peas and lentils.

Perhaps the relationship between cereals and civilization is also a product of the discipline which cereals impose upon their growers. The cereals are grown only from seed and must be planted and harvested in their proper season. In this respect they differ from the root crops, which in mild climates can be planted and harvested at almost any time of the year. Root-crop agriculture can be practiced by semi-nomadic peoples who visit their plantations only periodically. The growing of cereals has always been accompanied by a stable mode of life. Moreover, it forced men to become more conscious of the seasons and the movements of the sun, moon and stars. In both the Old World and the New the science of astronomy was invented by cereal growers, and with it a calendar and a system of arithmetic. Cereal agriculture in providing a stable food supply created leisure, and leisure in turn fostered the arts, crafts and sciences. It has been said that "cereal agriculture, alone among the forms of food production, taxes, recompenses and stimulates labor and ingenuity in an equal degree."

## From Grain-chewing to Bread

Today wheat is the cereal *par excellence* for breadmaking, and it is used almost exclusively for that purpose. But it is quite unlikely that breadmaking, a complex and sophisticated art, came suddenly into full flower with the domestication of wheat. Man may have begun by merely parching or popping the grain to make it edible. Primitive wheats, like other cereals, were firmly enclosed in husks, called glumes. Heating makes the glumes easy to rub off and allows the kernel itself to be more easily chewed or ground into meal. The scorching and parching of grains is still practiced on unripened cereals in parts of the Near East. In Scotland until recently barley glumes were sometimes removed by setting fire to the unthreshed heads. The Chippewa Indians still prepare wild rice by heating the unhusked kernels and tramping on them in a hollow log.

Hard-textured cereal grains with a certain moisture content explode and escape from their glumes when heated. In America the first use of corn was undoubtedly by popping. The earliest known corn had small vitreous kernels, and archaeological remains of popped corn have been found in early sites in both North and South America. In India certain varieties of rice are popped by stirring the kernels in hot sand. Many villages in India have a village popper who performs this service for his neighbors and provides himself with food by taking his toll of the product.

The botanical as well as archaeological evidence, though meager, indicates that wheat was first used as a parched cereal. The dwellings at Jarmo contain ovens which prove that this primitive economy knew the controlled use of heat. All the very ancient prehistoric kernels so far found are carbonized as if they had been over-parched. In itself this evidence is not telling, since only carbonized grains would be preserved indefinitely, but it is in harmony with other evidence. Finally, the most ancient wheats are species whose kernels would not be removed from the husks merely by threshing. The simplest method of husking them to make them edible would have been parching.

Probably the second stage in progress was to grind the parched grains and soak the coarse meal in water to make a gruel. For the toothless, both old and young, this must have been a life-saving invention. Gruel or porridge is well known as a primitive form of food. A gruel prepared from parched barley was the principal food of the common people of ancient Greece. American Indians prepared a kind of porridge from corn, which has its modern counterpart in "mush" and "polenta."

A gruel allowed to stand for a few days in a warm dwelling would become infected with wild yeasts. Fermenting the small amounts of sugar in cereal, the yeasts would have produced a mild alcoholic beverage. This would have pointed the way to leavened bread. It is questionable which art developed first—brewing or breadmaking. Some students believe that brewing is older even than agriculture, but there is no supporting archaeological or historical evidence. On the contrary, the earliest Egyptian recipes for beer described a process in which the grain was first made into half-baked loaves, which then became the raw material for beer-making. There is no doubt that brewing and the making of leavened bread are closely related arts, both depending upon fermentation by yeasts.

Modern breadmaking, however, had to await the appearance of new types of wheat. It is as much a product of the evolution of wheat as it is one of human ingenuity.

### From Wild Grass to Wheat

Wheat differs from most cultivated plants in the complexity of its variations. True, the other major cereals, rice and corn, are each differentiated into thousands of varieties, but these form a continuous spectrum of variation and hence are classed as a single botanical species. Wheat is separated into distinct groups which differ from one another in many ways and are therefore classified as separate species under the single Old World genus *Triticum*. The domesticated wheats and their wild relatives have been studied more intensively than any other group of plants, cultivated or wild, and from these studies, truly international in scope, a picture is beginning to emerge of the evolution of wheat under domestication.

Authorities differ on the number of distinct species of wheat. This article follows the classification of Nikolai Vavilov, the Russian geneticist and botanist who, with his colleagues, brought together for study more than 31,000 samples of wheat from all parts of the world. Vavilov recognized 14 species; other botanists have recognized fewer or more. All authorities agree, however, that the wheat species, whatever their number, fall into three distinct groups, determined by the number of chromosomes in their cells. The chromosome numbers (in the reproductive cells) of the three types are, respectively, 7, 14 and 21. They were discovered by T. Sakamura in Japan in 1918 and slightly later, but independently, by Karl Sax in the U. S. The numbers are closely associated with differences in anatomy, morphology, resistance to disease, productiveness and milling and baking qualities. It is interesting to note that August Schulz, a German botanist, had arranged the wheats into these three groups in 1913, well before their chromosome numbers were known.

The 14- and 21-chromosome wheats have all arisen from 7-chromosome wheat and related grasses, through hybridization followed by chromosome doubling. The cultivated wheats are the most conspicuous example of this "cataclysmic evolution," described by G. Ledyard Stebbins, Jr., in his article in SCIENTIFIC AMERICAN of April, 1951. It is the only known mechanism by which new true-breeding species can be created almost overnight.

Since different wild grasses have been involved in wheat's evolution, the species differ not only in the number but also in the nature of their chromosomes. Relationships of different sets of chromosomes are determined by studying the degree of chromosome pairing in the reproductive cells of hybrids. If the pairing is complete, or almost so, the chromosome sets (genoms) of the parents are regarded as identical or closely related. If there is no pairing, the parental genoms are considered to be distinct. Four different genoms, each comprising seven chromosomes, designated A, B, D

*Wheat field and farm buildings*

**FOURTEEN SPECIES OF WHEAT** are shown actual size. From left to right they are *Triticum aegilopoides* (wild einkorn), *T. monococcum* (einkorn), *T. dicoccoides* (wild emmer), *T. dicoccum* (emmer), *T. durum* (macaroni wheat), *T. persicum* (Persian wheat), *T. turgidum* (rivet wheat), *T. polonicum* (Polish wheat), *T.*

and G, are recognized in wild and cultivated wheats.

Another important difference in wheats is in their heads. Primitive cereals and many wild grasses have heads whose central stem is brittle and fragile, breaking apart when mature and providing a natural mechanism for seed dispersal. When such cereals are threshed, the heads break up into individual spikelets (clusters of one or more individual grass flowers) in which the kernels remain firmly enclosed in their husks. Under domestication this characteristic, so essential to perpetuation of the species in the wild, has been lost. New forms have evolved, not only in wheat but in other cereals, in which the stems are tough and the heads remain intact when mature. In such cereals threshing alone removes the kernels from their glumes. The cereals with free-threshing, naked grains are much more useful to man, especially for milling and baking, than those that cling stubbornly to their husks. In wheats, therefore, the naked varieties have almost completely superseded the primitive forms.

## Ancestors

The 7-chromosome wheats, probably the most ancient, consist of two species: *T. aegilopoides* and *T. monococcum*, known as wild einkorn and einkorn. Carbonized kernels of both were found at Jarmo, but whether they are the only wheats occurring in this ancient village site remains to be seen. Both species of einkorn have fragile stems and firm-hulled seeds. Their spikelets contain but a single seed, hence their name. Each has the same set of chromosomes, genom A, and they hybridize easily together to produce highly fertile offspring. Cultivated einkorn has slightly larger kernels than the wild form and a slightly tougher stem. Its heads do not fall apart quite so easily when ripe. Except for these slight differences the two species are essentially identical, and einkorn is

***timopheevi*** **(which has no common name),** ***T. aestivum*** **(common wheat),** ***T. sphaerococcum*** **(shot wheat),** ***T. compactum*** **(club wheat),** ***T. spelta*** **(spelt) and** ***T. macha*** **(macha wheat). The first two species have 7 chromosomes; the following seven, 14 chromosomes; the last five, 21 chromosomes (*see table on next two pages*).**

undoubtedly the domesticated counterpart of the wild species. Apparently little significant change has been wrought in them over the centuries.

Wild einkorn has its center of distribution in Armenia and Georgia of the Soviet Union, and in Turkey. It also occurs in the eastern Caucasus and in western Iran. Westward from Asia Minor it is a common grass on the sides of low hills in Greece and Bulgaria and a weed in the well-drained vineyards of southern Yugoslavia. Cultivated einkorn originated, according to Vavilov, in the mountains of northeastern Turkey and the southwestern Caucasus. However, if my identification of the kernels at Jarmo is correct, and if Jarmo represents the beginnings of agriculture, einkorn may have been domesticated first slightly farther south in eastern Iraq. Certainly it is an ancient cereal. Carbonized grains of it have been found in neolithic deposits of the lake-dwellers and in many other sites in central and northeastern Europe. Impressions of einkorn have been identified in neolithic pottery in Britain and Ireland. There are no records of its prehistoric occurrence in India, China or Africa.

Einkorn is still grown in some parts of Europe and the Middle East, usually in hilly regions with thin soils. Its yields are low, usually not more than 8 to 15 bushels per acre. A bread, dark brown in color but of good flavor, can be made from it if it is husked, but it is more commonly used as a whole grain, like barley, for feeding cattle and horses. Einkorn's importance lies not in its present use but in its progeny. It is the ancestor of all other cultivated wheats, with the possible exception of the type called emmer. Einkorn's descendants all have in common the set of seven chromosomes called genom A.

## Second Stage

In the next stage of evolution are the 14-chromosome species, of which Vavilov recognized seven. All these have come from the hybridization and chromosome doubling of a 7-chromosome wheat with a 7-chromosome related wild grass. The wheat parent in each case was undoubtedly einkorn, or possibly in one instance its wild relative, since all the species possess the genom A. But the wild-grass parent remains to this day unidentified and is the chief botanical mystery in the origin of cultivated wheats. This parent contributed a genom B to all in the group except one species. Edgar McFadden and Ernest Sears of the U. S. Department of Agriculture have suggested that genom B may have been derived from a species of *Agropyron*, a genus of weedy grasses which includes the pernicious couch grass of the northeastern U. S. Only one of the 14-chromosome wheats is found wild. This species, which is called wild emmer, is indigenous to southern Armenia, northeastern Turkey, western Iran, Syria and northern Palestine.

Closely resembling wild emmer, and possibly derived directly from it by domestication, is emmer, the oldest of 14-chromosome cultivated wheats and once the most widely grown wheat of all. An alternative possibility, however, is that emmer is the product of hybridization between einkorn and a 7-chromosome wild relative. The fact that crosses of wild and cultivated emmer are sometimes partly sterile indicates that the two forms may not be closely related and that one may be the product of an ancient hybridization and the other of a more recent one. There is at least no doubt about the antiquity of emmer. Well-preserved spikelets scarcely different from those of modern emmer have been found in Egyptian tombs of the Fifth Dynasty. Emmer may well have been the chief cereal of the Near East from very early times to the Greco-Roman period, for until the Jarmo find it was the only wheat found archaeologically in early sites of that region. Remains or impressions of it have also been common in neolithic sites in continental Europe, Britain and Ireland.

Emmer, like einkorn, has a fragile stem and clinging hull. Good bread and fine cake and pastry can be made from it, but most emmer today is fed to livestock. Some varieties are quite resistant to stem and leaf rust, the principal diseases of wheat, and have been useful in plant breeding.

The 14-chromosome wheats were the first to produce species with tough stems and with kernels that thresh free from their glumes. Four such species are known: *durum* (macaroni), *persicum* (Persian), *turgidum* (rivet) and *polonicum* (Polish). All have a more recent history than einkorn or emmer. The oldest, durum, first appeared in the Greco-Roman period about the first century B.C. One of the most recent, Polish wheat, unique for its massive heads and long, hard kernels, did not appear until the 17th century. None of these wheats except durum is of great commercial importance today. Durum wheat, the best variety for the manufacture of macaroni, spaghetti and other edible paste products, is grown fairly extensively in Italy, Spain and parts of the U. S. Rivet wheat is of some interest because it is the tallest-growing (four to six feet high) and under ideal conditions one of the most productive. However, its grains are soft, yielding a weak flour unsuitable for breadmaking unless mixed with stronger wheats. One variety of rivet called "miracle" or "mummy" wheat, with massive branched heads, has been persistently exploited as a rare and valuable wheat claimed to have been propagated from prehistoric grains discovered in ancient Egyptian tombs, usually in the wrappings of a mummy. The story in all of its versions is a complete fabrication. Wheat kernels, like seeds of other plants, are living metabolic systems with a maximum life expectancy of about 10 years. Furthermore, there is no evidence that rivet wheat was ever known in ancient Egypt.

One additional 14-chromosomewheat, *T. timopheevi*, which has no common name, deserves mention. This species was discovered in this century by Russian botanists and is known only in western Georgia, where it is grown on a few thousand acres. The species is of botanical interest because its second set of seven chromosomes, designated genom G, is different from that of any of the other 14-chromosome wheats. It is also of great practical interest because it is resistant to virtually all diseases attacking other cultivated wheats, including rusts, smuts and mildews. In the hands of skilled wheat breeders it may become the ancestor of improved wheats for the next century.

### Third Stage

The 21-chromosome wheats, of which there are five, are as a group the most recently evolved and the most useful today. All are cultivated; none has ever been known in the wild. All are products of the hybridization of 14-chromosome wheats containing the genoms A and B with a wild 7-chromosome relative of wheat (almost certainly a grass species of the genus *Aegilops*) containing the genom D. All are believed to have arisen from such hybridization after man, spreading the revolutionary art of agriculture, exposed his earlier cultivated wheats to hybridization with native grasses.

Two of the 21-chromosome wheats, *T. spelta* (spelt) and *T. macha*, are, like einkorn and emmer, hard-threshing species. *T. macha*, like *T. timopheevi*, is confined to western Georgia, where it is grown on not more than a few thousand acres. Spelt was once the principal wheat of central Europe. No archaeological remains of it have been found in the Near East or any part of Asia. There is no doubt about the hybrid origin of spelt, for it has now been synthesized by McFadden and Sears and independ-

| LATIN NAME | COMMON NAME | CHROMOSOMES NUMBER | CHROMOSOMES GENOMS | GROWTH | GRAINS |
|---|---|---|---|---|---|
| T. AEGILOPOIDES | WILD EINKORN | 7 | A | WILD | HULLED |
| T. MONOCOCCUM | EINKORN | 7 | A | CULTIVATED | HULLED |
| T. DICOCCOIDES | WILD EMMER | 14 | AB | WILD | HULLED |
| T. DICOCCUM | EMMER | 14 | AB | CULTIVATED | HULLED |
| T. DURUM | MACARONI WHEAT | 14 | AB | CULTIVATED | NAKED |
| T. PERSICUM | PERSIAN WHEAT | 14 | AB | CULTIVATED | NAKED |
| T. TURGIDUM | RIVET WHEAT | 14 | AB | CULTIVATED | NAKED |
| T. POLONICUM | POLISH WHEAT | 14 | AB | CULTIVATED | NAKED |
| T. TIMOPHEEVI | | 14 | AG | CULTIVATED | HULLED |
| T. AESTIVUM | COMMON WHEAT | 21 | ABD | CULTIVATED | NAKED |
| T. SPHAEROCOCCUM | SHOT WHEAT | 21 | ABD | CULTIVATED | NAKED |
| T. COMPACTUM | CLUB WHEAT | 21 | ABD | CULTIVATED | NAKED |
| T. SPELTA | SPELT | 21 | ABD | CULTIVATED | HULLED |
| T. MACHA | MACHA WHEAT | 21 | ABD | CULTIVATED | HULLED |

**SOME CHARACTERISTICS** of the 14 species, as well as their distribution and antiquity, are given in this table. The genoms are sets of inherited characently by H. Kihara in Japan. In both cases the researchers concluded that the botanical characteristics to be sought in the unknown 7-chromosome parent of spelt were possessed by *Aegilops squarrosa*, a completely useless wild grass which grows as a weed in wheat fields from the Balkans to Afghanistan. Both researchers hybridized this wild grass with wild emmer. McFadden and Sears doubled the chromosome number by treatment with colchicine; Kihara was fortunate in discovering a case of natural doubling. The hybrid was highly fertile and similar in characteristics to cultivated spelt. As a final step in a brilliant piece of inductive reasoning and genetic experimentation, McFadden and Sears crossed their synthesized spelt with natural spelt and obtained fully fertile hybrids. The results leave no doubt that the wild grass used in this experiment is one of the parents of cultivated spelt, and they suggest strongly that the other four 21-chromosome wheats are likewise hybrids in which the genom D has been derived from the same grass or a species close to it.

These experiments suggest that cultivated spelt originated in the region where the species of wild grass and wild emmer overlap. But the primitive hulled form of spelt has not been found there. An alternate possibility is that the wild grass hybridized not with wild emmer but with the cultivated species, which has had a much wider distribution. Vavilov concluded that hulled spelt originated in southern Germany. Earlier Elisabeth Schiemann, Germany's leading student of cereals, had placed it in Switzerland and southwest Germany. Both centers are not far from the northeastern limits of the area in which cultivated emmer and the wild grass are known to have occurred together. Thus the botanical and historical evidence are not far apart in indicating a central European origin.

The remaining three species of 21-chromosome wheats are *T. aestivum* (common), *sphaerococcum* (shot) and *compactum* (club). They are the true bread wheats, accounting for about 90 per cent of all the wheat grown in the world today. The three are closely related and easily intercrossed. Whether they are the product of three different hybridizations between 14-chromosome wheats and wild grasses, or of three diverging lines of descent from a single hybridization, is not known. Club and shot wheat differ from common wheat in a number of details whose inheritance is governed by a relatively small number of genes. It is possible, therefore, that the three species are descended from a single hybrid ancestor. Common wheat or something very like it has recently been produced by Kihara by crossing 14-chromosome Persian wheat with the wild grass used to synthesize spelt. Its chromosome number has not yet been doubled, but its botanical characteristics are those of common wheat.

Where and when the modern bread wheat first occurred are still matters for conjecture. Since Persian wheat is known only in a limited area in northeastern Turkey and the adjoining states of the Soviet Union, common wheat very probably originated there. Kernels of shot wheat have been found at the most ancient site in India, Mohenjo-Daro, dated about 2500 B.C. A wheat found in neolithic store-chambers in Hungary has been identified as club wheat. Impressions of grains of bread wheat, either common or club, have been found in the neolithic Dolmen period, dated between 300 and 2300 B.C. The earliest archaeological wheat in Japan, dated in the third century, is regarded by Kihara as a bread wheat. And since the 14-chromosome wheats evidently are recent introductions in China, it is possible that the wheat described in the Chinese classics for the Chou period (about 1000 B.C.) is a 21-chromosome bread wheat. All these items, none in itself conclusive, indicate that the bread wheats originated before the time of Christ but later than einkorn or emmer. A conservative guess would put their origin at approximately 2500 B.C.

## A Historic Explosion

Whether the bread wheats originated earlier than this or later, and whether they had one hybrid origin or three, they represent today the most rapid increase in geographical range and numbers of any species of seed-plant in history. They are now grown in all parts of the world from the Equator to the Arctic Circle. Originating probably not more than 5,000 years ago in the general region of Asia Minor, the new species have increased at an average rate of

| GEOGRAPHICAL DISTRIBUTION | EARLIEST EVIDENCE |
|---|---|
| VESTERN IRAN, ASIA MINOR, GREECE, SOUTHERN YUGOSLAVIA | PRE-AGRICULTURAL |
| ASTERN CAUCASUS, ASIA MINOR, GREECE, CENTRAL EUROPE | 4750 B. C. |
| VESTERN IRAN, SYRIA, NORTHERN PALESTINE, NORTHEASTERN TURKEY, ARMENIA | PRE-AGRICULTURAL |
| NDIA, CENTRAL ASIA, NORTHERN IRAN, GEORGIA, ARMENIA, EUROPE, MEDITERRANEAN AREA, ABYSSINIA | 4000 B. C. |
| ENTRAL ASIA, IRAN, MESOPOTAMIA, TURKEY, ABYSSINIA, SOUTHEASTERN EUROPE, U.S. | 100 B. C. |
| AGESTAN, GEORGIA, ARMENIA, NORTHEASTERN TURKEY | NO PREHISTORIC REMAINS |
| .BYSSINIA, SOUTHERN EUROPE | NO PREHISTORIC REMAINS |
| BYSSINIA, MEDITERRANEAN AREA | 17TH CENTURY |
| VESTERN GEORGIA | 20TH CENTURY |
| VORLD WIDE | NEOLITHIC PERIOD |
| ENTRAL AND NORTHWESTERN INDIA | 2500 B. C. |
| OUTHWESTERN ASIA, SOUTHEASTERN EUROPE, U.S. | NEOLITHIC PERIOD |
| ENTRAL EUROPE | BRONZE AGE |
| VESTERN GEORGIA | 20TH CENTURY |

**teristics, or combinations of sets. The chromosome number is a clue to the evolution of wheat. The species with larger chromosome numbers descended from those with smaller by hybridization and chromosome doubling.**

**HEAD** of common wheat is dissected to show the rachis (*lower right*) which bears the spikelets. Enclosing each kernel is a bearded glume. In some varieties the beard is absent. At lower left is a single spikelet of spelt, which during threshing remains intact and attached to a joint of the rachis.

about 75,000 acres per year until they now occupy almost 400 million acres. Their evolution and dispersal have been explosive phenomena in which man's principal part has been to recognize their usefulness and to open up new agricultural areas for their culture.

The particular value of the bread wheats lies not only in their productiveness and in their free-threshing, naked kernels, but in the peculiar quality of their gluten, the protein component. Of all the cereals only the bread wheats are capable of producing the light, fluffy, leavened breads we know today.

All known species of cultivated wheat, except einkorn and possibly emmer, came into existence spontaneously. Man played no part in their origin except as he spread their culture and their opportunities for natural hybridization over the earth. There is no evidence that ancient man gave much attention to selection of superior forms, or if he did, no evidence that he succeeded. The cultivated einkorn of today is scarcely different from the einkorn of millennia ago, and it, in turn, is no great improvement over wild einkorn. Essentially the same can be said about emmer. Consequently, to speak of primitive man as a plant breeder is to attribute more purposefulness to his activities than the evidence warrants.

Within the past century, especially since the rediscovery of Mendel's laws of inheritance in 1900, vast programs of wheat improvement have been undertaken in almost all the wheat-growing regions of the world. These have been especially successful in the U. S. and Canada, where a constant succession of new varieties has been introduced. Scarcely any state of the Union today grows extensively the principal varieties of wheat grown 50 years ago.

Early in the century the most common method of wheat breeding was "pure-line" selection as invented by Wilhelm Johannsen, a Danish botanist and geneticist. Johannsen had concluded from experiments on garden beans that self-fertilized plants such as beans, peas and cereals are racial mixtures of many pure lines, differing from one another in many characteristics but each genetically uniform. Continuous selection can have no effect in changing the characters of a genetically pure line, but a mixture of lines can be separated into its component parts and improvements effected by propagating the superior lines.

In practice the wheat breeder selects hundreds of individual heads from a variety, threshes each one separately and grows the progeny of each in a short row called a head row. In succeeding generations more and longer rows are grown, and the pure lines, each originating from a single head, are compared in productiveness and other characteristics. Among wheat breeders in the

U. S. it is standard procedure at this stage to use rows 16 feet long and one foot apart. Rows of this length and spacing simplify computation, since the yield of grain in grams can be converted to a bushel yield per acre by simply pointing off one decimal place. The more promising lines are increased still further in field plots and eventually one is chosen as the best, is named and is distributed to farmers.

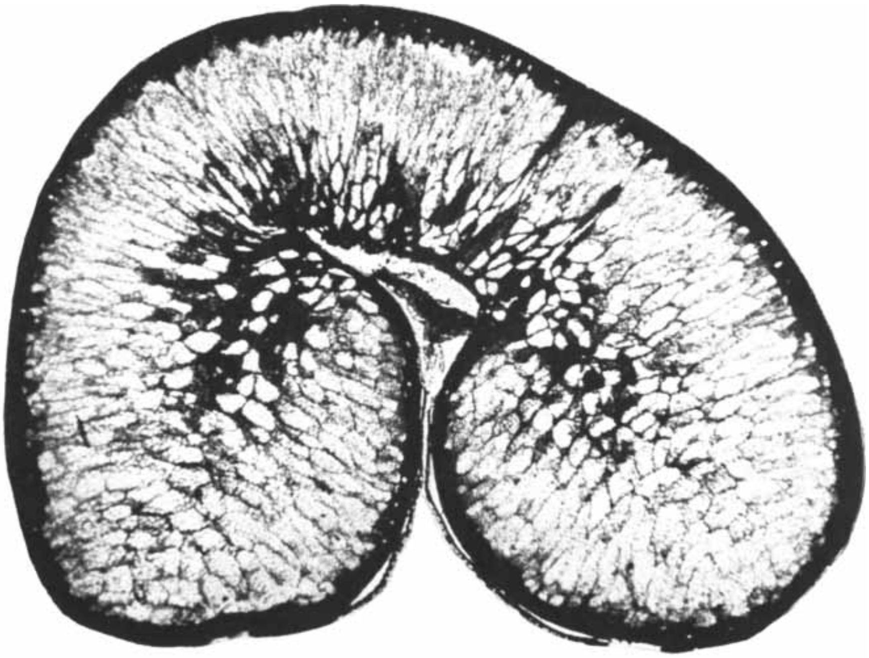
The two outstanding U. S. varieties produced by pure-line selection are both Kansas products. The first, Kanred (Kansas Red), was selected by Herbert Roberts of the Kansas Agricultural Experiment Station from Crimean, a hard, red, winter-type wheat introduced from Russia by Mark Carleton. The first head selections were made in 1906, and the improved pure line first distributed for commercial growing in 1917. By 1925 Kanred wheat, the product of a single head only 19 years earlier, was grown on nearly five million acres in Kansas, Nebraska, Colorado, Oklahoma and Texas. The second Kansas wheat, Blackhull, is the product of a single head selection made in 1912 from a field of Turkey wheat by Earl Clark, a farmer and plant breeder. Blackhull, like Kanred, was first distributed in 1917. By 1929 it occupied almost six million acres, principally in Kansas and Oklahoma.

### The Hybrid Wheats

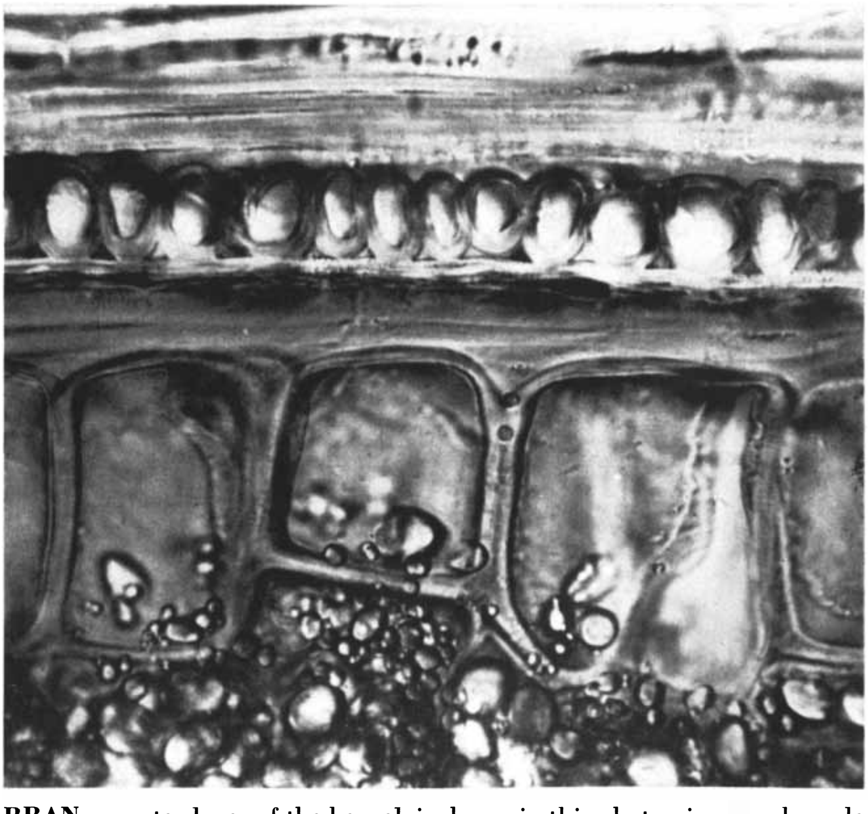
Pure-line selection merely sorts out from a variety the superior lines already there; it creates no new genetic combinations. To form a new variety the breeder employs hybridization. He selects as parents two varieties with the characteristics he seeks to combine. For example, one parent may be chosen for its superior milling and baking qualities, the other for its resistance to disease. To cross these two the breeder first emasculates one of them by removing the anthers, the male pollen-containing organs, with delicate forceps when these organs are full-grown but not yet ripe. Then he covers the emasculated head with a small glassine bag to prevent uncontrolled pollination. A few days later, when its female organs, the stigmas, have become receptive, the operator pollinates them with ripe anthers taken from the second parent.

Such pollinations produce seeds that grow into first-generation hybrid plants. These are quite uniform and nothing is accomplished by practicing selection among them. But in the second and subsequent generations genetic segregation creates new combinations as numerous and diverse as the hands in a shuffled deck of cards. The opportunities for creative selection are enormous. It is in the early generations following a cross that the plant breeder shows his skill, for at this stage he must select for propagation those combinations which approach most closely the ideal wheat he has in mind and discard those which do not meet his specifications. Eventually genetic segregation produces pure lines.

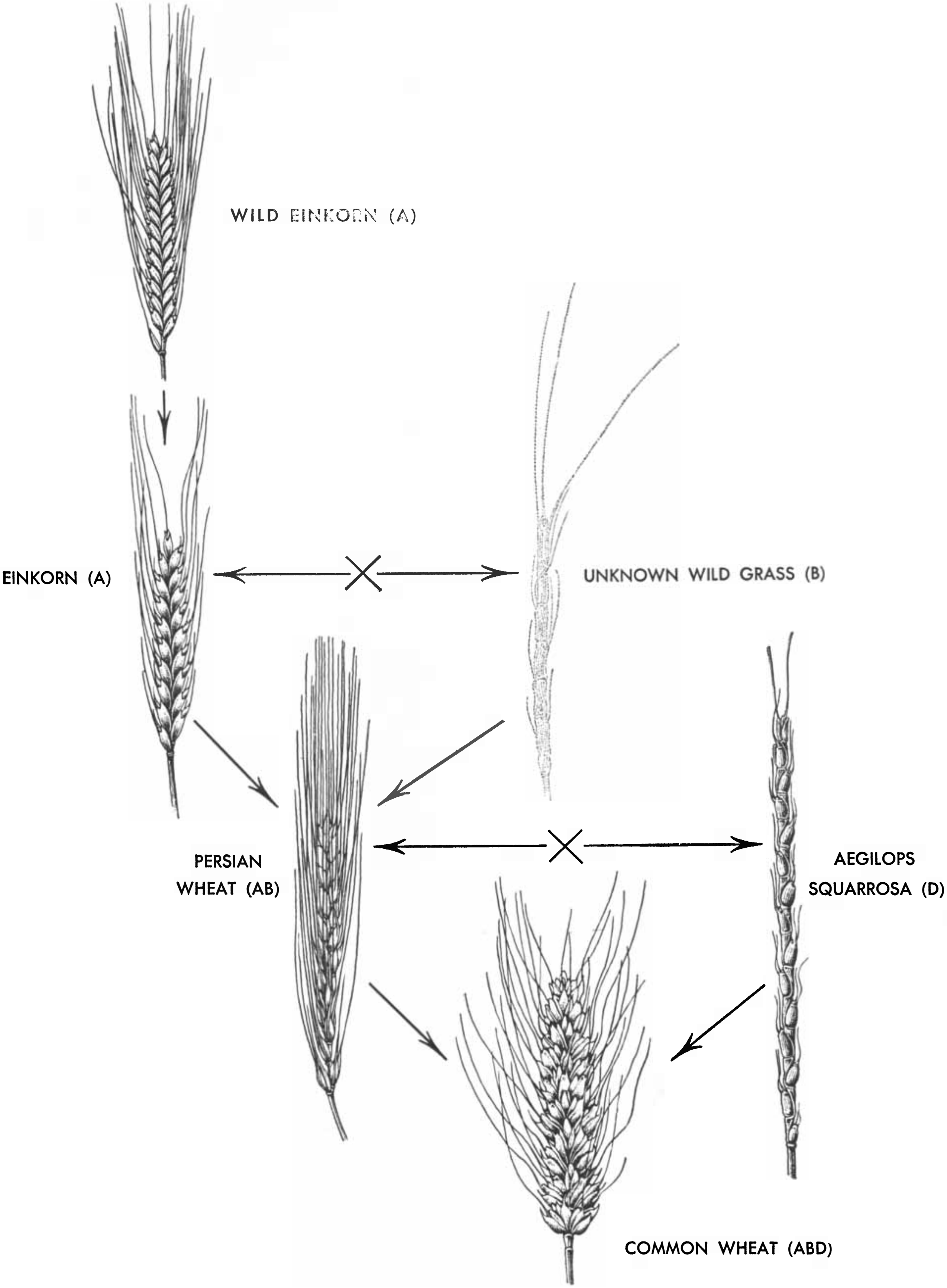
One of the earliest and greatest achievements in hybrid wheat was the development of the Marquis strain. This variety, a hybrid of early-growing Hard Red Calcutta from India and Red Fife from Poland, was produced in Canada by Charles Saunders, cerealist for the Dominion from 1903 to 1922. The cross from which Marquis wheat was derived



**KERNEL** of common wheat is photographed in cross section at the Northern Regional Research Laboratory of the U. S. Department of Agriculture. The interior of the kernel is the endosperm, from which flour is made.



**BRAN,** or outer layer of the kernel, is shown in this photomicrograph made at the Northern Regional Research Laboratory. At the bottom of the photomicrograph, which enlarges these structures 600 times, is the endosperm.




**EVOLUTION** of common wheat is outlined. Wild einkorn (7 chromosomes, genom A) evolved into einkorn, which, crossed with a wild grass (genom B), gave rise to Persian wheat (14 chromosomes, genom AB). When this wheat was crossed with another grass (genom D), common wheat (21 chromosomes, genom ABD) resulted.

had been made in 1892 by his brother Arthur under the direction of his father, William Saunders, who had been hybridizing wheats since 1888. The new hybrid was promising from the beginning. It was a few days earlier than the spring-planted varieties then commonly grown in Canada, thus often avoiding the first frosts. The grain yielded a cream-colored, strongly elastic dough with strong gluten and excellent baking qualities. Marquis wheat later set new standards for baking quality. By 1907, four years after the initial head selection, there were 23 pounds of seed. Distribution to farmers began in the spring of 1909. News of the new wheat spread swiftly from the prairie provinces down into our own spring-wheat belt. By 1913 Marquis seed was being imported into Minnesota and the Dakotas at the rate of 200,000 bushels per year. In 1918 more than 300 million bushels were produced, and the superiority of this variety over those previously grown was a factor in meeting the food shortage of World War I, just as 25 years later hybrid corn was a similar factor in World War II.

For 20 years Marquis was the "king of wheats" in Canada and the U. S., and during this period it served as a standard both in the field and in the milling and baking laboratory. Marquis was also used extensively as a parent in new hybrids and is the ancestor of many improved wheats, including Tenmarq, developed in Kansas by John Parker; Ceres, produced in North Dakota by L. R. Waldron, and Thatcher and Newthatch, bred by Herbert K. Hayes and his associates in Minnesota.

Today most new wheat varieties are produced by controlled hybridization rather than by pure-line selection, which is little used. The modern wheat breeder has many objectives. Usually his principal one is productiveness, but involved in this are many factors, including resistance to diseases and tolerance of unfavorable environmental conditions. To test new wheats for these characteristics, breeders have invented devices and methods for subjecting wheat to artificial drought, cold and epidemics of disease.

## Breeders *v.* Fungi

Breeding for disease resistance is especially important because wheat is a self-fertilized plant which, except for natural hybridization and occasional mutations, tends to remain genetically uniform. A field of wheat of a single variety, especially one originating from a single head, contains millions of plants which are genetically identical. If the variety happens to be susceptible to a disease, it serves as a gigantic culture medium for the propagation of the disease organism, usually a fungus. Thus the growing of new varieties over large acreages increases the hazards from those diseases to which they are susceptible. The result is a never-ending battle between the wheat breeders and the fungi.

The breeding of wheat for resistance to stem rust, a devastating disease, is a prime example. There are many kinds of stem rust. Pathologists, led by Elvin Stakman of the University of Minnesota, have devised ingenious methods of identifying them by inoculation of different hosts. The wheat breeder then develops a new variety which is resistant to the predominating races of stem rust. This is distributed to farmers and its acreage increases rapidly. But while the wheat breeder is hybridizing wheats, nature is hybridizing rusts. The reproductive stage of stem rusts occurs not on wheat but on an alternate host, the common barberry. On this plant new races of rust are constantly created. Although most of them probably die out, one that finds susceptible wheat varieties may multiply prodigiously and in a few years become the predominating race. The wheat breeder then searches the world for wheats resistant to the new hazard and again goes through all the stages of producing a new hybrid variety. The competition between man and the fungi for the wheat crop of the world is a biological "cold war" which never ends.

A wheat breeder must seek not only disease resistance and productiveness but also milling and baking quality. In modern mass-production bakeries with high-speed mixing machinery, dough undergoes stresses and strains which it was never called on to endure when kneaded by hand in the home. As a result wheat breeders have been compelled to subject their new productions to elaborate milling and baking tests which simulate the processes of commercial bakeries. A new wheat that proves superior in the field may be rejected in the laboratory.

In spite of the difficulties involved, the development of more productive varieties of wheat is one of the surest ways of increasing the food supply and raising living standards. When Mussolini drained the Pontine swamp in Italy, the Italian wheat breeder Alzareno Strampelli produced new varieties of wheat which flourished in the fertile soils newly opened to cultivation. An important part of the well-publicized Etawah Village Improvement Program in India is the growing of improved varieties of wheat developed by British and Indian geneticists. Mexico's agricultural program, sponsored by the Rockefeller Foundation in cooperation with the Mexican Government, owes much of its success to new rust-resistant varieties of wheat. Crossing the old varieties of Mexican wheat with rust-resistant wheats from the U. S., South America, Australia and New Zealand, the U. S. breeder Norman Borlaug and his associates, working closely with Mexican technologists, have bred new varieties so resistant to rust that they can be grown in Mexico's summer rainy season as well as in the winter dry season, heretofore its only season for growing wheat. The bulk of Mexico's wheat acreage is now devoted to new hybrids developed since 1943, while acreage and production have expanded substantially.

Hybridization among wheats is usually confined to varieties of one species, but interspecific hybrids also are employed and sometimes are successful. A notable example is the development of Hope wheat by McFadden from a cross of Marquis with Yaroslav emmer, a 14-chromosome wheat extremely resistant to stem rust, leaf rust and several other diseases. From this hybrid, which was partly sterile, McFadden succeeded in developing a 21-chromosome wheat which has a high degree of resistance to many races of stem and leaf rust. Unfortunately Hope wheat has a grain somewhat lacking in milling and baking qualities and the variety has never become important commercially. It has, however, been the parent of many modern varieties of wheat which are commercially grown, including Newthatch in Minnesota, Austin in Texas and several of the new varieties developed in Mexico.

## New Cereals

A future possibility in wheat breeding is the creation of wholly new types of cereals by species hybridization followed by artificial chromosome doubling, a man-made counterpart of wheat's earlier evolution in nature. In the U.S.S.R. and the U. S. wheat has been crossed with rye to produce a fertile, true-breeding hybrid cereal which combines the chromosomes of both. The hybrid, neither a wheat nor a rye, is more resistant to cold than wheat is, but less useful as a bread-making cereal. It has not become popular. Wheat has been crossed with a perennial wild grass to produce a new perennial cereal for which Russian agronomists have made fantastic claims. A field of this wheat, once planted, will, according to the Russians, yield a crop of grain year after year with little or no further attention except to gather the annual harvest. It turns out that this perennial "wheat" may have some promise as a forage grass for livestock, but so far little bread has been made from it and few people have been fed by it.

The idea of producing new cereal species by hybridization and chromosome doubling is, however, quite sound, and the possibilities inherent in it are far from exhausted. Some day new wheat species consciously created by man may replace those which arose spontaneously in nature.

# More on the Language of the Bees

*A sequel to our article of 1948, which told how bees communicate by dancing. Now it has been shown that, among other things, they sense the time and distinguish the members of different colonies*

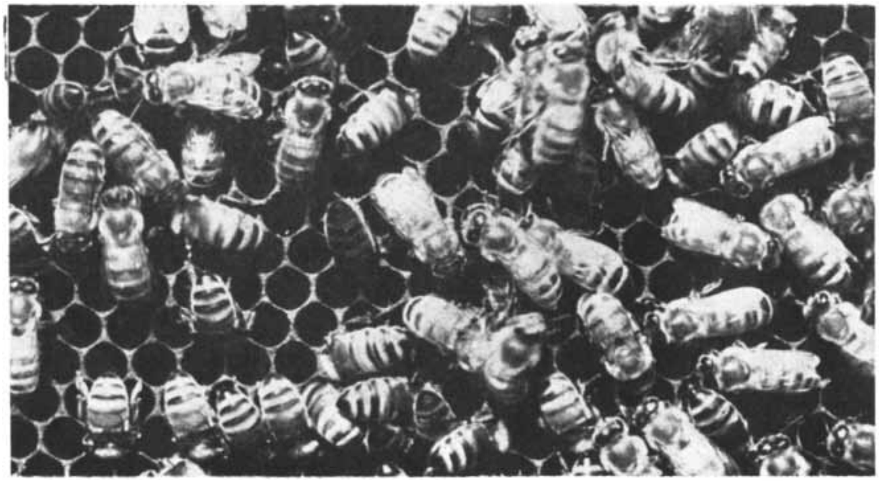
by Hans Kalmus

THE STUDY of communication among bees has become in recent years a source of unending fascination and astonishment to biologists. When the Austrian zoologist Karl von Frisch discovered the amazing dance language by which bees tell one another where to find food (see "The Language of the Bees," by August Krogh; SCIENTIFIC AMERICAN, August, 1948), he started a spate of investigation which has led to one surprise after another.

Observers of bees have always realized that they have an efficient system of communication; there was a time when some thought bees actually talk to one another like people. It is true that present-day investigators have not excluded the possibility that bees exchange audible sounds, but von Frisch showed clearly that their main method of "talking" is their symbolic dance on the comb. By the kind of dance and the direction of pointing, in relation to the sun, a bee tells other bees in the hive the distance and direction of a place where nectar, pollen or some other bee food can be found.

Von Frisch's deciphering of the dance language opened the way to the discovery of many things about bees' perceptions and behavior. One of the most interesting is the fact that their eyes are sensitive to the polarization of light, so that they can tell the position of the sun even when they can see only a small patch of blue sky. This is a sensitivity which the human eye lacks; to see what the sky looks like to a honeybee, we must look through a mosaic of polaroid filters.

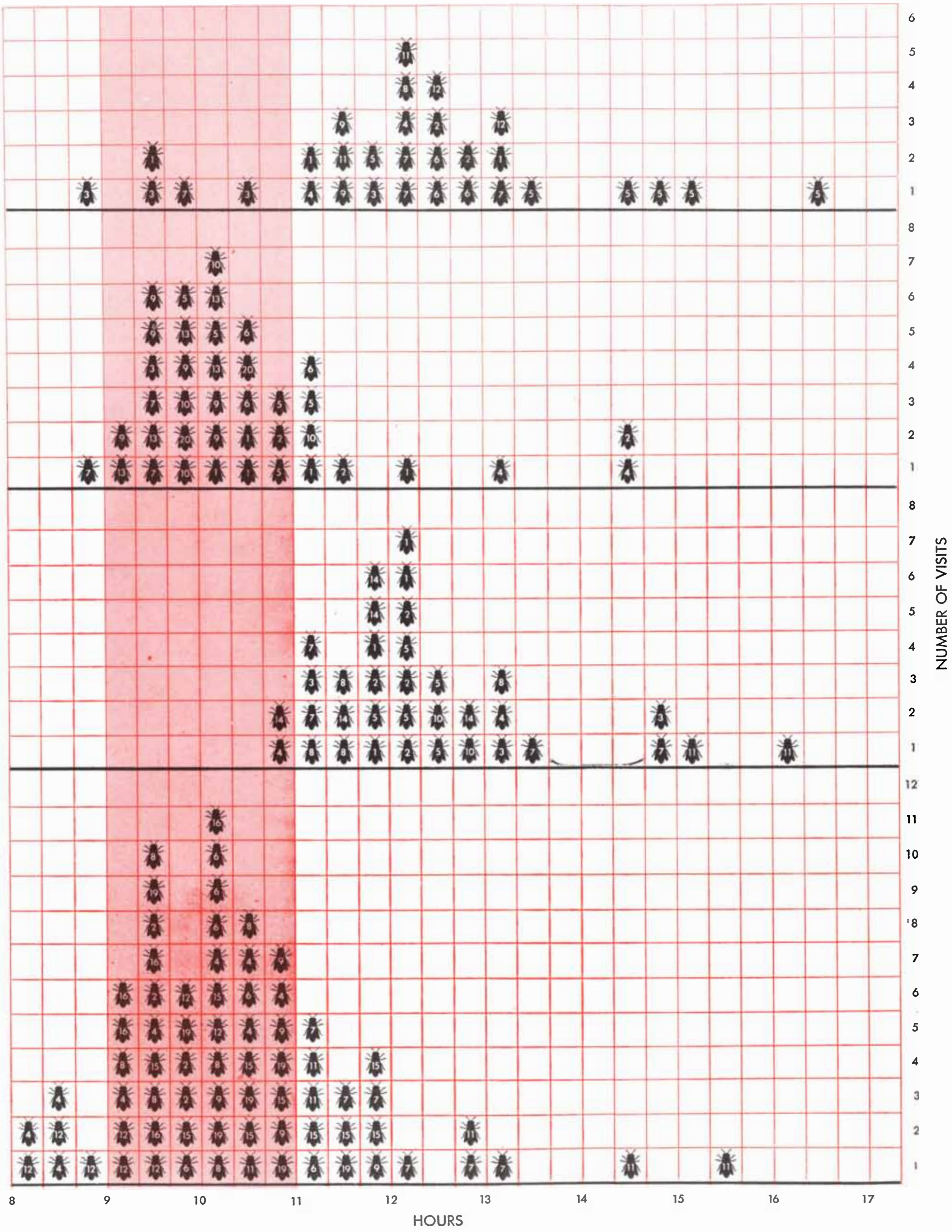
We have now carried the exciting story of bee communication a step further—and in a quite unexpected direction. Wonderful as the dance language of bees is, this newly-discovered method of communication is in some ways perhaps even more interesting. It has to do with the bees' metabolism and sense of smell.



**COMB IS CLEANED** by worker bees. By giving sugar syrup containing radioactive phosphorus to six bees in a colony of 25,000, it was discovered that within a period of four hours 62 per cent of the foraging bees and between 16 and 21 per cent of the bees on the combs had shared the syrup.

THE BEHAVIOR of a bee, like that of other animals, is governed to a large extent by its hunger—or the opposite. Every beekeeper knows that starved bees will sting not only man and beast but other bees, whereas a well-fed colony will lazily tolerate all sorts of poking around by outsiders. Apparently a bee's food-collecting activities are partly controlled by the degree of fullness of its honey bladder. When a foraging bee has filled and distended its honey bladder to a certain size, it returns to the hive. If an experimenter seizes a full bee which is about to take off from a syrup dish for home, and makes it disgorge some syrup by gently squeezing its abdomen, the bee will usually return to the dish to fill up again. On one occasion a snip of an experimenter's scissors which accidentally cut a feeding bee in two provided a dramatic demonstration of the powerful effect of a slack honey bladder. The bee, like the famous horse of Baron Munchausen, went on drinking from the syrup dish for many minutes, pumping an enormous amount of liquid through its open abdomen, before it finally dropped dead.

Our studies of the effects of food on bee behavior came about through the discovery of a metabolic clock which operates in these insects. The famous Swiss neurologist and entomologist Auguste Forel, who liked to have breakfast in his garden, found himself unable to do so because swarms of bees regularly invaded his table every morning at breakfast time. Why did they come at just that time—was it the position of the sun, the temperature, the opening of flowers? I made some experiments and




**METABOLIC CLOCK** of bees was demonstrated by feeding them at the same dish for four days between 9 and 11 a.m. (*red area*). The top group was then treated with carbon dioxide and the visits of its numbered members to the dish were counted. The second group was subjected to ether; the third, to cold. The bottom group was a control. The first and third groups arrived late because their metabolism had been slowed.

found that the bees' time sense is governed by the state of their metabolism. Bees which are fed for several consecutive days at a certain hour—say between 9 and 11 a.m.—will return to the feeding place at or a little before that hour each day. But if they are exposed to cold near freezing or to carbon dioxide, which slows their metabolic processes, their visit to the feeding place may be delayed for several hours. (Experiments on ants have shown that their time sense also is controlled by their body chemistry.)

It shortly developed that the metabolism of bees controls many other things besides their time sense. For instance, it seems to regulate the division of labor in the hive. A newborn worker bee spends its first days cleaning the cells of the honeycombs and feeding the brood. During this time it develops "feeding glands." From about the 10th to the 20th day it takes on various other tasks: some workers guard the entrance to the hive; others clean the hive, receive food and build combs. Now the feeding glands atrophy and wax-producing glands develop. Finally, in the last period of the worker's life it becomes a forager for pollen and honey, and its wax glands decline. But the many investigators who have studied bee colonies have been impressed by the plasticity and adaptability of the workers. A poor feeding season or an accident can cause some of them to change their functions. Moreover, it is well known that a change of diet can transform them: for instance, when worker bees are transplanted into queen cells and fed a protein-rich diet they may develop into substitute queens.

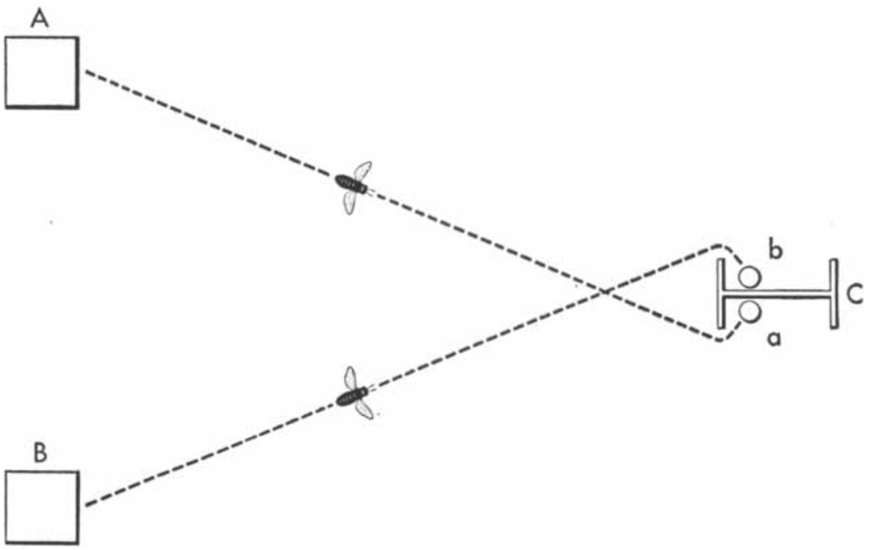
Now experiments with radioactive tracers, performed by C. R. Ribbands and H. L. Nixon at the Rothamsted Experimental Station in England, have demonstrated a remarkable sharing of food among the bees in a colony. In one experiment six bees from a colony of some 25,000 were fed a little sugar syrup containing radioactive phosphorus. Within four hours 62 per cent of all the colony's foraging bees and between 16 and 21 per cent of the bees on the combs were radioactive. After 27 hours 76 per cent of the foragers and 43 to 60 per cent of the bees on the combs were radioactive, and after 47 hours all the large larvae in unsealed cells also had radioactivity. Considering this rapid and widespread food-sharing, and the known effects on bee development of differences in diet, it seems reasonable to conclude that metabolic differences are the main cause of labor differentiation within a bee colony. (Incidentally, this experiment was of considerable practical interest to beekeepers, because it showed that a slow-acting insecticide —*e.g.*, parathion—may have a devastating effect on a bee colony, and a food-borne disease similarly may rapidly permeate the colony.)

ALL THIS was followed up by a most surprising discovery: differences in food may result in marking off one colony of bees from another! A quarter of a century ago von Frisch and G. A. Rösch in Germany noticed a phenomenon which suggested that a bee colony as a whole may have a distinctive odor of its own. They observed that after scouts from two distant hives had fed at two different dishes placed close together, the later arrivals from each colony usually went to the dish visited by their own scouts and not to the other. Apparently each colony identified its own dish by the odor. Curiously, this observation was disregarded for a long time, but recently Ribbands and I confirmed the finding at the Rothamsted Station. We proceeded to investigate the origin of the colony odor.

We started by experimenting with two obviously different colonies of bees —yellow Italian and black Swiss. Their hives were placed some distance apart. Scouts from the two hives were trained to visit and drink syrup from two different dishes, placed only two feet apart. While the entrance of hive A was blocked so that bees could not leave it, bees from hive B were fed at dish *b*; then hive B was blocked and bees from hive A were fed at dish *a*. After the scouts had been trained, both hives were unblocked and observers were stationed at each dish to count the visitors. During a four-hour observation period the dish to which the yellow scouts had been trained was visited by 31 newcomers from the yellow hive and 14 from the black hive. At the other dish there were 13 yellow visitors and 29 black ones. Since it is highly improbable (only one chance in 1,000) that such disproportions could occur strictly at random, we can assume that the first dish had a distinctive attraction for the yellow bees and the second for the black bees. And apparently, judging by the behavior of the bees as they approached the dishes, the attraction was the odor.

We had used different types of bees because it was thought that the odor differences between colonies might be genetic in origin. But when we repeated the experiment with bees of the same breed, we found, quite unexpectedly, that separate colonies of the same breed, and even the two halves of the same colony after being split apart, developed distinctive odors by which their members recognized them. In these experiments we marked feeders at the two different dishes with paint of two different colors to identify them. Then we opened the two hives in the evening and counted the marked bees. Again we found that foragers from a given hive tended to feed at the same dish.

WE NOW undertook a series of experiments to find out whether the differences in colony odor were due to differences in diet. In one experiment we removed the queen from a colony and divided the colony into three parts, each consisting of five combs. We set the three divided parts of the hive on sites 10 yards apart. Then we poured a mixture of heather honey and treacle over one of the sub-colonies and left the other two unfed. We proceeded to test the three new colonies, two at a time, for dish preferences. The bees from the colony which had been fed the honey and treacle showed a definite preference for a dish visited by their own scouts. When the bees from the two unfed hives were compared, they fed indiscriminately from both of the two dishes placed before them. But they preferred




**DISTINGUISHING ODOR of a bee colony was shown by first training bees of colony A to visit dish *a*, then training bees of colony B to visit dish *b*. The dishes were separated by a screen C. When the bees were allowed to visit the dishes freely, a significant number of them went to the correct dish.**

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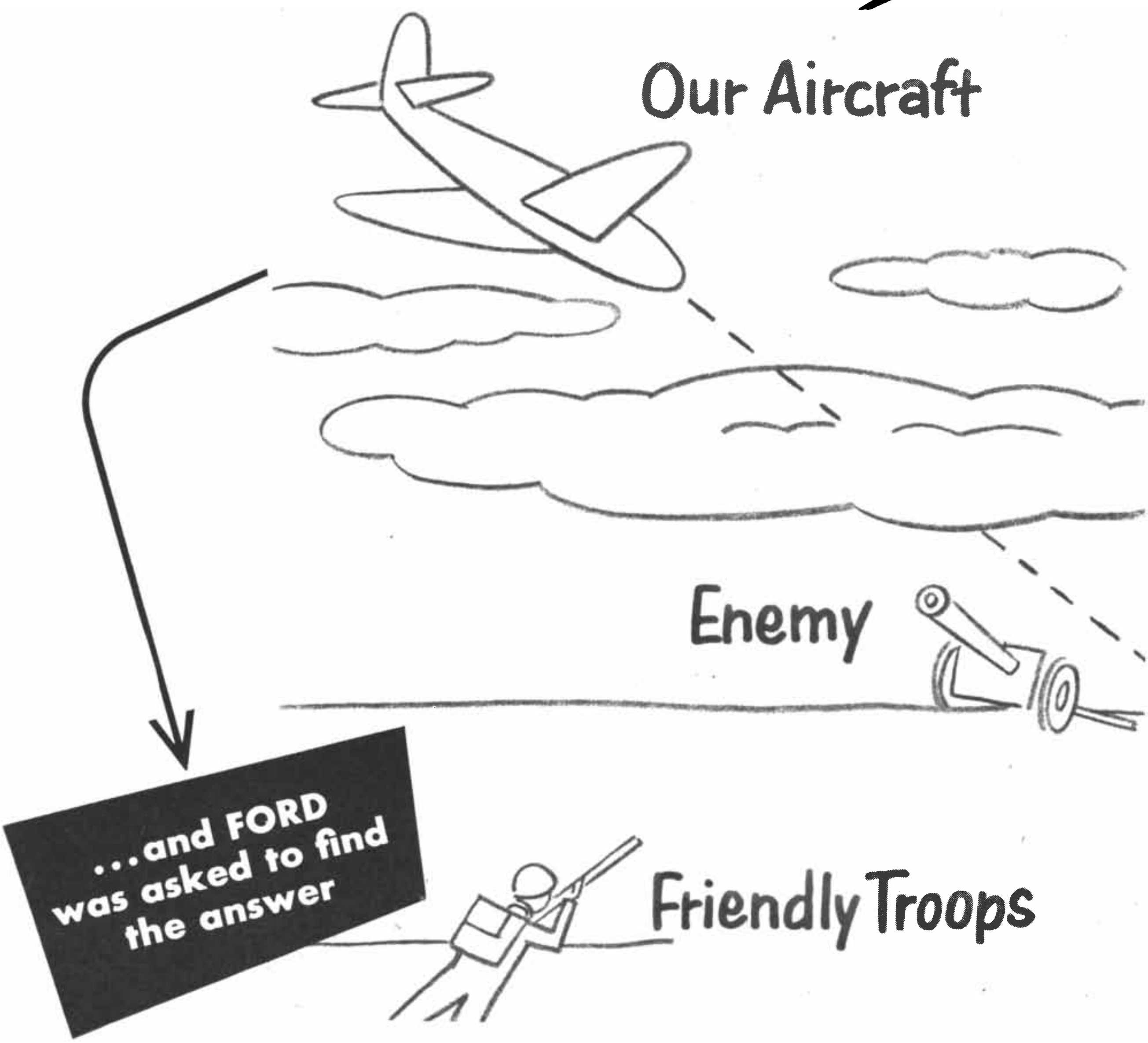


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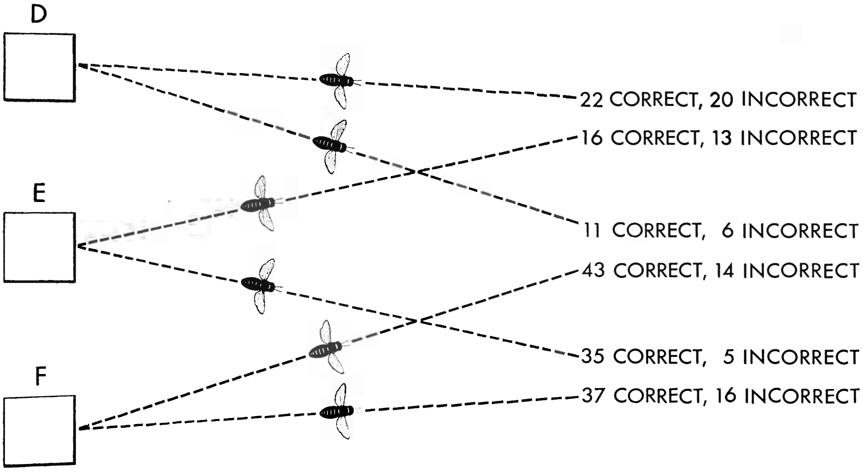



**ORIGIN OF ODORS** was demonstrated by separating a colony into thirds, D and E unfed and F fed with heather honey and treacle. The number of bees that visited the dish to which they had been trained indicated that the bees from the hive that had been fed heather honey and treacle were more readily distinguishable than the bees from the other two hives.

these dishes to the one favored by the pre-fed hive.

This experiment was made in the early fall, when natural sources of food for the bees were disappearing. During the summer, when a rich variety of food was available to the bees, the split parts of a colony usually developed distinctive odors within a few days. It seems that even a small difference in diet between one colony and another is sufficient to insure mutual recognition among the members of a colony and the detection of "foreigners." It would be interesting to find out whether different colonies retain this distinctiveness when they all feed on the same diet.

There may be other reasons for odor differences among colonies, such as the absence or condition of the queen or the strength and composition of the colony. But our experiments seem to show that those differences which guide the colony in following its scouts are due to diet.

THE DISCOVERY of the colony-odor phenomenon raises two interesting questions. In the first place, it suggests that bees possess an extremely acute sense of odor discrimination, far more sensitive in some respects than man's. They must be able to distinguish between mixtures of odors in which the percentages of the individual constituents differ very little. But an even more interesting point is the question as to what part the colony odor may play in a colony's social functions.

Bees, as everyone knows, are extremely clannish, and one colony will sometimes engage another in a fierce battle. Whether they fight depends on circumstances: clever beekeepers often can introduce a new queen into a colony or even combine two old colonies into one without any great outburst of hostility. But when hungry, bees are apt to gang up against strangers. Toward the end of summer bee colonies often rob one another of their honey, and there may ensue a battle at the entrance to a hive, or on the combs, which kills thousands of bees. In the darkness of the hive the bees apparently can tell friend from foe by the odor. We witnessed a bee battle in an experiment in which two colonies of bees were fed together on a dish containing syrup and a sand bottom. As long as there was plenty of syrup, the two colonies fed together fairly amiably. But when the syrup gave out, the bees became very agitated. First they dug furiously in the sand, and then they began to fight. They tried to drag one another away from the dish and took to stinging one another. In the main it was colony against colony in the fighting. We could tell this because the colonies were of visibly different types—one light Italian and the other dark Caucasian. The combatants were generally paired by opposites—light against dark.

In all likelihood scent plays a part in this violent tribal behavior. As to what the prime function of the colony odor is, however, we can only speculate. Bees are often seen to fan their abdominal scent glands near the hive entrance, perhaps to help guide the colony's foragers home. Sometimes they fan their scent over a rich source of food in the field, leaving an odor which will guide their colony mates there. Like dogs, which also have great powers of olfactory discrimination, bees mark a neighborhood with their distinctive body scent. It may be that in so doing they stake out a territory, as an English robin does.

At all events, it seems certain that bee colonies achieve much of their communication and social cohesion by means of their diet and metabolism. We shall doubtless learn a great deal more that is interesting and profitable as we gain a better understanding of their metabolic language.

# LEONHARD EULER AND THE KOENIGSBERG BRIDGES

## In a problem that entertained the strollers of an East Prussian city the great mathematician saw an important principle of the branch of mathematics called topology

Leonhard Euler, the most eminent of Switzerland's scientists, was a gifted 18th-century mathematician who enriched mathematics in almost every department and whose energy was at least as remarkable as his genius. "Euler calculated without apparent effort, as men breathe, or as eagles sustain themselves in the wind," wrote François Arago, the French astronomer and physicist. It is said that Euler "dashed off memoirs in the half-hour between the first and second calls to dinner." According to the mathematical historian Eric Temple Bell he "would often compose his memoirs with a baby in his lap while the older children played all about him"—the number of Euler's children was 13. At the age of 28 he solved in three days a difficult astronomical problem which astronomers had agreed would take several months of labor; this prodigious feat so overtaxed his eyesight that he lost the sight of one eye and eventually became totally blind. But his handicap in no way diminished either the volume or the quality of his mathematical output. His writings will, it is estimated, fill 60 to 80 large quarto volumes when the edition of his collected works is completed.

The memoir published below is Euler's own account of one of his most famous achievements: his solution of the celebrated problem of the Koenigsberg bridges. The problem is a classic exercise in the branch of mathematics called topology (see "Topology," by Albert W. Tucker and Herbert S. Bailey, Jr.; Scientific American, January, 1950). Topology is the geometry of distortion; it deals with the properties of an object that survive stretching, twisting, bending or other changes of its size or shape. The Koenigsberg puzzle is a so-called network problem in topology.

In the town of Koenigsberg (where the philosopher Immanuel Kant was born) there were in the 18th century seven bridges which crossed the river Pregel. They connected two islands in the river with each other and with the opposite banks. The townsfolk had long amused themselves with this problem: Is it possible to cross the seven bridges in a continuous walk without recrossing any of them? When the puzzle came to Euler's attention, he recognized that an important scientific principle lay concealed in it. He applied himself to discovering this principle and shortly thereafter presented his simple and ingenious solution. He provided a mathematical demonstration, as some of the townsfolk had already proved to their own satisfaction by repeated trials, that the journey is impossible. He also found a rule which answered the question in general, whatever the number of bridges.

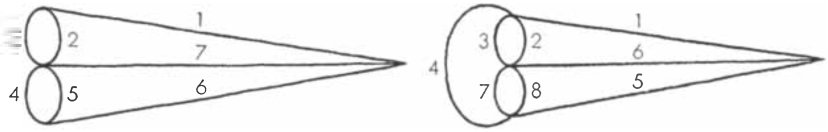
The Koenigsberg puzzle is related to the familiar exercise of trying to trace a given figure on paper without lifting the pencil or retracing a line. In graph form the Koenigsberg pattern is represented by the drawing on the left at the bottom of this page. Inspection shows that this pattern cannot be traced with a single stroke of the pencil. But if there are eight bridges, the pattern is the one at the right, and this one can be traced in a single stroke.

Euler's memoir gives a beautiful explanation of the principles involved and furnishes an admirable example of the deceptive simplicity of topology problems.—James R. Newman

by Leonhard Euler

The branch of geometry that deals with magnitudes has been zealously studied throughout the past, but there is another branch that has been almost unknown up to now; Leibnitz spoke of it first, calling it the "geometry of position" (*geometria situs*). This branch of geometry deals with relations dependent on position alone, and investigates the properties of position; it does not take magnitudes into consideration, nor does it involve calculation with quantities. But as yet no satisfactory definition has been given of the problems that belong to this geometry of position or of the method to be used in solving them. Recently there was announced a problem which, while it certainly seemed to belong to geometry, was nevertheless so designed that it did not call for the determination of a magnitude, nor could it be solved by quantitative calculation; consequently I did not hesitate to assign it to the geometry of position, especially since the solution required only the consideration of position, calculation being of no use. In this paper I shall give an account of the method that I discovered for solving this type of problem, which may serve as an example of the geometry of position.

The problem, which I understand is quite well known, is stated as follows: In the town of Koenigsberg in Prussia there is an island A, called Kneiphof, with the two branches of the river Pregel flowing around it. There are seven bridges—*a*, *b*, *c*, *d*, *e*, *f* and *g*—crossing the two branches [*see illustration at the top of page 68*]. The question is whether a person can plan a walk in such a way that he will cross each



*The figure at right can be drawn in one stroke; the one at left cannot* of these bridges once but not more than once. I was told that while some denied the possibility of doing this and others were in doubt, no one maintained that it was actually possible. On the basis of the above I formulated the following very general problem for myself: Given any configuration of the river and the branches into which it may divide, as well as any number of bridges, to determine whether or not it is possible to cross each bridge exactly once.

The particular problem of the seven bridges of Koenigsberg could be solved by carefully tabulating all possible paths, thereby ascertaining by inspection which of them, if any, met the requirement. This method of solution, however, is too tedious and too difficult because of the large number of possible combinations, and in other problems where many more bridges are involved it could not be used at all. . . . Hence I discarded it and searched for another more restricted in its scope; namely, a method which would show only whether a journey satisfying the prescribed condition could in the first instance be discovered; such an approach, I believed, would be simpler.

MY ENTIRE method rests on the appropriate and convenient way in which I denote the crossing of bridges, in that I use capital letters, A, B, C, D, to designate the various land areas that are separated from one another by the river. Thus when a person goes from area A to area B across bridge *a* or *b*, I denote this crossing by the letters AB, the first of which designates the area whence he came, the second the area where he arrives after crossing the bridge. If the traveler then crosses from B over bridge *f* into D, this crossing is denoted by the letters BD; the two crossings AB and BD performed in succession I denote simply by the three letters ABD, since the middle letter B designates the area into which the first crossing leads as well as the area out of which the second leads.

Similarly, if the traveler proceeds from D across bridge g into C, I designate the three successive crossings by the four letters ABDC. . . . The crossing of four bridges will be represented by five letters, and if the traveler crosses an arbitrary number of bridges his journey will be described by a number of letters which is one greater than the number of bridges. For example, eight letters are needed to denote the crossing of seven bridges.

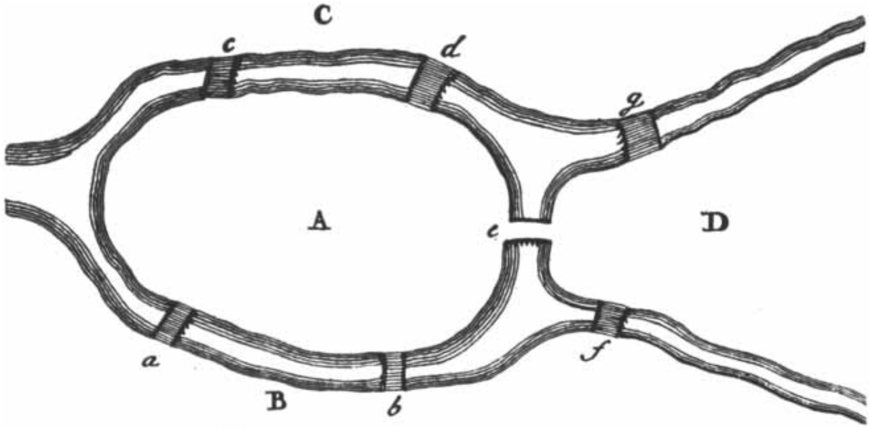
With this method I pay no attention to which bridges are used; that is to say, if the crossing from one area to another can be made by way of several bridges it makes no difference which one is used, so long as it leads to the desired area. Thus if a route could be laid out over the seven Koenigsberg bridges so that each bridge were crossed once and only once, we would be able to describe this route


*Leonhard Euler (pronounced oiler); born Basel 1707; died Petrograd 1783*

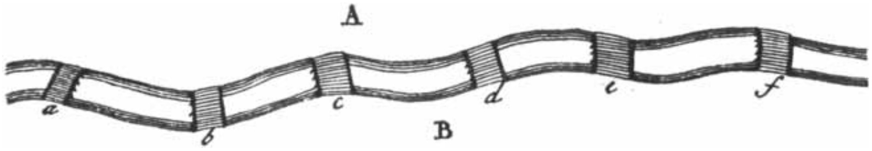
by using eight letters, and in this series of letters the combination AB (or BA) would have to occur twice, since there are two bridges, *a* and *b*, connecting the regions A and B. Similarly the combination AC would occur twice, while the combinations AB, BD, and CD would each occur once.

Our question is now reduced to whether from the four letters A, B, C and D a series of eight letters can be formed in which all the combinations just mentioned occur the required number of times. Before making the effort, however, of trying to find such an arrangement we do well to consider whether its existence is even theoretically possible or not. For if it could be shown that such an arrangement is in fact impossible, then the effort expended on finding it would be wasted. Therefore I have sought for a rule that would determine without difficulty, as regards this and all similar questions, whether the required arrangement of letters is feasible.

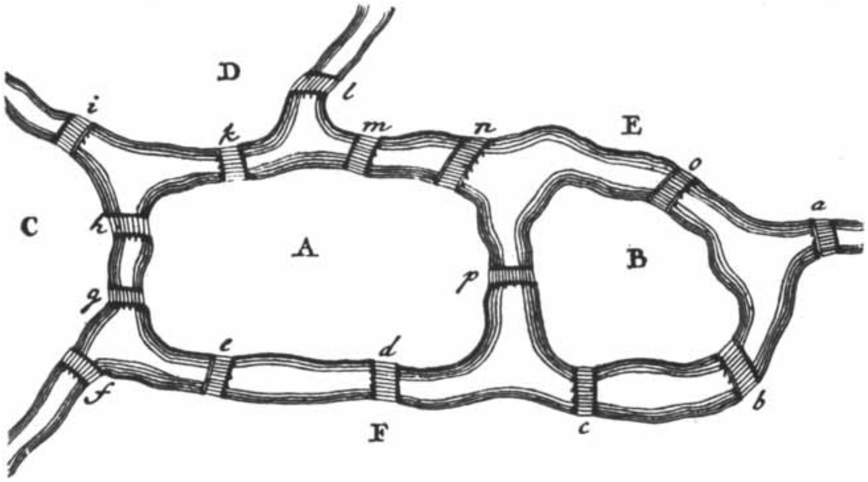
For the purpose of finding such a rule I take a single region A into which an arbitrary number of bridges, *a*, *b*, *c*, *d*, etc., lead [*middle illustration on the next page*]. Of these bridges I first consider only *a*. If the traveler crosses this bridge, he must either have been in A before crossing or have reached A after crossing, so that according to the above




*Seven bridges of Koenigsberg crossed the River Pregel*




*Euler used a simpler case to elucidate his principle*




*This trip is possible though the Koenigsberg one is not*

method of denotation the letter A will appear exactly once. If there are three bridges leading to A and the traveler crosses all three, then the letter A will occur twice in the expression for his journey, whether it begins at A or not. And if there are five bridges leading to A, the expression for a route that crosses them all will contain the letter A three times. If the number of bridges is odd, increase it by one, and take half the sum; the quotient represents the number of times the letter A appears.

LET US now return to the Koenigsberg problem [*top illustration above*]. Since there are five bridges leading to (and from) island A, the letter A must occur three times in the expression describing the route. The letter B must occur twice, since three bridges lead to B; similarly D and C must each occur twice. That is to say, the series of . . . letters that represents the crossing of the seven bridges must contain A three times and B, C and D each twice. But this is quite impossible with a series of eight letters [for the sum of the required letters is nine]. Thus it is apparent that a crossing of the seven bridges of Koenigsberg in the manner required cannot be effected.

Using this method we are always able, whenever the number of bridges leading to a particular region is odd, to determine whether it is possible in a journey to cross each bridge exactly once. Such a route exists if the number of bridges plus one is equal to the sum of the numbers which indicate how often each individual letter must occur. On the other hand, if this sum is greater than the number of bridges plus one, as it is in our example, then the desired route cannot be constructed. The rule that I gave for determining from the number of bridges that lead to A how often the letter A will occur in the route description is independent of whether these bridges all come from a single region B or from several regions, because I was considering only the region A, and attempting to determine how often the letter A must occur.

When the number of bridges leading to A is even, we must take into account whether the route begins in A or not. For example, if there are two bridges that lead to A and the route starts from A, then the letter A will occur twice—once to indicate the departure from A by one of the bridges and a second time to indicate the return to A by the other bridge. However, if the traveler starts his journey in another region, the letter A will occur only once, since by my method of description the single occurrence of A indicates an entrance into as well as a departure from A.

Suppose, as in our case, there are four bridges leading into the region A, and the route is to begin at A. The letter A will then occur three times in the expression for the whole route, while if the journey had started in another region, A would occur only twice. With six bridges leading to A, the letter A will occur four times if A is the starting point, otherwise only three times. In general, if the number of bridges is even, the number of occurrences of the letter A, when the starting region is not A, will be half the number of the bridges; when the route starts from A, one more than half.

Every route must, of course, start in some one region. Thus from the number of bridges that lead to each region I determine the number of times that the corresponding letter will occur in the expression for the entire route as follows: When the number of the bridges is odd, I increase it by one and divide by two; when the number is even, I simply divide it by two. Then if the sum of the resulting numbers is equal to the actual number of bridges plus one, the journey can be accomplished, though it must start in a region approached by an odd number of bridges. But if the sum is one less than the number of bridges plus one, the journey is feasible if its starting point is a region approached by an even number of bridges, for in that case the sum is again increased by one.

MY PROCEDURE for determining whether in any given system of rivers and bridges it is possible to cross each bridge exactly once is as follows: First I designate the individual regions separated from one another by the water as A, B, C, etc. Second, I take the total number of bridges, increase it by one, and write the resulting number at the top of the paper. Third, under this number I write the letters A, B, C, etc., in a column, and opposite each letter I note the number of bridges that lead to that particular region. Fourth, I place an asterisk next to each letter that has an even number opposite it. Fifth, in a third column I write opposite each even number the half of that number, and opposite each odd number I write half of the sum formed by that number plus one. Sixth, I add up the last column of numbers. If the sum is one less than, or equal to, the number written at the top, I conclude that the required journey can be made. But it must be noted that when the sum is one less than the number at the top, the route must start from a region marked with an asterisk, and . . . when these two numbers are equal, it must start from a region that does not have an asterisk.

For the Koenigsberg problem I would set up the tabulation as follows:

Number of bridges 7,
giving 8 (=7+1)

| | | |
|---|---|---|
| A | 5 | 3 |
| B | 3 | 2 |
| C | 3 | 2 |
| D | 3 | 2 |

The last column now adds up to more than 8, and hence the required journey cannot be made.

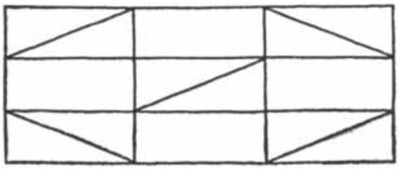
Let us take an example of two islands with four rivers forming the surrounding water [*bottom illustration on the opposite page*]. Fifteen bridges, marked *a, b, c, d,* etc., across the water around the islands and the adjoining rivers. The question is whether a journey can be arranged that will pass over all the bridges, but not over any of them more than once. I begin by marking the regions that are separated from one another by water with the letters A, B, C, D, E, F—there are six of them. Second, I take the number of bridges (15) add one and write this number (16) uppermost. Third, I write the letters A, B, C, etc., in a column and opposite each letter I write the number of bridges connecting with that region, *e.g.*, eight bridges for A, four for B, etc. Fourth, the letters that have even numbers opposite them I mark with an asterisk. Fifth, in a third column I write the half of each corresponding even number, or, if the number is odd, I add one to it, and put down half the sum. Sixth, I add the numbers in the third column and get 16 as the sum. Thus:

| | | 16 |
|---|---|---|
| A* | 8 | 4 |
| B* | 4 | 2 |
| C* | 4 | 2 |
| D | 3 | 2 |
| E | 5 | 3 |
| F* | 6 | 3 |
| | | 16 |

The sum of the third column is the same as the number 16 that appears above, and hence it follows that the journey can be effected if it begins in regions D or E, whose symbols have no asterisk. The following expression represents such a route:

EaFbBcFdAeFfCgAhCiDkAmEnAp-BoElD.

Here I have indicated, by small letters between the capitals, which bridges are crossed.

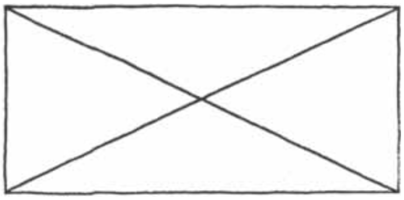


*This figure requires only one stroke*

BY THIS METHOD we can easily determine, even in cases of considerable complexity, whether a single crossing of each of the bridges in sequence is possible. But I should now like to give another and much simpler method, which follows quite easily from the preceding, after a few preliminary remarks. In the first place, I note that the sum of the numbers written down in the second column is necessarily double the actual number of bridges. The reason is that in the tabulation of the bridges leading to the various regions each bridge is counted twice, once for each of the two regions that it connects.

From this observation it follows that the sum of the numbers in the second column must be an even number, since half of it represents the actual number of bridges. Hence . . . if any of the numbers opposite the letters A, B, C, etc., are odd, an even number of them must be odd. In the Koenigsberg problem for instance, all four of the numbers opposite the letters A, B, C, D, were odd, while in the example just given only two of the numbers were odd, namely those opposite D and E.

Since the sum of the numbers opposite A, B, C, etc., is double the number of bridges, it is clear that if this sum is increased by two in the latter example and then divided by two, the result will be the number written at the top. When all the numbers in the second column are even, and the half of each is written down in the third column, the total of this column will be one less than the



*This figure requires two strokes*

number at the top. In that case it will always be possible to cross all the bridges. For in whatever region the journey begins, there will be an even number of bridges leading to it, which is the requirement. . . .

Further, when only two of the numbers opposite the letters are odd, and the others even, the required route is possible provided it begins in a region approached by an odd number of bridges. We take half of each even number, and likewise half of each odd number after adding one, as our procedure requires; the sum of these halves will then be one greater than the number of bridges, and hence equal to the number written at the top. But [when more than two, and an even number] of the numbers in the second column are odd, it is evident that the sum of the numbers in the third column will be greater than the top number, and hence the desired journey is impossible.

Thus for any configuration that may arise the easiest way of determining whether a single crossing of all the bridges is possible is to apply the following rules:

If there are more than two regions which are approached by an odd number of bridges, no route satisfying the required conditions can be found.

If, however, there are only two regions with an odd number of approach bridges the required journey can be completed provided it originates in one of these regions.

If, finally, there is no region with an odd number of approach bridges, the required journey can be effected, no matter where it begins.

These rules solve completely the problem initially proposed.

AFTER we have determined that a route actually exists we are left with the question how to find it. To this end the following rule will serve: Wherever possible we mentally eliminate any two bridges that connect the same two regions; this usually reduces the number of bridges considerably. Then—and this should not be difficult—we proceed to trace the required route across the remaining bridges. The pattern of this route, once we have found it, will not be substantially affected by the restoration of the bridges which were first eliminated from consideration—as a little thought will show. Therefore I do not think I need say more about finding the routes themselves.

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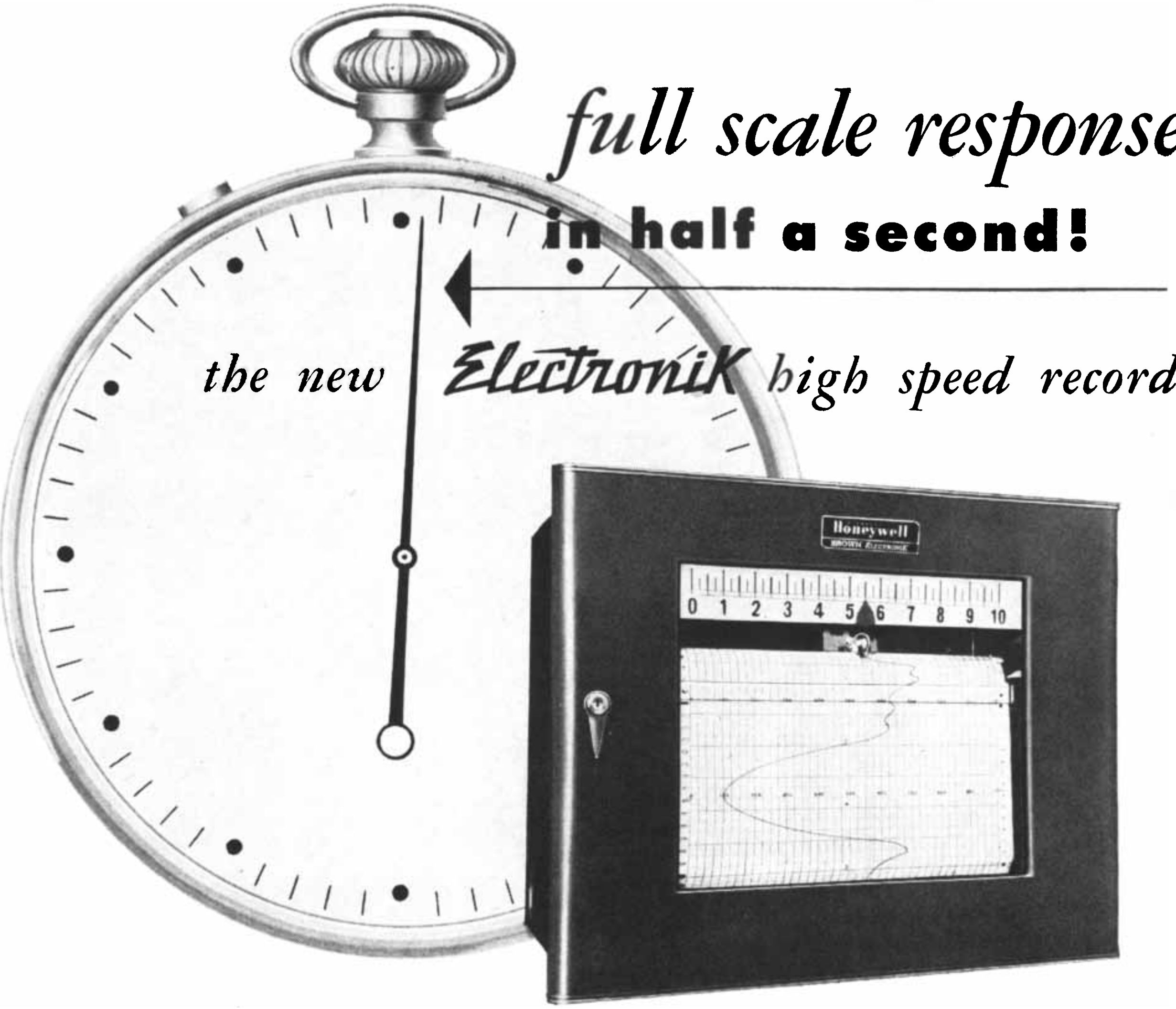


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# The Desert Rat

*A remarkable little animal can live in an environment such as Death Valley on dry food and no water at all. It is only recently that this physiological mystery has been solved*

by Knut and Bodil Schmidt-Nielsen

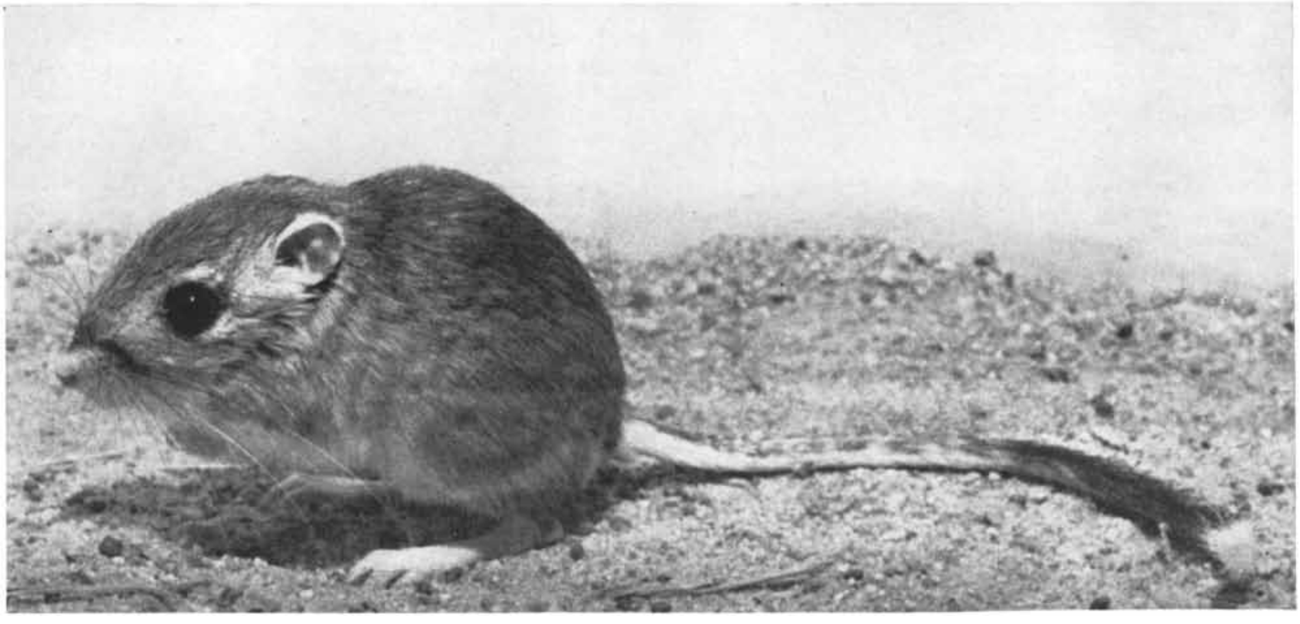
THERE IS a common impression that no higher animal can live long without drinking water. Certainly this is true of man and many other mammals; we need water at frequent intervals, and in a very hot, dry desert a man without water cannot last more than a day or so. An animal such as the camel can survive somewhat longer, but sooner or later it too must drink to refill its supply.

Yet we know that the waterless desert is not uninhabited. Even in desert areas with no visible drinking water within scores of miles, one will often find a fairly rich animal life. How do these animals get the water they must have to live? The body of a desert mammal has about the same water content (65 per cent of body weight) as that of a drinking animal, and it generally has no more tolerance to desiccation of the tissues, sometimes less. For many desert animals the answer is simple: they get their water in their food. These animals live on juicy plants, one of the most important of which is cactus. The pack rat, for example, eats large quantities of cactus pulp, which is about 90 per cent water. Thus it is easy to account for the survival of animals in areas where cacti and other water-storing plants are available.

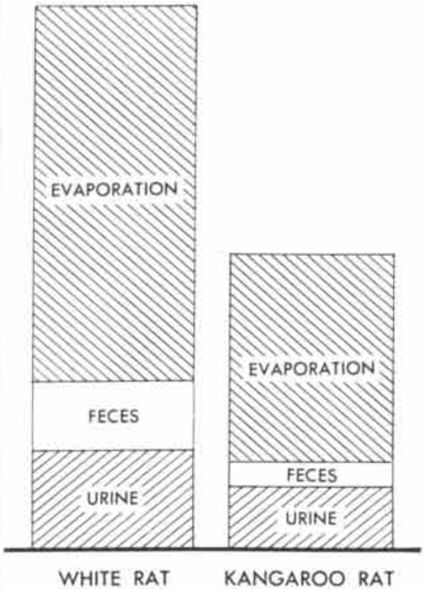
There are, however, animals which can live in areas altogether barren of juicy vegetation. An outstanding example is a certain general type of desert rodent which is found in all the major desert areas of the world—in Africa, in Asia, in Australia and in the southwestern U. S. Although the rats of this type seem to have evolved independently in the several areas and are not related to one another, all of them are similar in appearance and habits and all seem to be able to live with a minimum of water. How they do so has long been a puzzle to biologists.

During the past few years we have investigated intensively a rodent of this type—the so-called kangaroo rat that lives in deserts of the U. S. Southwest. In a field laboratory in Arizona and in biological laboratories at Swarthmore College, Stanford University and the University of Cincinnati we have studied the kangaroo rat's habits and physiology, and we now have a good understanding of how this rodent is able to get along on a diet so dry that other animals would soon die of thirst.

THE LITTLE kangaroo rat is not actually related to the kangaroo, though it looks a great deal like one. It hops along on long hind legs, and it has a long, strong tail which it uses for support and steering. It lives in a burrow in the ground by day and comes out for food only at night. The animal thrives in the driest regions, even in the bare sand dunes of Death Valley. Water to drink, even dew, is rarely available in its natural habitat. The kangaroo rat apparently has only a short range of movement—not more than a few hundred yards—and



**BANNERTAILED KANGAROO RAT** (*Dipodomys spectabilis*) from the Santa Rita Range of Arizona is photographed in the laboratory. It is called the kangaroo rat because of its powerful hind legs and long tail.




**WATER LOSSES** of the kangaroo rat (*right*) and the white rat (*left*) are compared at zero humidity.

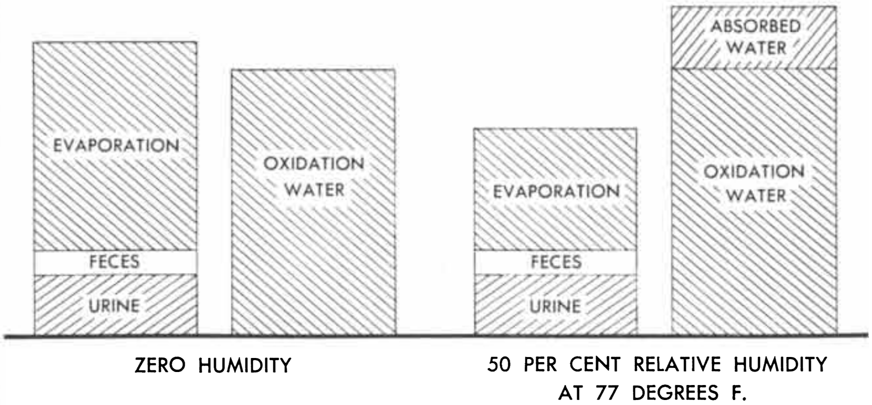
therefore does not leave its dry area to find juicy plants. Stomach analyses have shown that it seldom or never consumes any succulent vegetation. Its food consists of seeds and other dry plant material. In the laboratory it will live indefinitely without water and with no other food but dry barley seeds.

The first question to be answered was whether the kangaroo rat stores water in its body to carry it over long dry periods. It was found that the animal's water content was always about the same (some 65 per cent of body weight), in the rainy season or the dry season, or after it had been kept on dry food in the laboratory for several weeks. During eight weeks on nothing but dry barley in the laboratory some of the animals increased their body weight, and their water percentage was as high as at the beginning of the experiment; they had actually increased the total amount of water in their bodies. Furthermore, kangaroo rats which were given watermelon as well as barley to eat showed no higher water percentage in their bodies than animals maintained on a dry diet. They must therefore have eliminated the excess of water at the same rate as it was taken in. Altogether the experiments made clear that the kangaroo rat does not store water or live through dry periods at the expense of its body water.

There is only one way the kangaroo rat can get any substantial amount of water on its dry diet. That is by oxidizing its food. The oxidation of hydrogen or a substance containing hydrogen always forms water. Obviously the amount of water an animal forms in its metabolism will depend upon the hydrogen content of its food. The amount is simply a matter of chemistry and is the same in all animals. Oxidation of a gram of carbohydrate (starch or sugar) yields .6 of a gram of water; of a gram of fat, 1.1 grams of water; of a gram of protein, .3 of a gram of water. Protein produces relatively little water because a considerable part of its hydrogen is not oxidized but is excreted with nitrogen as urea.

Now the experimental diet of dry barley on which the kangaroo rats lived yields 54 grams of water for each 100 grams of barley (dry weight) consumed. If there is any moisture in the air, the barley will also contain a little absorbed water—about 13 grams per 100 grams when the relative humidity is 50 per cent at 75 degrees Fahrenheit. The kangaroo rat consumes 100 grams of barley in a period of about five weeks. Thus during that period its total intake of water is between 54 and 67 grams, depending on atmospheric conditions.

THIS is an astonishingly small amount of water for an animal of its size to subsist on. It can maintain its water balance only if its water losses are correspondingly small. The next step, therefore, was to find out how the animal manages to keep its water loss so low, if indeed it does. We proceeded to measure its losses of water through the three




**WATER BALANCE** of the kangaroo rat is shown under two different conditions of humidity. The first and third bars indicate water loss; the second and fourth, water gain. The term "absorbed water" refers to water in food.

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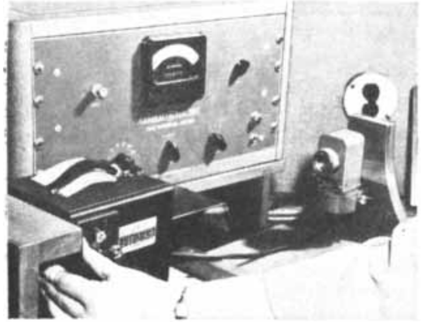

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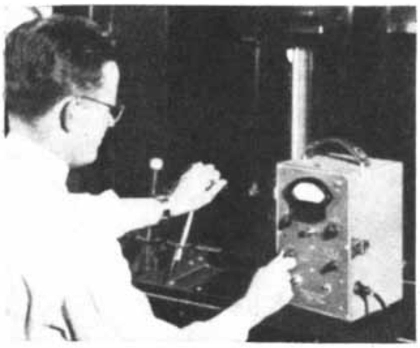

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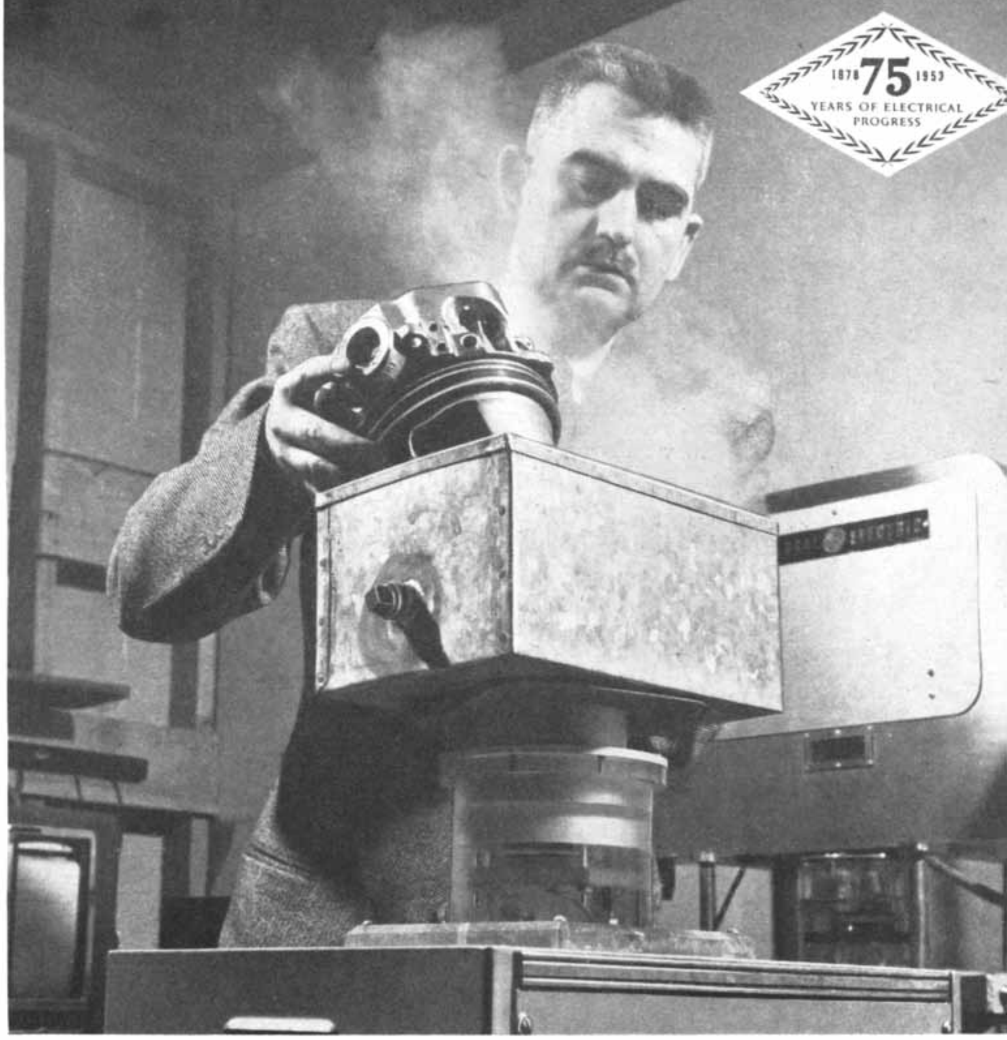

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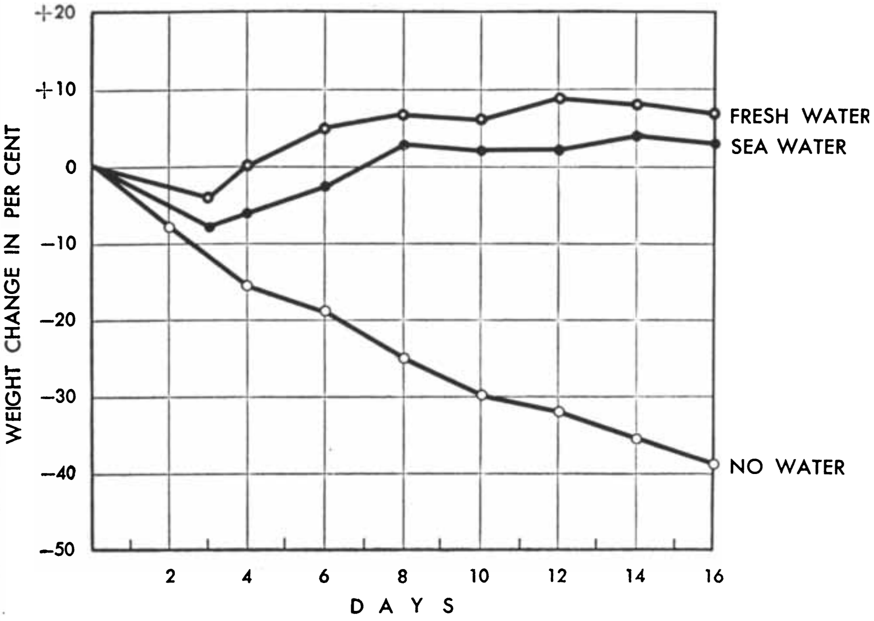


**WEIGHT CHANGES** of kangaroo rats fed either fresh water, sea water or no water showed that they could drink sea water without ill effects. Although kangaroo rats normally drink no water, they were induced to do so by a protein-rich diet that required water for the excretion of urea.

routes by which an animal eliminates water; in the urine, in the feces and by evaporation from the skin and the respiratory passages.

There is an animal, the African lungfish, which can get along for long periods without excreting any urine at all. When the stream or pond in which it is living dries up, it burrows into the mud and stays there until the next rain. The eminent authority on the kidney, Homer W. Smith [see "The Kidney," by Homer W. Smith; Scientific American, January], has found that during this time the urea content of the fish's blood may rise to the extravagant level of 4 per cent. Can the kangaroo rat similarly accumulate waste products and avoid urinating during a dry spell? We investigated and found that it could not: the urea and salt content of its blood did not rise when it was on a dry diet or fall when it had a moist diet. And it continued on its dry diet to excrete urea as usual.

However, we learned that it could get rid of its waste products with a very small output of water. The kangaroo rat has an amazingly efficient kidney. The concentration of urea in its urine can be as high as 24 per cent, whereas in man the maximum is about 6 per cent. Thus the kangaroo rat needs only about one fourth as much water to eliminate a given amount of urea as a man would. Its excretion of salts is similarly efficient. The animal can excrete urine about twice as salty as sea water!

The reason that a human being cannot tolerate drinking sea water is that the body is dehydrated in the process of getting rid of the salts. The saltiness of the kangaroo rat's urine suggested that this animal might be able to drink sea water and get a net water gain from it. Of course it was not easy to induce the kangaroo rat, which normally does not drink, to imbibe sea water. But we were able to make it do so by feeding it a high protein diet (soy beans) which formed very large amounts of urea and forced the rat to drink to avoid dehydration. The animal's kidney proved able to excrete both the excess of urea and the salts in the sea water. Drinking sea water actually enabled the animal to maintain its water balance. So far as is known, no other mammal can drink sea water with impunity.

From the known efficiency of the kangaroo rat's kidney we calculated that the animal uses 13 grams of water to excrete the waste products formed from 100 grams of dry barley. Measurement of the water content of its feces, which are exceptionally dry, showed that it loses about three grams of water by this route in metabolizing 100 grams of dry barley. There remained, then, the question of how much water the kangaroo rat loses by evaporation.

Very little escapes through its skin. Rodents have no sweat glands except on the toe pads, and the kangaroo rat has fewer sweat glands than most rats. All mammals lose a little water from the skin even where there are no sweat glands, and there is reason to believe that the kangaroo rat suffers less loss by this route than other mammals. It does, however, lose a considerable amount of water by evaporation from its respiratory tract. In the extremely dry desert air this loss could be serious. At zero humidity the loss by evaporation from the skin and respiratory tract would amount to some 44 grams of water during the five

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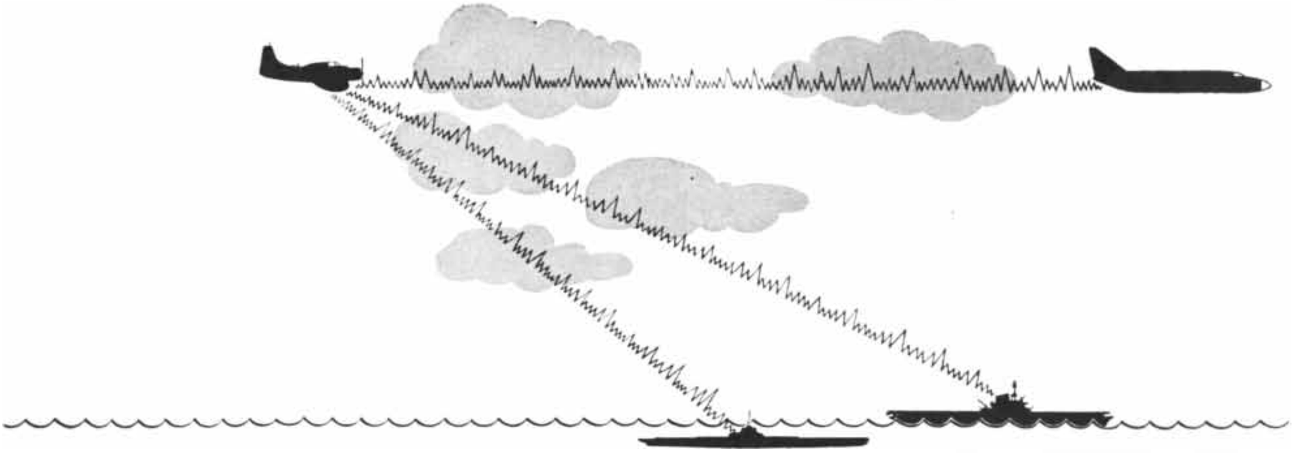

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weeks in which the rat metabolizes 100 grams of barley. At a relative humidity of 50 per cent and a temperature of 75 degrees the loss by evaporation would be about 25 grams.

WE CAN NOW add up the balance sheet of the kangaroo rat's water intake and outgo. At zero humidity its total intake on a diet of dry barley would be 54 grams, and the total loss would be 61 grams (14 in the urine, 3 in the feces and 44 by evaporation). At 50 per cent relative humidity at 75 degrees the intake would be 67 grams and the outgo only 43 grams. Thus it seems clear that the kangaroo rat cannot survive on a barley diet in completely dry air, for under those conditions it has a water deficit in spite of its marvelous mechanisms for water conservation. Actual tests showed that the minimum atmospheric conditions under which the animal can maintain its water balance on the dry diet is 10 to 20 per cent relative humidity at 75 degrees.

The desert atmosphere is often somewhat drier than this, but the explanation of the kangaroo rat's survival is that it is a night animal. During the day it stays in its burrow, where the air is always a little more humid than outside, even when the soil seems to be completely dry. To measure the temperature and humidity in the burrow we used a tiny instrument which included a humidity-sensitive hair hygrometer. The instrument makes a record on a smoked glass disk, which can be read afterward under a microscope. The recorder was tied to the rat's tail, and the animal dragged it into the burrow. It was secured by a thin wire so that the animal could not run away with the instrument. After 12 hours we opened the burrow and read the record. We found that in early summer in the Arizona desert the relative humidity inside the kangaroo rat's burrows ranged from 30 to 50 per cent, and the temperature from about 75 to 88 degrees. At night, in the desert outside the burrows, the relative humidity varied from 15 to 40 per cent and the temperature from about 60 to 75 degrees. The protection of the burrow by day provides just enough margin to enable the kangaroo rat to maintain its water balance and live in the driest of our deserts.

The same protection allows the kangaroo rat to survive the desert heat. A mammal such as man avoids overheating only by evaporating large quantities of water. The kangaroo rat cannot do this, nor can it tolerate a body temperature of much more than 100 degrees. It does not sweat or increase evaporation from its respiratory passages by panting, as a dog does. If it were exposed to the daytime heat in the desert, it would soon perish. The adaptations that permit it to thrive in the hot desert are its nocturnal habits and its extraordinary facilities for water conservation.

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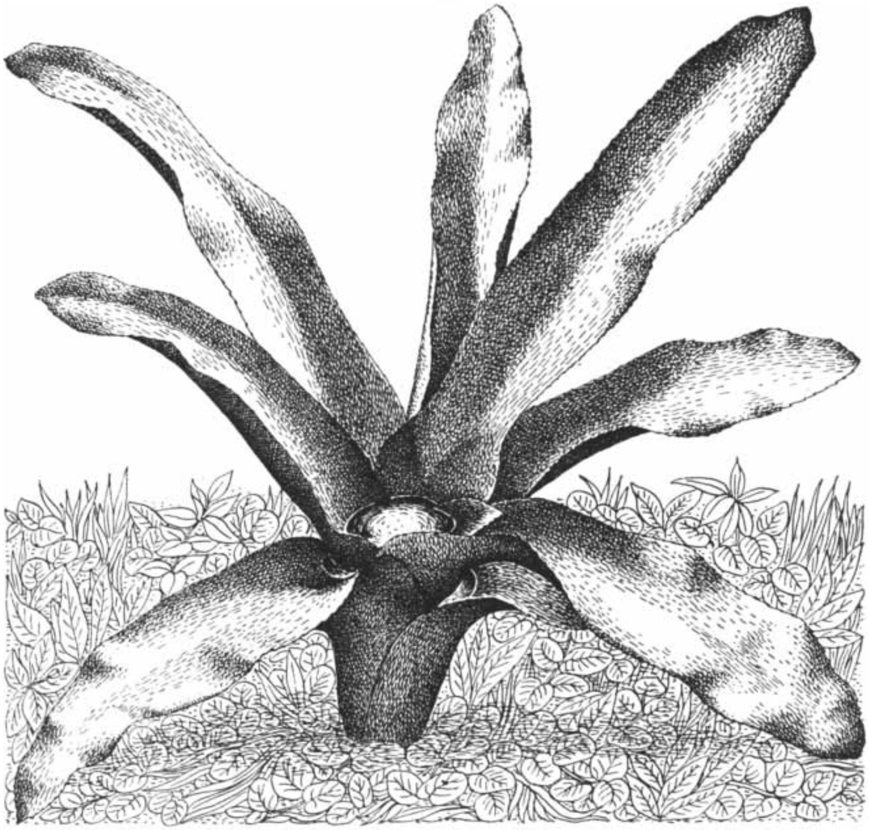
# Is Man Alone in Space?

*He sometimes wonders if, on a planet similar to the Earth, another genus Homo has arisen. An anthropologist considers the possibility in the light of what we know of evolution*

by Loren C. Eiseley

MAN bitterly resists the lonely thought that he may be the only creature of his kind in the universe. We are basically cosmopolitan; we long for companionship in the great adventure of space. We want to radio Mars and get back the equivalent of "How yuh, boys?" Our hope that we may not be alone in space is nourished by the theory of probability. In the millions of planets and infinity of time—surely there must be a possibility that man is not a unique event. If somewhere in the universe there is a world exactly like ours, why not a manlike creature there?

The probabilities are less favorable than they may seem. Man is not simply a matter of a throw of the dice which might have fallen just the same way on another planet. Even if there were another world exactly like ours in all its physical conditions, we still could not guarantee that identically the same life would emerge. Man, life, worlds are the product of multitudinous concatenations of singular events which could never be duplicated in their entirety. At any point in the last billion years the line of evolution that produced man might have taken another turning—and we would never have appeared. The proposition of duplicating man is something like that of the proverbial monkeys working through eternity to type Shakespeare's works again by chance—only the probabilities, if any, are much worse, and time is not infinite but limited.



**TANK PLANT,** a member of the bromeliad family, is an example of evolutionary adaptation to one unusual environment. The plant lives aloft in trees, obtaining water from rain or dew held in its closely fitted leaves. It is nourished by plant and animal matter that falls into the water.

Opposed to the attempt to project man across the light-years lies a series of well-nigh insurmountable physical and biological obstacles. In considering the likelihood that man has been duplicated on remote worlds, two important physical events have to be considered before we can turn to the nature of life itself: the age of the universe and the way in which solar systems come into existence. The answer to the first proposition should indicate the length of time in which statistical probability has operated; the answer to the second should give us some idea as to whether life is a rare or common occurrence in space.

Ironically enough, there are quite disparate views on both subjects. Fifty years ago there was a widely held belief in the infinity of time. While old star systems burned out and died, new systems emerged. "Eternal motion," wrote one weary Russian in 1875, "does not cease, and new worlds eternally develop in place of former ones." The idea of an eternal universe allowed the possibility of the spores of life drifting from the wreckage of burned-out systems to systems beginning anew, and an infinity of time in which man might arise again and again. But we have now acquired the growing suspicion that we live in an expanding universe which had an incredible beginning and threatens to have an even more fantastic end. Time, in the only sense we can know it, is limited, surprisingly limited. The evidence, though we shall not examine it here, is impressive and drawn from diverse sciences. It has led numerous students to acceptance of the following conclusion:

At some point approximately 4 to 10 billion years ago, all matter composing the known universe was concentrated under inconceivable pressures at one point in space. In this "monobloc," whose contracted density abolishes our everyday experience of space, time and matter, life is inconceivable. It could only emerge later, after the titanic explosion which sent both space and stars racing outward upon a course which threatens to carry the galaxies out of sight. "Standing on a cool cinder," remarks Canon Lemaître, "we see the slow fading of the suns." Their stores of radioactive energy, though great, are not inexhaustible, and unless some unknown source of renewal awaits them, they are destined to go dark.

IN THE LIGHT of this interpretation, it now becomes clear that whatever existed prior to the monobloc can have no bearing on the life of today. Infinite time is *not* at our disposal in estimating life's capacities, but rather the indeterminate moment in the afterglow from a great explosion whose fires are dying.

A few have attempted to escape the horns of the dilemma by recourse to the assumption that matter is somehow being created continuously in space, although this process has never been observed. In the apt words of Herbert Dingle of London University, "It exempts us from having to postulate a single initial miracle on condition that we admit a continuous series of miracles." The idea, true or untrue, has no supporting evidence.

We know that to achieve a single creature capable of advanced thought on the Earth has taken over one billion years. There is nothing in this time span, or in our knowledge of evolutionary processes, to suggest the easy duplication of man. To begin with, while the number of planetary systems may be large, most planets, on the evidence from our own system, probably are unsuitable for life.

The British biologist Cyril D. Darlington argues that "if a creature like man is a sound proposition on the Earth, then similar creatures, built on a similar plan, would also be well fitted to an existence on other planets." He dwells enthusiastically on the advantages of two legs, a brain in one's head and the position of surveying the world from the splendid height of six feet. Apparently he has never paused to consider why, if the advantages of the human body are so obvious, one creature alone, out of the million or more species currently inhabiting this planet, should have assumed this particular form. Moreover, it has been a very late experiment, and in spite of its "superb construction," the wounds of its evolutionary break with its origin still show quite plainly. In bad sinuses, easy rupture and maladjustments of 50 varieties, including varicose veins and a plethora of back and foot troubles, man reveals the imperfections of a bodily machine still in evolutionary adjustment to an environment different from that which he has only recently escaped. This is not to denigrate the real values of the human body and brain, but we must realize the incredible wanderings by which man has attained his present position if we are to estimate the statistical likelihood of a creature like man emerging on the red deserts of, say, Mars.

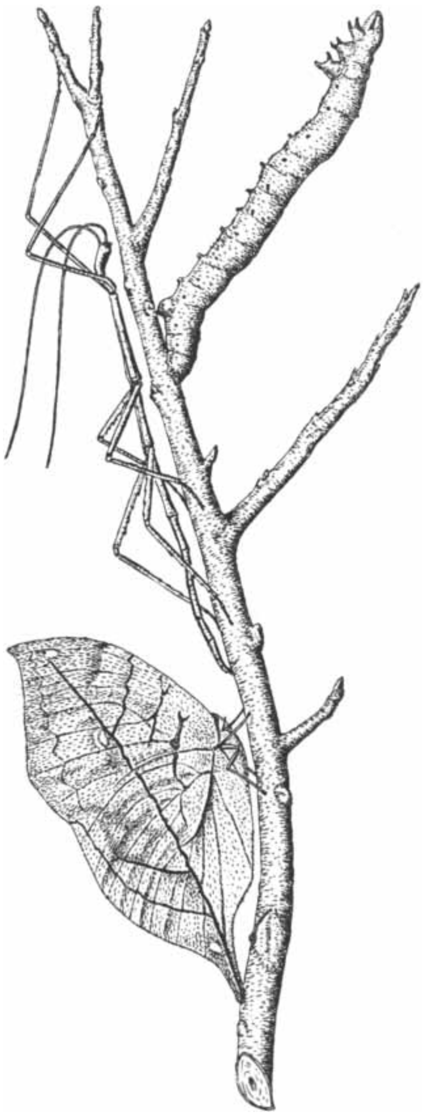
The artists who draw ingenious pictures of two-footed, thin-legged, big-chested Martians do not bother to consider just how the geologic and geographical background of Mars might have promoted (or hindered) such a development. Every organism has a history. Here we can learn from the multitude of different worlds present on the Earth. Surely, if any duplications of the life we know are to be observed, our own planet should be more apt to produce them than the unrelated worlds of space.

TO BE SURE, we can see examples of life mimicking life on every hand. Not long ago the noted deep-sea explorer Otis Barton climbed into an aluminum cage in the tropical rain forest of Africa and was cranked upward into a strange new world, similar to that of the other great rain forest in the Amazon basin. Almost 200 feet above ground, high in the tree tops, is an interwoven mass of vegetation teeming with animal life—a curious attic world. Like the deep sea, it has no seasons; light is the main consideration. Innumerable plants have climbed into this sheltered niche above the floods and turmoil of the world below. Climbing vines as thick as a man's thigh loop back and forth. Upon this mass of supporting cables has settled a weird assemblage of orchids, ferns and other strange plants which seek the sunlight and have learned to dispense with the ground below. Some are parasitic upon other plants; some depend on the precarious debris of their uncertain floor or the exhalations of trees. The eternal hot-house damp of the rain forest enshrouds them all and makes this dreamlike landscape possible.

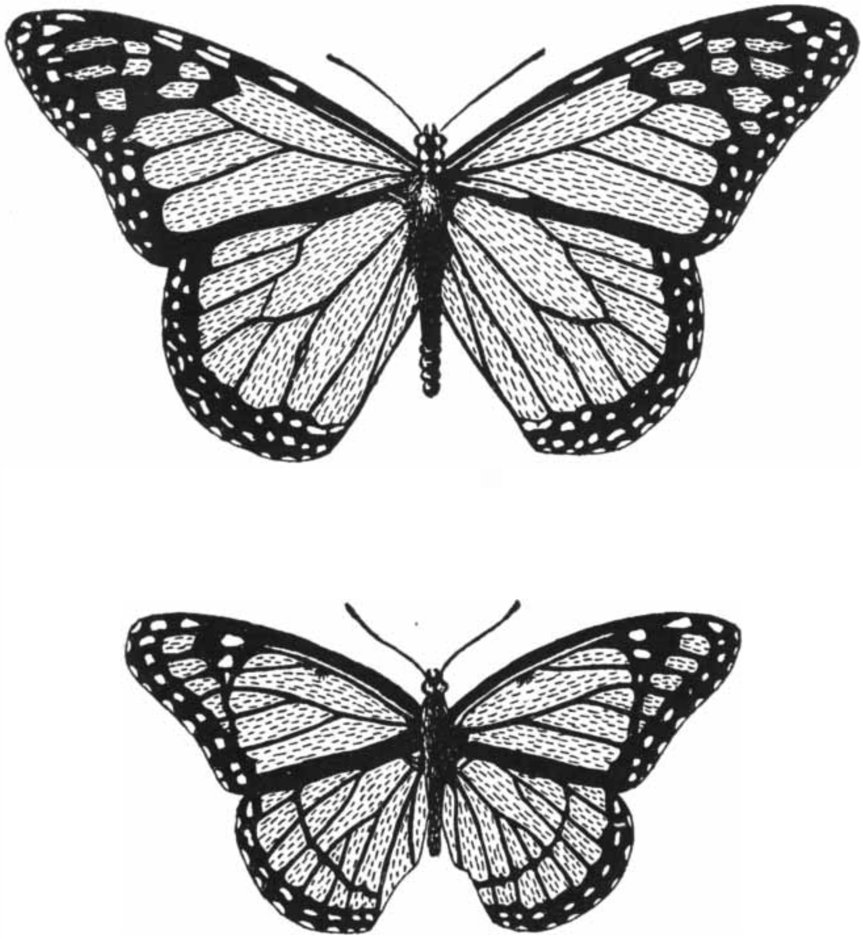
In the Amazonian attic are plants, known as bromeliads, which form tanks that catch and hold quarts of water. Dust and humus and drowned insects collect here to nourish the plants. Tree toads, frogs and numberless insects live their lives in these aerial ponds. Monkeys and protectively colored green tree snakes hunt by ancestral paths through the scent of the orchid gardens.

This world possesses some amazing duplications of living forms. Henry Bates, a keen 19th-century explorer of the Amazon, told how he suddenly encountered one day a menacing little monster which thrust itself through the leaves into his face. At first glance the startled Bates thought it was a poisonous viper. Actually it was an enormous caterpillar, with black pigment spots which looked like eyes. In the high chambers of the upper tree world are butterflies of diverse and distantly related families which are nevertheless surprisingly alike in coloration: beetles so burnished that they shine on the tips of vegetation like drops of morning dew, sticklike insects with legs like stiff, angular branches, bits of dead bark that turn out to be alive, spiders in the shape of flower buds, flies masquerading in the dress of stinging bees, crickets like wasps, brown and spotted butterflies that look like moldy leaves.

Resemblance to a dangerous insect or animal, as in the case of Bates' caterpillar, offers the protection of a formidable species to a harmless creature. Mimicry of a repulsive or ill-tasting species may save an insect from the birds. Adept



**CAMOUFLAGE is another example of evolutionary adaptation. Here a caterpillar, a "walking stick" and a leaf butterfly blend into a twig.**



**MIMICRY** of the monarch butterfly (*top*) by the viceroy butterfly (*bottom*) is thought to be due to the fact that the former species has an unpleasant smell which discourages its natural enemies. The viceroy butterfly, which does not have this odor, is presumably protected by the visual resemblance.

camouflage is so valuable to small life that natural selection may carry it to high peaks of perfection. Yet all this masquerade is only skin deep. The mimic never *becomes* the model, any more than the walking-stick insect becomes a twig. The mask may fool the mimic's enemies, but it will not deceive a zoologist.

SUCH PRINCIPLES have nothing to do with the possible duplication of man on other planets. No animal is likely to be forced by the process of evolution to imitate, even superficially, a creature upon which it has never set eyes and with which it is in no form of competition. Nor could an animal, however gifted in mimicry, ape a man if it came among men. Aside from the impassable anatomical obstacles, the individual sitting next to you in the theater could not conceivably be an insect masquerading as a man. Even if the body duplication (down to clothes) was perfect, the creature's instinct-controlled brain, its cold, clock-like reaction, in contrast to our warm mammalian metabolism, would make the masquerade hopeless.

Among the plants, too, we note many parallelisms. Yet the forms of the plants do not duplicate one another. Their relationships are not obscured, and what is even more interesting, a really remarkable invention such as the bromeliad reservoirs may distinguish the whole upper-story world. Nothing like them is known in the African forest. Their unique little ponds, making possible the growth of other aerial plants, have seemingly given the South American forest roof a luxuriance which the African forest cannot totally duplicate. One unique plant invention, in other words, has affected irretrievably the destinies of a great variety of other plants, animals and insects *in one particular world.* A historic incident, the rise and diffusion of a specific, natural invention on one continent has so channeled a little stream of life that numerous organisms will never be the same again because of the creation of those aerial marshes.

This event does not emerge as inevitable. Most curiously, botanists have noted that the bromeliad water tanks probably were developed originally not in the rain forest but in the desert. Here was an adaptation developed for one world which paradoxically enabled the bromeliads to leave that world for a very

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different one—the dappled sunlight of the orchid gardens. Anyone pondering the seeming stolidity of the plant world should consider it well—that long climb from a desert to a forest top.

It is out of such small events that worlds are altered beyond recall. As George Santayana wrote years ago: "An infinite number of solar systems . . . must have begun as ours began, but each of them must have deviated at one point from ours in its evolution, all the previous incidents being followed, in each case, by a different sequel."

ON THE great tablelands of Tibet, explorers say, the wind is always blowing. Dust devils dance endlessly across the landscape; air eats away the solid rock. Behind stones, under stones, buried in the soil, innumerable creatures hide from the force of the wind. Creatures which in other lands fly free and high here cower behind boulders or dart hastily from one bit of shelter to the next. Some insects have lost their wings. From birds to beetles, instincts have been altered in order to enable the animals to contend with this windy world. This is a land, the space writers sometimes argue, like the cold Martian desert itself.

Mars, with its thin air, its almost vanished oxygen and vast regions of desert, is a waste planet. A few apparently seasonal color changes suggest but do not entirely prove the possibility of some type of vegetation. That vegetation cannot be of a high order. There is simply not enough water on the planet to support a widespread forest and grass cover like that of our Earth. We need not explore these well-known facts extensively. Rather, what I should like to emphasize is the total lack of seas on Mars. The planet very early in its history lost a great deal of its water, and very likely it never did possess anything like the turbulence of our giant seas. On the Earth it is the constant circulation of water from sea to clouds to rivers and back to the sea that has nourished the higher life. The fossil hunters tell us that this circulation is probably indirectly responsible for the appearance of backboned animals. It is in the rivers of the early planet that the shape of man was born, for they were the birthplace of the vertebrates.

Here, then, is one of those deviant points upon which, as Santayana intimated, the destiny of a world might hang. A world like Mars, of feeble puddles, of leveled mountains, will breed a different life, if it breeds life at all. The pulse of the Earth to a very considerable extent is the sea's pulse. The altitudinal swing of the continents, the great periods of mountain building, rework the very shape of life itself. Multitudes of living things are forced to readapt upon the land and also in the sea. Upon Mars, back into a time as far as we can grope, the water has run scant and small. Equally scant and small we may expect its life to be. Nowhere in all that red array of sand and rock could a creature ever rise on a spine like ours. If anything comes forward in that cold and shriveling air, it will be pinched and meager beyond all the imaginings of Earth.

Every day worlds end and worlds begin; last night's puddle dries in today's heat and its little living world blows away. Day and night, winter and summer, on the thin edge of the tides or the immaterial edge of evening, there come into being lives which are adapted only to a fine-drawn instant of existence. A single mutation in an unknown, innocent virus, a change in the gaseous composition of the air around us, a rise of temperature by a few degrees—any of these might sweep the human world away. Before morning, however, something else would be creeping up the stairs or nesting in the abandoned attic.

IN THE thin terrestrial film, whose depth is only the brief distance from the Pacific deeps to the Himalayan roof of snow, life has experimented for one billion years. Its forms in certain instances have lived even without oxygen; they have endured pressures and rarefaction and devised incredible, cunning schemes for survival. The plant and animal species developed on Earth must range into the billions. But in all Earth's varied worlds man, "the sound proposition," has appeared but once.

It is not my contention that in the long cycles to come some of man's traits, even to an advanced brain, may not emerge once more in other living forms. The complex life of the social insects has been repeated no fewer than 30 times in the long history of diverse and only distantly related creatures. One thing, however, is apparent: the same life does not come again, the same hands will never twice build the golden cities of this world. The time stream, the on-pouring, whatever we may call it, is far more original than this. It is as though nature had all possible, all unlikely worlds to make and would make them before the systems lapsed away into darkness.

I think sometimes of the account of a traveler who, far up in the Himalayan snows, watched in astonishment a flight of lowland butterflies caught in one of the mysterious migratory impulses of their race. High in that desperately cold and thinning air, the delicate-winged insects, strung out over a great distance in a long, flickering line, were moving upward! The tattered columns wavered; stragglers dropped frozen in the snow. Nevertheless the dying creatures headed indomitably upward toward the blue ice of the peaks, their little wings beating in unison as though the march might have been boldly outward toward the moon. They were a living manifestation of discontent; they were life going about its immense business of changing worlds—or perishing in the attempt.

# What General Electric people are saying . . .

## L. T. RADER

*Dr. Rader is Manager—Electronic and Specialty Control Planning Study in the Control Department*

". . . Regardless of the principle chosen, whether it be a new approach or a modification of an old one, the skill of the designer in designing for inexpensive and easy manufacture often is the difference between success and failure.

Men with a good knowledge of manufacturing methods are invaluable in determining if punch-press stampings can be used instead of expensive screw-machine products, or if it is better to use punched phenolics instead of molded parts. They develop ingenious methods of fastening components together, break a unit down into subassemblies to give flexibility, make certain that standard parts are used where possible, and in general, make certain that over-all product costs are maintained at competitive levels.

Because designers have so many diverse problems to solve, they are always willing to try new materials that may offer design advantages. It is far easier—and less risky—to make ten samples of a pressure switch out of a new material and have them field tested, than it is to try the same material on a large and expensive machine.

Because of this, we find that insulating materials such as the silicones, permafil, nylon, and teflon are applied in small devices almost immediately upon discovery. Special magnetic materials like oriented silicon and alnico have also found immediate application. Plastics of every formulation and property and special metals like stainless steel, curie metal, beryllium copper, and Z-nickel have been used immediately upon development. In the area of current conduction and interruption, special alloys made of combinations of practically all known metals are used extensively for their special properties. Because of its nature and form, small apparatus design eagerly accepts new materials almost immediately upon their release to industry and finds useful work for them to perform.

*G. E. Review*

## C. G. SUITS

*Dr. Suits, a Vice President, is Director of the Research Laboratory*

". . . Some calculations have been carried out in our laboratory recently, to determine in detail the quantitative effect of some typical lattice defects on tensile strength of metals. For the case of alpha brass they show that the magnitudes involved are sufficiently large to account fully for the experimentally observed tensile strength of the actual crystalline material. This recent work has, for the first time, made possible a quantitative understanding of this most important property of crystals. It would be difficult to overestimate the value of this work for it seems certain that great progress may be expected from a full development of current studies of crystal defects.

The study of the growth of crystals has provided a particularly good opportunity to observe the role of defects and dislocations. When crystals are grown from solution it is observed that the growth rate may vary widely from one crystal to another of the same chemical composition, and this difference can be explained by the relative abundance and character of the dislocations present. A particularly important defect in this case is the lattice displacement known as an edge dislocation. This defect arises from the displacement of many layers of atoms relative to their neighbors, on a line perpendicular to a plane of the lattice. Consider the function of this edge dislocation in a crystal experiencing growth from a supersaturated solution. Atoms from the solution migrate to the crystal where they are held by surface forces, which however are particularly weak on an atomically smooth plane of a perfect crystal. In the neighborhood of the edge dislocation, by virtue of the geometry, these forces are very much greater, with the result that practically all of the crystal growth phenomena takes place at these points. The abundance or scarcity of such defects can thus account for a vastly different rate of crystal growth in different crystals of identical chemical composition, the most perfect crystals experiencing the slowest growth.

*at The American Philosophical Society*
*Philadelphia, Pa.*

## R. E. FALCONER

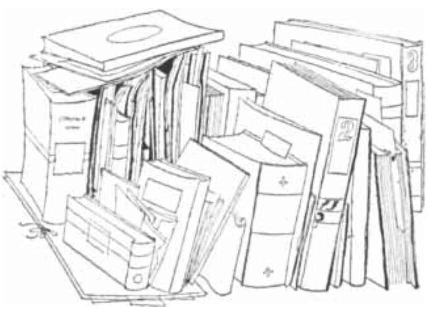
*Mr. Falconer is a meteorologist at the General Electric Research Laboratory*

". . . It seems to the author that there may be an electrical effect associated with the jet stream which can be readily detected by as simple a device as a radioactive collector and a suitable sensitive current indicator or recorder.

However, before drawing definite conclusions, observations at other locations around the country should be made to determine more definitely whether the electrical effects observed at Schenectady apply generally. It is suggested that a network of such instruments might be useful for continuously checking on the location of jet streams. Such information might be useful in detecting the possibilities of tornadoes, thunderstorms, turbulence, and general precipitation since all appear to be related to the effects of the jet stream.

The author has now found that a General Electric photoelectric recorder having a sensitivity of 0.266 microamperes shunted to read 0.50 microamperes full scale is about the right sensitivity to use. Such a recorder was recently installed and this eliminates the need for an electrometer which tends to drift and cause misleading results unless a frequent zero check is maintained.

*at The American Meteorological Society*
*Washington, D. C.*



# BOOKS

## *A general account of comets combined with an interesting new theory of their origins*

by James R. Newman

THE COMETS AND THEIR ORIGINS, by R. A. Lyttleton. Cambridge University Press ($5.00).

"OLD MEN and comets," wrote Dean Swift, "have been reverenced for the same reason; their long beards, and pretences to foretell future events." Anaxagoras and Democritus attributed comets to "the combined splendor of a concourse of planets." Aristotle, a renowned chronicler of old wives' tales about astronomy and meteorology, maintained that comets were exhalations from the Earth to the upper atmosphere. This hypothesis was so widely accepted that comets were not classified among the heavenly bodies in Ptolemy's *Almagest*.

Whatever the differences in the explanations of their physical nature, motions and causes, comets were until recent times universally regarded as presages, sometimes of happy augury, usually of death and disaster. The comet's sudden and mysterious appearance, its flaming flight across the sky, the swiftly changing aspect of its tail, its departure without a trace—all this inspired awe and fed superstition. When a comet is seen, "ther occurris haistily eftir it sum grit myscheif," said the *Complaynt of Scotlande* in 1549. Shakespeare (in Henry VI) wrote of "Comets importing change of Times and States." Milton's image in *Paradise Lost* is perhaps the most famous:

*On the other side,*
*Incensed with indignation, Satan stood*
*Unterrified; and like a comet burned,*
*That fires the length of Ophiuchus huge*
*In the arctic sky, and from his horrid hair*
*Shakes pestilence and war.*

The superstitions have all but vanished; myths about comets have been replaced by more fashionable irrationalisms. But the phenomenon itself is as impressive as ever, and as puzzling. The most recent edition of the *Encyclopaedia Britannica*, for example, reports that as late as 1946—when the article on comets was written—no plausible explanation of comet formation had been proposed. In *The Comets and their Origins* R. A. Lyttleton, a Cambridge mathematician, expounds a new, coherent and testable theory based on what he calls the "New Cosmology." Fred Hoyle, H. Bondi, and T. Gold have been in the forefront of the work underlying Lyttleton's study.

Lyttleton has explored the voluminous literature on comets and presents its main features in exemplary style. Tycho Brahe was the first to demonstrate what had already been conjectured by that strange combination of genius and muttonhead, Jerome Cardan: that comets are true celestial objects, far more distant than the moon. Tycho suggested that the path of the daylight comet of 1577 was a circle. Johannes Kepler, not realizing that comets could return—and were therefore subject to the rules of planetary motion which he himself had so brilliantly unfolded—concluded that they moved in straight lines. The German astronomer Johannes Hevelius conjectured their path as parabolic. It was Edmund Halley who, with the aid of Newton's theory of gravitation, finally solved the problem of cometary orbits. And the incomparable Robert Hooke, who rarely, if ever, pronounced on scientific subjects without saying something sensible, suggested that comet tails were formed by the pressure of the sun's rays. He was extraordinarily prescient: this is the view now generally adopted by astronomers.

Comets move in highly complicated three-dimensional curves. When these are simplified for computational purposes into so-called two-dimensional "osculating" orbits, it is found that the orbits are conic sections: hyperbolas, parabolas, ellipses. The osculating orbit is the path a comet would follow if it were subject only to the simple inverse-square attraction of the sun. While the sun is the dominating influence and lies at the focus of the conic, planets such as Jupiter cast the hem of their gravitational mantle over the comet, thus producing perturbations in its motion. In some instances the effect is very severe and results in a drastic change of orbit. Most osculatory orbits are parabolas, but a slight decrease or increase in the comet's speed converts the orbit into an ellipse or a hyperbola, respectively.

Astronomers have now determined the orbits of about 1,000 comets. The task is delicate and difficult. When a comet first comes into view, a provisional path is calculated on the basis of its behavior for a few days. It is then kept under constant surveillance so that its path with respect to the Earth may be computed with increasing precision. A crucial reference datum in this computation is the comet's perihelion point: it is necessary to ascertain the exact time at which the comet passes or will eventually pass in closest proximity to the sun. For a comet to be periodic, its orbit obviously must be elliptical; on a hyperbolic or parabolic journey the traveler will come to us literally out of the nowhere and vanish forever into the beyond. Yet it is precisely this determination—dependent on minute differences of curvature and subject to various circumstances that limit the accuracy of observation—which is so difficult to settle. Careful tracking may lead to the conclusion that a cometary orbit is hyperbolic near the sun; however, when the orbit is "extended further outwards from the observable part and backwards in time, by calculations making due allowance for the influence of the planets (Jupiter is usually the main perturbing agency), in every case it has been found that the comet has in fact come in from a finite distance, and is therefore to be regarded as a reappearance of a permanent member of the solar system as far as its orbital motion is concerned." Since Kepler's third law—that the square of the time of revolution of a planet is proportional to the cube of its mean distance from the sun—describes the time of revolution of a comet in its orbit, it is easy to see that the period of a comet calculated from a necessarily limited arc is "only weakly determined." This uncertainty helps to explain the extraordinary computational differences among leading astronomers. To cite only one illustration: the comet of 1680 has, according to the most accurate reckoning of the German astronomer Johann Franz Encke, a period of 8,814 years—not 170 years, as found by Leonhard Euler, or 575 years, as Halley calculated, or 5,864 years, as the Frenchman Alexandre Pingré said.

It must not be supposed that more than a small fraction of the comets chasing around the solar system ever have or ever will be seen. Even short-period comets (those traveling their circuit in less than 100 years) may disappoint us after a number of visits and fail to return. Brorsen's comet of 1846 (period 5.5 years) was not seen again after 1879, and Holmes's comet of 1892 (period 7 years) was not found in 1919 or 1928. Others, such as Encke's comet in 1944, are "missed through unfavorable circumstances but rediscovered at a later return." Halley's comet (period about 77 years) has been reasonably punctual for at least six centuries and may be looked for again in the spring of 1986. Comets of moderate period—of which about 40 are known—pay their homage to the sun every 100 to 1,000 years. But the great majority of comets have long orbital periods averaging about 40,000 years, according to the noted British expert A. C. D. Crommelin. It has been estimated that at least 300 long-period comets come to perihelion each century; if, then, the 40,000-year average is adopted, "we arrive at the amazing but inescapable conclusion that there must be at least 100,000 comets in the solar system with perihelion distances sufficiently small for them to become eventually observable." Moreover, there are many more with perihelion distances too great for the comets to be seen with present equipment if they remain in their existing paths.

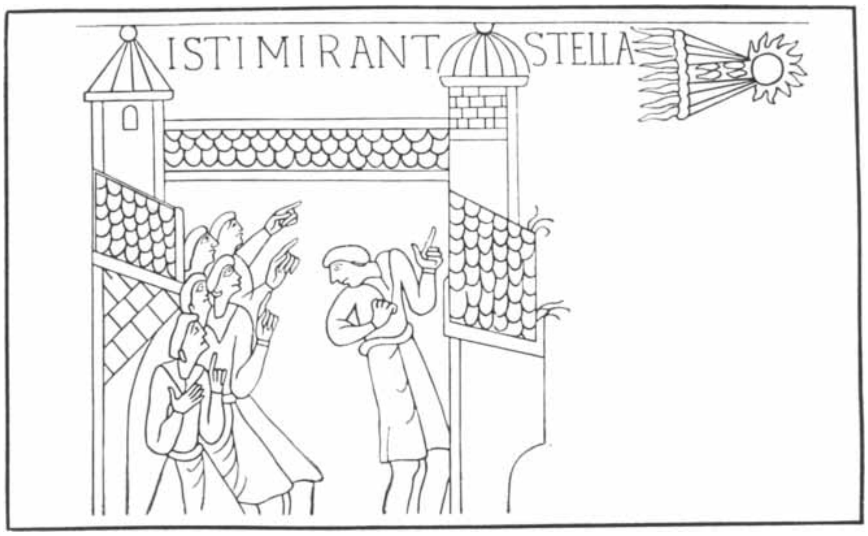
About six or seven comets are discovered each year. The way to find one is to have the qualities which made a success of Phil the Fiddler—industry, zeal and attentiveness. Good equipment and luck also help. In 1896 the U. S. astronomer Charles Perrine was at the Lick Observatory making loving observations of a comet he himself had discovered when he received a telegram from Kiel stating the position of the comet at that moment. The telegram had been jumbled in transmission and gave an entirely wrong position, more than two degrees from the correct one. Perrine, not knowing the message had been twisted, pointed his telescope to the indicated place—and found a new comet. The devotion and perseverance of astronomers is typified by the almost incredible labors of Joseph de Lalande and his staff in computing the date of the return of Halley's Comet in 1759. Monsieur Lepaute, one of Lalande's assistants, tells the story:

"During six months we calculated from morning till night, sometimes even at meals; the consequence of which was that I contracted an illness which changed my constitution during the remainder of my life. The assistance rendered by Madame Lepaute was such that without her we never should have dared to undertake the enormous labor with which it was necessary to calculate the distance of each of the two planets, Jupiter and Saturn, from the comet, separately for every degree, for 150 years."

The prediction was that the comet, having been delayed 100 days by the influence of Saturn and 518 days by that of Jupiter, would arrive at perihelion April 13, 1759. The actual date was only 32 days earlier, a tribute no less to the skill of the computers than to the theory.

What is a comet? Henry Norris Russell describes it as a "loose swarm of

*Daniel's Comet of 1907 had a fan-shaped tail with several "rays"*




*Halley's Comet of 1066 was depicted in the Bayeux tapestry*

separate particles" accompanied by dust and gas. An observer sees it as a queer object with a head that is no head (and which, in any case, is sometimes missing), and a tail that conforms to no definition of a tail found in any dictionary (and may also be missing). The head, when it is present, consists of a faintly luminous cloud, called the coma, enveloping a bright something called the nucleus. The coma is transparent and undergoes fantastic deformations as it passes the sun; the nucleus, thought to be made of "some kind of changing concentration of small particles," also can be expected to transform itself like a jinni—a fact which astronomers conveniently explain by classifying the nucleus as no more than an "apparent phenomenon." The most spectacular feature of a bright comet is its tail. This appendage has been known to extend more than 200 million miles and nearly 180 degrees across the sky. Comets, like young women presented at the Court of St. James's, seem to put on their tails as they approach the sun. As a general rule, the closer the perihelion distance, the more impressive the tail. As a comet approaches the sun the tail streams behind, but beyond perihelion it precedes the comet. This curious behavior is explained on the theory that the pressure of the sun's radiation affects the particles of the tail in the way the wind affects a plume of smoke. A comet can have more than one tail: Borelli's (1903) is said to have shown nine.

Comets are luminous partly because the small solid particles of which they are composed reflect, diffract and scatter the sun's light. But their spectrum, besides showing the familiar solar Fraunhofer lines, exhibits bright bands due to the emission by molecules of energy originally absorbed from solar radiation.

There is considerable variation in the sizes and shapes of comets and in their masses. A few cometary giants are greater in volume than the sun itself. The more normal specimens range in diameter from 20,000 to 200,000 miles. In 1909 Halley's comet, which is not atypical, had an observed coma 14,000 miles across when it was three times the Earth's distance from the sun; at a distance of two astronomical units the coma had swelled to 220,000 miles; at perihelion it had shrunk to 120,000 miles; later, at one unit distance, it had increased again to 320,000 miles. The prime example of shape-changing capacity is Biela's comet, a short-period wanderer (6.6 years). On its visit in 1846 it first startled observers by making its entrance in pear-shaped form; 10 days later it shattered the self-confidence of astronomers by dividing into two separate comets which "continued to travel in practically the same orbit, one preceding the other by about 175,000 miles." The twins appeared again in 1852, now eight times farther apart. They have not been seen since.

Biela's twinning, by the way, was discovered in the same year as the planet Neptune. Both events provided opportunities for the hapless Cambridge astronomer James Challis to demonstrate his exquisite incompetence. Challis managed to miss finding the planet Neptune after John Couch Adams had told him where and when to look for it. His excuse was that he was searching for comets. To complete the tableau, he observed the twinning of Biela's comet but attributed it to an optical illusion and failed to publish his finding, explaining his oversight later on the ground that he was too busy looking for Neptune.

I think it was Sir John Herschel who said that a comet could easily be packed into a portmanteau. Certainly the mass of a comet is insignificant compared to that of other celestial objects. The average comet, Lyttleton suggests, is only one 10-billionth as massive as the Earth.

Its weight comes to about a million million tons—too large for a portmanteau, but too small to produce observable gravitational perturbations. Spread this mass of small stones or rocks through a volume equal to that of the sun and there will be plenty of empty space between adjacent stones. On this assumption it is not surprising that comets are transparent. Lyttleton puts the density of the tail at "perhaps far less than" a trillionth of a trillionth of a gram per cubic centimeter, and supposes it to be made of a mixture of dust and gas. Meteors are related to comets; one plausible hypothesis is that they are simply the "debris of disintegrated comets."

The Lyttleton group's new theory of how a comet originates runs something like this: Genesis begins when the sun passes through a galactic dust cloud formed of material ejected in the explosion of a supernova. The sun's gravitational attraction starts these particles flying in orbits which are hyperbolic relative to the sun. Fix your attention now on an imaginary line through the center of the sun parallel to the direction of its motion—the so-called accretion axis. The particles of the cloud will converge toward this axis and will collide when they are at and near the axis at points behind the sun. If we consider two inelastic particles of the same mass moving from points on directly opposite sides of the accretion axis, and "symmetrically placed with respect to the direction of motion of the sun," it can be shown not only that a head-on collision will occur on the axis, but that the results of the impact will be to nullify the transverse components of the particles' motion, to leave unaffected the radial components away from the sun along the axis, and "to reduce the originally hyperbolic energies of the particles to elliptic values, and thus bring about their capture by the sun." The multiplication of this and similar effects, involving hordes of colliding particles, creates a stream of material trailing behind the sun along the path of its motion. Part of the stream, however, flows toward the sun and part away from it, because out to a certain distance the sun's gravitational pull draws the colliding particles inward along the accretion axis, while beyond a certain point material arriving at the axis has a radial velocity sufficient to overcome the sun's captive power. These particles will escape.

According to the Lyttleton theory the stream flowing toward the sun is acted upon by two opposing forces: the sun's gravitational field and the internal gravitation of the material within the dense stream itself. The latter pulls the stream together lengthwise. We may assume, says Lyttleton, that irregularities of density in the dust cloud, and the general unstable nature of the accretion process, produce in the stream centers of attraction around which particles tend to cluster. While the internal gravitation is of negligible importance where the stream is close to the sun, farther out it is sufficient to promote not only the formation of local clusters but a lumping together and separation of the stream into segments. It is these segments which, according to the theory, develop into comets. One asks why, since this entire part of the stream is flowing toward the sun, the comets are not sooner or later swallowed up by it. Lyttleton answers that much of the stream's material does fall into the sun, but some of the comets escape this fate by the attraction of planets, particularly Jupiter and Saturn. The effect of their gravitational fields is to endow nascent comets which are favorably placed with a sufficient angular momentum to sweep clear of the sun. He estimates that even if only a small percentage of all comets forming in the stream avoid extinction, "an average cloud might easily produce several thousand comets" that will survive.

It is impossible not to admire the working out of Lyttleton's system. It is coherent and—for the average reader, at any rate—excitingly persuasive. Astronomers and cosmologists, even those favorably disposed to the accretion hypothesis, will be harder to persuade; some, I am sure, will look at Lyttleton's conclusions with a fishy eye. None, however, will overlook the important fact that the central idea involves hypotheses "that can be subjected to quantitative tests—a feature hitherto completely absent from cometary theories." While these tests can yield confirmation only within orders of magnitude, their results are not to be despised, for as the British physicist Harold Jeffreys once pointed out, most incorrect physical hypotheses fail such tests "by many powers of 10."

This book is not always easy to read, but I recommend it highly. It impressed me so much that I now appreciate the feelings of a certain enthusiastic young lady from New Jersey (reported by Mary Proctor in her book on comets) who on the appearance of Halley's comet in 1910 declared her intention of following it "wheresoever it went." Only "temporary seclusion" in an asylum deterred her from this gallant pursuit.

### Short Reviews

FLEAS, FLUKES AND CUCKOOS, by Miriam Rothschild and Theresa Clay. Philosophical Library ($8.75). THE FULMAR, by James Fisher. William Collins Sons & Co., Ltd. ($7.00). BRITISH MAMMALS, by L. Harrison Matthews. William Collins Sons & Co., Ltd. ($5.00). Each of these volumes maintains the standard of an authoritative, uncommonly attractive British series known as "The New Naturalist Library." The Rothschild-Clay book is an excellent popular introduction to bird parasites. Birds have been described as "aviating zoological gardens." Here from two recognized authorities one may learn of the communities of animals, plants and bacteria which compose these gardens. Mr. Fisher spent 20 years in preparation for his exhaustive and fascinating account of the fulmar, whose name means "foul gull." This "primitive, rather stupid, but also successful shabby, white bird," which lives in the northern oceans, is such an efficient sailplane that it can cross the Atlantic before it is three months on the wing and can sail to windward in "the highest storms, and rest on the water, with great composure, in the most tremendous seas." Fisher describes the evolution of the fulmar, its distribution, history, spread, exploitation, color phases, behavior, life-cycle, parasites, predators and food; its "revolutionary spread" in Iceland, the Faeroe Islands, Britain and Norway. Matthews' book is an intelligent and readable survey of the mammals of the British Isles and seas, from moles to whales. It is a pleasant and dependable story, not overburdened with minutiae, just right for the general reader. Like other volumes of the series, these three books have fine illustrations and helpful bibliographies.

THE POLICY SCIENCES, edited by Daniel Lerner and Harold D. Lasswell. Stanford University Press ($7.50). Symposia of social studies are apt to be tedious and vaporous; this book is an exception. Its purpose is to describe today's research procedures in the social sciences and to explain how knowledge in this sphere can be applied to practical problems—primarily, to "guide political strategy toward world peace." Some of the general essays at the beginning of the book are quite incapable of guiding anyone anywhere, but these are offset by a goodly number of sensible and interesting contributions which give substance to the entire undertaking. Kenneth J. Arrow of Stanford University writes an excellent chapter on mathematical models in the social sciences. It is the first succinct and widely comprehensible survey of this important but difficult subject. Other noteworthy chapters include Rensis Likert's discussion of sample interviewing and the late Hans Reichenbach's essay on probability methods in social science.

THE WORLD'S OILFIELDS: THE EASTERN HEMISPHERE, edited by V. C. Illing. Oxford University Press ($20.00). SYNTHETIC PRODUCTS AND REFINERY PROCESSES, edited by B. T. Brooks and A. E. Dunstan. Oxford University Press ($35.00). These comprehensive studies continue an encyclopedic survey, *The Science of Petroleum*, of which the four main volumes were published in 1938. Leading experts have brought together an enormous amount of information on the petroleum resources and their development in Europe (excluding the U.S.S.R.), the Middle East, Africa, the Far East and Australasia. Maps, charts, photographs and folding plates add to the usefulness of these supplements to an authoritative reference work on which contributors, editors and publishers have lavished meticulous care.

ARISTOTLE'S PHILOSOPHY OF MATHEMATICS, by Hippocrates George Apostle. The University of Chicago Press ($6.00). Aristotle's views on mathematics are scattered through his works; he wrote no systematic treatise on the subject—at least none is extant. The author of this book attempts to reconstruct Aristotle's mathematical philosophy and to present it in organized form. The net result is a dense academic essay which philosophers, historians of science and students of Aristotle may find useful, are likely to debate and will certainly enjoy.

APPRAISING PERSONALITY: THE USE OF PSYCHOLOGICAL TESTS IN THE PRACTICE OF MEDICINE, by Molly Harrower. W. W. Norton & Company, Inc. ($4.00). This book is directed to practicing physicians who are assumed to have the dimmest of notions of what projective tests are, why and when they are administered, what information they can yield and how the physician can use the data thus gained. Dr. Harrower uses the dialogue form with less beauty than Socrates and less brilliance than Freud, but it serves as a simple if irritating teaching device. The book will be useful to the many non-medical people as well as physicians who have wondered what the Rorschach is, what it can do and why. It also describes less familiar tests such as the Szondi, the Sentence Completion, the Figure Drawing and the Most Unpleasant Concept tests; it indicates how the Wechsler-Bellevue Intelligence Scale can be used in appraising personality as well as intelligence. The absence of the Thematic Apperception Test and the Lowenstein and World tests is strange and unfortunate. Nonetheless, the material covered gives a picture of what clinical psychologists can do with the techniques now available.

CHILD PSYCHOTHERAPY, by S. R. Slavson. Columbia University Press ($4.50). The founder and leader of group psychotherapy in America has written a clear and full account of the psychic life of children and the tools that have been developed to improve or alleviate their emotional disturbances. Slavson's concepts of the dynamics of personality are Freudian. His application of these concepts to the treatment of children derives from Anna Freud. Many of the group techniques are his own contribution.

GROUP PSYCHOTHERAPY, by Florence B. Powdermaker, Jerome D. Frank and others. Harvard University Press

($6.50). The U. S. Veterans Administration undertook a careful clinical study of methods and procedures which could be used with groups of patients under the care of therapists using differing techniques. This book describes what occurred in group sessions and contains a careful analysis of the methods of observation and an evaluation of what was done.

PSYCHOANALYTIC THEORIES OF PERSONALITY, by Gerald S. Blum. McGraw-Hill Book Company, Inc. ($3.75). During the past 25 years theories of personality have been as common as measles, but a good bit more difficult to diagnose and classify. Blum compares the various theories that are founded on psychoanalysis, matching Freud's concepts against those of Jung, Adler, Rank and Reich and such neo-Freudians as Horney, Fromm, Thompson, Sullivan, Kardiner, Erikson and Alexander. He supplements these comparisons with critical notes indicating what research has been done, or might be done, to test the several concepts. The book does an excellent job of presenting the essence of the conflicting theories.

### Notes

JOSIAH WILLARD GIBBS, by Lynde Phelps Wheeler. Yale University Press ($4.00). The revision in this new edition consists mainly of an additional appendix giving fresh information about Gibbs's life from a large collection of letters recently made available to the author.

DATING THE PAST: AN INTRODUCTION TO GEOCHRONOLOGY, by Frederick E. Zeuner. Methuen & Co., Ltd. ($9.25). Material has been added to the text, to the appendix and to the bibliography of this third edition. The book now carries developments in the various branches of geochronology up to December, 1951.

THE MATHEMATICAL THEORY OF NON-UNIFORM GASES, by Sydney Chapman and T. G. Cowling. Cambridge University Press ($10.50). The second edition of this well-received account of the kinetic theory of viscosity, thermal conduction and diffusion in gases has minor changes in the text and contains a group of notes, added in 1951, to bring the discussion up to date. The publishers sensibly offer the notes in a separate volume ($1.00) for the benefit of those who already own the 1939 edition.

THE PSYCHOANALYTIC STUDY OF THE CHILD, edited by Ruth S. Eissler, Anna Freud, Heinz Hartmann, Ernest Kris and others. International Universities Press ($7.50). More than 20 papers are contained in the 1952 volume (the seventh) of this interesting and well-established annual. As usual, it covers a broad range of topics, many of which will interest parents and workers in the sphere of social relations as well as psychoanalysis.

THE PRINCIPLES AND PRACTICE OF AVIATION MEDICINE, by Harry G. Armstrong. The Williams and Wilkins Company ($7.50). This is the third edition of a manual written by the Surgeon General of the U. S. Air Force. The author has revised and reorganized the text and has added four new chapters. The scope of this volume is not confined to military flying; it will interest physicians generally.

THE PERSONALITY OF ANIMALS, by H. Munro Fox. Penguin Books (50 cents). Professor Fox has rewritten this delightful little book without diminishing its charm. He has added two chapters and provided a new set of illustrations. Warmly recommended to readers young and older.

LECTURES ON THEORETICAL PHYSICS, (Volume I, Mechanics; Volume III, Electrodynamics), by Arnold Sommerfeld. Academic Press, Inc. (Volume I, $6.50; Volume III, $6.80). English translations by E. G. Ramberg and Martin O. Stern of well-known lectures by a famous teacher.

ATLAS OF ANCIENT AND CLASSICAL GEOGRAPHY, revised by John Warrington. E. P. Dutton & Co., Inc. ($4.50). Eighty pages of maps and plans and a historical gazetteer compose this revised version of a handy, authoritative companion to classical studies.

THE WORKS OF ARISTOTLE, Volume XII, translated into English under the editorship of Sir David Ross. Oxford University Press ($3.00). This volume in the Oxford Aristotle series consists of "selected fragments" of essays on rhetoric, the Pythagoreans, good birth, wealth, prayer and so on.

THE RIDDLE OF CANCER, by Charles Oberling. Yale University Press ($5.00). Revised edition of a widely applauded introduction to the problems of cancer. The author is a prominent European investigator who since 1948 has been director of the Institute of Cancer Research at the University of Paris.

THE ELEMENTS OF NUCLEAR REACTOR THEORY, by Samuel Glasstone and Milton C. Edlund. D. Van Nostrand Company, Inc. ($4.80). A manual for persons professionally interested in nuclear reactors, published under contract with the AEC. The topics include nuclear structure and reactions, production and diffusion of neutrons, homogeneous and heterogeneous reactors, reactor control.

# THE AMATEUR SCIENTIST

*The archaeology of New York City, and some incidental information on Palomar Mountain*

Conducted by Albert G. Ingalls

DR. THEODORE KAZIMIROFF, a New York City dentist, is often called by his friends "the amateur archaeologist of Broadway." To officials of the Heye Museum of the American Indian he is known as one of the outstanding lay authorities on the Algonquin and Iroquois tribes. During the past 34 years Dr. Kazimiroff, now 39, has found more than 45,000 Indian artifacts, nearly all of them within the city limits of New York. He has also taken degrees at Manhattan College and New York University, married, fathered an 11-year-old colleague named Ted, Jr., attracted professional recognition for amateur work in the fields of botany, mineralogy, geology and zoology, and served as official historian of the Borough of the Bronx. His patients sometimes have to wait quite a while for appointments.

Dr. Kazimiroff has carefully catalogued his Indian collection and kept a running account that relates it scientifically to the prehistory of the American Indian. Some day he plans to present the results of all this work to the Heye Museum. Judging by the rate at which the collection is growing, the Museum may be pressed for room in which to house it unless Dr. Kazimiroff makes his presentation soon. This summer he hopes to reap several hundred new items from three promising sites on Manhattan Island where building construction is scheduled to get under way. "I expect to keep on digging for another 30 years at least," he says. "We have barely scratched the surface. We have a long way to go before we can claim we know very much about the way the Indian lived prior to the coming of the paleface."

Dr. Kazimiroff made his start in archaeology during the summer of 1919. His father was a nature student and the family spent a lot of time in New York City parks. On one of these nature walks young Ted's attention was caught by a sharp bit of flint in the shape of a triangle—a typical Iroquois arrow point. As Ted bent over to pick it up, the senior Kazimiroff gave his son the first rule of the good archaeologist: Never disturb an artifact until you have carefully noted its location and surroundings. "It was not many years before I learned the value of that rule from first-hand experience," he says. "Good records pay off. Not only do they lead you to other finds, but like the individual pieces of a growing jigsaw puzzle, each specimen helps to spell out the story—in my case the story of what men and women were doing on Broadway centuries before skyscrapers displaced the forests. It is in these stories that I find the fascination of amateur archaeology. Unless an object can be related to the lives of the people who made and used it, you have added nothing to your collection but a valueless souvenir.

"Archaeology has another strong appeal, too. Like psychoanalysis and other disciplines that center on people, archaeology is both an art and a science. Hence its study never becomes routine or dull. I sometimes get the discouraging notion that the perfect archaeologist would have to learn everything about everything, plus acquiring all the tricks of a master diplomat. Around New York City, at least, a gift for diplomacy and the ability to act fast are almost as vital to an amateur archaeologist's success as his trowel and notebook.

"An experience involving one of my most important finds illustrates this point. Back in 1938 when preparations were under way for the New York World's Fair, a group of promoters decided to build a trailer parking lot in the Ferris Point section of the Bronx, near the north end of the Bronx-Whitestone Bridge. Their plans called for excavating a large site adjoining residences in the vicinity. While driving out that way early one afternoon I noticed that the soil had been cut from three sides of a house so that it was left standing on a pillar of earth about six feet high. What attracted me chiefly was a burned patch in the earth midway up one face of the pillar—a patch with clean, dark edges about 18 inches across. That, I said to myself, must be the remains of an Indian fire pit. I knew the property owner could not permit the pillar to remain exposed for long because erosion would set in. The foundation needed the support of a concrete wall. Hence if the fire pit was to be investigated it was now or never. Experience had taught me that in New York City it pays to dig first and ask for permission later.

"So I pulled my car over to the site and went to work. I had scarcely touched the burned patch before an assortment of shells and fragments of pottery began to tumble out. The nature of the material convinced me that here was the site of an Algonquin burial ground, or at least of a village that had been inhabited for a long time.

"The work had been going nicely for about half an hour when suddenly the property owner appeared from around the corner, waving his arms and demanding to know precisely what I thought I was doing to his house. It seemed that he was not at all happy about the trailer project, despite the fact that he had already collected substantial damages from the contractors. My digging was just about the last straw. I talked fast, explained who I was, where I came from, the importance of the find to science and wound up with a strong appeal to his better nature. Finally he drove off to his job grumbling that I'd better have that hole filled in by the time he returned.

"I went on digging, and the farther I went, the more I found. When the sun went down, I hooked an extension light to the battery of my car and kept digging. It must have been about midnight when the owner returned. You should have heard him! By that time I had burrowed in so far that only my heels were showing. I scrambled out of the hole and tried to pacify him but it was no use. He telephoned the police. While he was talking I piled my notes and specimens into the car and commenced shoveling the dirt back into the hole. When I heard the approach of a siren, I lit out for home.

"Field archaeology requires the development of intuitive gifts much like those of Sherlock Holmes. One of the most important of these is 'differential perception'—the ability to glance at a stretch of terrain and single out, almost subconsciously, any object or surface feature that departs from the natural state. Perhaps you spot the thin edge of a shell protruding from a bare patch in the grass on the summit of a hill. Mollusks do not grow on hilltops, so you investigate. Or you may be at the beach and see a peculiarly roughened pebble which stands out in contrast with the myriad that have been polished by the sand. You look closely and discover that it is covered with peck marks—a proof of aboriginal handiwork.

"With practice, many features of the landscape which previously escaped notice will begin to catch your attention—a slight rise or depression in the surface of a vacant lot or hillside, a half-concealed entrance to a natural cave, subtle changes in the boundary or color of the strata exposed by a cliff or the walls of an excavation. It takes only a minute to check such clues and record them in your notebook. Most of your entries, of course, will ultimately prove disappointing. But every now and then you will strike it rich. Unless the site is in danger of immediate destruction, as is frequently the case when heavy construction is in progress, you should immediately report your find to the nearest professional archaeologist.

"As Kathleen Kenyon points out in her excellent book *Beginning in Archaeology*, all excavation is destruction, and therefore no inexperienced person should undertake it on his own. The best way to acquire experience is under the direction of a professional archaeologist. Most professionals welcome the assistance a serious amateur can contribute during excavations, particularly if the amateur discovered the site in the first place. You can always count on the professional to give you technical advice by telephone when a site is about to be destroyed and you have little time in which to work. Moreover, he will help you classify and interpret your specimens and will recommend the best methods of cleaning and preserving them.

"Archaeology leads into nearly all the sciences, but especially into botany and geology. In September, 1944, for instance, I was walking down Broadway when I noticed a large Scotch elm at the corner of Broadway and 230th Street. It was a magnificent specimen with a trunk nearly five feet thick. Since the Scotch elm is not native to the U. S., I realized that this obviously aged specimen must have been planted by very early colonists. I snapped a photograph, made a note to investigate the tree's history and within a few weeks located some old maps showing the location of buildings that had been erected by the colonists in the vicinity of the tree. Then through the courtesy of the Kingsbridge Historical Society I reviewed a collection of old drawings and early photographs of the area. Finally I came across one showing an elm of the familiar outline; the branching pattern of a tree is as characteristic as the fingerprints of a person. My snapshot and the early picture of the Scotch elm matched perfectly! A little more research uncovered the full story. The tree once sheltered Coxe's Tavern, a famed resort of the Revolution's gay blades. The Tavern stood on the ancient site of the long-lost Algonquin village of Shorak Apkok.

"The story of the rediscovery of the site touched off some publicity, but everyone soon dismissed it. Seven years later, on the afternoon of May 1, 1951, I received an urgent telephone call from the Reverend William A. Tieck, pastor of St. Stephen's Methodist Church. 'You'd better rush over here right away,' he exclaimed. 'They're cutting your tree down!' I made a hurried excuse to two patients in the office and dashed off. The giant elm crashed to the ground just as I arrived.

"A contractor was about to commence excavating the site for a new Post Office building. Remembering Shorak Apkok, I asked the contractor to call me if his power shovel bit into anything that looked like Indian relics. Two days later he telephoned: 'We're hitting bones, and if you want to do anything about them you better get over here. I can give you only a couple of hours.' I called George Younkheere, a fellow amateur, and we met at the site. Within a short time we established the fact that 230th and Broadway mark the location of a once bustling Indian village. Near the end of our precious two hours we located the skeleton of a white man with a musket ball in his chest [*see photograph at right*]. Unfortunately our operations were terminated at this point. A disgruntled employee of the contractor telephoned the police that we were digging up dead people. Local ordinances forbid the removal of human remains without a special permit. We hurried home just ahead of the cops."

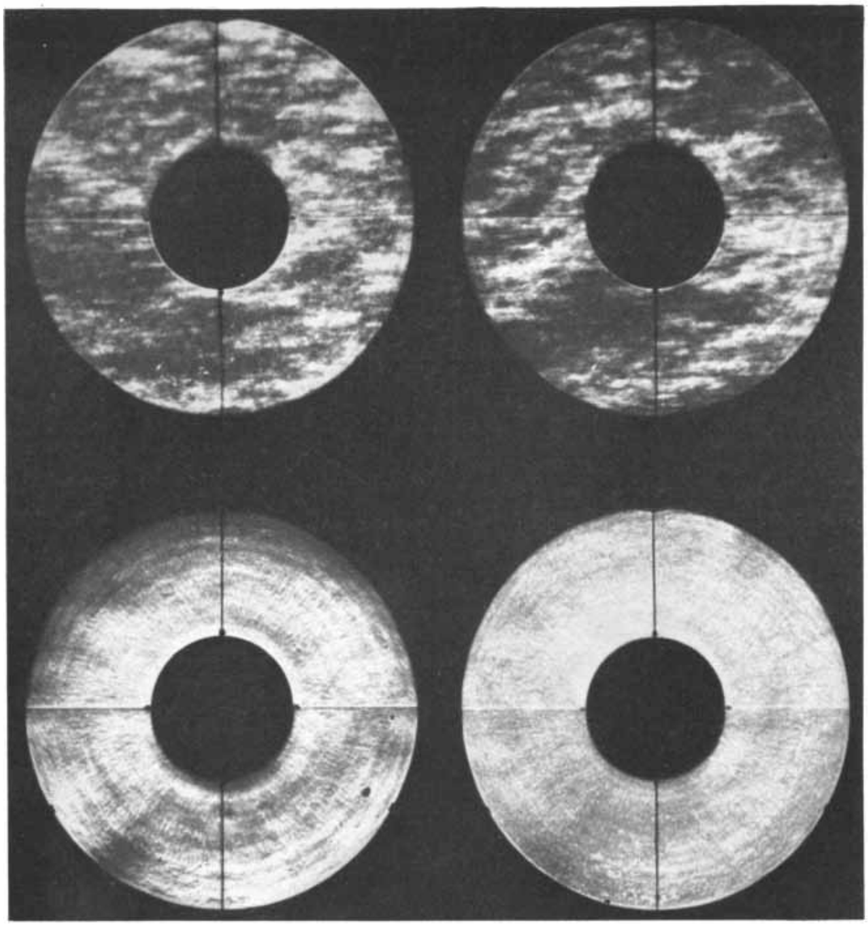
Dr. Kazimiroff is strongly attracted by the so-called "banner stones" of the Indians. These curiously shaped artifacts are peculiar to North America and are found east of the Mississippi from Florida to the interior of Quebec. Generally they are made of relatively soft stone and range in shape from flattened ellipsoids to fantastic winged forms. All share a common feature: they are pierced by a finger-sized hole which extends through their long dimension. From the study of banner stones left in progressive stages of manufacture, it appears that the hole was made by feeding sand and water to a drill made of a hollow reed and rotated between the palms.

Students of Indian lore used to think that the banner stones were primarily ornamental and were fitted onto a shaft and waved like a banner. But this early hypothesis is not supported by evidence, Dr. Kazimiroff says. A. C. Parker, of the University of the State of New York, pointed out that the stones might have been used as flywheels on pump drills. There are forms in the shape of a pickax which could have been used as supports for pipes or, as some insist, as knitting needles for making nets. Dr. Kazimiroff suggests that any of the stones would serve admirably as a tool for dressing and rounding the shafts of arrows.

"It is most interesting and challenging," he says, "that nearly all these strange artifacts were made either prior to or immediately following the advent of the white man in North America. Banner stones belong to the prehistory of the Indian. It would seem that either some object from Europe replaced it or the intrusion of Europeans so modified the delicately balanced culture of the Indian that his banner stone became obsolete. Some day the puzzle of these stones may be solved.

"They have already shed some light on the Indian's ways. For example, in 1932 my friend John Johnson picked up a fragment of dark green soapstone on a beach along the Sound just north of the Bronx. It seemed to be part of a banner stone, because one edge bore a section of the characteristic hole. In 1939 the two of us were walking along the same beach when John stopped suddenly and began staring over my shoulder. When you are out with John, it is

*Dr. Kazimiroff excavates a skeleton*



*Knife-edge tests made at the focus of the 200-inch mirror*

easy to get the feeling that this 'differential perception' business can be carried too far; his practically verges on the supernatural. But this time instead of turning in the direction he was looking I happened to glance down at the sand between his feet, and there was the upturned end of a beautiful dark green stone. I gave him a mighty shove, stooped down and claimed it. We brushed the sand away carefully, made our notes and then lifted the stone for examination. It was the bottom half of a banner stone. Its color reminded us of the fragment Johnson had found seven years before. That night we fitted the two pieces together and they matched! We have a local rule that the fellow who finds the biggest piece of an artifact takes possession of the whole thing. So John gave his fragment to me. I now had the bottom half and one upper quarter. In 1942 Ralph Robertson, another member of our gang, was casually combing the same stretch of beach and chanced to pick up the remaining fragment, about 200 feet from the point where I had made my find. The collection of this particular artifact thus spanned 10 years and represented the work of three persons.

"Now that we had the complete stone, what did it tell us? We knew that this variety of soapstone occurs only in a relatively small region of New England. Thus its presence on a beach near the Bronx indicated trade between the Indian tribes of New England and those of New York. If all those who picked up artifacts manufactured from this and similar rocks would make accurate notes and inform others of their finds, the growing accumulation of data might one day enable archaeologists to map these ancient trade routes. Many routes, of course, have already been determined approximately by this method.

"I would give a great deal to complete the assembly of a certain banner stone in my collection. Its workmanship is the most beautiful I have ever seen. Doubtless it is of Algonquin origin, for the stone work of these quiet people was far superior to that of the warlike Iroquois. Howard Smolleck picked up the first fragment of this kind. In 1937 three of us, including Johnny Johnson, packed our sleeping bags and other gear for a weekend on Staten Island in the neighborhood known to residents as 'Indian burial ridge.' The abundance of sea food had made this seaward region a favorite site for the Algonquins for many centuries—and hence a happy hunting ground for us. By late afternoon of the final day each of us had picked up three or four arrow points, but nothing of particular interest. Then Howard, who was off by himself, spotted a yellowish bit of stone that looked like a triangular chip from the unglazed edge of a dinner plate. We decided it was doubtless part of a banner stone, but one feature puzzled us. A tiny indentation, a sawtooth-like depression, marked one corner. This set us really scouring the area. A little later Johnny found a second fragment, but it did not fit with Howard's piece nor carry the strange marking.

"In 1940 near the same location I discovered two large notched sections, and one of them fitted with Howard's fragment. We visited the site many times after that, but without luck. Then one dull, threatening day in 1942 I spent several hours there all by myself. A few sprinkles were enough to start me home. When I reached the ferry that connects Staten Island with Manhattan I learned that fog had halted traffic on the lower bay and to kill time I strayed over to the Staten Island Museum of Arts and Sciences for a chat with the curator. He was occupied with a visitor. Browsing by myself through some of the display cases, I found a chip that looked as though it belonged with our banner stone. I asked the curator for his records on the chip. Sure enough, it had been found right on our spot—half a century before. The curator insisted that I take it home with the compliments of the Museum. It proved to be the missing link that tied all our fragments together. You might call this an example of successful field work inside a museum! Two large sections of the opposite wing are still missing. We often wonder if they are buried beyond recovery in the field or, almost as bad, gathering dust among the curios of some souvenir hunter. Perhaps another half-century will turn them up. If so, we may some day crack the riddle posed by those challenging notches."

Dr. Kazimiroff recently took us on a personally conducted tour of his collection. It is largely housed in the oversized basement of his home, along with a shop fitted out for cleaning and processing specimens. One display case drew our attention. It held a row of skulls, and we could not help noticing that the teeth had been treated with special care. We asked the doctor for his professional opinion of the Indian's oral pathology.

"I can tell you this much," he said, "if folks today had teeth like theirs, I'd have to become a full-time archaeologist or starve!"

RECENTLY Ira S. Bowen, director of the Mount Wilson and Palomar Observatories, reported in the *Journal of the Optical Society of America* some fresh and interesting information on difficulties that were experienced in adjusting the mirror of the 200-inch telescope.

"The first of the difficult optical problems encountered in the construction of this instrument," he wrote, "arose from the great size of the 200-inch mirror, combined with the fact that it must retain its figure in all orientations and when exposed to the temperature changes of the outside air at night. Thus it can easily be shown that the flexure of a circular disk under its own weight varies directly as the fourth power of its diameter and inversely as the square of its thickness. Even if one follows the usual practice of keeping the mirror thickness a constant fraction of the diameter (normally about one eighth), the flexure increases as the square of the aperture. Likewise the problems caused by thermal distortion increase rapidly with the size of the mirror, since the time required for a mirror to come to thermal equilibrium after its surroundings have made a sudden change in temperature varies as the square of the thickness of the mirror.

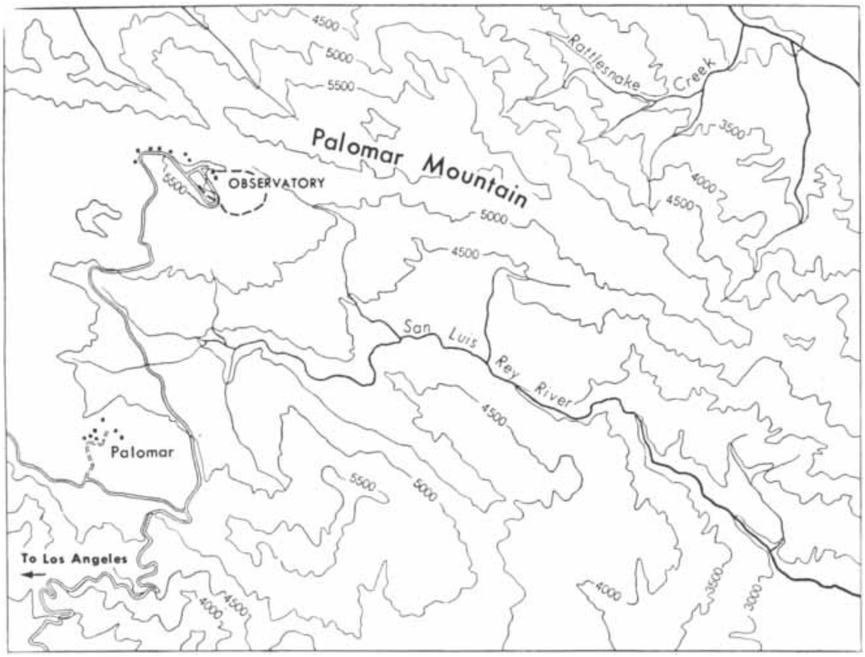
"In order to attain a maximum stiffness with a minimum weight, the 200-inch mirror was cast with a ribbed structure. The over-all thickness of the structure is 24 inches, while the maximum thickness of any section is only four or five inches. This of course has the added advantage that the time of reaching thermal equilibrium is reduced by a factor of about 25 compared to a corresponding solid disk. To decrease thermal effect further, Pyrex glass was used rather than ordinary plate glass.

"In spite of these efforts, however, the 200-inch mirror is a very flexible mirror, compared to most small mirrors. Thus its flexure under its own weight is the same as that of a 60-inch mirror one seventh of an inch thick. Given the conventional three-point support, it would deflect 500 to 1,000 times the permissible amount. Obviously it was necessary to provide a very elaborate support system to eliminate distortion as the telescope moves from one position to another. For this purpose the mirror was laid out in 36 approximately equal sections, each centered about one of the 36 circles in which the ribs meet. For each of these sections a balance-type support was provided. The supports were so designed as to supply, in all orientations of the mirror, components of force, both normal and parallel to the surface of the mirror, equal to the corresponding components of the gravitational pull on the section of the mirror assigned to the support. It was found necessary to design this support system to balance the gravitational forces with an accuracy of .1 to .2 per cent. In operation the mirror floats on this system of balances. Three of the balances located at 120-degree intervals in the outer row are locked in position to define the mirror.

"It is therefore obvious that for very large mirrors of this type the support system must be considered as an integral part of the optical unit. The only significant tests of the mirror are those in which the mirror is resting on its support system in the range of orientations in which it will be used in the telescope. It was therefore necessary to do the final figuring of the mirror in the dome on the mountain, on the basis of tests made under these operating conditions. This in turn required the use of a star as a source, which introduced the various complications that arise from 'seeing' conditions caused by turbulence in the atmosphere. Thus if one takes an instantaneous photograph of a knife-edge test on a large mirror using a star as a source, one sees the pattern shown here [*see upper two photographs on the opposite page*]. In general, this schlieren-type pattern of the air turbulence is moving very rapidly across the field with the velocity of the upper air currents. Such a pattern therefore covers up all but the grossest knife-edge effects caused by errors in the mirror surface. If, however, instead of making visual observations or taking short exposure photographs, one uses a much fainter star so that exposures of 20 to 80 seconds are required, it is found that the turbulence pattern gives a very good representation of the mirror errors [*see lower photographs on the opposite page*].

"The grinding and preliminary figuring of the mirror was carried out in the optical shop in Pasadena between 1936 and 1948. This work was done by Marcus Brown working under the supervision of Dr. J. A. Anderson. During this period


*A commemorative stamp and the postmark of Palomar Mountain*




*Topographic map of Palomar Mountain*

all tests were made with the axis of the mirror in a horizontal position. The mirror was moved to Palomar Mountain in November, 1947. After nearly a year and a half of adjustment and modification of the support system the final figuring was carried out by Don Hendrix. A total of only nine hours of polishing was required for the final figuring on the mountain. The accompanying tests, however, took a total of five months. By providing for this adjustment of the support system, followed by final figuring on the mountain, we were able to avoid the difficulties that have been encountered in some large reflectors in which the performance in astronomical work was much poorer than that promised by the laboratory tests."

WITH seeming logic on their side, many writers and periodicals have recently renamed Palomar Mountain "Mount Palomar," obviously to parallel the name of Mount Wilson. The Observatory's astronomers insist on calling it Palomar Mountain. Which is correct? The answer depends upon the answer to another question. Has the outside world a right to change a long-established geographical name against the will of the local residents?

Palomar means dovecote. The name was given the mountain by the early Spanish settlers. From about 1860 to 1880 many people called it Smith Mountain, after "Long Joe" Smith, a rancher who lived on it until he was murdered by a ranch foreman infatuated with Smith's Indian wife. Between 1880 and 1900 the name Palomar regained equal currency with Smith. The Ninth Annual Report of the State Mineralogist in 1889 called it Palomar Mountain.

In 1900 the several dozen residents of the mountain top petitioned the U. S. Board on Geographic Names for the restoration of the original name, and asked that the local post office be renamed from Nellie (the name of the postmistress) to Palomar Mountain or Palomar. The U. S. Board on Geographic Names, established by Congress to provide a central authority for standardizing geographic names and their spelling for official use in the Federal Government departments, approved the name Palomar and disapproved Smith. The Board's peculiarly punctuated decision read: "Palomar: mountain . . . (Not Smith.)." Following this ruling, the U. S. Geological Survey's local topographic map in the edition of 1903 designated the mountain as "Palomar Mt."

All this took place years before the Palomar Mountain Observatory was thought of. Thus the name Palomar Mountain was not given to the mountain by the Observatory. Nor has the Observatory wished to change the name even if it could. J. A. Anderson of the Observatory wrote some years ago: "We sincerely hope that Palomar Mountain will always retain its present beautiful name."

In 1948 the U. S. Post Office issued a special three-cent stamp depicting the dome of the 200-inch Hale telescope and designating it as Palomar Mountain Observatory. Clean and simple in design, this azure blue stamp, shown on the preceding page, as canceled at Palomar Mountain, Calif., has uncommon artistic merit, and is prized by philatelists for additional reasons.

Palomar Mountain is not a typical mountain peak but a rectangular fault block of crystalline rocks six miles across at the top, thrust up about 4,000 feet above the surrounding country. Its top is a rolling plateau. The Palomar Mountain post office lies near one edge of the plateau. The small and unincorporated hamlet or concentration of houses near the post office is designated as Palomar on an Army Map Service topographic map issued in 1942. The post office near the hamlet of Palomar serves about 25 families in the locality during most of the year and several times as many in summer when the tourist cabins are filled. The observatory is at the center of the plateau, three miles from the village.

Adalind S. Bailey, postmistress at Palomar Mountain, points out that "'Palomar Mountain' has dignity and character, which 'Mt. Palomar' lacks, besides which Mt. Palomar is incorrect."

It has often been said that the name Palomar Mountain is irregular and eccentric because the generic word "mount" should properly precede the name of a mountain. A check of the names of the U. S. peaks of 13,500 feet elevation and over, most of which are in the Rockies and Sierras, shows that only 24 are called "Mount," while 59 are named "Mountain." Such names as Bald Mountain, Pole Creek Mountain, Rolling Mountain, Fisherman Mountain and Table Mountain would sound peculiar if they were reversed. Two famous mountains in Georgia are Kenesaw Mountain and Stone Mountain. If non-residents should call these Mt. Kenesaw and Mt. Stone the residents of Georgia might blow up higher than Everest Mountain.

There is no logic about names.

PATRICK MOORE is secretary of the part amateur, part professional British Astronomical Association's Lunar Section, of which H. P. Wilkins, author of the 300-inch map of the moon, is the director. Moore, with the collaboration of Wilkins, has written a book titled *A Guide to the Moon*, and W. W. Norton and Company has published it ($3.95). Though it assumes no knowledge by the reader of lunar science (selenology) it proceeds well into the study of the moon's mapped detail (selenography). It contains a simple map of the moon, with a feature-by-feature description of its surface, by the use of which a selenologist may become a selenographer. Because of its more advanced chapters on the lunar atmosphere (one 10,000th as dense as that of the earth), on the origin of the craters (volcanic), on the surface changes (some of which are accepted by Moore), on life on the moon (scanty and primitive), on the other side of the moon (about like this side), and on future journeys to the moon (realistically discussed), a selenographer will find it a worthwhile addition to his library. Moore is now helping Wilkins prepare a complete description of the lunar surface based on the 300-inch map, to be published within the year.

# INDEX OF ADVERTISERS

*JULY, 1953*

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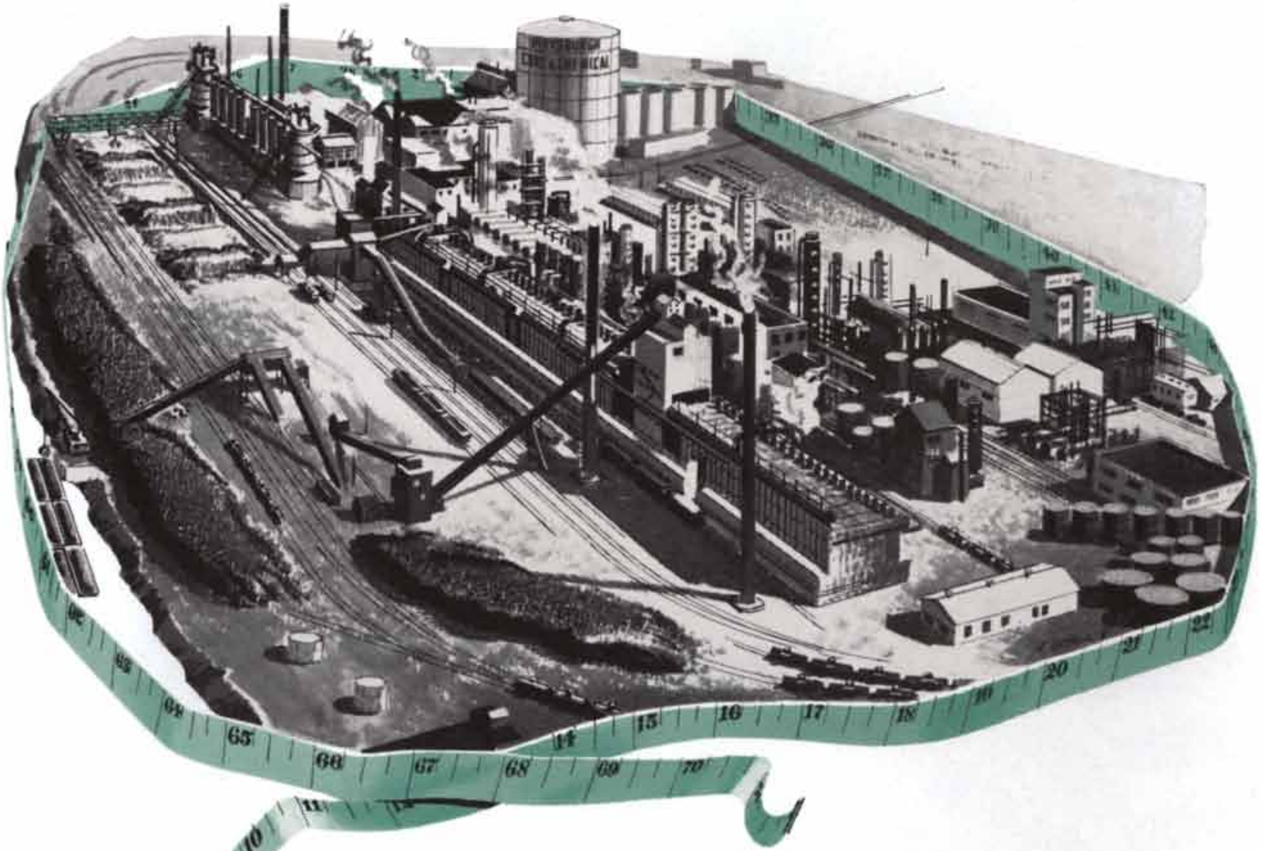

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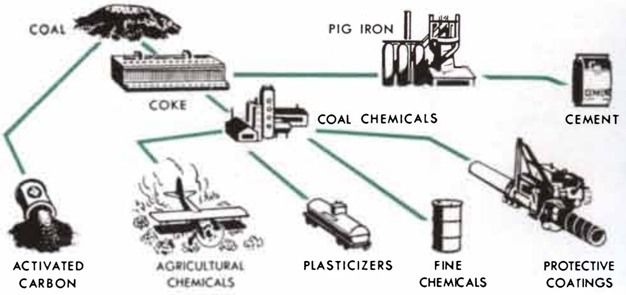


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