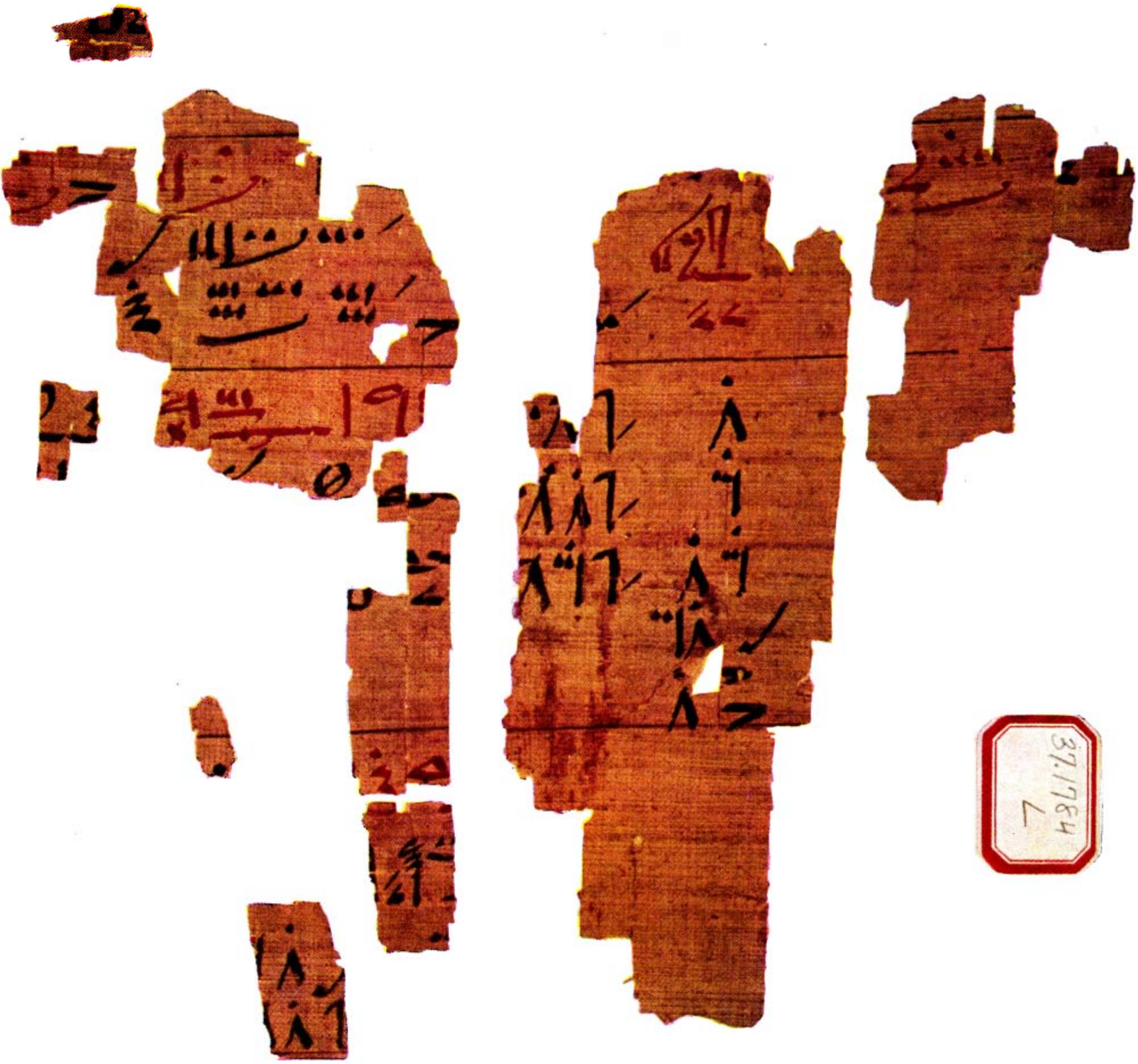
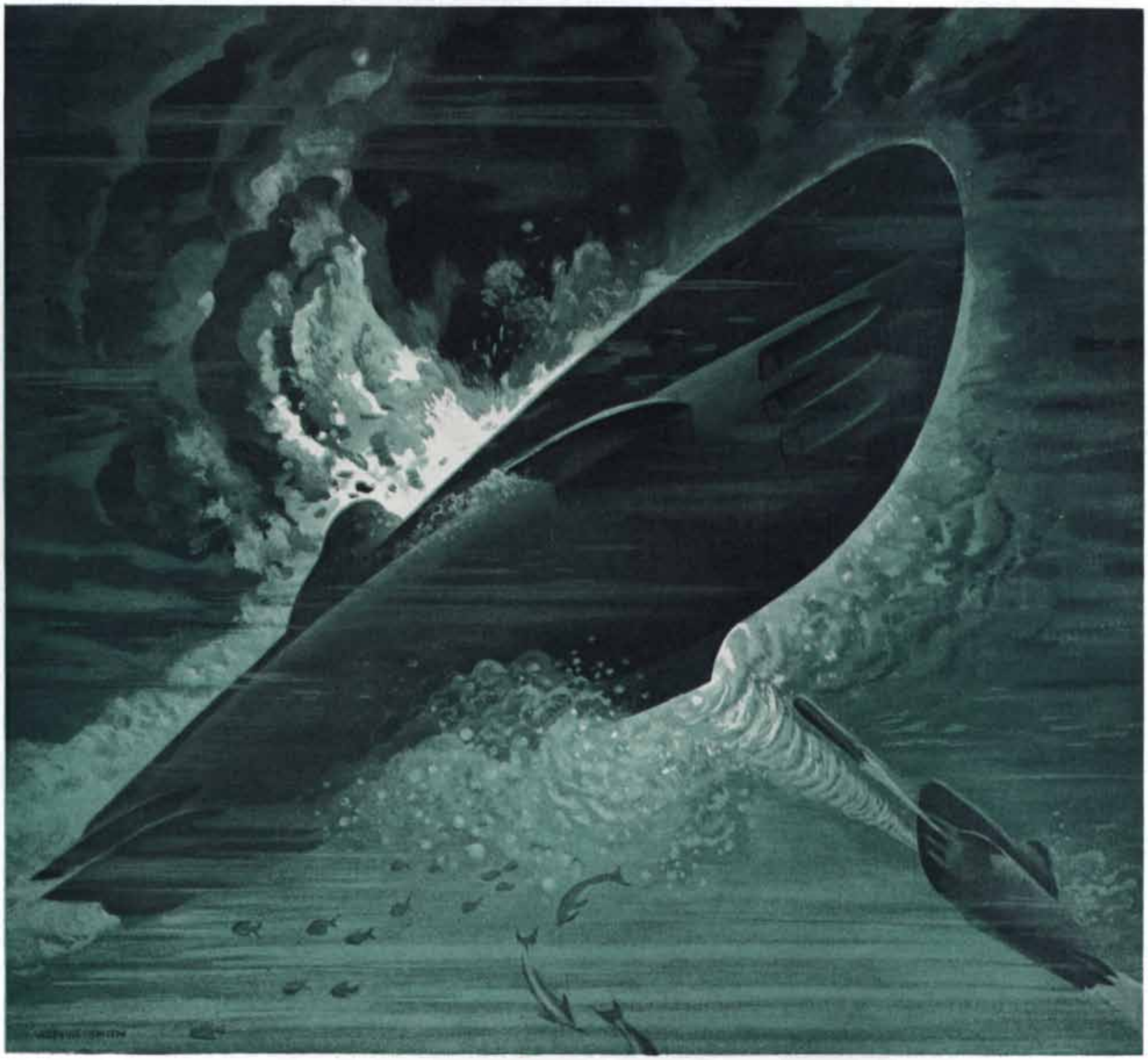
SCIENTIFIC AMERICAN



MATHEMATICAL PAPYRUS

FIFTY CENTS

August 1952



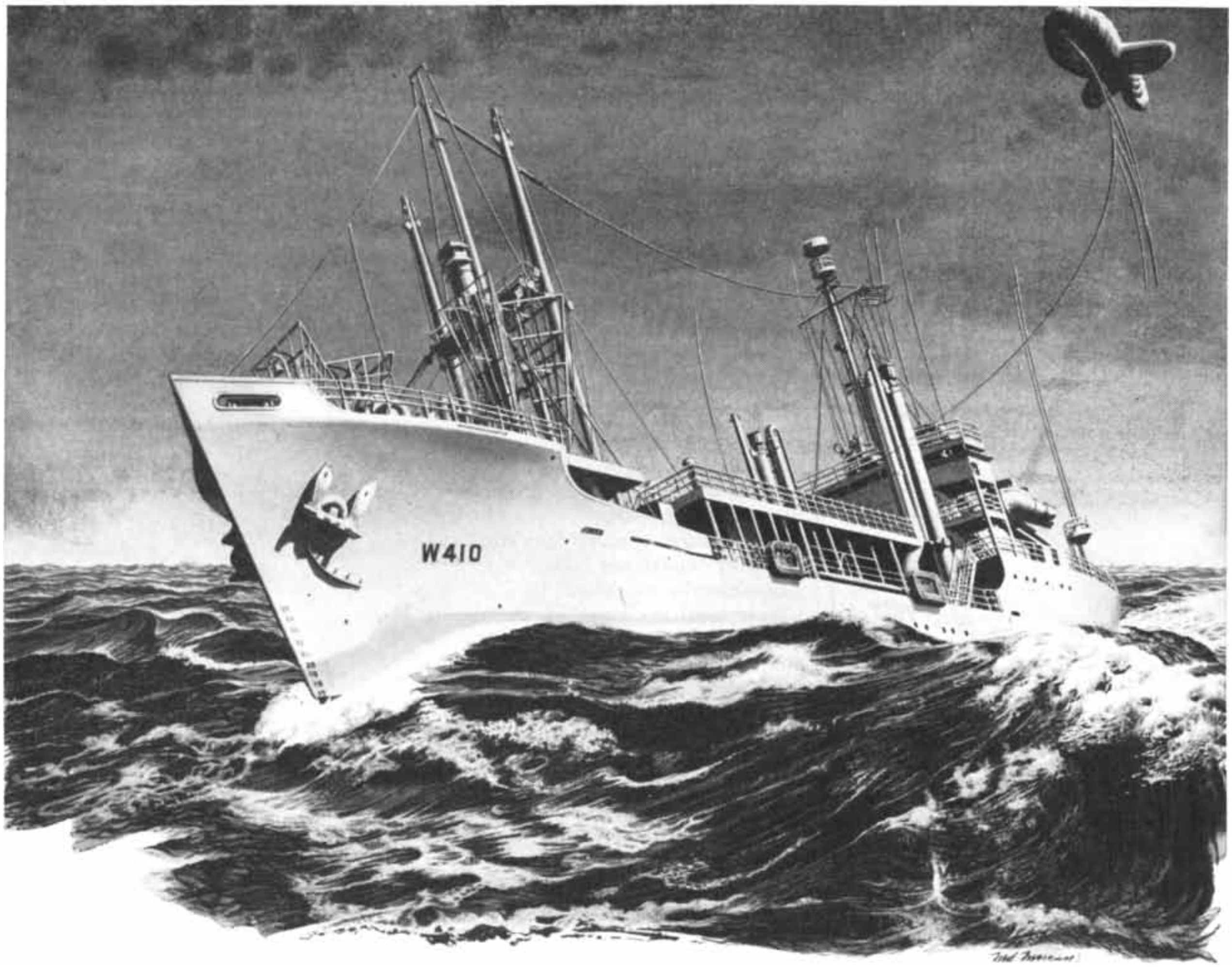
Deep-sea dog fight

Our sea battles of the future may be fought by high-speed submarines on the eeriest battleground of all time—deep beneath the sea. For the first time in naval history submarines are now being designed expressly to track and destroy other submarines while totally submerged.

The detection and missile-guiding systems which make this possible are the result of bringing the magic of electronics to problems of automatic control and computation too complex for rapid solution by man. Working closely with the Armed Forces for 34 years, Arma Corporation has played a leading part in this field in basic research, design, development and production.

Electronics provides a whole new arsenal of defense weapons. In important areas of this field Arma is pacing the developments. *Arma Corporation, Brooklyn, N. Y.; Mineola, N. Y.; Subsidiary of American Bosch Corporation.*

ARMA ADVANCED ELECTRONICS FOR CONTROL



The *U.S.C.G. Cutter Courier*—armed with Truth, not guns—will use its RCA transmitter to beam messages of hope to Iron Curtain countries, and will also be a good-will ambassador to the free nations.

Freedom's clear voice goes to sea

When broadcasting Freedom's message to Iron Curtain countries, transmitters must contend with deliberate radio interference, created to "jam" the air. Aboard the Truth Ship *Courier,* a powerful RCA transmitter fills most of one cargo hold, while a second hold contains Diesel generators which produce 1,500,000 watts of electrical power. Amidship, a special deck is the launching platform for a barrage balloon which carries the antenna high aloft.

In operation, the *Courier's* radio voice will follow regular schedules, so that listeners—often tuning in at serious risk—will know when broadcasts are coming through. These people are seeking to learn the Truth, and want to hear it despite the thousand jamming stations built in an effort to keep Freedom's messages from penetrating the Iron Curtain.

Development of broadcast equipment for use on land and sea is only one example of RCA pioneering in research and engineering. It is your assurance of finer performance in all products and services of RCA and RCA Victor.

* * *

See the latest in radio, television, and electronics in action at RCA Exhibition Hall, 36 West 49th Street, N.Y. Admission is free. Radio Corporation of America, RCA Building, Radio City, New York 20, N.Y.

RCA

Radio Corporation of America

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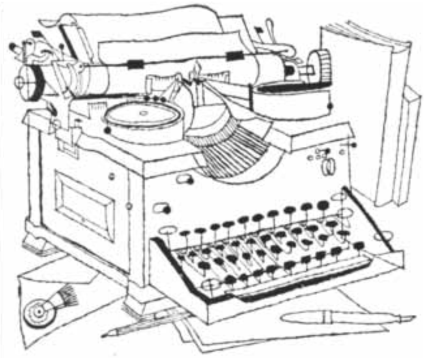

LETTERS

Sirs:

I read with great interest Mr. Ingalls' account of ruling engines, and I appreciate his kind remarks about the Mount Wilson gratings. The article conveys admirably a feeling for the difficulties of the ruling art, particularly as they existed a decade or more ago. Mr. Ingalls failed to emphasize, however, that the difficulties he discussed have by now largely been overcome by the application of accumulated experience and modern materials. Sound engineering principles, aimed always at maximum simplicity of the fundamental parts, together with skilled workmanship, have yielded consistently satisfactory results. No longer need a properly designed ruling engine be regarded as possessing a capricious personality, as in the days of Michelson.

Of Mr. Ingalls' "seven demons," friction and wear were by far the worst; they have been exorcised by the use of Graphitar slider bearings operating on hard-surfaced, stress-free Nitralloy steel ways (in particular, a cylindrical monorail for the reciprocating diamond carriage). With these ways and a rigid, normalized base-casting resting on a three-point support, warpage and creep present no serious problems. Vibration is avoided by mounting the accessory driving mechanism on a separate foundation, and by a design in which only the lightweight diamond carriage reciprocates. In a properly fitted nut and bearings, dust cannot enter to cause trouble, and in these days temperature control is a minor problem.

The newer and better of the Mount Wilson ruling engines (operating at a speed of 18 to 24 grooves per minute) has produced to date 65 gratings, of which one of the largest (8 by 5 inches) is providing in current research a resolving power of 600,000. Occasionally the edge of the ruling diamond may fail to maintain a perfect groove-form throughout the several miles of ruling on one plate; in other respects, a failure is now rarely experienced.

While the older and larger Mount Wilson machine is not capable of ruling with the precision of the newer one, it has produced some 85 gratings, many of which have contributed greatly to astronomical research. Several of these are still in use; its most recent product is a single grating 18 inches square. Therefore it hardly seems necessary to refer to this machine as a "failure."

H. W. BABCOCK

Mount Wilson and Palomar Observatories
Pasadena, Calif.

Sirs:

In my article I wrote that the best of the 8-by-5-inch Babcock gratings are the finest in existence today. Even more could be said: they are practically perfect. The distinction is that heretofore nearly all of the best of the world's gratings have been faulty to quite a considerable degree.

In his letter Dr. Babcock describes the high quality of his 8-by-5-inch gratings ruled on the newer, smaller engine but says nothing about the quality of the 18-inch grating recently ruled on the older and larger engine. To many this might imply that the problem of the very large grating had at last been dramatically solved, an event that would electrify the world of physics. I have been told, however, that the 18-inch grating is a special type, with larger tolerances than the conventional grating and with widely spaced grooves on Lucite for use on a Schmidt camera.

In his own article in the *Journal of the Optical Society of America* Dr. Babcock wrote that the older and larger Mount Wilson engine produced the grat-

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Fishermen used to have a devil of a time hooking fish like this in the hot summer time.

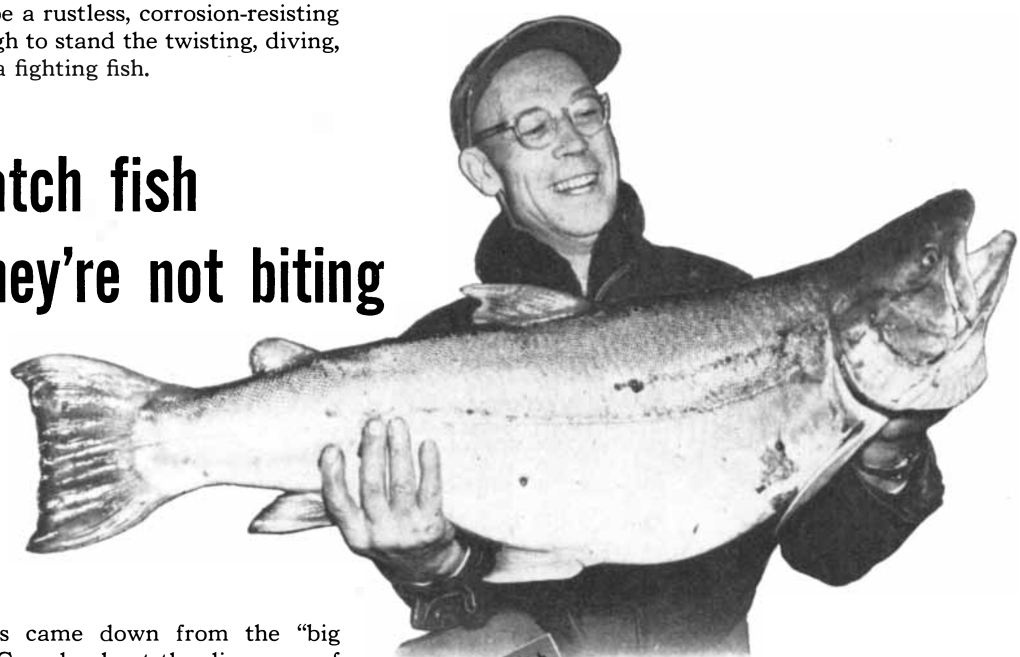
Trouble was that big fish like to stay way down on the cool lake bottom. Ordinary trolling line just wouldn't go down there.

All sorts of gadgets were tried. Trick sinkers and attachments were devised to get the hook down where the fish could grab it. The lines themselves were cored with heavy substances to make them sink.

Finally, *metal* lines were given a trial. They went down all right. But other difficulties came up. They were too heavy. Too thick, too awkward altogether. To be flexible enough for easy handling, the wire line had to be light and fine. To be fine, the metal had to be very strong.

It also had to be a rustless, corrosion-resisting metal . . . and tough to stand the twisting, diving, leaping yanks of a fighting fish.

How to catch fish when they're not biting



Then the news came down from the "big muskie" lakes of Canada about the discovery of a line that has revolutionized deep trolling from mountain lakes to coastal seas: MONEL Line.

Today, wherever you see fresh water and salt water fishermen trolling for the big ones 'way down deep, you find them using Monel lines... and catching the biggest fish in the hot summer months when fishing used to be "dead."

New World's Record! Nelson Higgins, of Pullman, Wash., beat the previous world record by nearly three pounds when he caught this 32-pound Dolly Varden at Lake Pend Oreille, Idaho, on Monel line.

If you are interested in fishing, you'll want to write for your free copy of "How To Catch Fish When They're Not Biting." It contains 44 pages packed with tips and useful information. Address Fishing Editor, The International Nickel Co., Inc.

When you need help...

Like the fishermen, you too may face metal selection problems.

When you are up against a situation where the right metal may protect the "fine line" of *your* production, Inco's engineers may be able to help.

Why don't you write them today and outline your problem? Just send the details to *Forward Planners* at International Nickel Co., 67 Wall Street, New York 5, N. Y.

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ings he now mentions in his letter, "the largest of which is of eight-inch size," and continues, "This machine has failed to produce larger gratings of high quality. . . ." I therefore supposed I was safe in writing, not that the machine was "a failure," but that it failed in ruling gratings wider than eight inches. That is, it failed on the larger sizes for which it was primarily built. I should, however, have mentioned the 85 smaller gratings it did contribute to science.

ALBERT G. INGALLS

Cranford, N. J.

Sirs:

In your mention of our work on cis-trans isomers of vitamin A in vision in the June issue, there were several errors. In your department "Science and the Citizen" you say that "George Wald of Harvard University reported further progress in his studies of the biochemistry of vision. . . ." The experiments were performed by Dr. Ruth Hubbard and myself, and were reported at the meeting of the Federation for Experimental Biology by her. They show that to synthesize the light-sensitive pigment of rod vision, rhodopsin, in a purified enzyme system, a specific cis-isomer of vitamin A is needed. Presumably the same is true in the living organism.

In spite of our efforts to guard this situation from being misinterpreted, it has already caused considerable confusion. This comes from carrying over statements about the efficacy of vitamin A in an enzyme system which synthesizes rhodopsin to statements about the nutrition of the whole animal. Ordinary crystalline vitamin A, which is the all-trans isomer, and synthetic vitamin A—again primarily the all-trans isomer—are ineffective in our enzyme system. This is not to say, however, as does your correspondent, that they do not cure night-blindness.

The point is that vitamin A isomerizes in the body. It probably is true that any isomer of vitamin A taken in the diet is converted in the body to the same mixture of all possible isomers. For this reason, it is not necessary to eat the specific isomer of vitamin A that forms rhodopsin, to make it available in vision.

Small differences have been detected in the nutritional effectiveness of certain geometrical isomers of vitamin A fed to rats, but they are so small as to have little practical significance. Pending more exhaustive tests, it seems safe to assume that the inclusion of any vitamin A isomer in the diet will fulfill all the nutritional needs for this vitamin.

GEORGE WALD

Harvard University
Cambridge, Mass.

50 AND 100 YEARS AGO

AUGUST, 1902. "E. Rutherford and F. Soddy find that the radioactivity of thorium compounds is the consequence of changes in which new types of matter are formed, and they conclude, therefore, that it is a manifestation of subatomic chemical change."

"The most recent theory of electrolysis is that advanced in 1887 by the Swedish scientist Arrhenius. According to this theory, some of the molecules of a dissolved electrolyte are, by the mere process of solution, already dissociated into ions, the degree of ionization increasing with increased dilution. He justified such a radical hypothesis by calling attention to the fact that many gases show apparent variations from Avogadro's law, and that this variation is generally explained by assuming that such a gas undergoes dissociation. Naturally a theory embodying such radical conceptions met with great opposition. Chemists are reluctant to accept the idea of, for example, free Na and Cl in a solution of sodium chloride. Moreover, objection was made that the theory rested on a rather slender experimental foundation. Nevertheless, the theory is gradually being accepted by scientists. It furnishes a satisfactory explanation of many phenomena, and its very able exponents have adduced much evidence tending to establish the theory."

"In the United States the use of narcotic plants is confined mainly to tobacco smokers, but it is interesting to note that the use of Indian hemp is spreading throughout the Southwest. The effect of this drug is well known from accounts published in the daily press and elsewhere. The common Mexican name of the plant is *mariguana*. It is not uncommonly asserted by Mexicans that sometimes a single dose of hemp will cause long-lasting insanity. Van Hasselt, a Dutch authority on poisonous plants, also asserts that a single dose of this drug may cause mania for months, but the best pharmacologists are agreed that such might be the case only when the person affected is already badly diseased by the use of drugs or otherwise. The Department of Agriculture is at present engaged in an investigation of the curious behavior of these weeds."

"Yellow fever, tropical fever, 'yellow jack,' or 'black vomit,' is the most serious of the diseases that prevail in tropical countries. There is no doubt that it is a contagious disease; but the cause of it is not well understood. Since we are certain of the epidemic and contagious character of the disease, our ignorance as to the exact nature of its parasite does not prevent us from endeavoring to ascertain what may be the methods and processes through which it is transmitted. The question at present seems to be pretty nearly solved, owing to the experiments made last year by the American Commission in Cuba. It seems to be established that it is the mosquito that propagates the disease to the healthy subject and thus serves as a go-between to the contagion. The result of these researches may be given in a few words. Nearly all the subjects who were bitten by the contaminated mosquitoes contracted the disease. Inversely, all those who, duly preserved from the bite of the mosquitoes, exposed themselves to the common causes up to then invoked, such as lying upon bedding soiled by the dejecta of patients in an imperfectly ventilated room at a moist heat of 33 degrees, remained proof against the disease."

"X-rays can burn the tissues, setting up some yet obscure form of electrolytic action. It is claimed strenuously by good authorities that there is a healing action in malignant skin diseases, due to this new electrical radiation."

"To point to the hurry and stress of modern town life as the cause of half the ills to which flesh today is heir has become almost a commonplace in etiological diagnosis. The old-fashioned complaints might almost excite a medical man's pity, so much do they seem to be crowded out by those active widespread young fellows, neuritis, neurasthenia and a whole young family of nervous illnesses, the offspring of the strained existence of today. We may imagine future generations perfectly calm among a hundred telephones and sleeping sweetly though airships whiz among countless electric wires over their heads and a perpetual night traffic of motor cars hurtles past their bedroom windows. As yet, it must be sorrowfully confessed, our nervous systems are not so callous."

AUGUST, 1852. "It is said that since the completion of the railroad through Northern Indiana, the wolves which came from the north, and were

Ceramics and Man through the Ages

Cretan Commercial Ceramics

Centering in the commercially powerful island of Crete, the Aegean Civilization (3000-1200 B.C.) marked the transition of culture from Asia to Europe. The Cretans were taught the use of pottery wheels by Egyptian craftsmen, and attained distinction in nearly every form of the potter's art.

The Cretan potter developed a glaze rivaling the consistency and delicacy of porcelain, mastered the technique of faience, and in his most perfect product, the graceful "egg shell" Kamares ware, dared to thin the ceramic walls to a millimeter's thickness! He signed his name to his work, and his trademark was highly sought throughout the Mediterranean world until the end of the Golden Age, about 1400 B.C. Such perfection was not seen again for nearly 1000 years.

ALCOA Alumina is widely used in the perfection of modern commercial ceramics. Added to whiteware bodies, it reduces firing deformation, increases strength, permits thinner sections, improves whiteness. It prevents sagging in glazes at higher temperatures, resists chemical attack and mechanical and heat shock. ALCOA Alumina is also widely used in optical glass and fine tableware, vitreous enamels and high-temperature refractories.

ALCOA has had wide experience in the production of aluminas to meet specific needs of the ceramic industry. This experience is available to you for the asking.

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CRETAN POTTERY
Octopus Vase, 1600-1500 B.C., Candia Museum
Palace Style Vase, 1500-1350 B. C., National Museum, Athens

For a free chemical analysis of Cretan Pottery, write to ALCOA. (Fragments for analysis, courtesy of the University Museum, Phila.)

so savage on the flocks to the south, have not been seen south of the track. The supposition is that the wolves mistrust the road to be a trap, and they will not venture near its iron bars."

"Recent experiments with the screw propeller, in the French Navy, have settled the question of the superior economy and advantages of uniting steam with canvas in vessels of war. The solution of the practicability of the application of propellers to armed sailing ships, and their adoption in the British and French navies, renders it absolutely necessary that American vessels should be provided also with this additional motive power. A conflict with a French and American seventy-four, the former using both steam and canvas, and our own vessel only the latter, would be a most unequal struggle."

"Barbers often tell us that razors get tired of shaving, but if laid by for twenty days they will then shave well. By microscopic examination it is found that the tired razor, from long stropping by the same hand and in the same directions, has the ultimate particles or fibers of its surface or edge all arranged in one direction, like the edge of a piece of cut velvet; but after a month's rest, these fibers rearrange themselves heterogeneously, crossing each other and presenting a sawlike edge. These and many other instances are offered to prove that the ultimate particles of matter are always in motion."

"A new plan for building steamers has been reported from England, and an experimental boat built to run from London to Boulogne. This boat is 235 feet long, 20 feet beam, of 250 tons burden, and has an engine of 50 horsepower. If it meets the expectations of the inventor and builders, two immense vessels of 10,000 tons and 1,000 horsepower will at once be built on the same plan. Bah, a vessel of 10,000 tons burden and 1,000 horsepower. What a piece of nonsensical news!"

"Professor Agassiz offers boys in the vicinity of Cambridge 12½ cents each for each egg of a turtle they will bring him, with care, covered with moist earth, and carried in such a way as to prevent being shaken or rolled about. The Professor is engaged in watching the growth of turtles as they are forming within the egg."

"In consequence of the prevalence of disease in the West, and along all the avenues of approach leading to the city of Cleveland, the meeting of the American Association for the Advancement of Science, appointed for the 18th of August, has been postponed for the present year by the Standing Committee."

THE COVER

The photograph on the cover shows several fragments of the celebrated Rhind Papyrus, an Egyptian mathematical document of 1700 B.C. (*see page 24*). Purchased by A. Henry Rhind in 1858, most of the papyrus is in the British Museum. These fragments, however, are in the Brooklyn Museum. They were first recognized in the famous collection of Egyptian medical papyri that was assembled by Edwin Smith.

THE ILLUSTRATIONS

Cover photograph by Keturah Blakely

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17	U. S. Department of Agriculture
19	U. S. Department of Agriculture (*top*); Dow Chemical Company (*bottom*)
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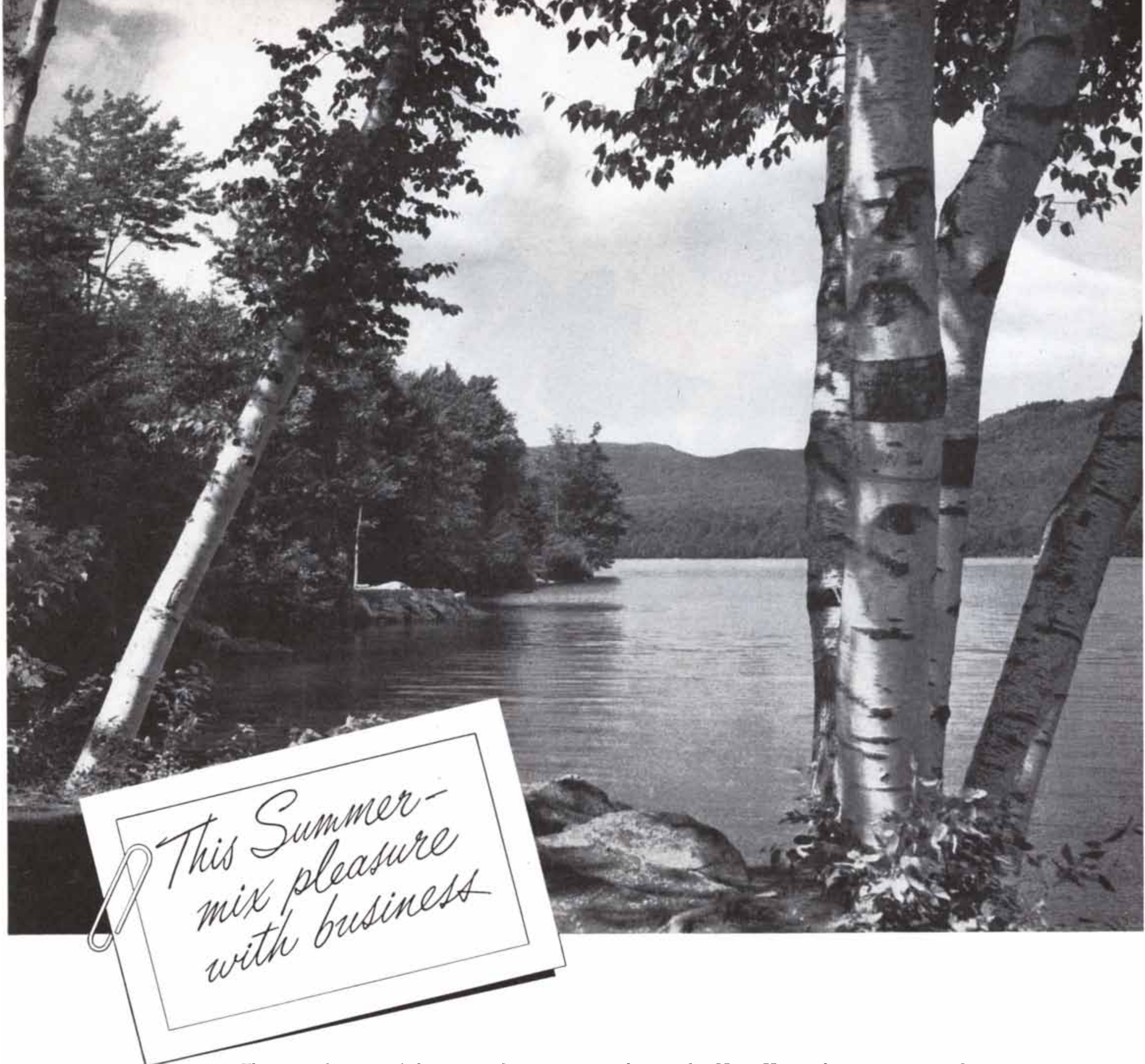

This is only one of the many beauty spots that make New Hampshire an outstanding vacation land in America. Here you can find the answer to vacation yearnings . . . seashore or mountains . . . lakes, rivers or streams . . . hunting, fishing, golf . . . or just plain "resting", New Hampshire offers them all, together with modern conveniences.

Also in New Hampshire is the Marion Electrical Instrument Company — located in one of the historic Amoskeag Mill buildings in Manchester. Not far from Boston (Mass.), on your way to the White Mountains, Manchester offers excellent stop-over facilities. To customers and friends alike we say — this summer mix business with pleasure . . . vacation in New Hampshire and be sure to visit us at Marion and see how fine instruments are made.

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marion meters

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Vaccine for cows keeps longer

because of **high vacuum**

(and so does a 2-ton Timken roller bearing)

People who make vaccines for cows and those who make giant roller bearings have a common problem—shelf life. DPi high vacuum engineering solves it for both and, strange as it may seem, in much the same way.

The common enemy is water. If the last residual traces of it are removed from such delicate stuff as vaccine powder, the shelf life increases by six times and the manufacturer's distribution costs go down accordingly.

In the case of the bearings, invisible amounts of water underneath the protective coating of petrolatum often caused disastrous and costly corrosion of the beautifully machined surface while the bearings lay waiting for a call from a steel mill. Now, at Timken Roller Bearing Company, between the cleaning bath and the storage coating bath, a 20-minute stay in high vacuum (9 microns Hg) can get rid of the insidious bit of water for sure. Bearings remain in perfect condition until ready for use.

Getting rid of troublesome traces of water, air, or other gases at the lowest possible cost is DPi's specialty. If your industry has such a problem, it's a good idea to talk it over with our high vacuum engineers. Just write ***Distillation Products Industries,*** Vacuum Equipment Department, 751 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

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SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR AUGUST, 1952 VOL. 187, NO. 2

ARTICLES

DEPARTMENTS

What's Happening at CRUCIBLE

about REXWELD hard-surfacing rod

The general use of hard surfacing consists of overlaying the work piece with a different alloy. This is done to improve the properties of a specific area of the work piece from the standpoint of resistance to abrasion, heat, corrosion, or a combination of these properties. Hard surfacing rods of the Rexweld type are ordinarily never recommended for joining, but only for overlay on such products as valves, oil pump parts, mixer shafts.

here's how REXWELD is made

Rexweld, a very high alloy material, is melted in small furnaces. It is tapped into small ladles and poured into molds in sizes of $\frac{1}{8}''$ diameter and larger. Prior to processing the rod further, each heat is thoroughly tested for weldability. After test, the rod is cut off with an abrasive wheel and ground. It may be shipped flash ground or centerless ground for gas welding. If long lengths are required for automatic or semi-automatic gas welding, the rod is butt welded to the desired length. For arc welding, the rods are coated and tested for arc weldability. After finishing,the rod is marked to identify grade and is ready to ship.

here are some REXWELD features

Cut welding time: Rexweld builds up and holds an edge better, reducing the amount of welding time.

Increase production: Rexweld flows more readily on flat surfaces. In machine gas welding operations valve companies have reported an increase in production per shift using Rexweld.

Less porosity tendency: Because of its smoother flowing and better wetting properties Rexweld has less tendency for porosity.

Better wearing quality: Tests have shown that Rexweld has better wearing qualities.

REXWELD ups die production 10 times

A well-known Chicago forging concern employs a hot-working upsetting operation that consists of upsetting a 2″ piece of round stock 4″ long to a $1\frac{3}{4}''$ thickness with a 4″ OD. This blank is then hot formed and trimmed; made ready for machining into an automotive transmission gear. Before hardfacing with Rexweld, the company averaged 4,000 to 5,000 pieces per set of upsetter plates. With Rexweld the upsetter plates turned out 45,000 pieces. Then, the plates were removed, re-hard surfaced and used again!

This concern is also using Rexweld for building up cutting edges for intricate hot-work blanking dies, such as the male and female cutting edges of a seven-fingered star-shaped die set. Due to the intricacy of the dies, it is very difficult to build up cutting edges eliminating check cracking which would cause spalling deposits, but Rexweld is doing it every day at this plant.

engineering service available

If you are looking for ways to increase the life of your tools and production equipment, or you have a problem that hardsurfacing can solve, feel free to call in Crucible. Our hardsurfacing and welding specialists can help you. Crucible Steel Company of America, General Sales and Operating Offices, Pittsburgh, Penna.

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Midland Works, Midland, Pa. • Spaulding Works, Harrison, N. J. • Park Works, Pittsburgh, Pa. • Spring Works, Pittsburgh, Pa.
National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

SCIENTIFIC AMERICAN

AUGUST, 1952 VOL. 187, NO. 2

Chemical Agriculture

Farming is being revolutionized by new fertilizers, insecticides, fungicides, weed killers, leaf removers, soil conditioners, plant hormones, trace minerals, antibiotics and synthetic milk for pigs

by Francis Joseph Weiss

IN MARCH, 1951, the Iranian Government asked the U. S. for immediate help in an emergency. Swarms of locusts were growing so rapidly along the Persian Gulf that they threatened to destroy the entire food crop. The U. S. responded by sending some Army planes and insecticide. The few planes took off with a load of about 10 tons of the insecticide aldrin and sprayed the area. The operation almost completely wiped out the locusts overnight. For the first time in history a country-wide plague of locusts, which since Biblical times has been synonymous with disaster, was nipped in the bud.

This dramatic episode illustrates better than figures the revolution that chemistry has brought to agriculture. Insect control of course is only one aspect of that revolution. Nor is chemistry in agriculture itself an entirely new thing. In the 17th century chemists and physiologists began to look for what they called the "principle of vegetation"; in the 18th century they were trying to isolate specific plant nutrients, and by the 19th century the growth of exact knowledge and the improvement of analytical methods were bringing important benefits to plant and animal husbandry. But in the past half-century there has been a great stride forward and a change in point of view—toward what may be called "chemical agriculture."

Until 1900 agricultural science was based on the idea of providing ideal *natural* conditions for the growth and reproduction of crops and livestock. Under such a theory, improvements upon nature were inevitably haphazard. In this century agriculturists have awakened to the possibilities of improving on nature, as indeed man has been doing ever since he began to till and cultivate. To work out systematically artificial means for obtaining the best possible yields—this is the new viewpoint represented by the term chemical agriculture.

As Lavoisier observed, "La vie est une fonction chimique," we are learning how to use chemicals to encourage desirable features and eliminate undesirable ones in plants and animals, to protect and improve useful organisms and to destroy or control unwanted ones. Since this new scientific approach to all branches of agriculture has coincided both with a tremendous expansion of biochemical knowledge and an almost explosive development of the chemical industry, the impact of chemical agriculture upon farm production has been enormous.

THE ELEMENTS with which we start are sun and air, soil and water. There is not much a farmer can do about the sun or air. But from the time of Adam we have dug and we have watered. First with sticks and other crude implements, then with machines cleverly devised for varying conditions, we have labored to work the soil into proper shape to hold the moisture, nourish the seed and support the crop. And where water has been scarce, we have built irrigation systems; even in the earliest times these were often of monumental scale.

What can chemistry do for the soil? Let us begin with its physical condition. Agriculture is just now taking a keen interest in the recent discovery that certain organic polyelectrolytes are 200 to

FIELD OF CORN in Kansas was stripped of leaves by grasshoppers. Such attacks can now be controlled with insecticides.

SOIL CONDITIONER was used in the greenhouse seedbed above. No conditioner was used in the bed below. After watering, untreated bed packed so the seeds could not sprout.

1,000 times more effective as soil conditioners than manure, peat moss, or plant residues. Since they are not subject to bacterial decomposition, they retain their aggregating strength much longer. A particularly effective polyelectrolyte is the sodium salt of hydrolyzed polyacrylonitrile. It is now commercially available under several trade names and promises to become a valuable tool to the farmer and gardener. The loose, granular soil that it produces encourages productivity and checks erosion.

The structure of the soil is no more important to plant growth than its content of nutrient minerals. Chemical agriculture is making impressive headway in the taxing work of maintaining the mineral balance. A number of minerals are needed and they must be present in just the right amounts—too much can be as harmful as too little. The dissolving action of the rain is constantly leaching out the soil's more readily soluble mineral salts, and cultivation accentuates this process. But the minerals can be restored to the soil by marine algae and waste products of the fishing industry, which are valuable sources of the needed trace minerals. The commercial distribution of trace minerals recovered from the sea promises to be a boon to many farming areas. They will supplement and enhance the action of the bulk minerals in artificial fertilizers.

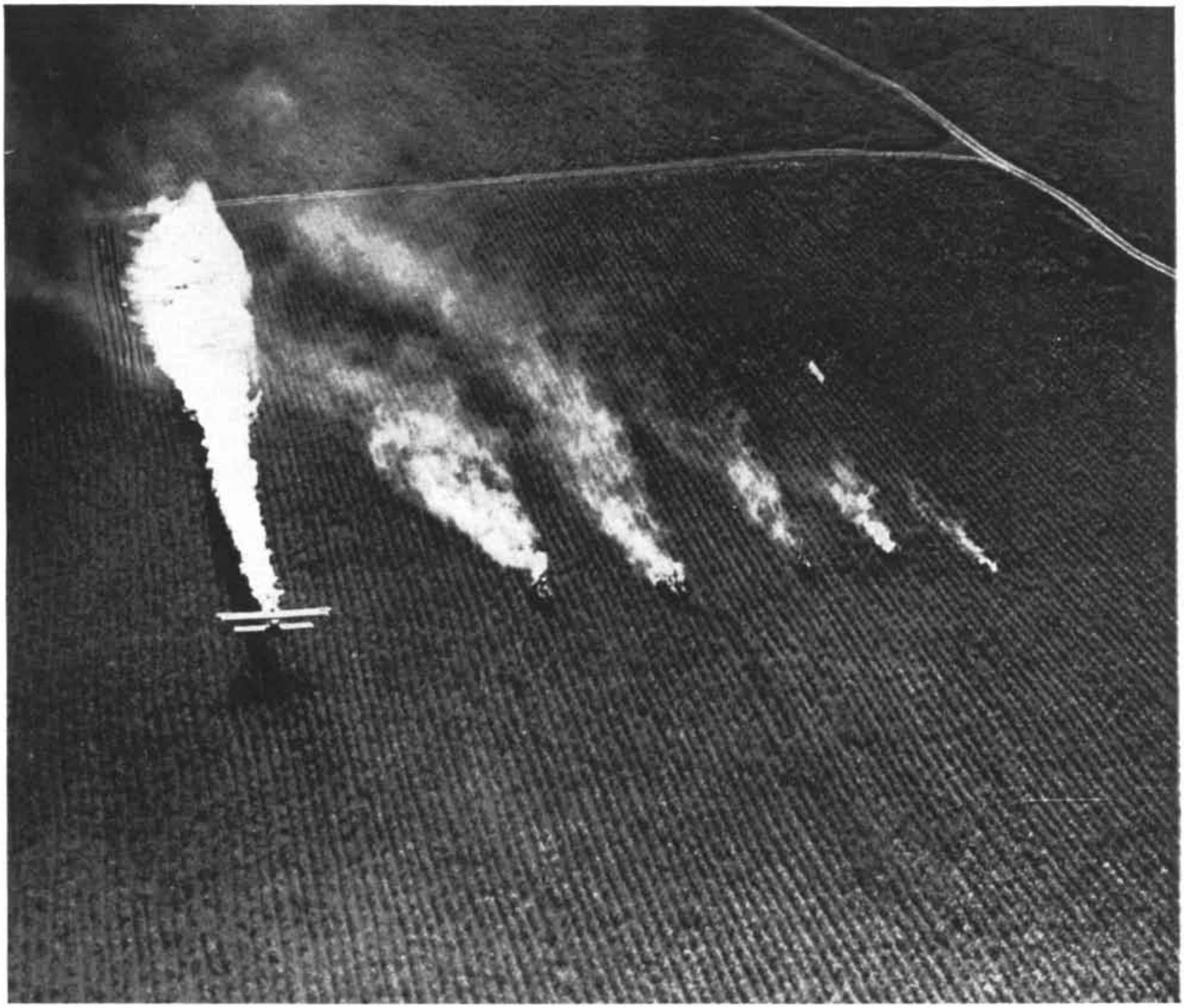
When the mineral content rises excessively, the soil may become so saline or so alkaline as to produce poorly, if at all. This situation prevails in arid regions where the highly mineralized ground water evaporates and deposits soluble salts or alkalis in the upper strata of the soil. Excessive concentrations of neutral salts such as sodium chloride or sodium sulfate develop high osmotic pressures in the soil which prevent the roots from absorbing water. High alkalinity not only breaks the soil structure down into hardpan but also lowers the free oxygen content and produces microbiologic conditions which few plants can tolerate. Irrigation in such cases only makes the condition worse, unless water of extremely low mineral content can be supplied and adequate drainage provided. Since in most areas of the world not the land but the water supply is the limiting factor, our land resources could be extended by millions of acres of good soil if only water of low mineral content were available in ample quantities.

The dream of making deserts bloom is being brought closer to realization by recent developments in the synthesis of extremely thin plastic membranes from coal-tar and petroleum chemicals. These "permionic" membranes have the remarkable capacity of demineralizing hard water—even sea water—without heat or chemicals. In the presence of a very low electric current, they split the water into two streams. Two-thirds of the flow becomes a fresh-water stream containing no salt; the remaining one-third is a brine solution from which valuable salts can be recovered. Energy consumption per thousand gallons is as low as 20 kilowatt-hours for sea water and 3 kilowatt-hours for irrigation water. If this method of water demineralization is generally adopted and sea water becomes available for irrigation purposes, the way stands open for a breath-taking expansion of the world's arable land.

IT IS USUAL to think of soil as the basic factor in crop production, but if we look closer into its physiological functions we see that they are more incidental than essential. Soil acts merely as the carrier of moisture and mineral nutrients and as a mechanical support. That these services can be provided by other means is shown not only by numerous aquatic plants but by a number of successful experiments in water, sand and gravel culture. There are sometimes considerable advantages in growing plants without soil: better nutrient control, less waste of fertilizers, elimination of diseases originating in the earth. At this stage of development it is extravagant to claim, as some scientists do, that we could feed ourselves by soilless agriculture, even if all our soil reserves were gone, but already the economic feasibility of soilless culture has been demonstrated in some areas of limited crop production and under certain emergency conditions. During the war U. S. troops on Ascension Island grew fresh fruits and vegetables in water to supplement their Army rations.

Chemical agriculture is now preparing to go a step further by using plants whose natural habitat is water to produce food on a commercial scale. The most promising organism found thus far for this purpose is the green alga *Chlorella,* which can be grown in huge tanks or plastic cylinders on minerals and gas mixtures under optimum photosynthetic conditions. If this alga were fed to other organisms of high nutritional value, foodstuffs of standard composition could be manufactured to order. But here we pass beyond the limits of agriculture into the new and unexplored field of synthetic food production.

Since time immemorial man has resigned himself to wasting most of the seed he sows. Many seeds are eaten by birds, insects or rodents or destroyed by fungi. Others cannot develop in competition with more vigorous weeds or fail to emerge through the hard crust of the soil. Knowing this, farmers sow many times more seed than they expect to harvest. Except for the tremendous waste involved in this practice, the result would be satisfactory if destruction were evenly distributed over the planted area. In practice, however,



SIX DIFFERENT WAYS of dusting cotton are shown in this aerial photograph. From right to left it is done by hand, by hand from a mule and a horse, by mule-drawn machine, by power machine and by airplane.

thin patches tend to alternate with thick ones, which must laboriously be thinned. Since World War II "pelletized" seeds, with an artificial protective coating, have become commercially available. The coating materials that have been used successfully are methylcellulose mixed with powdered feldspar and colloidal aluminum silicate (montmorillonite). Such seed pellets work well in planting lettuce, tomatoes and sugar beets, but we still do not have the ideal pelletizing material, and we are a long way from applying the technique generally in agriculture, forestry, and horticulture.

ALTHOUGH it has long been known that the growth and development of animals is controlled by hormones, the part played by these substances in plant life was only recently discovered. Plants, like animals, will respond to synthetic hormones, and numerous compounds are now being investigated for their ability to change the life processes of plants in economically desirable directions. The most spectacular chemical of this type is 2,4-D, the powerful growth hormone that kills broad-leaved weeds. The discovery of this useful property in 2,4-D has prompted investigation of a wide variety of chemicals suspected of being selective herbicides. It has been found already that 2,4,5-trichlorophenoxy-acetic acid, called 2,4,5-T, is highly effective against woody plants and therefore useful in brush control. The sodium, calcium and ammonium salts of trichloro-acetic acid as well as the free acid, called TCA, kill weedy grasses such as Johnson grass, Bermuda grass and quack grass. Armed with these three new compounds, a grower can fight almost any weed that invades his fields.

Regulation by hormones is not limited to the eradication of weeds. For instance, indolebutyric acid, when applied to unfertilized ovaries of tomato plants, brings about the development of seedless fruits which often surpass the pollinated ones in size and flavor. A chemically related hormone, indoleacetic acid, stimulates root formation in cuttings from such trees as apple and pine, which normally take hold only with great difficulty. Hormone treatment of cuttings has become a regular practice in nurseries and is especially valuable in the rapid introduction of new varieties. The premature fall of apples and oranges can be prevented by spraying the trees with 2,4-D. This practice now saves orange and apple growers millions of dollars every year. In similar fashion, hormone sprays have been developed to delay flowering in areas of early frost, to thin out blossoms of fruit trees that tend to produce too much fruit of an inferior quality, to defoliate cotton and to destroy the foliage of potatoes and other tuber crops, which harbors pests and hampers harvesting.

In the field of insecticides we continue to gain, although strains resistant to DDT are developing among some insects, notably the common housefly. To DDT there have now been added several other effective poisons: aldrin, methoxychlor, chlordane and BHC (benzene hexachloride). Yet poison sprays, however effective, have the drawback that they must be applied several times a season. Now there is a promising new development which may spare the farmer that trouble. It is the so-called "systemic insecticide"—a substance which the plant can absorb through its foliage or roots and send to all its parts, and which is harmless to the plant but poisonous to the insects that feed on it. This possibility has been brought about mainly by the discovery of new phosphorus-organic compounds. It is a most significant step in man's unending struggle against pests. Instead of allowing insects to kill his plants, he has equipped the plants to kill the insects! In this instance, as in many other branches of chemical agriculture, careful research must make certain that the technique proposed will have no ill effect on the eventual human consumer.

JUST AS nature's way is not necessarily the best for plants, so it may not always be the most efficient method of raising animals. With the aid of chemicals we are getting results in the breeding and raising of animals that could never be obtained by nature. Artificial insemination, assisted by chemicals, is one example. Today more than 90 per cent of our dairy cows are artificially inseminated. Through proper dilution of semen, a good sire can serve 50 to 100 times as many cows as would be possible in natural mating. Diluters should maintain or even improve upon the natural medium surrounding the spermatozoa by furnishing the necessary supply of nutrients and providing the right osmotic pressure, hydrogen-ion concentration, viscosity and buffering capacity. Among the many substances used in diluters the best known are mixtures of egg yolk, glucose, galactose, potassium biphosphate, sodium phosphate, sodium sulfate, lecithin and gum acacia. Formulas for diluters are constantly being improved, and artificial insemination is being extended to ever more animals, among them horses, sheep, poultry, rabbits and mink.

It has always been taken as axiomatic that young mammals are absolutely dependent on milk. This scientifically unproved notion may be responsible for an immense and unnecessary waste. Millions of farm animals, especially pigs and lambs, are lost each year because their mothers lack enough milk to nourish them or because they are killed accidentally (by being crushed, suffocated, etc.) while suckling. Even under modern farm practices in the U. S. it has been estimated that up to 30 per cent of the pigs born fail to mature. Recently agricultural scientists conceived the idea of raising pigs on a synthetic "milk," and they composed mixtures of proteins, amino acids, vitamins and minerals, fortified with growth-assisting antibiotics. Their synthetic milk proved to be more nourishing than the natural product, which in the case of sows is low in iron and copper and fluctuates in its content of the B-vitamins. Piglets raised on the artificial food weigh 50 pounds after 56 days (the normal nursing period) instead of the usual 22 pounds, and they are generally healthier. Sows are ready for a new mating almost immediately after they have borne a litter.

This artificial milk is made in part from a material that used to be a noxious waste product of the fishing industry. The water fraction obtained from the steam processing of the fertilizer fish menhaden and from other industrial fish products is known as "stick water." It contains many valuable minerals, water-soluble proteins, amino acids, vitamins and other ingredients not yet chemically defined. Until the Second World War fish-meal and fish-oil manufacturers overlooked the nutritive value of this waste material, and it was not until they were required to do something about the public nuisance of their sewage that they started to recover fish solubles by centrifuging, vacuum evaporation and condensation. These materials are now our richest source of the growth-promoting vitamin B_{12}, containing as much as a quarter of a milligram per pound. Since the concentrated waste also contains all essential amino acids, other B vitamins and minerals, it is almost an ideal base for "synthetic milk." To it are added such substances as dried skim milk, lard, corn oil, lecithin, yeast, oil-soluble vitamins and traces of antibiotics.

Young calves also respond favorably to vitamin B_{12} and antibiotics. In the case of cattle the addition of certain amino acids and minerals to the feed stimulates the microflora of the rumen to break down the crude fiber content of the ration into assimilable carbohydrates, so that the animals can digest 68 per cent of this material, instead of the usual 20 per cent. Think of what such utilization of the hundreds of millions of tons of cellulosic waste on our farms and in our forests could mean to our economy!

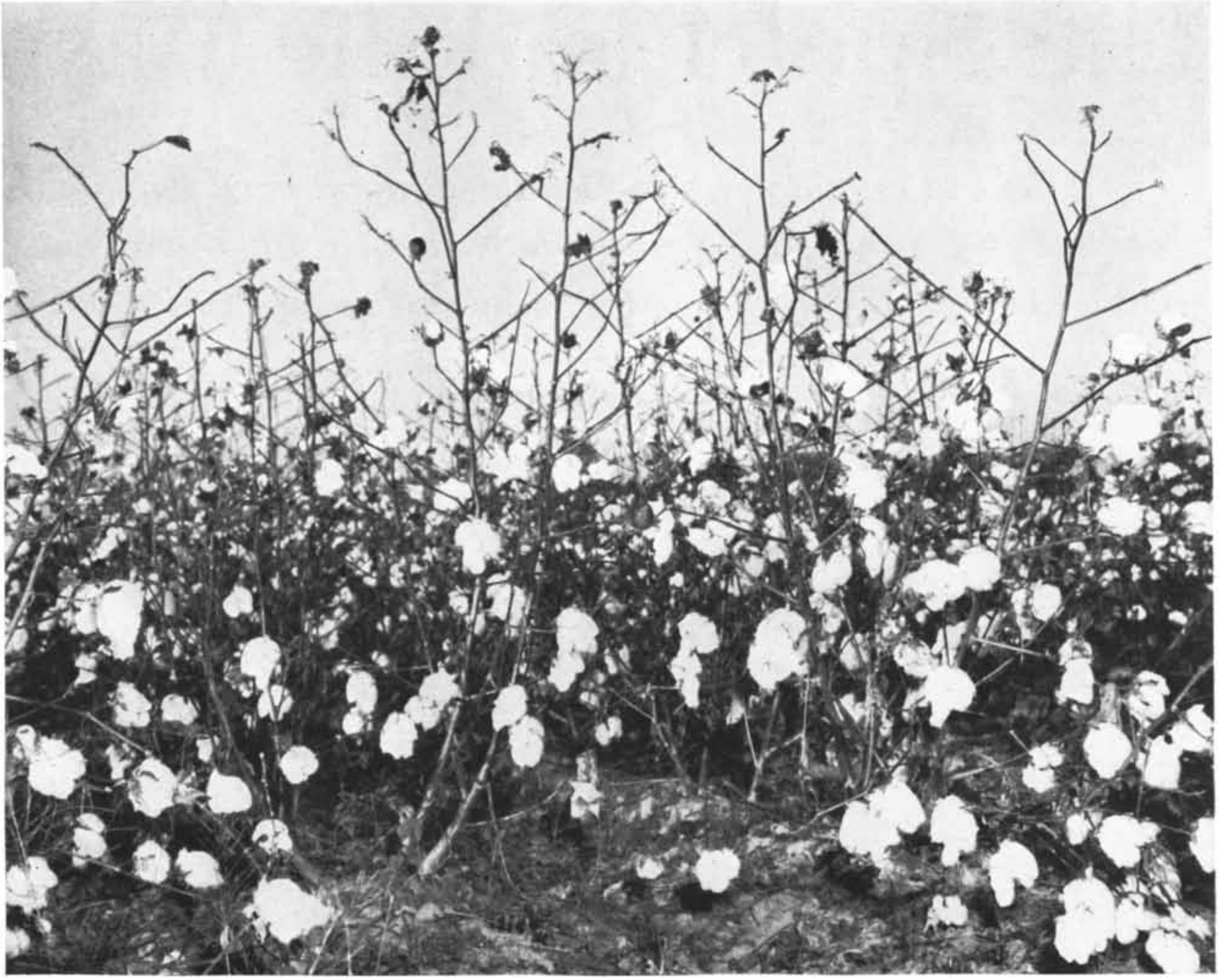
Chemical agriculture has also made great progress in the last few years in the poultry field. The feeding of antibiotics to poultry is now almost routine. Scientists of the U. S. Department of Agriculture, while testing arsenic compounds against the common poultry disease coccidiosis, recently discovered accidentally that certain derivatives of phenylarsonic acid also stimulate the growth of chickens. Pursuing this fortunate discovery, they finally determined that these arsenic compounds, added to ordinary feed in almost infinitesimal amounts (less than a thousandth of one per cent) increase the growth of chickens by about 10 per cent.

WHEN OUR nation was founded, its agricultural efficiency was relatively low. Farming occupied most of our population. The development of agricultural machinery reversed this ratio: whereas in 1820 about 72 per cent of the population worked in agriculture, the proportion in 1950 was only about 15 per cent. It is no exaggeration to say that our present standard of life would have been quite impossible without the enormous increase of efficiency in all branches of agriculture. And chemical agriculture, still in its infancy, should eventually advance our agricultural efficiency at least as much as machines have in the past 150 years.

The losses inflicted on our crops and animals by pests are still appalling. It has been estimated that destruction by insects runs as high as $4 billion a year, and fungi and other plant diseases cost us $4 billion more. Weeds—sapping our soil, choking irrigation ditches, poisoning farm animals, harboring insects and afflicting us with allergic ailments—present another bill of about $5 billion. Thus the total damage to our agricultural production from preventable causes is about $13 billion. Our gross farm production in 1950 was $31 billion; thus elimination of pests and unwanted weeds could increase our food and fiber by 42 per cent.

Our population is growing by more than two million persons a year. For every four people sitting down to a meal in 1950 there will be another person at the table in 1975. How can we fill the extra plate? We cannot add greatly to our cultivated area. Much can be gained by improved fertilization and by improving the breeds of crops and animals. But the most spectacular contribution will be made by the adoption of chemical methods of agriculture. They will combine the nutrients of the sea with those of the land to yield more plentiful food. Here is a challenge for anyone who deplores the passing of the American frontier—our new frontier is science and technology. Let us free ourselves of the dismal philosophy of Robert Malthus, who in arriving at his theory took all factors into consideration—except human ingenuity!

Francis Joseph Weiss is the author of Manpower, Chemistry, and Agriculture, *a report of the Subcommittee on Labor and Labor-Management Relations of the Senate Committee on Labor and Public Welfare.*



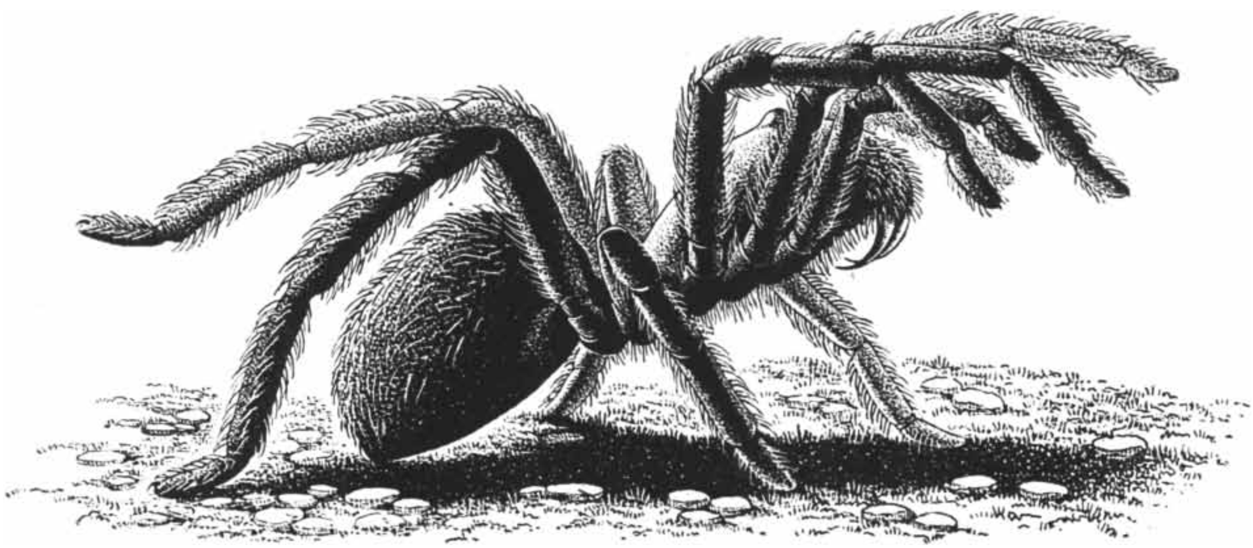
LEAVES WERE REMOVED from these cotton plants by calcium cyanamid at the Delta Branch Experiment Station of the Department of Agriculture. Removing the leaves makes it easier to harvest cotton by machine.

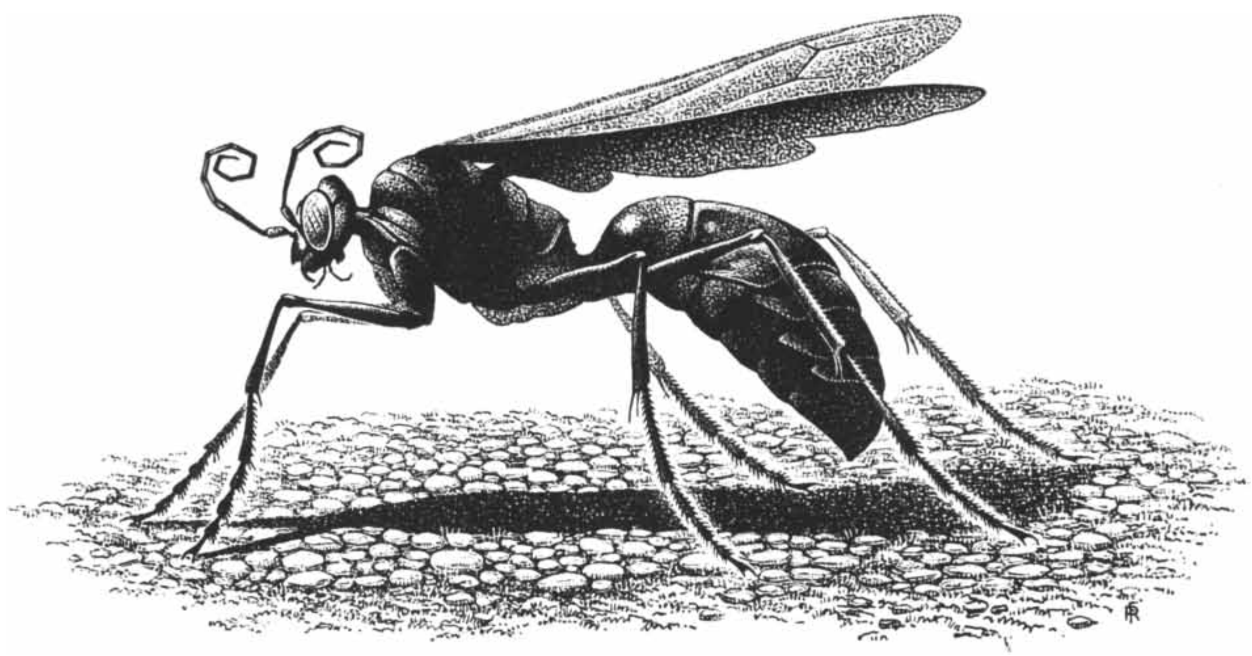
WEEDS ARE CONTROLLED in an experimental cornfield by means of the chemical 2,4-D. At the left is a part of the field that was sprayed with the chemical. At the right is a part of the field that was not sprayed.

The Spider and the Wasp

About the odd relationship between the tarantula and the giant wasp Pepsis. Although the tarantula can easily kill Pepsis, one species permits the wasp to sting it and lay an egg in its body

by Alexander Petrunkevitch





SPIDER AND WASP are the tarantula *Cyrtopholis portoricae* (*top*) and the digger wasp *Pepsis marginata* (*bottom*). The tarantula is shown in an attitude of defense. The wasps of the genus Pepsis are either a deep blue or blue with rust-colored wings. The largest species of the genus have a wingspread of about four inches.

TO HOLD ITS OWN in the struggle for existence, every species of animal must have a regular source of food, and if it happens to live on other animals, its survival may be very delicately balanced. The hunter cannot exist without the hunted; if the latter should perish from the earth, the former would, too. When the hunted also prey on some of the hunters, the matter may become complicated.

This is nowhere better illustrated than in the insect world. Think of the complexity of a situation such as the following: There is a certain wasp, *Pimpla inquisitor*, whose larvae feed on the larvae of the tussock moth. *Pimpla* larvae in turn serve as food for the larvae of a second wasp, and the latter in their turn nourish still a third wasp. What subtle balance between fertility and mortality must exist in the case of each of these four species to prevent the extinction of all of them! An excess of mortality over fertility in a single member of the group would ultimately wipe out all four.

This is not a unique case. The two great orders of insects, Hymenoptera and Diptera, are full of such examples of interrelationship. And the spiders (which are not insects but members of a separate order of arthropods) also are killers and victims of insects.

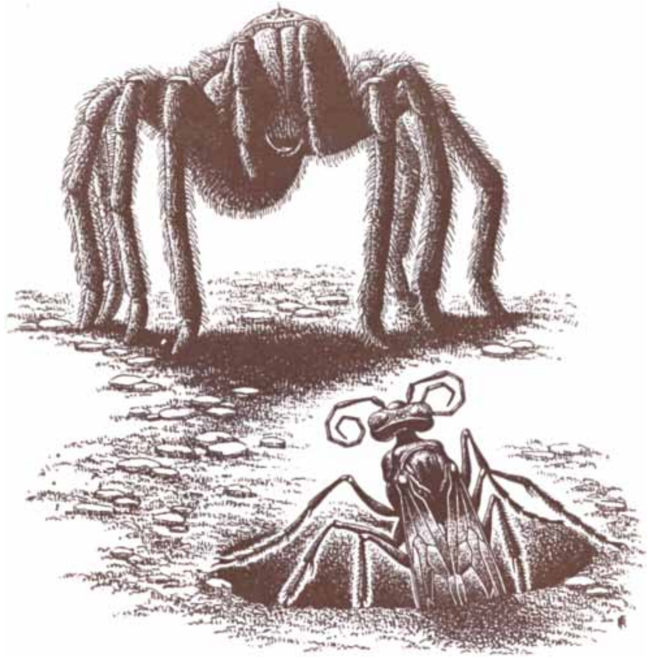
The picture is complicated by the fact that those species which are carnivorous in the larval stage have to be provided with animal food by a vegetarian mother. The survival of the young depends on the mother's correct choice of a food which she does not eat herself.

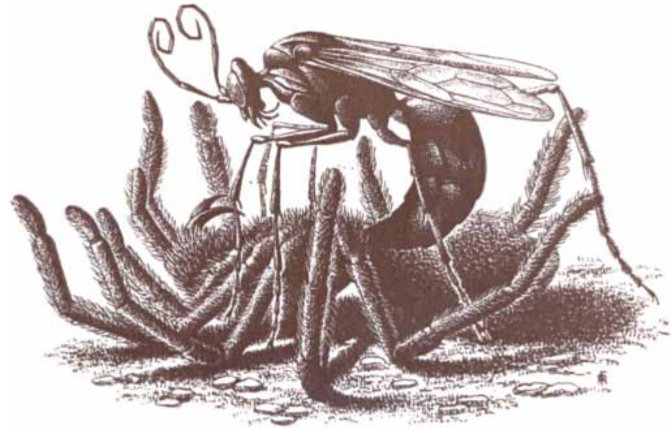
In the feeding and safeguarding of their progeny the insects and spiders exhibit some interesting analogies to reasoning and some crass examples of blind instinct. The case I propose to describe here is that of the tarantula spiders and their arch-enemy, the digger wasps of the genus Pepsis. It is a classic example of what looks like intelligence pitted against instinct—a strange situation in which the victim, though fully able to defend itself, submits unwittingly to its destruction.

MOST tarantulas live in the Tropics, but several species occur in the temperate zone and a few are common in the southern U. S. Some varieties are large and have powerful fangs with which they can inflict a deep wound. These formidable looking spiders do not, however, attack man; you can hold one in your hand, if you are gentle, without being bitten. Their bite is dangerous only to insects and small mammals such as mice; for a man it is no worse than a hornet's sting.

Tarantulas customarily live in deep cylindrical burrows, from which they emerge at dusk and into which they retire at dawn. Mature males wander about after dark in search of females and

NEST OF THE MUD DAUBER WASP illustrates an intricate predatory relationship. A single cell of the nest, enlarged 10 times, contains one pupa of a secondary predator and five smaller pupae of a tertiary predator.





DEATH OF THE SPIDER is shown in these drawings. In the first drawing the wasp digs a grave, occasional-

occasionally stray into houses. After mating, the male dies in a few weeks, but a female lives much longer and can mate several years in succession. In a Paris museum is a tropical specimen which is said to have been living in captivity for 25 years.

A fertilized female tarantula lays from 200 to 400 eggs at a time; thus it is possible for a single tarantula to produce several thousand young. She takes no care of them beyond weaving a cocoon of silk to enclose the eggs. After they hatch, the young walk away, find convenient places in which to dig their burrows and spend the rest of their lives in solitude. Tarantulas feed mostly on insects and millepedes. Once their appetite is appeased, they digest the food for several days before eating again. Their sight is poor, being limited to sensing a change in the intensity of light and to the perception of moving objects. They apparently have little or no sense of hearing, for a hungry tarantula will pay no attention to a loudly chirping cricket placed in its cage unless the insect happens to touch one of its legs.

But all spiders, and especially hairy ones, have an extremely delicate sense of touch. Laboratory experiments prove that tarantulas can distinguish three types of touch: pressure against the body wall, stroking of the body hair and riffling of certain very fine hairs on the legs called trichobothria. Pressure against the body, by a finger or the end of a pencil, causes the tarantula to move off slowly for a short distance. The touch excites no defensive response unless the approach is from above where the spider can see the motion, in which case it rises on its hind legs, lifts its front legs, opens its fangs and holds this threatening posture as long as the object continues to move. When the motion stops, the spider drops back to the ground, remains quiet for a few seconds and then moves slowly away.

The entire body of a tarantula, especially its legs, is thickly clothed with hair. Some of it is short and woolly, some long and stiff. Touching this body hair produces one of two distinct reactions. When the spider is hungry, it responds with an immediate and swift attack. At the touch of a cricket's antennae the tarantula seizes the insect so swiftly that a motion picture taken at the rate of 64 frames per second shows only the result and not the process of capture. But when the spider is not hungry, the stimulation of its hairs merely causes it to shake the touched limb. An insect can walk under its hairy belly unharmed.

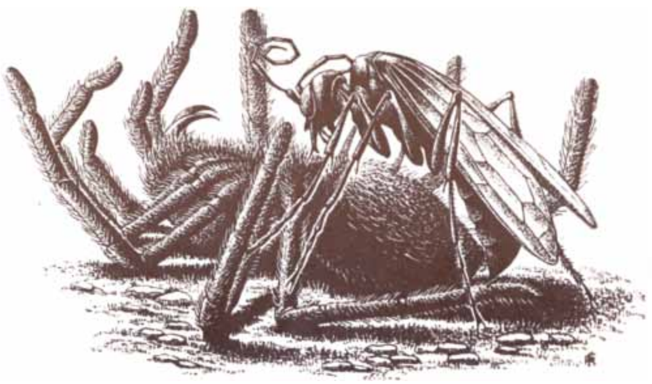
The trichobothria, very fine hairs growing from disklike membranes on the legs, were once thought to be the spider's hearing organs, but we now know that they have nothing to do with sound. They are sensitive only to air movement. A light breeze makes them vibrate slowly without disturbing the common hair. When one blows gently on the trichobothria, the tarantula reacts with a quick jerk of its four front legs. If the front and hind legs are stimulated at the same time, the spider makes a sudden jump. This reaction is quite independent of the state of its appetite.

These three tactile responses—to pressure on the body wall, to moving of the common hair and to flexing of the trichobothria—are so different from one another that there is no possibility of confusing them. They serve the tarantula adequately for most of its needs and enable it to avoid most annoyances and dangers. But they fail the spider completely when it meets its deadly enemy, the digger wasp Pepsis.

These solitary wasps are beautiful and formidable creatures. Most species are either a deep shiny blue all over, or deep blue with rusty wings. The largest have a wing span of about four inches. They live on nectar. When excited, they give off a pungent odor—a warning that they are ready to attack. The sting is much worse than that of a bee or common wasp, and the pain and swelling last longer. In the adult stage the wasp lives only a few months. The female produces but a few eggs, one at a time at intervals of two or three days. For each egg the mother must provide one adult tarantula, alive but paralyzed. The tarantula must be of the correct species to nourish the larva. The mother wasp attaches the egg to the paralyzed spider's abdomen. Upon hatching from the egg, the larva is many hundreds of times smaller than its living but helpless victim. It eats no other food and drinks no water. By the time it has finished its single gargantuan meal and become ready for wasphood, nothing remains of the tarantula but its indigestible chitinous skeleton.

The mother wasp goes tarantula-hunting when the egg in her ovary is almost ready to be laid. Flying low over the ground late on a sunny afternoon, the wasp looks for its victim or for the mouth of a tarantula burrow, a round hole edged by a bit of silk. The sex of the spider makes no difference, but the mother is highly discriminating as to species. Each species of Pepsis requires a certain species of tarantula, and the wasp will not attack the wrong species. In a cage with a tarantula which is not its normal prey the wasp avoids the spider, and is usually killed by it in the night.

Yet when a wasp finds the correct species, it is the other way about. To



ly looking out. The spider stands with its legs extended after raising its body so the wasp could pass under it. In the second drawing the wasp stings the spider, which falls on its back. In the third the wasp licks a drop of blood from the wound. In the final drawing the spider lies in its grave with the egg of the wasp on its abdomen.

identify the species the wasp apparently must explore the spider with her antennae. The tarantula shows an amazing tolerance to this exploration. The wasp crawls under it and walks over it without evoking any hostile response. The molestation is so great and so persistent that the tarantula often rises on all eight legs, as if it were on stilts. It may stand this way for several minutes. Meanwhile the wasp, having satisfied itself that the victim is of the right species, moves off a few inches to dig the spider's grave. Working vigorously with legs and jaws, it excavates a hole 8 to 10 inches deep with a diameter slightly larger than the spider's girth. Now and again the wasp pops out of the hole to make sure that the spider is still there.

When the grave is finished, the wasp returns to the tarantula to complete her ghastly enterprise. First she feels it all over once more with her antennae. Then her behavior becomes more aggressive. She bends her abdomen, protruding her sting, and searches for the soft membrane at the point where the spider's leg joins its body—the only spot where she can penetrate the horny skeleton. From time to time, as the exasperated spider slowly shifts ground, the wasp turns on her back and slides along with the aid of her wings, trying to get under the tarantula for a shot at the vital spot. During all this maneuvering, which can last for several minutes, the tarantula makes no move to save itself. Finally the wasp corners it against some obstruction and grasps one of its legs in her powerful jaws. Now at last the harassed spider tries a desperate but vain defense. The two contestants roll over and over on the ground. It is a terrifying sight and the outcome is always the same. The wasp finally manages to thrust her sting into the soft spot and holds it there for a few seconds while she pumps in the poison. Almost immediately the tarantula falls paralyzed on its back. Its legs stop twitching; its heart stops beating. Yet it is not dead, as is shown by the fact that if taken from the wasp it can be restored to some sensitivity by being kept in a moist chamber for several months.

After paralyzing the tarantula, the wasp cleans herself by dragging her body along the ground and rubbing her feet, sucks the drop of blood oozing from the wound in the spider's abdomen, then grabs a leg of the flabby, helpless animal in her jaws and drags it down to the bottom of the grave. She stays there for many minutes, sometimes for several hours, and what she does all that time in the dark we do not know. Eventually she lays her egg and attaches it to the side of the spider's abdomen with a sticky secretion. Then she emerges, fills the grave with soil carried bit by bit in her jaws, and finally tramples the ground all around to hide any trace of the grave from prowlers. Then she flies away, leaving her descendant safely started in life.

IN ALL THIS the behavior of the wasp evidently is qualitatively different from that of the spider. The wasp acts like an intelligent animal. This is not to say that instinct plays no part or that she reasons as man does. But her actions are to the point; they are not automatic and can be modified to fit the situation. We do not know for certain how she identifies the tarantula—probably it is by some olfactory or chemo-tactile sense—but she does it purposefully and does not blindly tackle a wrong species.

On the other hand, the tarantula's behavior shows only confusion. Evidently the wasp's pawing gives it no pleasure, for it tries to move away. That the wasp is not simulating sexual stimulation is certain, because male and female tarantulas react in the same way to its advances. That the spider is not anesthetized by some odorless secretion is easily shown by blowing lightly at the tarantula and making it jump suddenly. What, then, makes the tarantula behave as stupidly as it does?

No clear, simple answer is available. Possibly the stimulation by the wasp's antennae is masked by a heavier pressure on the spider's body, so that it reacts as when prodded by a pencil. But the explanation may be much more complex. Initiative in attack is not in the nature of tarantulas; most species fight only when cornered so that escape is impossible. Their inherited patterns of behavior apparently prompt them to avoid problems rather than attack them. For example, spiders always weave their webs in three dimensions, and when a spider finds that there is insufficient space to attach certain threads in the third dimension, it leaves the place and seeks another, instead of finishing the web in a single plane. This urge to escape seems to arise under all circumstances, in all phases of life and to take the place of reasoning. For a spider to change the pattern of its web is as impossible as for an inexperienced man to build a bridge across a chasm obstructing his way.

In a way the instinctive urge to escape is not only easier but often more efficient than reasoning. The tarantula does exactly what is most efficient in all cases except in an encounter with a ruthless and determined attacker dependent for the existence of her own species on killing as many tarantulas as she can lay eggs. Perhaps in this case the spider follows its usual pattern of trying to escape, instead of seizing and killing the wasp, because it is not aware of its danger. In any case, the survival of the tarantula species as a whole is protected by the fact that the spider is much more fertile than the wasp.

Alexander Petrunkevitch is emeritus professor of zoology at Yale University.

THE RHIND PAPYRUS

In 1700 B. C. an Egyptian scribe named A'h-mosè set down his "knowledge of existing things all," a document which is now the principal source of what we know of Egyptian mathematics

by James R. Newman

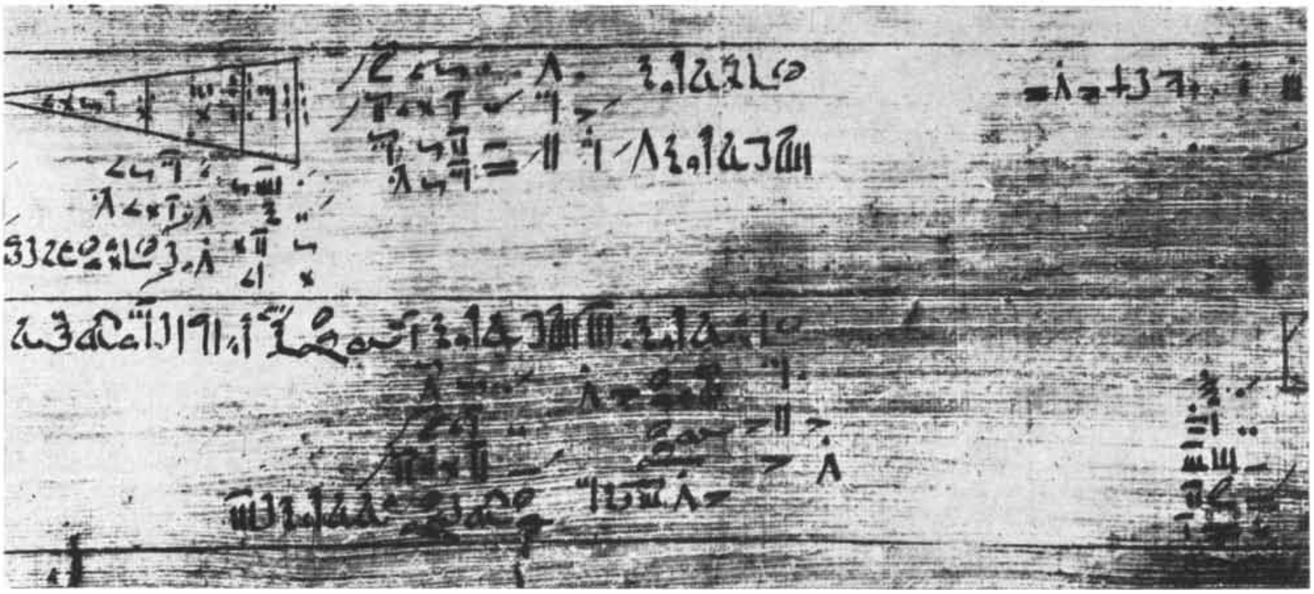
IN THE WINTER of 1858 a young Scottish antiquary named A. Henry Rhind, sojourning in Egypt for his health, purchased at Luxor a rather large papyrus said to have been found in the ruins of a small ancient building at Thebes. Rhind died of tuberculosis five years later, and his papyrus was acquired by the British Museum. The document was not intact; evidently it had originally been a roll nearly 18 feet long and 13 inches high, but it was broken into two parts, with certain portions missing. By one of those curious chances that sometimes occur in archaeology, several fragments of the missing section turned up half a century later in the deposits of the New York Historical Society. They had been obtained, along with a noted medical papyrus, by the collector Edwin Smith. The fragments cleared up some points essential for understanding the whole work.

The scroll was a practical handbook of Egyptian mathematics, written about 1700 B.C. Soon after its discovery several scholars satisfied themselves that it was an antiquity of first importance, no less, as D'Arcy Thompson later said, than "one of the ancient monuments of learning." It remains to this day our principal source of knowledge as to how the Egyptians counted, reckoned and measured.

The Rhind was indited by a scribe named A'h-mosè (another, more sonorous form of his name is Aāh-mes) under a certain Hyksos king who reigned "somewhere between 1788 and 1580 B.C." A'h-mosè, a modest man, introduces his script with the notice that he copied the text "in likeness to writings of old made in the time of the King of Upper [and Lower] Egypt, [Ne-ma] 'et-[Rê]." The older document to which he refers dates back to the 12th Dynasty, 1849-1801 B.C. But there the trail ends, for one cannot tell whether the writing from which A'h-mosè copied was itself a copy of an even earlier work. Nor is it clear for what sort of audience the papyrus was intended, which is to say we do not know whether "it was a great work or a minor one, a compendium for the scholar, a manual for the clerk, or even a lesson book for the schoolboy."

The Egyptians, it has been said, made no great contributions to mathematical knowledge. They were practical men, not much given to speculative or abstract inquiries. Dreamers, as Thompson suggests, were rare among them, and mathematics is nourished by dreamers—as it nourishes them. Egyptian mathematics nonetheless is not a subject whose importance the historian or student of cultural development can afford to disparage. And the Rhind Papyrus, though elementary, is a respectable mathematical accomplishment, proffering problems some of which the average intelligent man of the modern world—38 centuries more intelligent, perhaps, than A'h-mosè—would have trouble solving.

Scholars disagree as to A'h-mosè's mathematical competence. There are mistakes in his manuscript, and it is hard to say whether he put them there



THE PAPYRUS was originally a roll 13 inches high and almost 18 feet long. This photograph shows a small section of it about 4 inches high and 10 inches wide. Hieratic script reads from right to left and top to bottom.

or copied them from the older document. But he wrote a "fine bold hand" in hieratic, a cursive form of hieroglyphic; altogether it seems unlikely that he was merely an ignorant copyist.

IT WOULD BE misleading to describe the Rhind as a treatise. It is a collection of mathematical exercises and practical examples, worked out in a syncopated, sometimes cryptic style. The first section presents a table of the division of 2 by odd numbers—from 2/3 to 2/101. This conversion was necessary because the Egyptians could operate only with unit fractions and had therefore to reduce all others to this form. With the exception of 2/3, for which the Egyptians had a special symbol, every fraction had to be expressed as the sum of a series of fractions having 1 as the numerator. For example, the fraction 3/4 was written as 1/2, 1/4 (note they did not use the plus sign), and 2/61 was expressed as 1/40, 1/244, 1/488, 1/610.

It is remarkable that the Egyptians, who attained so much skill in their arithmetic manipulations, were unable to devise a fresh notation and less cumbersome methods. We are forced to realize how little we understand the circumstances of cultural advance: why societies move—or is it perhaps jump—from one orbit to another of intellectual energy, why the science of Egypt "ran its course on narrow lines" and adhered so rigidly to its clumsy rules. Unit fractions continued in use, side by side with improved methods, even among Greek mathematicians. Archimedes, for instance, wrote 1/2, 1/4 for 3/4, and Hero, 1/2, 1/17, 1/34, 1/51 for 31/51. Indeed, as late as the 17th century certain Russian documents are said to have expressed 1/96 as a "half-half-half-half-half-third."

The Rhind Papyrus contains some 85 problems, exhibiting the use of fractions, the solution of simple equations and progressions, the mensuration of areas and volumes. The problems enable us to form a pretty clear notion of what the Egyptians were able to do with numbers. Their arithmetic was essentially additive, meaning that they reduced multiplication and division, as children and electronic computers do, to repeated additions and subtractions. The only multiplier they used, with rare exceptions, was 2. They did larger multiplications by successive duplications. Multiplying 19 by 6, for example, the Egyptians would double 19, double the result and add the two products, thus:

	1	19
╲	2	38
╲	4	76
Total	6	114

The symbol ╲ is used to designate the sub-multipliers that add up to the total multiplier, in this case 6. The problem 23 times 27 would, in the Rhind, look like this:

╲	1	27
╲	2	54
╲	4	108
	8	216
╲	16	432
Total	23	621

In division the doubling process had to be combined with the use of fractions. One of the problems in the papyrus is "the making of loaves 9 for man 10," meaning the division of 9 loaves among 10 men. This problem is not carried out without pain. Recall that except for 2/3 the Egyptians had to reduce all fractions to sums of fractions with the numerator 1. The Rhind explains:

"The doing as it occurs: Make thou the multiplication 2/3 1/5 1/30 times 10.

	1	2/3	1/5	1/30
╲	2	1 2/3	1/10	1/30
	4	3 1/2	1/10	
╲	8	7 1/5		

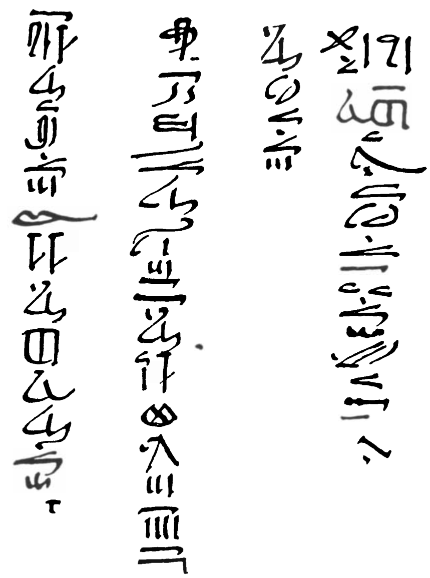
Total loaves 9; it, this is."

In other words, if one adds the fractions obtained by the indicated multiplications (2 + 8 = 10), he arrives at 9. The reader, understandably, may find the demonstration baffling. For one thing, the actual working of the problem is not given. If 10 men are to share 9 loaves, each man, says Aʿh-mosè, is to get 2/3, 1/5, 1/30 (*i.e.*, 27/30) times 10 loaves; but we have no idea how the figure for each share was arrived at. The answer to the problem (27/30, or 9/10) is given first and then verified, not explained. It may be, in truth, that the author had nothing to explain, that the problem was solved by trial and error—as, it has been suggested, the Egyptians solved all their mathematical problems.

AN often discussed problem in the Rhind is: "Loaves 100 for man 5, 1/7 of the 3 above to man 2 those below. What is the difference of share?" Freely translated this reads: "Divide 100 loaves among 5 men in such a way that the shares received shall be in arithmetical progression and that 1/7 of the sum of the largest three shares shall be equal to the sum of the smallest two. What is the difference of the shares?" This is not as easy to answer as its predecessors, especially when no algebraic symbols or processes are used. The Egyptian method was that of "false position"—a mixture of trial and error and arithmetic proportion. Let us look at the solution in some detail:

"Do it thus: Make the difference of the shares 5 1/2. Then the amounts that the five men receive will be 23, 17 1/2, 12, 6 1/2, 1: total 60."

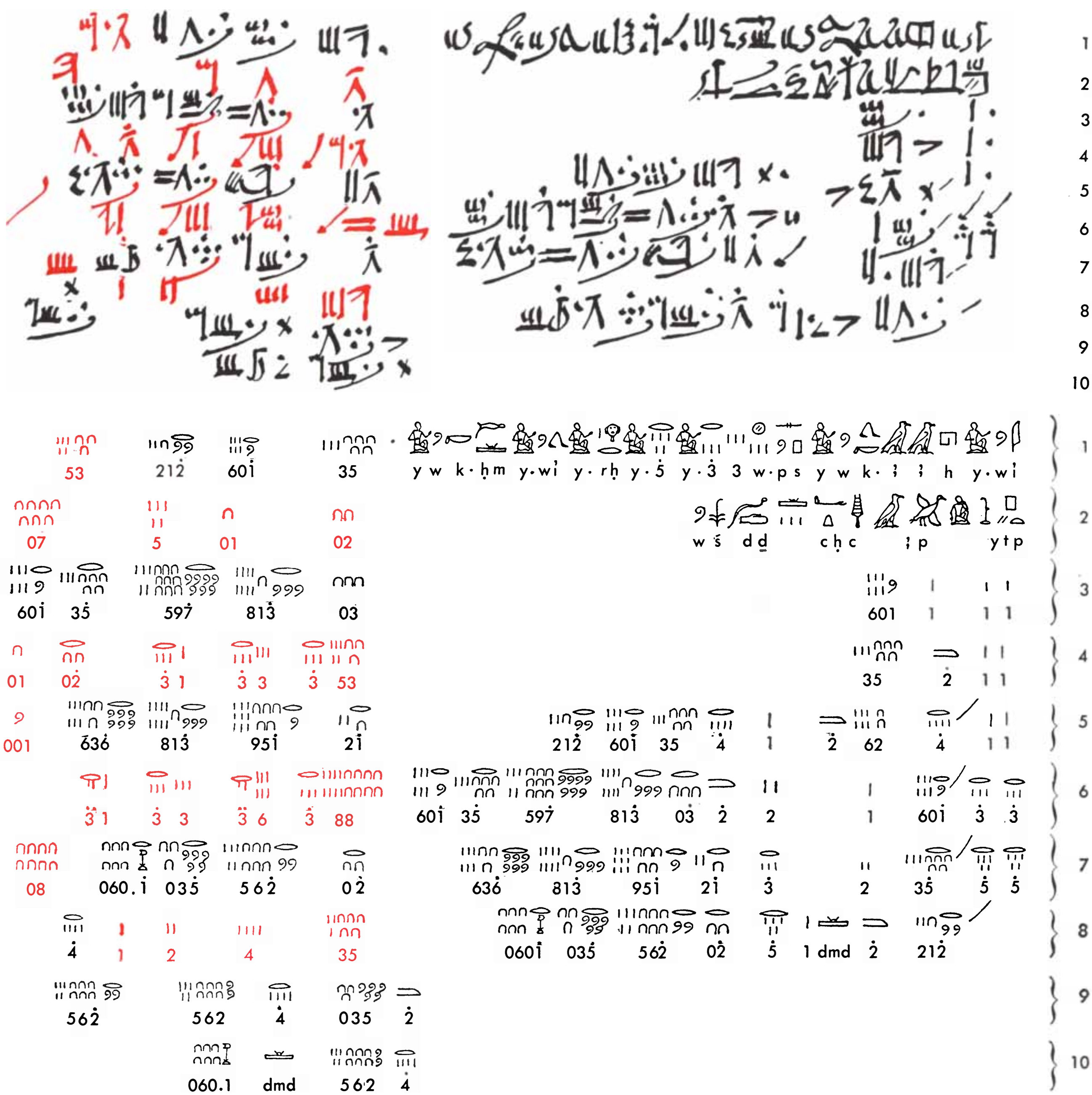
Now the assumed difference 5 1/2, as



PART OF TITLE PAGE of the papyrus is reproduced in facsimile. Here the hieratic script reads from top to bottom and right to left. It has been translated: "Accurate reckoning of entering into things, knowledge of existing things all, mysteries . . . secrets all. Now was copied book this in year 33, month four of the inundation season [under the majesty of the] King of [Upper and] Lower Egypt, 'A-user-Rêʿ, endowed with life, in likeness of writings of old made in the time of the King of Upper [and Lower] Egypt, [Ne-ma] ʿet-Rêʿ. Lo the scribe Aʿh-mosè writes copy this."

we shall see, turns out to be correct. It is the key to the solution. But how did the author come to this disingenuously "assumed" figure? Probably by trial and error. Arnold Buffum Chace, in his definitive study *The Rhind Papyrus*—from which I have borrowed shamelessly—proposes the following ingenious reconstruction of the operation:

Suppose, as a starter, that the difference between the shares were 1. Then the terms of the progression would be 1, 2, 3, 4, 5; the sum of the smallest two would be 3, and 1/7 of the largest three shares would be 1 5/7 (1 1/2, 1/7, 1/14 Egyptian style). The difference between the two groups (3 minus 1 5/7) would be 1 2/7, or 1 1/4, 1/28. Next, trying 2 as the difference between the successive shares, the progression would be 1, 3, 5, 7, 9. The sum of the two smallest terms would be 4; 1/7 of the three largest terms would be 3, and the difference between the two sides, 1. The experimenter might then begin to notice that for each increase of 1 in the assumed common difference, the inequality between the two sides was reduced by 1/4,



ìw·y h3̈·kwy sp·w 3 3̇ · y 5̇ · y ḥr·y ìw·y mḥ·kwy pty p3 ʿḥʿ ḏd św

Go down I times 3, ⅓ of me, ⅕ of me is added to me; return I, filled am I. What is the quantity saying it?

1	1
1	1
1	1
3̇	3̇
5̇	5̇

1	4̇	53	1̇06	2̇12		
2	2̇	30	3̇18	7̇95	5̇3	1̇06
3̇	1̇2	1̇59	3̇18	6̇36		
5̇	2̇0	2̇65	5̇30	1̇060		

	1	106
	2̇	53
\	4̇	26 2̇
\	1̇06	1
\	5̇3	2
\	2̇12	2̇
	dmd	1
	Total	

53	1̇06	2̇12				
20	10	5				35
30	3̇18	7̇95	5̇3	1̇06		
35 3̇	3 3̇	1 3̇	2̇0	10		70
1̇2	1̇59	3̇18	6̇36			
88 3̇	6 3̈	3 3̇	1 3̈			100
2̇0	2̇65	5̇30	1̇060			
53	4	2	1			80
				4̇		2̇65

2̇	530
4̇	265
4̇	265
dmd	1060
Total	

PROBLEM 36 of the papyrus begins: "Go down I times 3, 1/3 of me, 1/5 of me is added to me; return I, filled am I. What is the quantity saying it?" The problem is then solved by the Egyptian method. At the top of the opposite page is a facsimile of the problem as it appears in the papyrus. The hieratic script reads from right to left. The characters are reproduced in red and black, as they are written in the papyrus. In the middle of the page is a rendering in hieroglyphic script, which also reads from right to left. Beneath each line of hieroglyphs is a phonetic translation. The numbers are given in Arabic with the Egyptian notation. Each line of hieroglyphs and its translation is numbered to correspond to a line of the hieratic. At the bottom of the page the phonetic and numerical translation has been reversed to read from left to right. Beneath each phonetic expression is its English translation. A dot above a number indicates that it is a fraction with a numerator of one. Two dots above a 3 represent 2/3, the only Egyptian fraction with a numerator of more than one. Readers who would like to trace the entire solution are cautioned that the scribe made several mistakes that are preserved in the various translations.

1/28. Very well: to make the two sides equal, apparently he must multiply his increase 1 by as many times as 1/4, 1/28 is contained in 1 1/4, 1/28. That figure is 4 1/2. Added to the first assumed difference, 1, it gives 5 1/2 as the true common difference. "This process of reasoning is exactly in accordance with Egyptian methods," remarks Chace.

Having found the common difference, one must now determine whether the progression fulfills the second requirement of the problem: namely, that the number of loaves shall total 100. In other words, multiply the progression whose sum is 60 (see above) by a factor to convert it into 100; the factor, of course, is 1 2/3. This the papyrus does: "As many times as is necessary to multiply 60 to make 100, so many times must these terms be multiplied to make the true series." (Here we see the essence of the method of false position.) When multiplied by 1 2/3, 23 becomes 38 1/3, and the other shares, similarly, become 29 1/6, 20, 10 5/6 and 1 2/3. Thus one arrives at the prescribed division of the 100 loaves among 5 men.

THE AUTHOR of the papyrus computes the areas of triangles, trapezoids and rectangles and the volumes of cylinders and prisms, and of course the area of a circle. His geometrical results are even more impressive than his arithmetic solutions, though his methods, as far as one can tell, are quite unrelated to the discipline today called geometry. "A cylindrical granary of 9 diameter and height 6. What is the amount of grain that goes into it?" In solving this problem a rule is used for determining the area of a circle which comes to Area = $(8/9\,d)^2$, where d denotes the diameter. Matching this against the modern formula, Area = πr^2, gives a value for π of 3.16—a very close approximation to the correct value. The Rhind Papyrus gives the area of a triangle as 1/2 the base times the length of a line which may be the altitude of the triangle, but, on the other hand—Egyptologists are not sure—may be its side. In an isosceles triangle, tall and with a narrow base, the error resulting from using the side instead of the altitude in computing area would make little difference. The three triangle problems in the Rhind Papyrus involve triangles of this type, but it is clear that the author had only the haziest notion of what triangles were like. What he was thinking of was (as one expert conjectures) "a piece of land, of a certain width at one end and coming to a point, or at least narrower at the other end."

Egyptian geometry makes a very respectable impression if one considers the information derived not only from the Rhind but also from another Egyptian document known as the Moscow Papyrus and from lesser sources. Its attainments, besides those already mentioned, include the correct determination of the area of a hemisphere (some scholars, however, dispute this) and the formula for the volume of a truncated pyramid, $V = (h/3)\,(a^2 + ab + b^2)$, where a and b are the lengths of the side of the square and h is the height.

I should like to give one more example taken from the Rhind Papyrus, something by way of a historical oddity. Chace offers the following translation of the hard-to-translate Problem 79:

"Sum the geometrical progression of five terms, of which the first term is 7 and the multiplier 7.

"The sum according to the rule. Multiply 2801 by 7.

\ 1	2801
\ 2	5602
\ 4	11204
Total	19607

"The sum by addition

houses	7
cats	49
mice	343
spelt (wheat)	2401
hekat (half a peck)	16807
Total	19607"

This catalogue of miscellany provides a strange little prod to fancy. It has been interpreted thus: In each of 7 houses are 7 cats; each cat kills 7 mice; each mouse would have eaten 7 ears of spelt; each ear of spelt would have produced 7 hekat of grain. Query: How much grain is saved by the 7 houses' cats? (The author confounds us by not only giving the hekats of grain saved but by adding together the entire heterogeneous lot.) Observe the resemblance of this ancient puzzle to the 18th-century Mother Goose rhyme:

"As I was going to St. Ives
I met a man with seven wives.
Every wife had seven sacks,
Every sack had seven cats,
Every cat had seven kits.
Kits, cats, sacks and wives,
How many were there going
to St. Ives?"

(To this question, unlike the question in the papyrus, the correct answer is "one" or "none," depending on how it is interpreted.)

A CONSIDERABLE difference of opinion exists among students of ancient science as to the caliber of Egyptian mathematics. I am not impressed with the contention, based partly on comparison with the achievements of other ancient peoples, partly on the wisdom of hindsight, that the Egyptian contribution was negligible, that Egyptian mathematics was consistently primitive and clumsy. The Rhind Papyrus, though it demonstrates the inability of the Egyptians to generalize and their penchant for clinging to cumbersome calculating processes, proves that they were remarkably pertinacious in solving everyday problems of arithmetic and mensuration, that they were not devoid of imagination in contriving algebraic puzzles, and that they were uncommonly skillful in making do with the awkward methods they employed.

It seems to me that a sound appraisal of Egyptian mathematics depends upon a much broader and deeper understanding of human culture than either Egyptologists or historians of science are wont to recognize. As to the question how Egyptian mathematics compares with Babylonian or Mesopotamian or Greek mathematics, the answer is comparatively easy and comparatively unimportant. What is more to the point is to understand why the Egyptians produced their particular kind of mathematics, to what extent it offers a culture clue, how it can be related to their social and political institutions, to their religious beliefs, their economic practices, their habits of daily living. It is only in these terms that their mathematics can be judged fairly.

James R. Newman is a consultant in the literature of mathematics for the Library of Congress.

ASTHMA

The sickness that makes its victims gasp for breath has definite physiological causes. These are often amplified by psychological mechanisms, suggesting that the two aspects be treated together

by William Kaufman

SEVERE asthma is one of the most dramatic and dreadful diseases that a human being can have. When an attack strikes, each breath becomes a noisy, wheezy struggle for survival. The desperate patient concentrates all his energy, emotion and attention on a fight to get enough air into and out of his lungs to support life. Sometimes he may not survive the attack. Repeated attacks, even if not fatal, may turn the sufferer into a chronic invalid, and in time he may develop serious cardiovascular and lung complications.

Since asthma is not a reportable disease, we do not know just how many people suffer from this illness, but it is certainly one of our major health problems. The Public Health Service has estimated that in 1948 there were almost four million victims of hay fever and asthma in the U. S., which would make these allergic conditions the third most common cause of chronic illness in the nation, exceeded only by cardiovascular and rheumatic diseases.

We shall consider here the widespread, often serious condition called allergic bronchial asthma. Primarily it is caused by the individual's hypersensitivity to some external agent, such as a food, drug, pollen, dust, bacterial byproduct or animal emanation. But there are psychological factors as well, because the patient reacts as a total biodynamic unit to his illness and life situations.

The allergenic substance, either breathed in or carried by the bloodstream, attacks the susceptible individual's bronchial tubes. Almost at once the mucous membrane lining the tubes swells, the smooth muscle in the tube walls goes into spasm and a thick, sticky mucus is secreted. All this constricts and chokes the passages. It becomes extraordinarily difficult to suck fresh air into the lungs or, even more important, to blow the trapped stale air out of the lungs. To the very real threat of death by asphyxia the patient responds by mobilizing all his resources. As he struggles mightily to breathe, his body is racked by paroxysms of coughing to free his bronchial tubes of the mucus.

After recovering from the attack, the patient may seem perfectly well, no different from anyone else. But the appearance is deceptive—a person who has experienced asthma *is* different!

HIS unexpected, suffocating illness suddenly made him helpless, entirely dependent on others. His doctor gave him epinephrine to relax his bronchial tubes and reduce the allergic swelling; the drug made him jittery and faint, caused his heart to race and pound, heightened his anxiety. He was given various other drugs: intravenous injections and later rectal suppositories of aminophylline, perhaps cortisone, ACTH, medicated aerosols. He may have received oxygen or an oxygen-helium mixture through a mask. Perhaps a bronchoscope was thrust unpleasantly into his tubes to suck out the mucus. And all through his illness he watched and reacted with terror to the concern and tension in the faces of his family, friends and possibly the doctor.

After such an ordeal the patient loses much of his self-confidence and lives in fear of a return of the attack. For example, if he learns that his asthma was precipitated by dog's dandruff, he not only will avoid contacts with dogs but may even be made tense and anxious by the distant barking of dogs or by seeing an advertisement of dog food in a magazine. His unconscious reactions change his whole personality. He no longer lives the give-and-take life of a normal adaptive adult but seeks to establish an umbrella of protection against the many stresses of everyday living. He requires from everyone the warm, protective love that a mother gives her helpless baby. When he fails to receive such babying from his family, friends, business associates or physician, he may suffer an asthmatic attack. The patient is as allergic to rejection as he is to a physical or chemical agent.

After a series of severe, intermittent attacks of bronchial asthma, the patient may become more or less incapacitated. Not knowing when he will feel well or be sick, he may develop a pattern of neurotic behavior which is a human counterpart of the confusion induced in rats exposed to frustrating stimuli in the famous experiments of Norman Maier at the University of Michigan. Often the patient sharply constricts his field of interest and activity, fears to compete with others, avoids new or strange situations, prefers to do certain things over and over again in a compulsive manner, and gradually does less and less more and more carefully.

In short, the patient who has allergic bronchial asthma presents psychological as well as physiological problems, and he frequently needs psychotherapy.

Most asthmatic adults who consult an allergist have had repeated attacks. They are difficult to treat, because they have deeply ingrained patterns of aberrant behavior which vary from person to person; each requires individualized psychobiological management.

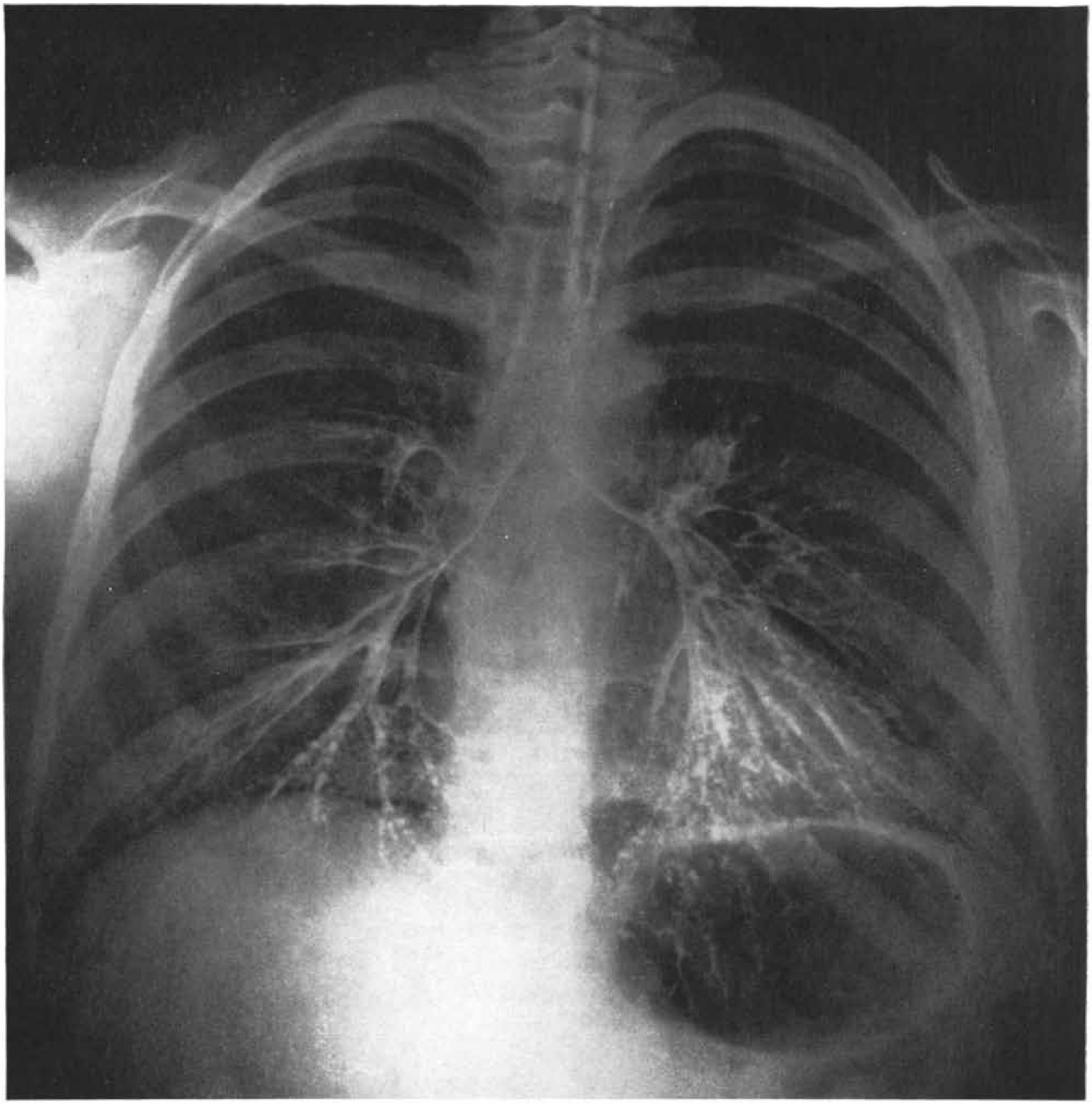
The most common pattern is fear and dependency. This type of person may try to disguise his basic personality by loud talk and bragging, but his bravado melts away quickly whenever he has to meet a real challenge.

Another type of asthmatic patient tends to be dreamy and escapist. He may eventually be so rooted in the world of fantasy that when he stops having asthma attacks—which constitute his only hold on reality—he becomes schizophrenic and needs to be institutionalized.

Then there is the individual who reacts with intense anger and hostility to his illness, to healthy people and to those who do not do his bidding. Often this anger is turned toward himself, and the patient becomes gloomy and depressed, sometimes even attempting to take his life. Another type is the grieving patient, who may be relieved of his asthma for a time by weeping when he is deeply disturbed. Other patients show a paranoid tendency, building up a systematic picture of being harmed by others. Finally, there are hyperactive patients who keep perpetually on the move, as if to ward off an asthma attack.

THE treatment of allergic bronchial asthma is simple in theory but difficult in practice. The patient's bronchial-tube structures are hypersensitized to bacterial infection or to some material he inhales, eats or takes in the form of medication. If the offender can be identified, it may only be necessary to get rid of the harmful agent, either by eliminating it from the patient's diet or environment, or by treating an infection, or by desensitizing the patient with injections. But when the allergic basis cannot be found, we must rely on preventive measures—drugs such as epinephrine, aminophylline, sedatives, antihistaminics, cortisone, ACTH, oxygen, and so on. These must be administered according to the emotional as well as physical needs of the patient. For example, a depressed asthmatic may do poorly on sedatives but well on dexedrine, a cerebral stimulant. A schizoid patient may develop a frank psychosis if his asthma is too thoroughly relieved; in a sense, his sanity depends on his having his asthma. An excited, hyperactive asthmatic will do better with sedatives than with stimulants, and such a patient may require smaller than average amounts of epinephrine to control his asthma.

Physicians must be alert to the conditioned psychological reactions of their patients. A patient who has had severe ragweed asthma and has been desensitized by treatment walks into his doctor's office. He is cheerful and happy—until his eye lights on a vase on the doctor's desk which he believes contains ragweed, but which actually contains a plastic replica of ragweed. Within seconds the patient may develop an asthmatic attack. But if the doctor tells him



NORMAL BRONCHIAL TUBES are revealed by this X-ray photograph of the chest. The bronchi were made visible by coating them with a small amount of peanut oil containing iodine, which is relatively opaque to X-rays. The peanut oil was introduced into the trachea by means of the tube which can be seen at top center.

that it is only a plastic model of the ragweed plant, the attack ceases abruptly.

What happened? The patient's nervous system reacted to the danger of ragweed. His cholinergic (parasympathetic) nerves became overactive, constricting the bronchial tubes and starting the wheezing, difficult breathing. When the patient learned that the threat was not real, the stimulus for this behavior was turned off, and the psychogenically induced asthma ceased.

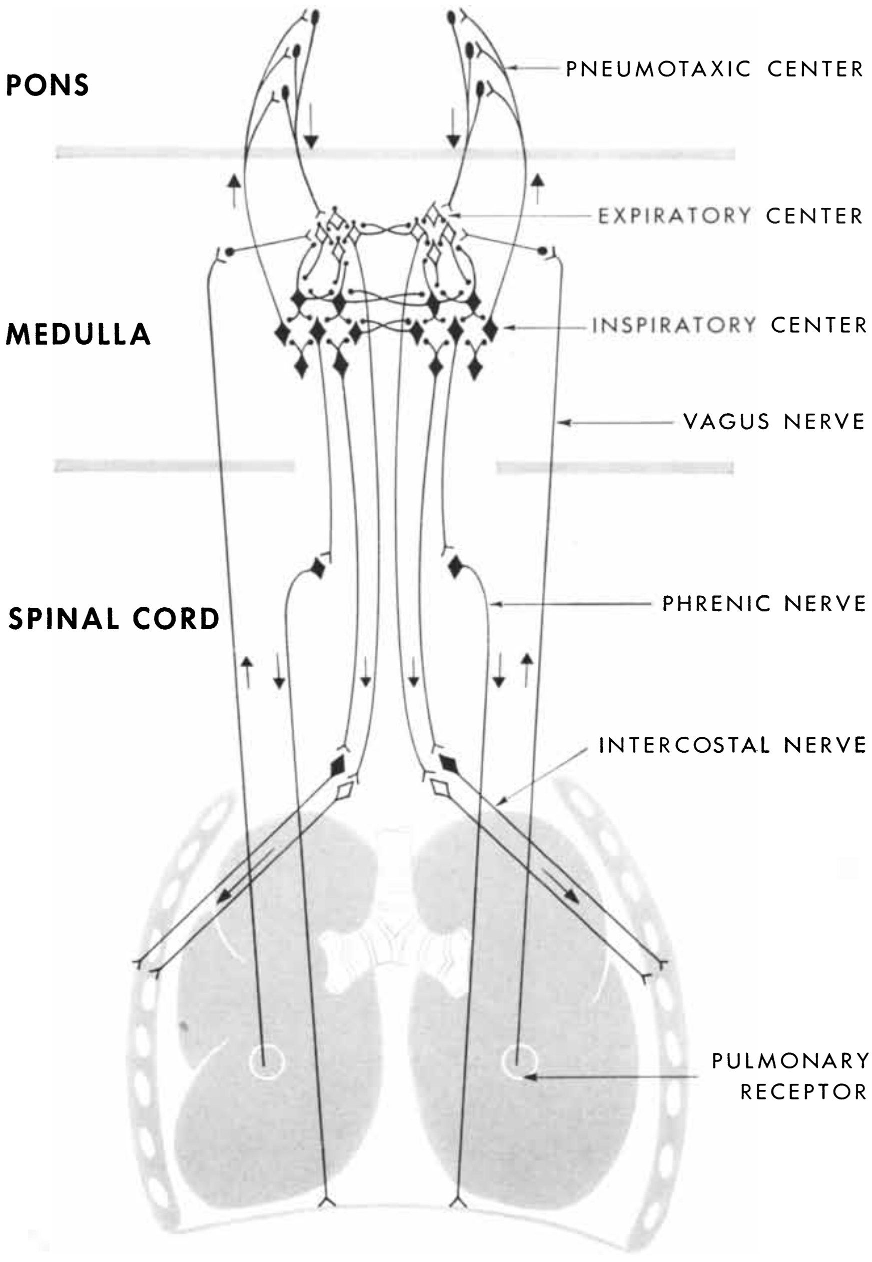
PSYCHOGENIC asthma has recently been induced experimentally in guinea pigs by the Swiss physicians B. Noelpp and I. Noelpp, a husband and wife research team at the University of Zurich. First they hypersensitized guinea pigs to egg white so that whenever the animals inhaled a mist containing minute amounts of egg white, they developed allergic asthma. Then the experimenters sounded a note of a certain pitch each time they exposed the animals to the substance. After many repetitions they tried sounding the note alone, but were disappointed to find that only 18 per cent of the guinea pigs developed asthma in response to the conditioned stimulus. They decided that the stress under which human beings live might be an important conditioning factor in the production of psychogenic asthma; perhaps the guinea pigs, living in ideal laboratory conditions, were under too little stress. The Noelpps learned that intermittent flashing of a bright light is a stressful stimulus to a guinea pig. They subjected the animals to such flashing light for a time and then tried the conditioning experiment again. This time nearly every one of the guinea pigs developed asthma in response to the conditioned noise signal. The attack was indistinguishable from the allergic asthma previously induced when the animals breathed egg-white vapor.

Allergists have observed repeatedly that a patient is much more likely to suffer an asthma attack in response to a stimulus when he is under stress than when he is emotionally serene. For example, a person who is allergic to chocolate may sometimes eat chocolate with immunity when he is on vacation and free from occupational and other stress.

The emotional impact of a first asthmatic attack is much the same in children as in adults, with one important exception. A child, already dependent on his parents for safety and protection, is made even more dependent. Hence the emotional problems of a person whose asthma began in childhood are much more complex and more difficult to manage successfully through psychotherapy than those of an adult who acquired asthma during adulthood. In spite of treatment for his allergies, an asthmatic child may continue to have attacks as long as he remains under the same roof with his parents. This may result either from the parents' failure to supply the child with emotional security or from overprotection. Removed to an institution which specializes in caring for asthmatic children, such a child may recover in a relatively short time, even without being given special allergic therapy. He gradually loses his fears of illness and of rejection and finds that other children who were just as sick as he have become healthy. This gives him a real sense of inner security. After living away from home for several years, the child can often return to his parents' home without suffering the stresses which were the psychological background for his attacks of asthma.

THE STRATEGY of treatment of allergic bronchial asthma must always be concerned with two objectives: the short-term goal of ending the attack and making the patient as comfortable as possible, and the long-term goal of preventing future attacks. Although we are far from having all the answers to this complex problem, in most instances excellent results can be obtained by a skillful blending of the right kind of allergic and psychological treatment.

William Kaufman is a member of the psychosomatic committee of the American College of Allergists.



NERVOUS MECHANISM of breathing is outlined by this highly schematic drawing. Shown in gray at bottom are the trachea, lungs, rib cage and diaphragm. The arrows indicate the direction in which nerve impulses travel.

IDEA-PLASTICS

... from Du Pont Polychemicals Department

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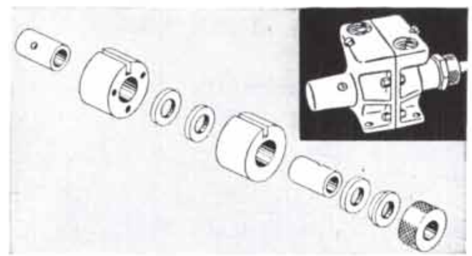
pump parts are mechanically strong—won't lend themselves to galvanic pitting and erosion



Finding durable materials for the impeller, bearing and packing in chemical process pumps is sometimes a difficult problem for pump manufacturers. Conventional bearings are often subject to erosive pitting . . . impellers tend to gall after short periods of use. But one manufacturer found the solution for all 3 parts in one material—Du Pont "Teflon" tetrafluoroethylene resin.

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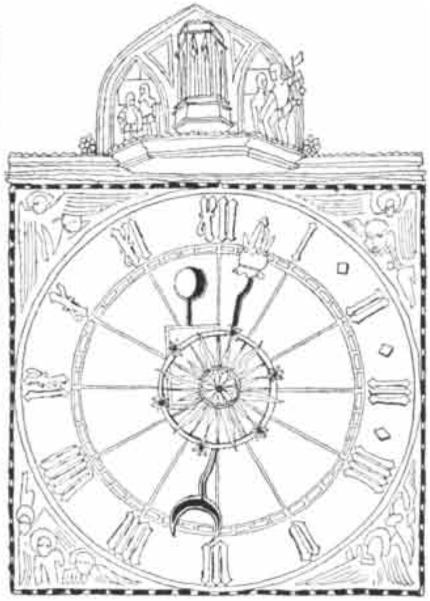


Famine in 25 years?

BY 1975 there will be about 190 million mouths to feed in the U. S. Unless the nation increases its agricultural productivity at a faster rate than it is doing, many of them will go hungry, reports Byron T. Shaw, Administrator of the Agricultural Research Administration of the U. S. Department of Agriculture.

Shaw estimated that the U. S. will need the equivalent of 115 million additional acres of cropland in 1975 if its population is to eat as well as today. Since 1935 the nation has added 38 million acres to the total under cultivation for food and has gained the equivalent of 64 million acres by more efficient farming. This increase of 102 million acres was more than enough to keep pace with the increase in population. But we have now begun to fall behind, adding the equivalent of about five million acres per year as against a need of seven and a half million.

In the next 25 years, Shaw said, we can expect 15 million additional acres to be released from growing fodder for horses and about 30 million to be added by irrigation, drainage, clearance and flood control. That will leave a deficit of about 70 million acres. It will have to be made up by more efficient production and improved distribution and marketing of farm products. "We have already made great strides in this direction," declared Shaw, "but we are not making them fast enough."

Shaw listed these areas for improvement:

Insects and disease: We are losing 10 per cent of all farm animals from diseases and parasites. Brucellosis alone cuts the annual milk supply by a billion pounds a year. Insects cost us $4 billion worth of crops and livestock annually (*see page 15*).

Soil conservation: Much of our farm-land is deteriorating. In the Midwest it is decreasing in productivity at an average rate of about seven-tenths of one per cent per year; for Iowa the figure is one per cent.

Farming techniques: We have not come close to realizing the full potential from fertilizer use. The best farms produce about double the yield of the average farm.

Marketing and distribution: Half a billion to a billion dollars worth of grain is damaged in storage each year. For some fresh fruits and vegetables there is a 30 per cent spoilage between the farm and the consumer. Nearly half of the eggs produced drop below A quality before they reach the markets.

Food from Sewage

GREEN ALGAE can turn sewage into a high-protein food, a group of University of California workers have found. One of the chief problems in sewage treatment is supplying oxygen. The California experimenters tried growing algae in sewage pools to provide the necessary oxygen by photosynthesis. They discovered that as algae manufactured oxygen they also utilized the rich store of nitrogen and phosphorus in the sewage to grow and multiply. In a single day the sewage in a tank is almost completely converted into algae. Any harmful bacteria left in the product can be eliminated by drying and pasteurizing it.

It is estimated that 1,000 to 1,500 pounds of dry algae can be produced per million gallons of sewage per day. The algae are about 50 per cent protein and thus are an extremely nutritious food product. And sewage is a much cheaper medium on which to grow algae than the artificial cultures with which other groups have been experimenting.

Because of the "psychological factor" the researchers do not advocate using sewage-grown algae for human food, but point out that it would be excellent animal fodder. The studies so far have been on a laboratory scale. They will be extended to a pilot-plant operation upon completion of an 80-foot oxidation pond which is under construction.

Old-Age Hygiene

SOME 13 million U. S. citizens are over 65. In 1900 the figure was 3 million. The medical and social needs of this older group have now received official recognition by the U. S. Public Health Service, which is establishing a program on the "hygiene of aging." The

PHS will advise local health departments on setting up special health guidance plans for the aging group and assist the departments in planning their activities to take into account the special needs of the aged. Dr. Cletus L. Krag, formerly of the Division of Gerontology at the Washington University School of Medicine, is director of the program.

No Soup

WITH THE de Havilland Comet in service on a London-to-Johannesburg run, the British have ushered in the age of jet travel. Last month the English journal *Aeronautics* published a detailed description of the new plane.

The Comet, a four-engine turbojet ship with a capacity of 36 passengers, cruises at about 500 miles per hour and at 35,000 to 40,000 feet. It makes the trip from London to Johannesburg in six hops, covering some 6,700 miles in just under 24 hours, of which 19 are spent in the air.

The jet engines are simple, dependable and easy to service. The four engines are synchronized to fire in unison by means of a stroboscope, and the ship flies with very little vibration. Passengers say a flight is like a glide on ice skates.

A complete engine change can be made at a way station in four or five hours. The engines are highly sensitive to the outdoor temperature, particularly at take-off; a rise in temperature of one degree Centigrade sometimes makes it necessary to reduce the load by the weight of a passenger and his baggage. Failure of an engine, even on take-off, is not as serious in the Comet as in conventional aircraft. The propellerless engines are mounted close together and close to the center line of the plane, so that a sudden imbalance causes little sway. The plane can cruise and land on three engines.

Jet travel is not, however, all beer and skittles. The plane runs so smoothly that its instrument needles sometimes get stuck. Furthermore, each leg of the journey (about 1,000 miles) is covered so quickly that there is no time to serve hot soup with meals.

Selective Particle Counter

WHEN A supersonic missile or plane speeds through the air, it sets up a conical shock wave. In much the same way, a charged particle racing through an insulating material faster than light can travel through that material sets up an electromagnetic shock wave in the form of visible and ultraviolet light. This light is known as Cerenkov radiation (see SCIENTIFIC AMERICAN, October, 1951).

University of Chicago physicists are now using Cerenkov radiation to count high-speed particles. As an individual particle passes through Lucite or water, the light it generates is caught on the sensitive cathode of an amplifying photoelectric cell, where it produces a measurable electric pulse.

The advantage of the Cerenkov counter is in its high selectivity. In a mixed beam of particles it will count only those moving faster than light in the medium. Furthermore, it can be made to select particles within a narrow range of speed. This ability depends on the fact that the apex angle of the conical shock wave depends on the speed of the particle—the slower the particle, the wider the cone. Thus the light comes off at different directions for particles of different velocities, and a lens and diaphragm can be placed to gather light in the direction representing a given speed.

The counter is being used in conjunction with the Chicago synchrocyclotron to study protons, electrons and charged mesons produced in the accelerator.

Thin Fibers

ONE POUND of nylon can now be stretched into a single thread 400,000 miles long. Workers at the Naval Research Laboratory in Washington are turning out nylon and other plastic fibers 50 times finer than a human hair. The superfine threads are used to make filter cloths for aerosols—microscopic particles suspended in air.

Molten nylon is forced through a small hole into a high-speed hot-air current formed by two converging jets. The air stream stretches out the molten plastic into a thread which can be produced at the rate of 7,000 feet per second. Fed onto a moving screen, the fiber forms a dry fabric of random mesh. The fabric is high in flexibility and tensile strength, because these qualities increase with decreasing fiber diameters.

Nova de Novo

ETA CARINA, the southern nova that has brightened and faded more than once since astronomers began observing it, is now growing brighter again. So reports Olin J. Eggen, of the University of California's Lick Observatory, who has just returned from an astronomical expedition to Australia.

One night Eggen and Gerard de Vaucouleurs, a French astrophysicist, turned their telescope on Carina's position and failed to find the star, as they thought. Instead, they saw a star some four times brighter than what they were looking

Adventurers in Research..

Dr. Clinton R. Hanna

SCIENTIST-INVENTOR

Hoosier-born scientist whose gun stabilizer revolutionized tank combat during World War II. He enrolled in Westinghouse graduate student course right after graduation from Purdue University in 1922. His inventive talents earned him rapid advancement to head of Development Division in 1930, Manager of Electromechanics Department in 1937, and Associate Director of the Research Laboratories, his present position, in 1944.

Where human muscles and reflexes aren't quite up to the job, the electromechanical regulator can do it many times faster and more accurately. Proof of that is in the career of Dr. Clinton R. Hanna, who has developed a whole family of these devices in his 30 years with Westinghouse. It was his gyroscope-controlled gun stabilizer that during World War II enabled Allied tanks to fire accurately even when traveling over rough terrain, and helped swing the tide of battle against the enemy in Africa. When heavy seas sent ship-based radar antennas bobbing erratically, Dr. Hanna designed a system for stabilizing them in the roughest weather. And when the U. S. Navy sought a way for submarines to lie perfectly motionless and quiet below the surface, Dr. Hanna was one of the men called upon to tackle the problem.

The soft-spoken, 51-year-old Westinghouse scientist has some 100 patents to his credit in the field of regulators. One of his earliest was a device for controlling the speed of steel mill roller motors. Strangely enough, it was this device which led a visiting Army officer to wonder if the same principle could be applied to stabilizing tank guns. Dr. Hanna thought it could and proceeded to prove it. Now an improved version for modern U. S. tanks is on the production line.

Quiet and methodical, the Westinghouse scientist likes to probe for new and difficult applications in his field, isn't swerved by the failure of previous searchers to come up with the right answers. Still a laboratory man at heart, he spends as much time looking over budding, new projects as he does at his associate director's desk.

Dr. Hanna's latest achievement is the development of an automatic pilot with unlimited maneuverability. The conventional autopilot just doesn't have this flexibility; if called upon to perform loops, rolls, or other such maneuvers, its gyroscopes will "tumble" or fall out of their original alignment, causing the plane to go into erratic and dangerous gyrations.

The Westinghouse scientist solved the problem by devising three non-tumbling gyroscopes that stay locked to the plane no matter what maneuvers the aircraft employs.

These are but a few of the high lights in the career of "Clint" Hanna, adventurer in research. The larger picture should certainly include many other contributions, mainly those that have aided in the improvement of numerous Westinghouse products that feature electrical control and regulation. They make it abundantly clear that it is the know-how and experience of scientists like Dr. Hanna which are the cornerstones of industrial progress. Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. G-10228

YOU CAN BE SURE... IF IT'S Westinghouse

for. They soon realized that it must be Carina in process of flaring up again. Examination with photoelectric equipment, which the Lick astronomers had brought with them, confirmed the fact that the star is slowly brightening.

Eta Carina was not included in the first catalogue of the visible stars, made by Ptolemy in A.D. 142. In 1677 Sir Edmund Halley reported that it had become easily visible to the naked eye. In 1834 Sir John Herschel found it to be as bright as the North Star. By 1843 it outshone all the stars in the sky except Sirius, the dog star. After 1860 it started to fade rapidly, and by 1900 it had diminished to magnitude eight, invisible to the naked eye. Its new explosion may again make Carina the queen of the southern skies (see "The Southern Sky," by Bart J. Bok; Scientific American, July).

Double Star

A GIGANTIC double star that revolves faster than any ever observed before has been discovered by the Canadian astronomer Joseph A. Pearce. Called V382 Cygni, it had been known as a variable star with a very rapid fluctuation—45 hours. Studying the shifts in the spectral lines from the star, Pearce was able to prove that it consisted of two stars which eclipsed each other on our line of sight. The larger star is nearly 800 times as big as the sun; the smaller, about 600. Their density is only about one-twentieth that of the sun. The distance between the nearest surfaces of the two bodies is only 2,500,000 miles, and the gravitational attraction between them is so great that it pulls each star into the shape of an egg. The lighter star travels around the heavy one at 450 miles per second.

Faster Computers

TWO NEW electronic calculators, smaller, faster and with better memories than their predecessors, have just been completed. One is at the Institute for Advanced Study at Princeton, the other at the Los Alamos Scientific Laboratory.

The Princeton machine, which has been six years in development, was designed by a team under the direction of the mathematician John von Neumann. This calculator served as a prototype for the Los Alamos device, which is called MANIAC, for Mathematical Analyzer, Numerical Integrator and Computer. MANIAC can do in one and a half hours a problem which took ENIAC, a more primitive brain, 24 hours. The new computer contains only 3,000 vacuum tubes as against 18,000 in ENIAC.

Von Neumann's calculator is now being applied to problems in meteorology. It is making 24-hour forecasts

of the general weather pattern at an altitude of about 18,000 feet over Canada, the U. S. and about one-third of the Atlantic Ocean. In doing this the machine considers weather data from 361 grid points over North America and performs some 1,660,500 operations on the figures to obtain an hour-by-hour prediction. The designers estimate that when operating at top speed the machine will complete a forecast in 48 minutes. Jule G. Charney, the meteorologist working with Institute scientists on this study, hopes to extend the analysis to about eight levels of altitude, and, through the computations made possible by the machine, to learn more about the basic forces underlying our weather, particularly the way in which the sun's heat energy is changed into energy of motion of the atmosphere.

VHF Transistors

A FURTHER advance in transistors that takes them into the very high frequency range has just been announced by the Radio Corporation of America. Its engineers have succeeded in making a point-contact transistor which oscillates at a frequency of 225 megacycles per second. This opens the way for its use in television, FM radio and other VHF applications. The higher frequency was achieved by adjusting the spacing of the transistor's contact points and the resistance of its germanium crystal.

Training Doctors

MEDICAL education is getting a new appraisal. A committee of prominent educators which has been studying the problem for two years has just issued a report on the first phase of its investigation: premedical training.

A major problem in premedical education, the report says, is that of 20,000 students applying annually to medical schools, only about one-third are admitted. The undergraduate schools thus have a great responsibility, which they are not now meeting, to provide guidance so that fewer students will pursue what is for them an impossible educational goal.

The committee finds that there is too much emphasis on science in the premedical curriculum and far too little on the humanities and liberal arts. It urges medical schools to reduce their entrance requirements in technical subjects and to put their admissions procedures under the direction of "persons sympathetic with the aims of liberal education." The study is being made under the direction of Harry J. Carman, dean emeritus of Columbia College. A complete report, covering premedical and medical training, will be published in about six months.

Another group which has been look-

ing at medical education is the American Psychiatric Association. In its report, *Psychiatry and Medical Education,* medical schools are criticized for giving inadequate training in psychiatry and for failing to develop in their students a deeper understanding of the whole person. Physicians, as now trained, tend to be insensitive to the emotional needs of their patients, says the Association. The psychiatrists' report also takes medical schools to task for restricting admissions on the basis of geography, sex, race and religion.

A study of the racial and religious aspects of medical school admissions in New York State was published last month by the American Jewish Congress and the New York State Committee for Equality in Education. The Congress reported that it had found "continued discrimination against Jewish applicants." Among the 72 winners of medical scholarships in competitive examinations in New York last year, Jewish students had more than twice as much difficulty in gaining admission to medical school as non-Jewish students. Cornell University Medical School was said to have the lowest acceptance rate of Jewish scholarship winners over the three-year period of the study. Last year, of two non-Jewish scholarship winners who applied, Cornell accepted both; of 17 Jewish scholarship winners, it accepted one.

Science-Writing Awards

THE first annual Kalinga prize for popular writing in science was recently awarded by UNESCO to Louis de Broglie, French physicist and Nobel prizewinner. The award, worth one million francs ($2,800), was established by B. Patnaik, an Indian industrialist, and is named for an ancient Indian empire. The purpose of the prize is to focus attention on the need for popular understanding and broad use of science, particularly in underdeveloped areas, such as India.

De Broglie, noted chiefly for the development of wave mechanics, has written a number of popular scientific books, including *Matière et Lumière* and *Physique et Microphysique.* He is honorary president of the French Association of Science Writers.

The late Howard W. Blakeslee, for 25 years science editor of the Associated Press, has been awarded a posthumous medal by the American Medical Association to honor "a distinguished layman who has served to advance the ideals of American medicine and who contributed notably to the public welfare." The American Heart Association has set up a Howard W. Blakeslee award to be given annually to the person whose creative efforts in any mass medium contribute the most to public understanding of cardiovascular diseases.

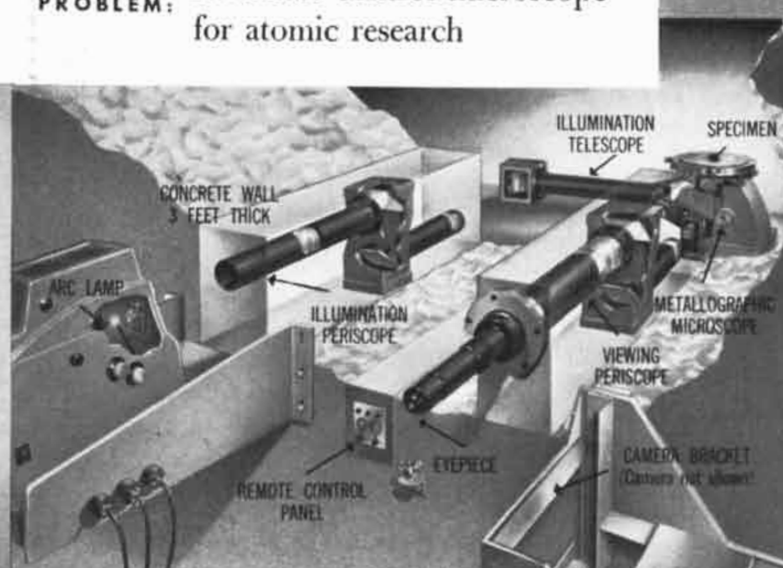
PROBLEM: To tell if water is polluted

ANSWER: The water your child swims in, or the food you give your family can be "safe" or "unsafe." One thing Public Health Departments *must* have to label food or water correctly is an accurate count of bacteria in the samples. American Optical has developed an improved Darkfield "Colony Counter," which makes the bacteria colonies in samples of food or water show white . . . and without glare . . . on a dark background. Bacteria counting can now be easier, more positive, and much less tiring.

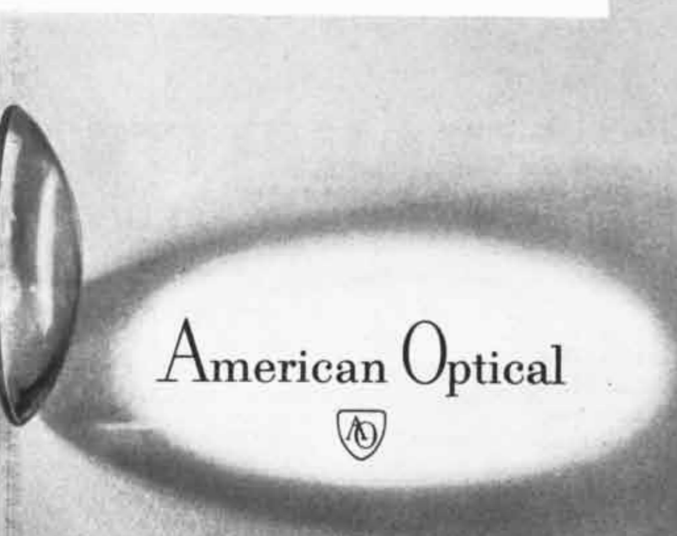
PROBLEM: To detect people who can't tell red from green

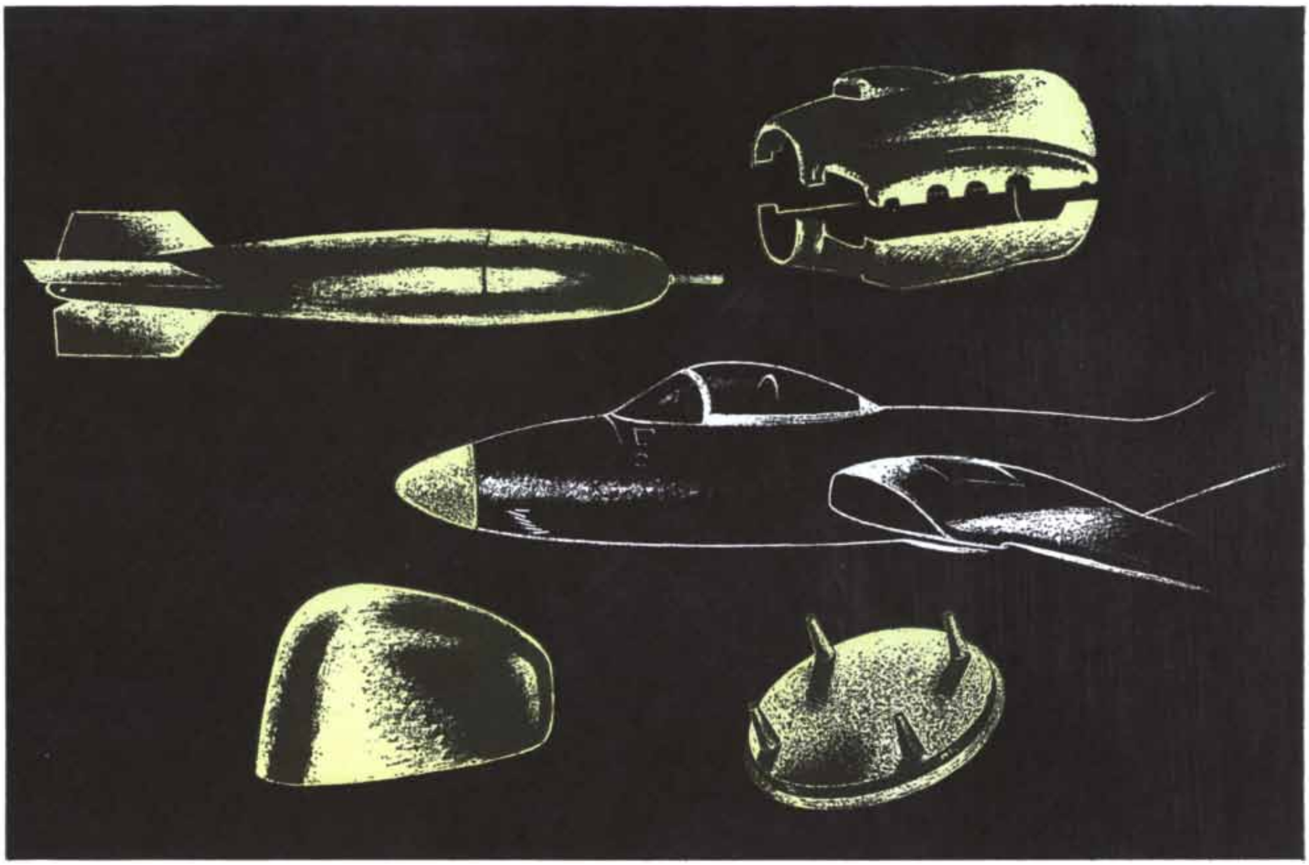
ANSWER: Red and green look alike to some people. These people can be in danger as pedestrians, drivers or in certain jobs. To screen out those who can't or won't tell their weakness, American Optical offers intricate charts of different-colored spots. Normal eyes will see a numeral among the colors; but color-deficient eyes will see either a different numeral or none at all.

PROBLEM: A remote-control microscope for atomic research



ANSWER: How can a man look at "hot" radioactive materials under a microscope when nuclear rays can kill at three feet? For General Electric, American Optical has built a photomicroscope which combines periscope, camera, and lighting. This instrument can be controlled and used through three feet of protective concrete, which completely blocks radiation. Write us about your development problems. Please address American Optical Company, 35 Vision Park, Southbridge, Massachusetts.





MICROWAVES

They are radio waves that range in length from about a quarter of an inch to two feet. Investigated during the war for their utility in radar, they are now widely applied in communication

by J. R. Pierce

WITHIN a generation radio waves have changed our lives and linked the human race together. We have filled the air with them, in many wavelengths. There are the long radio waves in the broadcast band which travel a little beyond the horizon in the day and go thousands of miles at night. There are shorter radio waves that bounce around the earth, linking the continents by telephone and telegraph. Still shorter waves that reach only to the horizon carry FM and television signals. The still shorter microwaves, rifled in sharp beams, relay TV from hilltop tower to hilltop tower across the country. And still shorter radio waves—but the still shorter radio waves are not called radio at all: they are known as heat and light. One warms you before the radiator, and by means of the other the contents of this page reach your eyes in what might be called short-range radio facsimile transmission.

Radio waves are easy enough to describe in these terms, but what, precisely, are they? That is not so simple. We can begin to understand them by considering the familiar waves on water, which illustrate the basic principles of wave motion.

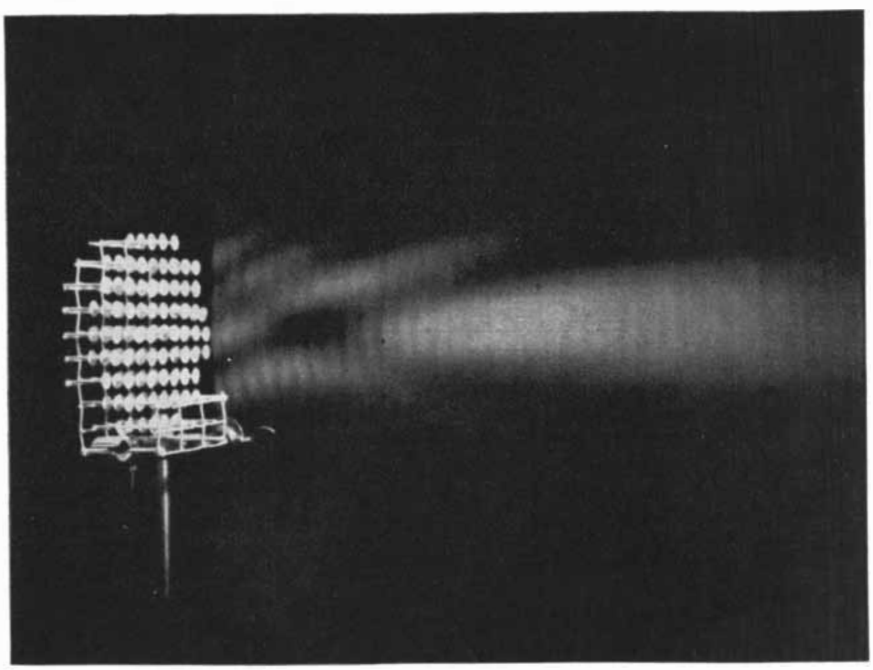
One of the first things that occurs to us is to measure the waves in some way, to attach numbers to them. We can measure their wavelength—the distance between crests. They also have a velocity, and we can estimate this by noting how fast their crests move along past a boat bobbing up and down on them. We can measure their frequency by counting the number of wave crests that pass the boat per minute or second. The frequency can also be calculated from the other two numbers: it is the velocity divided by the wavelength.

Just what happens in a wave that makes it the peculiar thing that it is? Let us imagine ourselves moving along with a wave above its crest, as we might in a helicopter. The water in the wave, which has been lifted above the level of the ocean and set in motion, has two forms of energy. It has potential energy: like that of a car at the top of a hill, or of water behind a dam. Its motion also gives it kinetic energy: like the energy of a rapidly coasting car, or of a spinning flywheel. As the crest moves forward, water ahead of it is scooped up and set in motion, and the water behind it simultaneously falls and loses its forward motion, much as does gravel sliding down from the back of a moving dump truck. Thus the two kinds of energy flow with the wave, being continually transmitted to the water ahead of it and continually lost by the water left behind it.

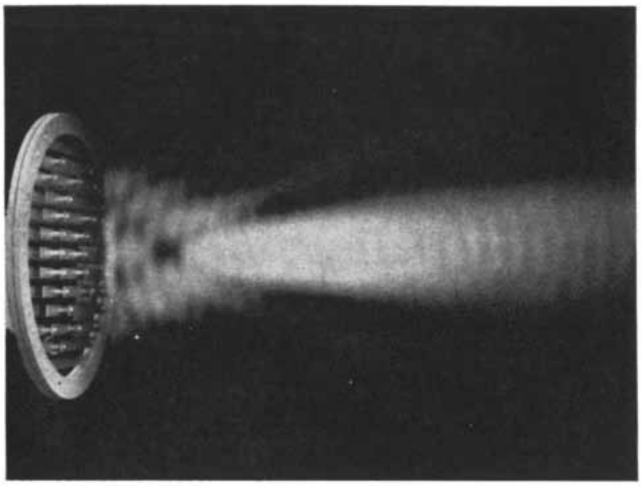
Like water waves the impalpable waves of radio have wavelength, velocity and frequency and involve a continual flow of two forms of energy. But they also have more complex properties, and for our understanding of them we are indebted to the great British physicist James Clerk Maxwell.

Maxwell's Equations

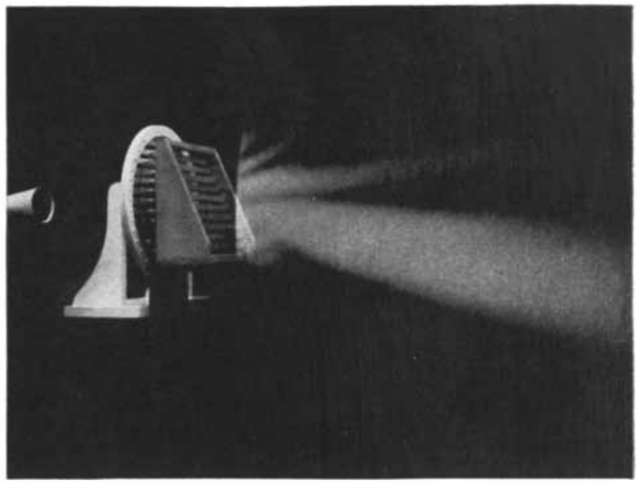
Maxwell came to lay the foundation for radio through studying the laws of electricity and magnetism. He recognized that electric and magnetic fields were forms of storage of energy in space. Electric and magnetic fields had been known before, but the correct equations



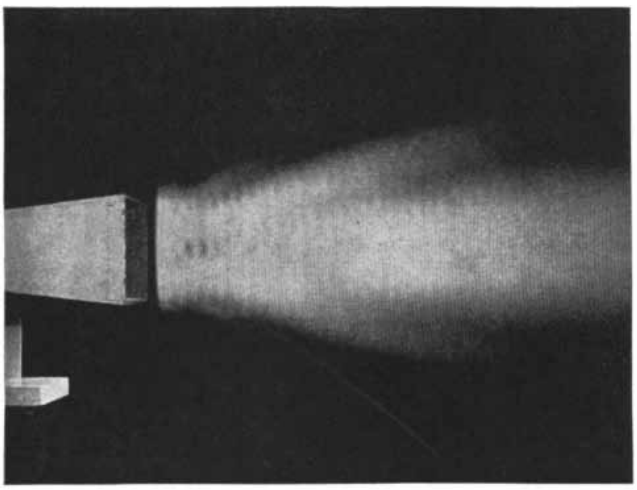
SOUND WAVES of the same length as microwaves are focused by an array of disks. Microwaves would behave in the same way. The waves are made visible by a scanning technique developed by W. E. Kock and F. K. Harvey of Bell Telephone Laboratories. In this technique a microphone and a small electric light are swung back and forth across the beam in such a way that the strength of the sound signal is indicated by the brightness of the light. The swinging light is then photographed by a time exposure.



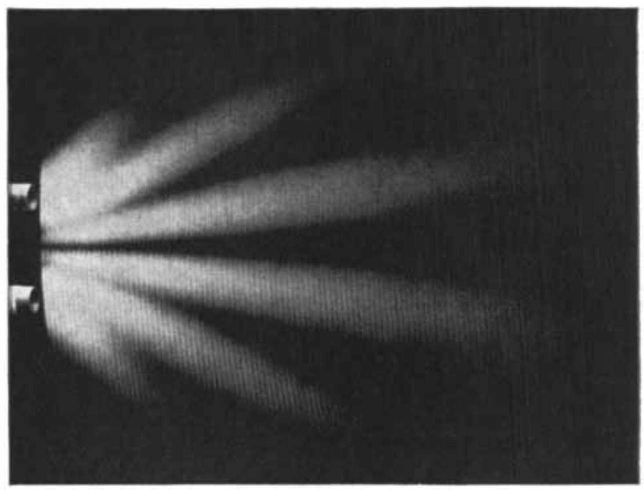
LENS composed of metal strips focuses sound waves in much the same way as the disks on the preceding page. These photographs were also made by Kock and Harvey.



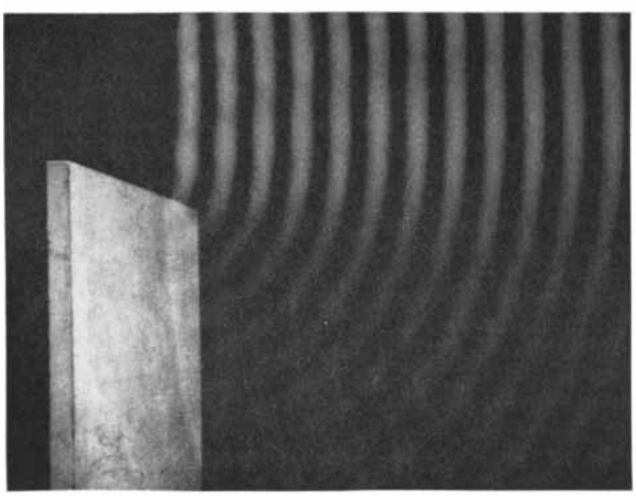
PRISM composed of metal strips is placed in front of the strip lens, tilting the focused sound beam downward. At the far left is the horn that emits the sound waves.



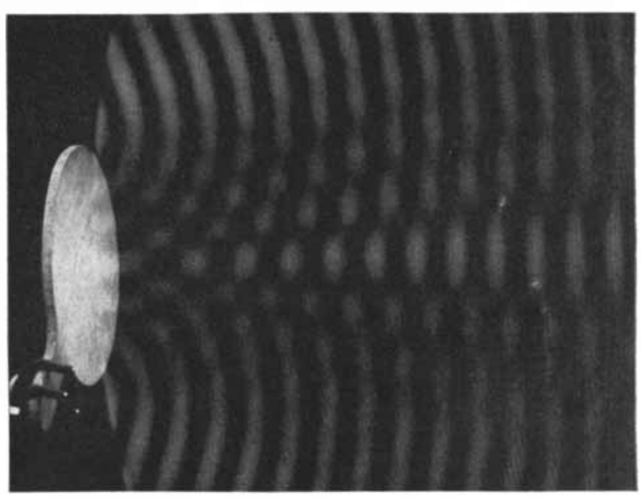
SQUARE HORN emits sound waves in this pattern. Most of the energy is concentrated in the long central lobe, but some of it is in the lobes at top and bottom.



TWO ROUND HORNS emit sound waves that are out of phase. The result is that the waves along a line between and parallel to the horns are canceled out.



STRAIGHT EDGE diffracts a row of perpendicular sound waves so that their lower ends are curved. The source of the sound waves is to the left of the plate.



ROUND PLATE diffracts sound waves so that they interfere with one another. The reinforcement and cancellation of the waves creates the pattern in the center.

governing their behavior had not. These equations Maxwell deduced, and he published them in his great book on electricity and magnetism in 1873.

I once saw a play, *Wings Over Europe*, in which the scientist hero died rapturously muttering Maxwell's equations. As a tool in the hands of physicists and engineers Maxwell's equations have far more practical meaning than Einstein's on general relativity, and yet, while the latter have often appeared in print in popular articles, Maxwell's equations have been rather slighted. These pregnant equations are reproduced at the right. They describe the relations between electric and magnetic fields: the laws that each obeys, and the way in which a change in one produces the other. Their two brief lines sum up a tremendous range of natural phenomena.

Electric and magnetic fields cannot be seen or touched or tasted, and it is hard to describe them in words except by analogy. A magnetic field may be regarded as analogous to the kinetic energy of a swiftly moving automobile, and an electric field as analogous to the potential energy of a heavy body raised to a height. Just as the swiftly moving car can coast up a hill, losing kinetic energy and gaining potential energy, so a magnetic field can decay and produce an electric field. Just as a car coasting down a hill loses potential energy and gains velocity and kinetic energy, so a decaying electric field can produce a magnetic field. Maxwell's equations are the law of such changes.

His equations deal with waves composed of electric and magnetic fields—electromagnetic waves. Studying his equations, Maxwell found that they predicted that such waves should travel through any medium which did not conduct electricity. And he found that their speed through air or a vacuum should be the same as the speed of light! Was light perhaps the electromagnetic waves his equations described?

Physicists of that day were skeptical: they regarded his conjectures on the nature of light as more ingenious than true. Experimental demonstration was needed. But to test his theory by experiments with light was an impracticable enterprise, for the wavelength of light is so short (about 20 millionths of an inch) and the frequency of oscillation so high (600 million million times a second) that it seemed hopeless to produce such waves by means of electric circuits, or to measure their electric and magnetic fields with electric instruments.

Maxwell's fruitful equations suggested, however, another possibility. They implied that rapidly changing currents should produce electromagnetic waves. Why not try to produce waves of longer wavelengths than light and see how they behaved? In 1888 the German physicist Heinrich Hertz per-

$$\oint E_s \, ds = -\iint \mu \frac{\delta H_n}{\delta t} \, dA$$

$$\oint H_s \, ds = \iint \left(J_n + \epsilon \frac{\delta E_n}{\delta t} \right) dA$$

μ = permeability of vacuum

ϵ = dielectric constant of vacuum

ds = element of length

dA = element of area

E_s = electric field along any closed path

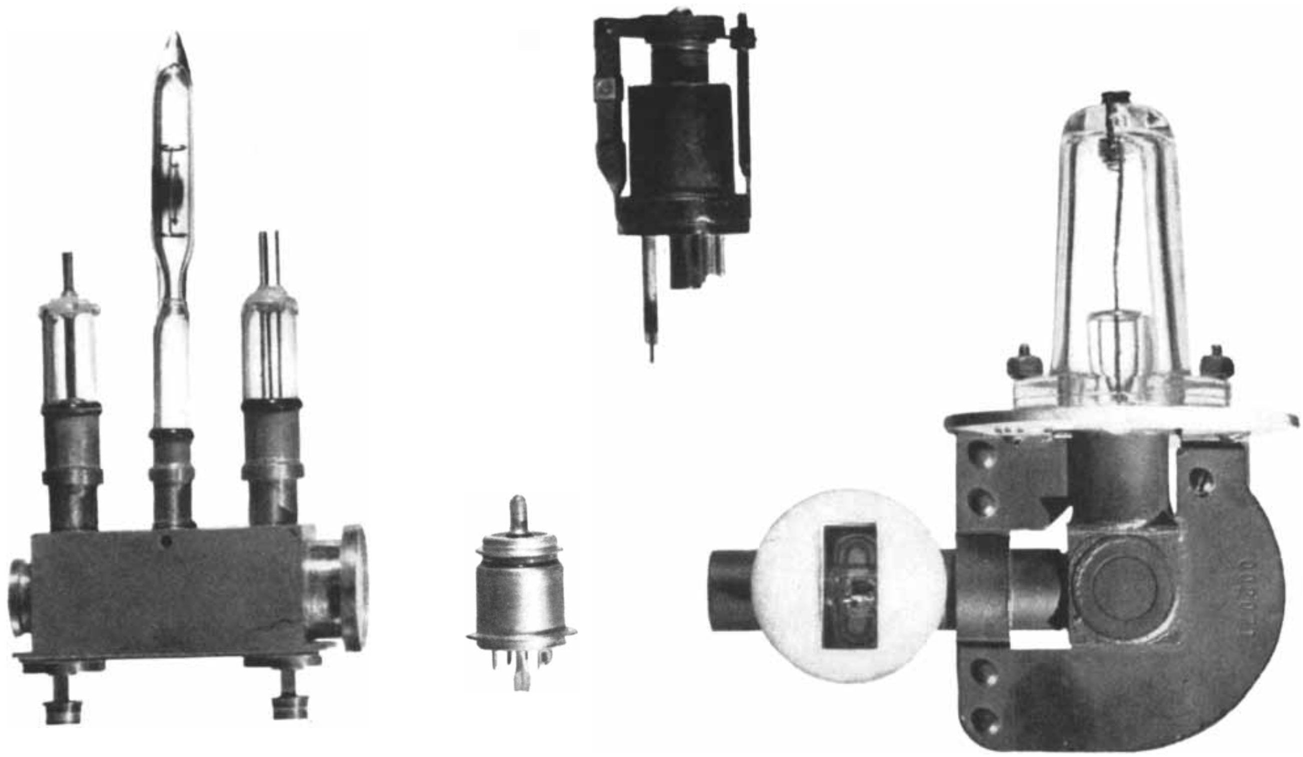
$\frac{\delta H_n}{\delta t}$ = rate of change in strength of magnetic field

H_s = magnetic flux along any closed path

J_n = density of convection current perpendicular to a surface bounded by the path

$\frac{\delta E_n}{\delta t}$ = rate of change in strength of electric field

MAXWELL'S EQUATIONS, which describe the behavior of microwaves and all other forms of electromagnetic radiation, are at the top of this illustration. The terms of the equations are defined in the list below.



FOUR MICROWAVE TUBES are shown in this photograph. At the left is a 6.25-millimeter traveling wave tube. The small tube at lower left center is a 7.5-centimeter microwave triode. At top center is a klystron that will generate waves from 7.6 to 8.8 centimeters in length. At the right is a 3-centimeter magnetron.

formed that historic experiment. He set up a very simple apparatus: To two metal plates, one charged very positive and the other very negative, were connected two rods with their ends close together, leaving a spark gap between them. When the voltage across the gap reached a certain level, the gap sparked and a sudden current flowed across. The current oscillated back and forth across the gap, and the oscillating current produced the first deliberately made electromagnetic waves. The waves traveled across the room, and Hertz detected them with an almost closed ring of wire, in which the waves induced a current that made tiny sparks jump across the gap between the ends of the ring.

Hertz went on to show that his waves could be reflected by a metal plate, just as light waves are reflected from a mirror; that they could be bent by a prism of pitch, just as light is refracted by a prism of glass; that they traveled with the same velocity as light.

Hertz's waves were the first microwaves. Their frequency was 500 million cycles per second (500 megacycles), and their length was about two feet. (Modern microwaves range in length from around a quarter of an inch to two feet.)

There is something of a paradox in the fact that the first man-made radio waves were microwaves, and today, more than 60 years later, microwaves are considered the newest thing in radio. The physicists and engineers who developed from Hertz's discovery the beginnings of radio quickly went from microwaves to longer wavelengths. There were good reasons for this: microwaves could not be transmitted farther than the short distance to the horizon, and it was very much harder to generate large powers at microwave wavelengths than at long wavelengths.

The vacuum tube, invented just before the First World War, made it possible to go to shorter and shorter wavelengths—as short as 1.5 meters (a little under five feet), which is used in television. And physicists retained their interest in microwaves, developing special types of tubes and equipment, including the magnetron and klystron, to handle them.

How, mainly under the stimulus of World War II, the microwave art rapidly expanded when the need arose is by now a well-known story (see "Radio Waves and Matter," by Harry M. Davis; Scientific American, September, 1948). The war supplied a tremendously important application of microwaves in radar and the equipment for generating high-power microwave signals. Microwaves suddenly changed from a laboratory tool to a major industry.

A Common Size

In trying to understand microwaves it is of primary importance to keep in mind their size. The behavior of waves is governed by their size in relation to the dimensions of things with which they interact. Let us go back to the example of the ocean waves. Suppose that one wants to build a breakwater, parallel to the shore, to protect the shore from waves coming straight in from the ocean. How long must he make it? Experience shows that this depends on the length of the waves. If we were thinking in terms of light or of radio waves, we would say that waves which strike the shore illuminate it. The purpose of the breakwater is to cast a "shadow"—a region of calm water where waves do not strike. It is a fundamental property of waves that objects cast distinct shadows only when they are large compared with a wavelength.

Of course the distance between the breakwater and the shore is important too. If a breakwater a mile long were put miles and miles out from the shore, it would not cast a distinct shadow. The waves would in effect bend around the ends and meet again some distance behind it. Where the crests of waves from the opposite ends arrived at the same time and reinforced each other, the waves would be high; where they met out of phase, the disturbance would be small. There would be a complicated pattern of disturbance behind the breakwater; its technical name is "diffraction pattern."

Light waves are so small that almost any object we think of is large in comparison. Thus in the case of light most objects cast very distinct shadows. The waves of broadcast radio are about a quarter of a mile long. They will flow around a small hill and cast little or no shadow behind it. Because the transmitting antennas that send them out are small compared with a wavelength, such waves are broadcast from the transmitter in all directions; it takes an antenna many wavelengths in size to focus waves in a beam.

Much of the fascination of microwaves arises from the fact that they are in the range of sizes of most common objects. This makes them easier to handle and study than long radio waves or the minute light waves. For instance, with a little wire as the transmitting antenna one can broadcast microwaves in all directions; with a "dish" only 10 feet in diameter one can send them out in a narrow beam. For detecting microwaves we can use a crystal rectifier, which is just a little piece of silicon with a fine wire touching the surface. A crystal rectifier or crystal diode changes microwaves to direct current, which can be observed by means of a sensitive meter or galvanometer. Equipped with a crystal diode, a short wire antenna sticking out from it and a sensitive meter to read the current produced by the diode, one can explore a region in which microwaves travel and see where they are strong and where they are weak. Many microwave measurements are made in essentially this way.

To measure the length of waves that whiz by at 186,000 miles a second may seem no easy task, but there is actually a simple way, which Hertz used when he produced the first microwaves. When waves are reflected straight back from a flat surface, the incoming and reflected waves combine to form what are called standing waves. A quarter of a wavelength from the surface the crest of a reflected wave meets the crest of the next wave. At this point the combined crests give a strong signal. Half a wavelength from the surface the crest of a reflected wave coincides with the trough of the next wave, and the signal at this position is weak or zero. Thus strong and weak signals alternate at quarter-wavelength intervals from the surface. By determining with a detector where these distances are, one can easily measure the wavelength.

Standing-wave measurements are the backbone of microwave experimentation. They are used to determine not only wavelength but how much of the wave has been reflected. The reflected wave can cancel the incoming wave completely at any point only if all of the wave is reflected. If the wave is only partly reflected, the signal will nowhere be zero. One important use of standing-wave measurements is in designing devices which are meant to absorb microwaves instead of reflecting them.

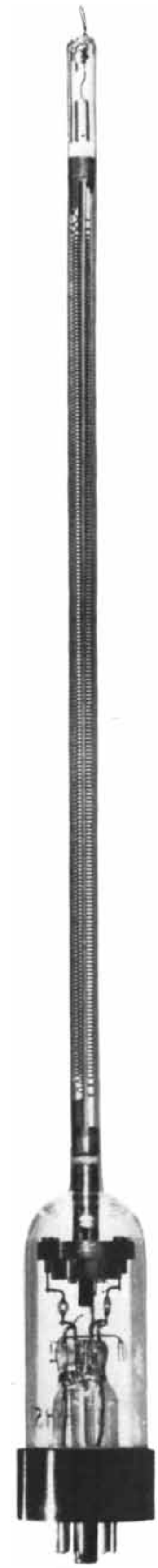
Like light, microwaves can be focused by means of concave mirrors. The larger the diameter of the mirror compared with the wavelength, the narrower is the beam. The 600-inch radio telescope of the Naval Research Laboratory can focus three-centimeter microwaves into a sharp beam less than a tenth of a degree wide. A concave mirror can also be used as a receiving antenna.

To act as a directional antenna a mirror must be shaped just right, so that the waves sent out from various parts of its surface travel along with their crests together and add up. There are other ways of making directional antennas. One is to use a horn like a megaphone. Microwaves sent into the small end spread out and leave almost uniformly over the large end. If the large end of the horn is many wavelengths in diameter, it can give a very narrow beam.

Horn antennas of the short, squat type need a lens at the mouth to correct for the difference in distance traveled by various parts of the wave. Such a lens could be made of glass. However, while glass is an admirable material for optical goods, 10-foot microwave lenses made of glass would be unduly heavy and expensive. What can one use as a substitute? It has been found that an array of regularly spaced little metal disks, close together in comparison with the length of a microwave, fills the bill nicely (*see photograph on page 43*). The disks are electrically excited by microwaves, just as the molecules of glass in a lens are by waves of light. Some microwave communication systems use lenses made of such arrays of disks, or sometimes of strips of metal.

Waveguides

In any radio system the waves not only are broadcast and received through the air but must also be guided within the transmitting and receiving equipment. In ordinary radio this is done by wires, much as wires transport a telephone message or electric power. Now a pair of wires will guide microwaves, but in a very unsatisfactory manner. The currents fluctuate much more rapidly than do those in a power line or a telephone line—perhaps 10,000 million times a second, as opposed to 60 times a second for power or a few thousand times a second in telephony. The very rapidly fluctuating currents tend to radiate microwaves from bends and irregularities into space. The waves just leak off the wires. Hence in microwave radio wires are replaced by metal pipes called waveguides, which carry the waves very satisfactorily when the diameter of the pipe is about the same size as the wavelength. Among micro-



TRAVELING-WAVE TUBE that generates 7.5-centimeter microwaves accelerates electrons in long coil.

wave workers waveguides have become affectionately known as "plumbing."

Waves of a given frequency can go through a pipe in many patterns, called modes, each with a different wavelength and velocity. When the pipe is small, only one mode can travel. The wave goes through the pipe in a well-ordered manner, but it dissipates fairly rapidly with distance because of electrical losses in the walls of the pipe. Consequently small waveguides are used to carry microwaves only for short distances. For a frequency of 50,000 megacycles per second, corresponding to a wavelength of 1/4 inch, an appropriate guide size is 3/16 inch by 3/32 inch.

In a bigger pipe, the loss of energy is much less. Potentially, in a two-inch pipe a 50,000-megacycle signal might be sent 30 miles and then amplified and sent on again. The trouble is that in a large pipe many modes travel together, and at irregularities or bends one mode is converted into others, so that the wave pattern becomes chaotic. Nevertheless, the prospect of long-distance transmission is so attractive that the Bell Telephone Laboratories have built a narrow 300-foot-long building to study the propagation of microwaves through long sections of waveguide.

Traveling-Wave Tube

The waveguide is only one of many gadgets that microwaves have brought to radio. There are the cavity resonator (which is used to produce high electric fields, to filter signals, to provide circuits in vacuum tubes, and so on), the magnetron and the klystron (used to produce bursts of high power, notably as pulses for radar), and a host of others. But the story of most of them has frequently been told, and this is not the place for a detailed catalogue of microwave equipment.

There is, however, a relatively new type of microwave tube which merits particular notice. This is the traveling-wave tube. It is of special interest because it promises to be of increasing importance in the field of microwaves and because it well exemplifies the wave nature of microwaves.

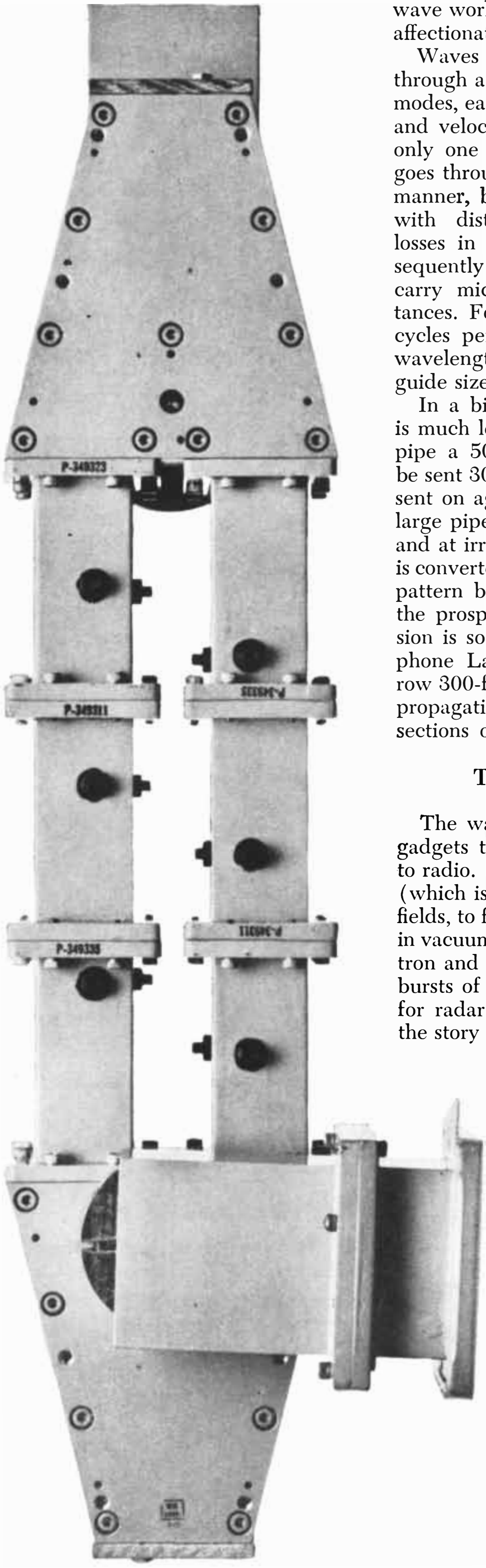
Like the klystron, the traveling-wave tube makes use of a long beam of swiftly traveling electrons. In the klystron a microwave resonator is used to build up strong electric fields, which accelerate and bunch the electrons as they pass quickly through a hole in the resonator. In the traveling-wave tube, on the other hand, the electric fields are not very strong. Instead, an electromagnetic wave is guided along beside the electron stream in such a way that the wave travels at almost the same speed as the electrons. Thus an electron continues to be acted on by the wave crest as it moves along, and the effect builds up.

Several different means can be used to slow the wave down so that it will travel with the same speed as the electrons. The most common practice is to use a coil of wire or a helix, much like a stretched screen door-spring. For a tube to amplify 7.5 centimeter waves, the coil might be a tenth of an inch in diameter and 10 inches long. The wave will travel along the wire of the coil with almost the speed of light. If there are 130 inches of wire in the 10-inch coil, the wave will travel down the coil with about 1/13 the speed of light, and this is just about the speed of electrons accelerated by a voltage of 1,600 volts.

The signal to be amplified is fed from a waveguide onto the coil or helix at the end near the source of electrons. The electrons and the wave travel along together and the wave acts on the electrons of the beam to bunch them. The electron-bunches in turn act to strengthen the wave in the circuit. After a little distance of travel, the wave increases in strength so that, in a typical case, its power doubles in less than an inch of travel. We can visualize the waves as waves on water, and we can think of the electron stream as a breeze that blows gently past the waves and raises them higher and higher as they travel.

Traveling-wave tubes give much more gain than other microwave tubes. One traveling-wave tube can amplify the power of a signal by 10,000 times, while a microwave triode gives an amplification of only 10 times, and klystrons give something intermediate. Moreover, traveling-wave tubes can amplify shorter microwaves than other devices can. Tubes made at the Bell Telephone Laboratories have amplified waves of 50,000 megacycles. Besides this, traveling-wave tubes will amplify bands of frequencies thousands of megacycles wide, in contrast to the narrow range amplified by klystrons or triodes. This is important because the amount of information a signal can carry is proportional to the width of the band of frequencies comprising it. To carry the human voice in telephony requires a band of frequencies 4,000 cycles wide, and one television signal takes about a thousand times that band width, or four million cycles.

It is easy to see that one of the great benefits of microwaves is the huge addition that it will make to our channels of communication. The section of the



WAVEGUIDES carry microwaves in relay equipment. This assembly separates microwave channels in a receiver and adds them in a transmitter.

microwave-range between 6 centimeters and 7.5 centimeters, for instance, covers a band width of 1,000 megacycles—a band 1,000 times as broad as that covered by all of the conventional AM broadcast stations together.

By making it possible to amplify broad bands of frequencies in one tube, the traveling-wave tube may permit the sending of several television signals through one piece of equipment, so that separate equipment will not be needed for each television channel as at present. This intriguing possibility is for the future. In their present commercial use, as in a microwave radio relay system built for the British Post Office by Standard Telephones and Cables, Ltd., they merely replace triodes or klystrons and do a somewhat better job.

In some communication systems information is sent by means of short pulses. As each pulse conveys a certain amount of information, the more pulses that can be sent in a second, the more information. It is therefore desirable to make the pulses as short as possible, and this requires a large band width. With traveling-wave tubes in the transmitter and receiver, microwave pulses lasting only a few billionths of a second have been sent and received over a path 22 miles long between branches of the Bell Telephone Laboratories at Holmdel and Murray Hill, N. J. These pulses are less than a tenth as long as the shortest pulses used in wartime radar. They travel through space as microwave signals less than 10 feet long. In addition to their possible uses in communication, such short pulses may improve the resolving power of radar. A radar can see targets separately only if they are separated by a distance comparable to the length of the radar pulse as it travels through space. Pulses as short as 10 feet might distinguish individual planes in a formation.

Noise

In any form of radio one of the most important matters to be considered is noise. When you listen to a weak broadcasting station, there is a frying or hissing noise in the background which is particularly noticeable in the absence of speech or music. When you watch television you may see a snowlike fluctuation even where the picture is supposed to be smooth black or gray. Similar disturbances are characteristic of all electrical communication. They are due to randomly fluctuating electric signals, either in nature or unavoidably produced by the transmitting and receiving equipment itself. Noise is what determines how powerful a signal we must have. In electrical communication the signal reaching the receiver must be enough larger than the noise to give the desired quality of communication. In radar one may detect a signal equal to or even smaller than noise. In television, telephony and radio the signal should be many times as powerful as the noise.

Now the power of the received signal can be increased by stepping up the power of the transmitter, by concentrating the power into a narrower beam with a larger transmitting antenna or by using a larger receiving antenna to intercept more microwave energy. Year after year microwave receivers are improved, so that they add less and less noise to the signal. So far as we know there is no physical limit to the possible improvement in this respect, and it is not idle to talk about receivers which would add essentially no noise to the received signal. We would still not be rid of noise, however. There would be noise from the earth, for warm bodies radiate microwaves just as they radiate waves of heat and light. If we pointed our noiseless receiver at the night sky, away from the Milky Way, we would receive perhaps less than 1/30 as much noise power, for the temperature of space dotted with ordinary stars is probably less than 10 degrees above absolute zero. If we pointed the receiver at the hot sun, we would get perhaps 30 times the signal the warm earth gave us, as the temperature of the sun is ordinarily around 10,000 degrees absolute. And from other points in the sky we might receive strong signals from so-called radio stars, often invisible, which radiate microwaves.

Thermal radiation sets an ultimate limit to the sensitivity of receivers in detecting weak signals. The province of the temperature or apparent temperature of natural bodies belongs to physics and astronomy, but the limitation imposed by thermal noise dominates all microwave applications. For this reason, the noisiness of present receivers is measured in terms of thermal noise.

A very good microwave receiver may have a noise figure of five, meaning that it generates a noise five times that which would be received from a body at the arbitrarily chosen temperature of 68 degrees Fahrenheit. Most of the receivers in use generate noise amounting to about 30 times on this scale. How much electric power does this noise represent? That depends on the width of the band of frequencies to which the receiver responds. For a band width of five megacycles, such as might be used in radar, the noise amounts to less than a millionth of a millionth of a watt. Let us assume that a radar can detect a signal which is just as strong as the noise, and that it sends out a signal of one million watts. It can detect a target if the echoed signal it receives has a millionth of a millionth of a millionth of the power sent out. And it needs to do this to see a tiny object over a hundred miles away!

I have not spoken of one form of noise with which we are familiar, the static of ordinary radio. In microwave radio there is no static! The fact that microwaves were not utilized for so many years after Hertz's discovery is an indication that man found it very hard to generate microwaves. Nature apparently finds it equally difficult, at least here on earth. Thunderstorms produce no microwave static. Neither do man-made devices, such as automobile ignition, X-ray machines or the like. One of the greatest advantages of microwaves is the freedom from natural and man-made interference.

Strange Reflections

The microwave art is not completely free from natural disturbances, however. Occasionally on a coast-to-coast television program, which is relayed *via* microwave towers in 106 hops across the country, you may see the picture dissolve briefly into a shower of speckles. This may be caused by any of several kinds of natural interruption in one or more of the 106 links. At the shorter wavelengths used in radar, intense rainfall can cause serious scattering of the waves, much as fog scatters light. In microwave communication, which generally operates at wavelengths longer than five centimeters, rain causes only slight interference. But there is another effect which may be much more serious: ground reflections.

When a microwave beam spans rough country, especially wooded areas, the part of the signal that strikes the ground is scattered and lost, and only that part which passes directly through the air reaches the receiver. Over water, however, or over the salt flats of Utah, microwaves that strike the water or ground are almost completely reflected. The reflected and direct waves reach the receiver by different paths, and whether they add to or cancel each other depends on the heights of the transmitting and receiving towers. Under such conditions relatively short towers may be better than tall ones, or it may be best to use a short tower at one end of the path and a tall tower at the other.

On the moon, where there is no atmosphere, reflections would cause no serious trouble. One would merely choose tower heights to make the direct and reflected waves add. On the earth variations in the atmosphere, particularly the decrease in density with height and the presence of water vapor near the ground, make the waves behave erratically. Since waves in the higher air travel faster than those near the ground, the path of the microwaves tends to bend toward the earth. At sea on calm nights microwaves sometimes hug the earth for hundreds of miles, instead of soaring into space beyond the horizon, because they are bent toward the sea,

TALL TOWERS **support the transmitting and receiving antennas of the American Telephone and Telegraph Company microwave relay system. At the left is a steel tower near La Salle, Mich. Second from the left is a**

reflected, bent toward the sea, reflected again, and so on. Even much less-pronounced effects will so alter the relative lengths of paths of direct and reflected waves as to cause them to cancel when, under other circumstances, they would add. Stratification of the air on very calm nights can make microwaves travel over two or more paths even without reflection from the ground. It is the bending of paths, from these various causes, that produces most of the fading encountered in microwave reception.

All of these phenomena, as yet imperfectly evaluated, affect the design of microwave communication systems. Year on year more data are gathered, and slowly our knowledge increases. With respect to propagation, microwave communication is and will for a long time be in a stage of doing and learning. Fortunately microwaves have a fundamental advantage over some of the waves we must work with today, such as the short-wave radio used in transatlantic telephony. Short-wave radio gets across the Atlantic by virtue of the fact that it is reflected around the earth by the ionosphere. But the reflection is erratic and sometimes fails altogether. Microwaves can be controlled better for the distances over which they are transmitted, and their range can be lengthened by relays. Even present microwave links give very reliable service indeed when they are compared with transatlantic telephony.

Microwaves at Work

The uses of microwaves by now make up a large catalogue. Astronomers study microwaves that come to us from the sun, the stars and clouds of gas in space for new "light" on those distant bodies. Physicists employ microwaves, as they use light, X-rays and beams of electrons, in deducing and measuring the properties of molecules, atoms and nuclei which are small far beyond the range of sight. Nuclear physicists harness microwaves to accelerate electrons and ions for bombarding nuclei and to study nuclear reactions.

In technology radar is still the most extensive application of microwaves. Because radar is largely military, much radar work is classified, and this makes it difficult to talk about it. In general, however, one can say that the microwave part of radar has not changed greatly since the war. Magnetrons with somewhat higher powers have been used. More tunable tubes have been produced. Microwave lenses have come into use as antennas, along with concave reflectors or mirrors. What has changed mainly is the complexity and use of radar systems. Present-day radars supply information to far more complex computers for use in pointing guns, and they not only can locate enemy planes but also are capable of directing guided missiles to them.

The chief civilian application of microwaves lies in the field of communications. As far back as 1931 the International Telephone and Telegraph Company, in collaboration with the Laboratories of Telephonic Material of France, used microwaves to bridge the channel from Calais to Dover. Their experimental microwave link operated on a wavelength of 18 centimeters and used a power of a few tenths of a watt. It supplied a single telephone circuit. On the verge of World War II preliminary steps toward microwave communication were being taken in this country. The wartime effort on radar interrupted this work. But the British, who frequently get there first in new fields of technology, made considerable use during the war of a microwave system known as Wireless Set No. 10.

concrete tower between Chicago and Milwaukee. Third from the left is a tower overlooking Salt Lake City. At the right is a double tower with its receiving antennas at one level and its transmitting antennas at another.

Before the end of the war two multichannel microwave communication systems had been built in this country, one by the Radio Corporation of America and the other by the Bell Telephone Laboratories. The latter still provides telephone service to Catalina Island. Early postwar days saw development of several microwave links for single-hop television transmission from pick-up to studio and from studio to transmitter. Similar inexpensive microwave systems find a variety of uses, including voice communication around airports. The use of single-hop systems was followed by development of various radio relay systems for voice communication along long pipelines, power lines and other purposes.

The most elaborate postwar application of microwave radio relay has been the Bell System's coast-to-coast microwave radio relay system for telephone and television, which was put into operation in 1951. The antennas carrying its 106 links across the country are located in all sorts of places, ranging from squat buildings on mountain peaks to tall concrete or steel towers on level plains. The antennas consist of horns with artificial dielectric lenses 10 feet square. The microwave frequency is around 4,000 megacycles per second. The transmitting tube is a triode with about half a watt power output. Such a long common-carrier system must meet much stricter requirements than a shorter, privately owned system. The system has a stand-by channel and elaborate alarm and control circuits to assure continuous service on all the relays.

The Future

What is the future of microwave communication? It has obvious advantages over stringing wire, particularly over water or rugged terrain. Some argue that it is and will be cheaper to install and maintain microwave systems than wire systems anywhere. If this proves to be so, microwave systems will be built up to the point where we run out of air channels. Indeed, this saturation will perhaps eventually be reached in any event. We may then add to the channels by putting microwaves in waveguide pipelines.

Microwave communication has much to recommend it in primitive areas or in areas where war or unrest is common. The French call a microwave link a Hertzian cable, and it is one cable that cannot be cut. As long as the transmitters and receivers can be defended, communication can be maintained.

If men ever go to the moon or to the planets, microwaves will provide easy communication back to earth. An earth-moon or even an earth-Mars microwave link could be set up with present microwave equipment—provided we can get to the far end to make the installation! Perhaps somewhat nearer is the possibility of a satellite vehicle circling the earth above the atmosphere. Such a vehicle could be used as a microwave relay point for round-the-world television and other communications.

Whatever the future developments, they will fit into the unalterable pattern of Maxwell's equations and the properties of waves slowly elucidated by the research of the past century. They will be new aspects of a science we already know. If they prove startling in their newness, they will be even more startling in their oldness, for they can be no more than as yet unseen parts of a pattern, a science, founded on the work of Maxwell and Hertz.

J. R. Pierce is director of electronics research at the Bell Telephone Laboratories.

Running Records

In which a curve is plotted on the basis of the best human performance at each competitive distance, suggesting what marks are the most likely to be surpassed and by how much

by M. H. Lietzke

MEN have been running foot races for thousands of years, but only within the last hundred have clocking devices made it possible to record their times accurately. With some 75 years of clocked competition now on record, it is increasingly difficult for an athlete to get his name in the record book. It seems worth-while to analyze some of the best efforts to see which records are most likely to be broken and to judge human physiological limits in running.

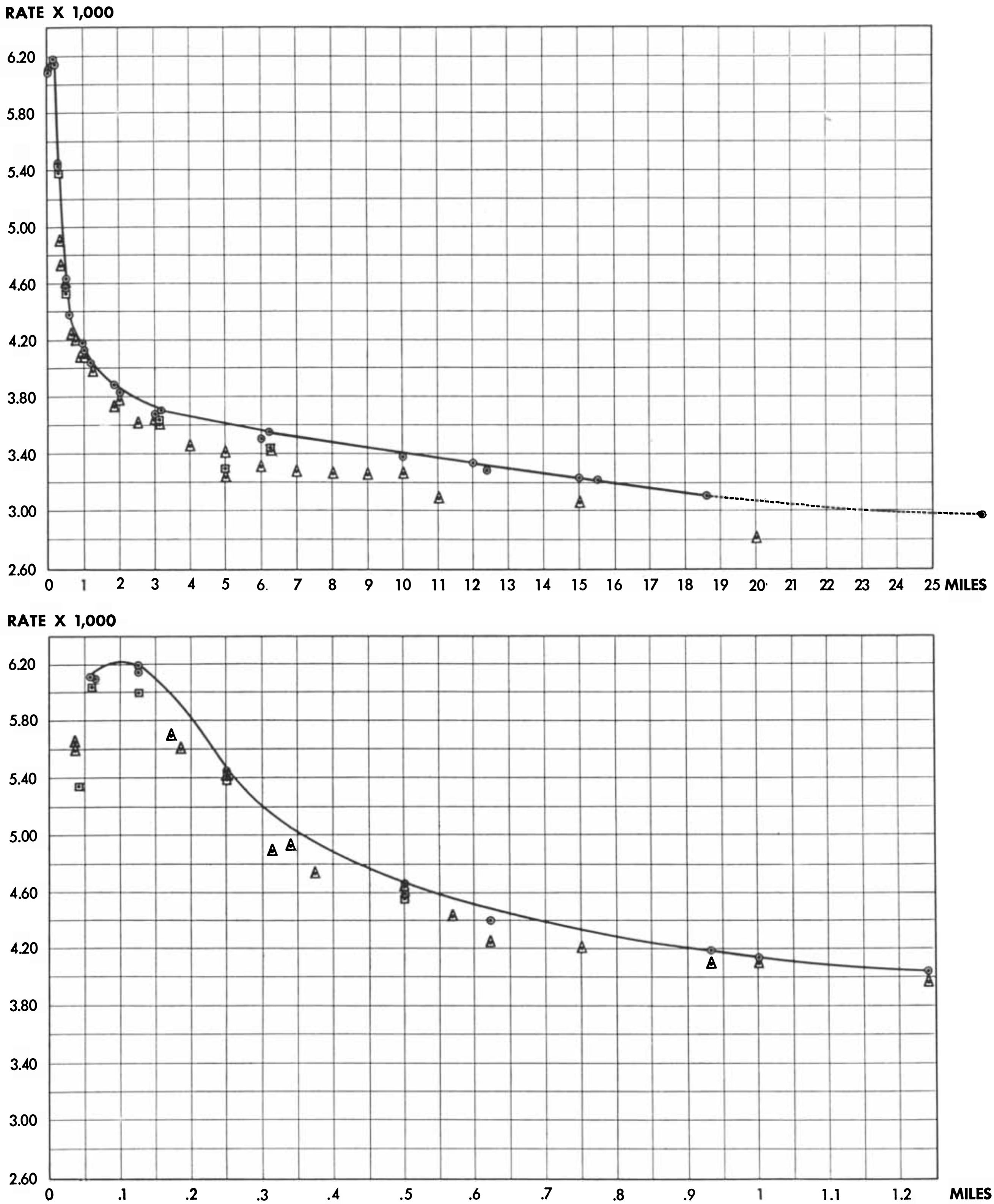
On the opposite page are two charts plotting the world-record performances at the various distances run in races. The performances are given in terms of the average speed over the full distance in each case, rather than the total time for the race, because comparisons are easier in this form. A smooth curve can be drawn through the best world records. (For convenience semilogarithmic plots are used.) Presumably the points on the curve represent the limit, or very close to the limit, of track athletes' possible achievement at each given distance. Where a world record (or American or Olympic record) for a particular distance falls below the curve, that record should be improvable by the amount that it falls below. For example, the American four-mile record, set by Don Lash in 1937, is 19:17.3. His average rate for the distance was .00346 mile per second. But the curve, on the basis of the world records at 5,000 and 10,000 meters, indicates that it should be possible to run four miles at an average speed of .00361 mile per second. Thus the American four-mile mark might be improved by 1:4.4.

One of the charts here shows the world, American and Olympic records at distances up to the Marathon, and the other, a blow-up of part of the same curve, gives the detailed records at distances from 60 yards to 1.25 miles. From these curves it is calculated that the record for 100 meters should be broken by 0.1 second; for 200 meters, by 0.2 second; for 1,000 meters, by 3.1 seconds; for 20,000 meters, by 46.3 seconds; for 880 yards, by 1.9 seconds; for 2 miles, by 3.3 seconds; for 3 miles, by 5.9 seconds; for 6 miles, by 30.1 seconds, and for 10 miles, by 21 seconds. The American and Olympic records of course are much more vulnerable, as many more of them fall below the world-record curve.

Naturally the records that lie on the curve, and are least likely to be broken, generally were set at the distances most often run. Most of the poor records, considerably below the curve, are for distances infrequently timed outdoors,

DISTANCE	TIME HOURS: MINUTES: SECONDS	RATE MILES PER SECOND	RECORD HOLDER	COUNTRY	YEAR
100 YARDS	9.3	.00611	PATTON	U.S.	1948
220 YARDS	20.2	.00619	PATTON	U.S.	1949
440 YARDS	46.0	.00543	McKENLEY	JAMAICA	1948
880 YARDS	1:49.2	.00458	WOODERSON WHITFIELD	GREAT BRITAIN U.S.	1938 1950
1 MILE	4:01.4	.00414	HAEGG	SWEDEN	1945
2 MILES	8:42.8	.00383	HAEGG	SWEDEN	1944
3 MILES	13:32.4	.00369	HAEGG	SWEDEN	1942
6 MILES	28:30.8	.00351	HEINO	FINLAND	1949
10 MILES	49:22.2	.00338	HEINO	FINLAND	1946
15 MILES	1:17:28.6	.00323	HIETANEN	FINLAND	1948
100 METERS	10.2	.00609	OWENS DAIRA	U.S. U.S.	1936 1941
200 METERS	20.2	.00614	LaBEACH PATTON	PANAMA U.S.	1948 1941
400 METERS	45.8	.00544	RHODEN	U.S.	1950
800 METERS	1:46.6	.00466	HARBIG	GERMANY	1939
1,000 METERS	2:21.4	.00439	GUSTAFSUN HANSENNE	SWEDEN FRANCE	1946 1948
1,500 METERS	3:43	.00418	HAEGG STRAND	SWEDEN SWEDEN	1944 1947
2,000 METERS	5:07	.00404	REIFF	BELGIUM	1948
3,000 METERS	7:58.8	.00388	REIFF	BELGIUM	1949
5,000 METERS	13:58.2	.00371	HAEGG	SWEDEN	1942
10,000 METERS	29:02.6	.00356	ZATOPEK	CZECHOSLOVAKIA	1950
20,000 METERS	1:03:01.2	.00328	CASAPLAR	HUNGARY	1941
25,000 METERS	1:20:14	.00322	HIETANEN	FINLAND	1948
30,000 METERS	1:39:14.6	.00312	VANIN	U.S.S.R.	1949

PRINCIPAL WORLD RECORDS for men are given here not only in time but also in rate: the average speed of the runner over the entire distance.

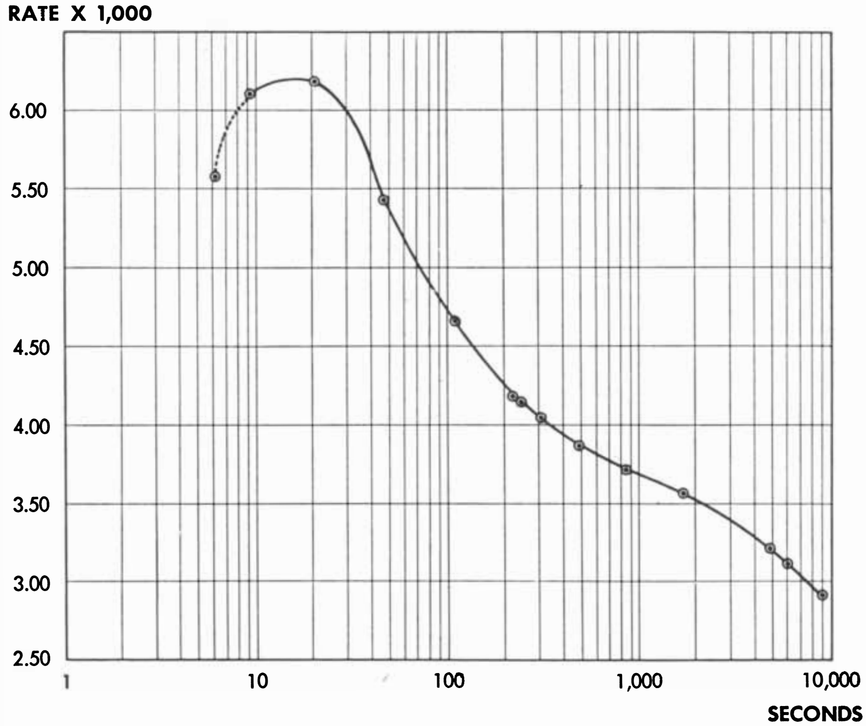


⊙ WORLD RECORD

⊡ OLYMPIC RECORD

△ AMERICAN RECORD

RATE AND DISTANCE of world, Olympic and American records are the coordinates of these two charts. The curves, however, are plotted only on the basis of the world records. At the top is a curve for the records from 100 yards to the distance of the unofficial Boston Marathon. At the bottom is the same curve from 100 yards to 2,000 meters, slightly less than 1.25 miles. At some points two records appear to be given for the same distance; this is because the distances of some races run in yards and in meters are almost identical. At .5 mile on the bottom chart, for example, records are given for 800 meters (874.44 yards) and for 880 yards (804.67 meters).



RATE AND TIME of world running-records are the coordinates of this chart. The time scale is logarithmic, exaggerating the shape of the curves shown on page 53. The initial rise and fall of the curve is due to the effect of starting. The curve begins to straighten at 140 seconds; this is apparently due to the effect of "second wind." The dotted line at the beginning of the curve extends it to include the unofficial world record for 60 yards.

such as 300 yards, 600 yards, 1,000 yards, 3 miles, and so on. It is also clear that some of the listed world records must have been broken in races in which the runners were timed at another distance; for instance, when Melvin Patton set the world record for 220 yards at 20.2 seconds, he must have run 200 meters in about 20.1, but the recognized 200-meter record is 20.2. Likewise, when Emil Zatopek ran 10,000 meters in 29:2.6, he must have covered 6 miles in about 28:3.0, almost 28 seconds better than the listed record, but he was not timed at the 6-mile distance.

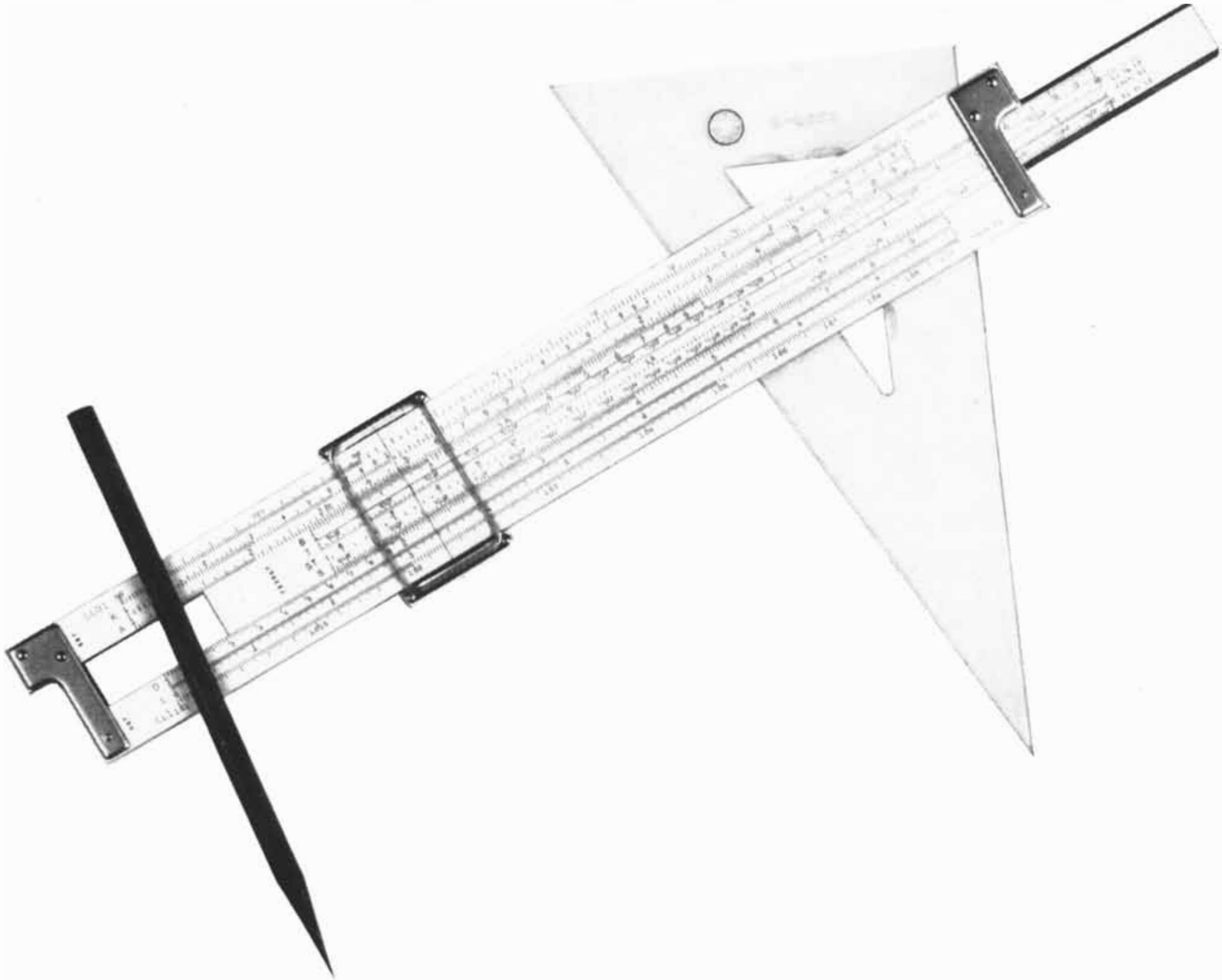
When the world-record times for various distances are plotted against the average speeds represented by those times, a curve is derived from which several interesting conclusions can be drawn. The maximum in the curve occurs at 15 seconds. The best average speed for that time is .00630 mile per second. This corresponds to a distance of about 150 meters, and that apparently is the optimum distance to run from a standstill start if one wishes to achieve the maximum rate. Since this distance provides a runner with the chance to prove his maximum rate of speed, it would seem a more logical race than the now standard 100- and 200-meter events.

After 150 meters the curve rapidly declines. But at 140 seconds, corresponding to a distance of about 1,000 meters, the curve begins to flatten out. This, presumably, is the distance at which a runner begins to get the benefit of his "second wind." In races beyond 10,000 meters, however, the average speed falls off sharply again—apparently a reflection of the effects of exhaustion.

The same kind of analysis as reported here for men's running records has been made for women's track records, for walking records and for swimming. In general the pattern is the same: in each sport there are records which should be improved, some by substantial amounts. Women runners, for example, should be able to cut .1 second from their 100-yard-dash record, .3 from the 220 record, 1.5 seconds from their best time for 800 yards and 3.8 seconds from the Olympic record for this distance.

Walking and swimming records are more erratic than the running figures. Fewer times lie on the best-performance curves, so that relatively more of the world records in these events should be broken. In the case of women's swimming, only 4 marks out of 17 fall on the curve. In men's swimming records the times for 1,000 yards and 1,000 meters are the farthest out of line, because those distances are seldom clocked. Swimmers' average speeds drop sharply up to about 220 yards and then level off.

M. H. Lietzke is a chemist at Oak Ridge National Laboratory.



ON THE ORIGIN OF GLACIERS

Numerous theories have been devised to account for the occasional advance of the great ice sheets. Most plausible to the geologist is a hypothesis that relates the growth of glaciers and mountains

by Charles R. Warren

ON SOME DAYS the temperature at Chamberlain, S. D., where I have been doing field work on glacial deposits, reaches 115 degrees in the shade—if you can find any shade in that arid, treeless region. How can glaciers ever have existed there? The great swings of climate—from warm and dry to cold and moist—that are recorded in the stratified history of the earth are still one of the most baffling and controversial puzzles in geology. Theories are plentiful—too plentiful—but it has been hard to reconcile any of them with all the known facts. This article is a report on a recently proposed theory which seems to account for the facts so beautifully and so completely that I believe it will win wide acceptance.

First let us look at the major difficulty over which attempts to explain the ice ages generally stumble. Many of them attribute the glaciations primarily to fluctuations in the amount of heat received from the sun. Some argue that the fluctuations are due to the wobbles of the earth's axis and variations in its orbit around the sun. Cyclic hypotheses of this kind suffer from the difficulty that the cold periods have come at irregular intervals and apparently at the same time all over the earth, instead of alternately in the Northern and Southern Hemispheres, as the shift hypothesis would require. The chief stumbling block, however, is more fundamental. Most of the hypotheses, based on the four ice ages and thaws of the past million years, fail to explain the long warm, glacier-free intervals which have prevailed for hundreds of millions of years on earth.

During most of the earth's history its climate has been too warm for widespread glaciation. The earliest big freeze that we can detect in its strata came some 800 million years ago. Then followed a period of 200 to 300 million years when temperatures were equable and no major ice sheets formed. In late Pre-Cambrian or early Cambrian times, a little more than 500 million years ago, came another glacial period. When these glaciers disappeared, there was a 300-million-year interval during which the climate became so warm that coral reefs grew north of Hudson Bay. The ice next returned in the Permian Period about 200 million years ago, and again gave way to a long warm period, in which

SEWARD GLACIER in southeastern Alaska flows down to the sea. In the background are the St. Elias Mountains. This aerial photograph was made by Col. Walter A. Wood, Jr., of the Arctic Institute of North America.

palms and crocodiles flourished in the Dakotas. Then, a million years ago, came the Pleistocene, which has not yet run its course; we are in a thawing stage of its fourth ice sheet. We know much more about the extent of the Pleistocene, of course, than about the earlier glaciations. At its height glaciers spread unbroken across North America as far south as Kentucky and over Scandinavia, the British Isles, the North and Baltic Seas and down into Germany and Russia. Ice also covered the pampas of Southern Argentina. In the Alps, the Himalayas, the Rockies and the mountains of New Zealand glaciers extended far below their present termini; even in the Tropics the snow line was almost 3,000 feet lower than today.

THIS, THEN, is the history: a few comparatively short periods of glacial activity separated by long eras of tropical weather over most of the earth. Instead of asking what caused the ice ages, we may well start at the other end. We would be a long way toward answering the question of why glaciations occurred if we could explain why they did not occur throughout most of geologic time. The geologist who has taken this approach and proposed the new theory is Richard Foster Flint, professor of geology at Yale University.

Under usual conditions, and most of the time, the solar warming of the earth does not permit the spread of glaciers. This suggests that ice sheets are launched by drastic changes in the earth itself. During the history of our planet there have been several great paroxysms of mountain-building, each of which made major changes in its geography and conditions of life. In these general upheavals, not to be confused with local mountain growths that come more frequently, the earth gave a convulsive shudder (if a movement taking millions of years may be called that), and mountains rose where shallow seas had rolled before. Flint points out that the world-wide glaciations have come precisely at the times when these mountain-building convulsions took place. There was much mountain-building about 700 million years ago, at the beginning and end of the Paleozoic Era and, finally, during the period in which we live. Today the emergent mountains stand higher and are more widely distributed than during most of the geologic past.

This correlation indicates that without mountains there can be no continental glaciers, and one can readily see why this may be so. High mountains serve as catchment areas to collect snow and start glaciers. The ice sheets can spread widely over the continents only when mountain-building is general. As continents emerge, the polar regions are less effectively warmed by marine currents, such as the Gulf Stream. At the same time the mountains obstruct the circulation of winds, so that the high latitudes are chilled and ice sheets grow. Flowing down from the mountains, they spread out into a piedmont glacier. This sheet may then become extensive enough to lower the temperature still further by reflecting the heat of the sun. Snow surfaces absorb only 20 per cent of the sunlight falling on them—a fourth as much as areas of rock, earth or vegetation. In the colder climate that results, ice gradually builds up to a height where it forms its own area of high altitude and its own precipitation-catching barrier to the winds. The ice spreads, especially westward, as that is the direction from which the cyclonic storms bring snow, and a continental glaciation is underway. Then, as the mountains are eroded and flattened in the course of time, the earth returns to its usual warm climate for hundreds of millions of years —until the next convulsion.

ON THE mountain-building hypothesis alone, however, one would have a hard time explaining the frequent surges and retreats of the glaciers during our own period of the past million years. As we have seen, there have been four ice ages during the Pleistocene, separated by long interludes of warmer climate than we have today: periods when, the geological evidence indicates, ice disappeared from Greenland and Antarctica and Osage oranges grew in Canada. Furthermore, the four main glacial stages have been divided into substages of lesser advances and retreats of ice sheets. At Two Creeks in northeastern Wisconsin, for example, lie the buried tree stumps of a forest which grew up after the last ice age but was later bulldozed flat by a readvance of ice. Four such substages of freezing and thawing occurred in the fourth glacial stage.

How can one account for all these advances and retreats of the glaciers? No geologist could countenance the suggestion that the mountains have bobbed up and down four times in the past million years, and it would be absurd to believe that they could have danced any such ponderous jig as would explain the four substages of the Wisconsin glaciation. Flint combines topographic upheaval with the idea of solar fluctuation. He suggests that throughout the geologic past the temperature of the sun may have varied on either side of a mean perhaps comparable to its present value, with irregular fluctuations. Mountain glaciers would grow and shrink according to these changing heat conditions. But only at those times in the earth's history when mountains everywhere "reached up, as it were, to meet the falling temperature part way," would widespread glaciation occur. Perhaps, as Harry Wexler argued in a recent article in SCIENTIFIC AMERICAN ("Volcanoes and World Climate," April), the dust from volcanic eruptions during the mountain-building period contributed to the lowering of the earth's temperature. Within a glacial period fluctuations in the sun's heat would cause retreats and advances of the ice such as occur in the glacial stages and substages.

Flint's hypothesis seems to me to account for every factor in the problem that has proved a stumbling block to other explanations. Its only weakness is

TIME SCALE (MILLIONS OF YEARS AGO)

WARMER

PRESENT WORLD CLIMATE

COLDER

AVERAGE HEIGHT OF LAND

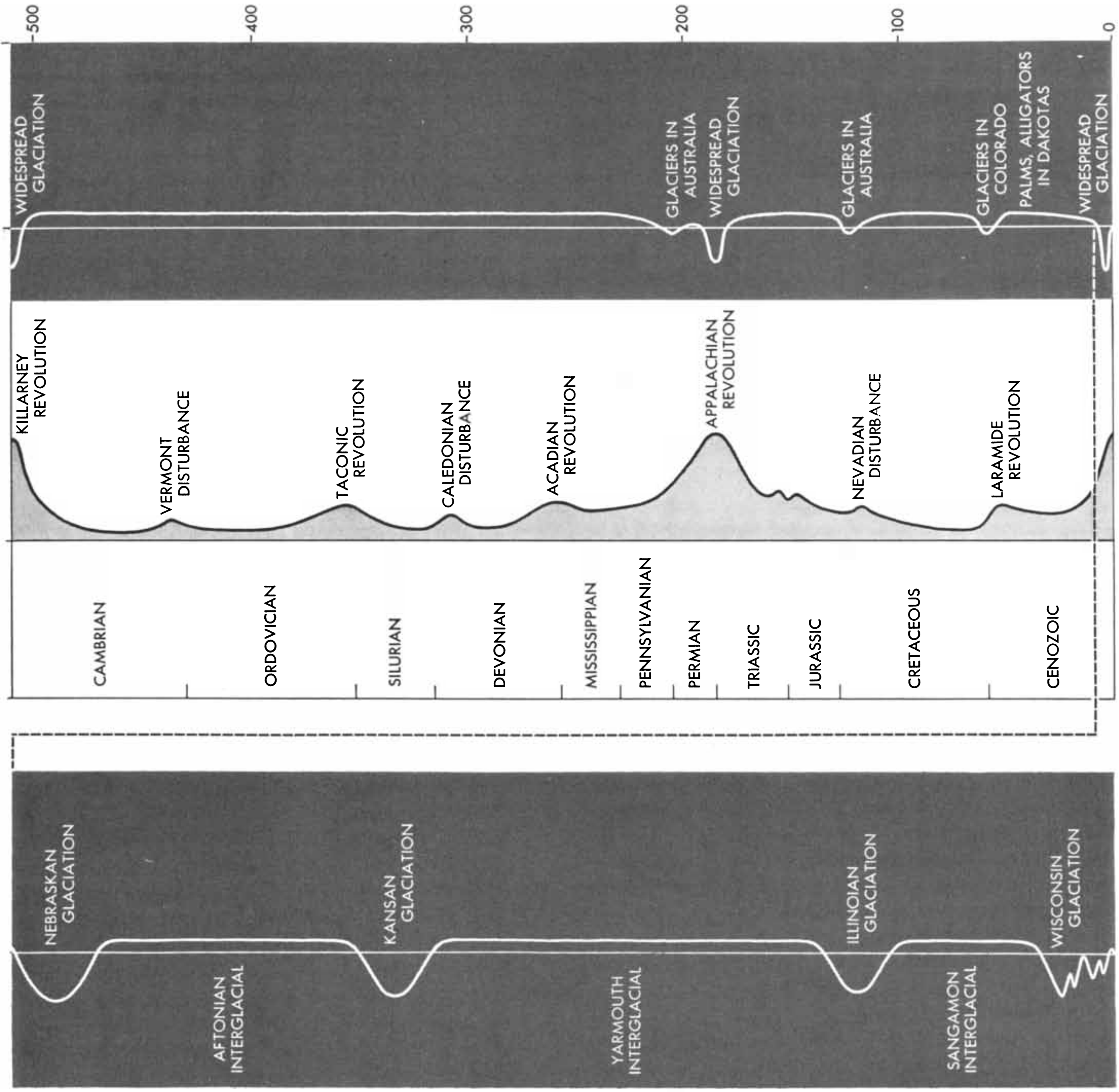
GEOLOGIC TIME SCALE

WARMER

PRESENT WORLD CLIMATE

COLDER

GLACIERS FORM when continents are high. At the top of this chart is a curve roughly outlining the climat-



ic changes that have occurred during the past 500 million years. On the same time-scale below this curve is another showing the average height of the land. At the bottom is a curve showing the climatic fluctuations of the past million years. The segment of the top curve that is represented by the bottom curve is exaggerated.

one pointed out by Flint himself: we have no proof that the sun's energy varies as much as this hypothesis requires. But regular measurements made by the Smithsonian Institution since 1918 have shown that the solar "constant" has varied by as much as three per cent from its average value during the past third of a century. It seems altogether possible that over a longer period it could vary by 10 per cent. Flint has calculated that a 10 per cent drop could, in combination with other factors, bring on a new glaciation at the present time. On the other hand, a 10 per cent increase in the sun's heat would give the earth a climate as warm as that in past interglacial periods.

The theory of solar fluctuation is supported by abundant evidence of marked climatic variations within postglacial times. It is believed that world climates today average two or three degrees warmer than a century ago, and considerably higher than 500 years ago. In the 14th century the estuary of the Thames at London often froze solid, and heavy oxcarts crossed from Denmark to Sweden over the Kattegat, which never freezes now. Before that, however, the world was warmer.

More extreme and spectacular fluctuations of the same irregular nature may account for the stages and substages of the ice ages.

Charles R. Warren wrote this article when he was assistant professor of geology at Washington and Lee University. He is now associated with the U. S. Geological Survey.

D'Arcy Thompson

The British biologist who died four years ago at 88 was a man of unique mold. His great book* On Growth and Form *dealt with all life in terms of physics and mathematics

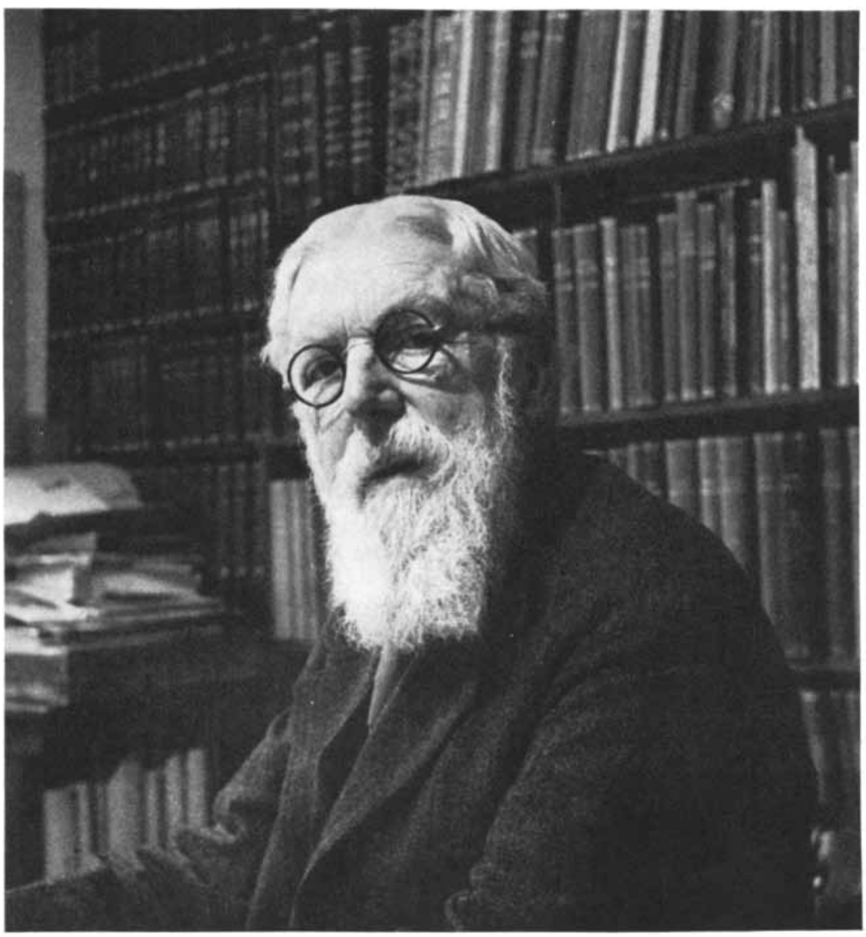
by John Tyler Bonner

D'ARCY WENTWORTH THOMPSON was one of those men who, despite the rich and varied achievement of their lives, are remembered for a single book. Malthus was such a man, William Harvey another; Machiavelli, in a different field, was a third. Thompson's book was *On Growth and Form*, one of the most remarkable creations in the literature of biology. Published first in 1917 and republished in a much expanded edition in 1942, when Thompson was 82, it was very nearly a life's work. The book is unique. It is the only treatise in all science that deals comprehensively with the physical basis for the form, the symmetry and the structure of organisms. It is a depository of original ideas that have influenced developmental biology, a history of science, a work of literature whose style has few peers in the field of biology. And yet for all this—partly, indeed, because of it—the book is frequently condemned or dismissed by experimental scientists.

D'Arcy Thompson remained an arresting and glamorous figure until his death at the age of 88 four years ago. What kind of man was he, and how did he come to produce his singular book?

Thompson's life had more pattern, more growth and form, than the lives of most men. The pattern was laid primarily by his father, himself a remarkable personality. The elder Thompson was a man who disapproved of the way he had been educated and who wrote vigorously both on his own experience and on education in general. He had emerged from Cambridge University at 23 a splendid example of 19th-century British education: full of Latin and Greek (from the age of seven, he said, his "treadmill" had been "a Latin-and-Greek machine") with a seasoning of mathematics. Of physics, philosophy, natural history, law, political and social science, he had learned only what the ancients had written. Thompson senior felt keenly that this training had not fitted him for his place or time in the world; he observed that he had been taught in this way "because youth had been so educated from the days of Augustus Caesar." He took a teaching position at the Edinburgh Academy, resolved to make some renovations of the prevailing system. The classics, he insisted, must be broadened to include not only the ancients but Shakespeare, Goethe, Cervantes—all the works of man that we now call the humanities. These radical ideas were not well received by the school's Board of Directors. Thompson became professor of Greek at Queens College in Galway, Ireland.

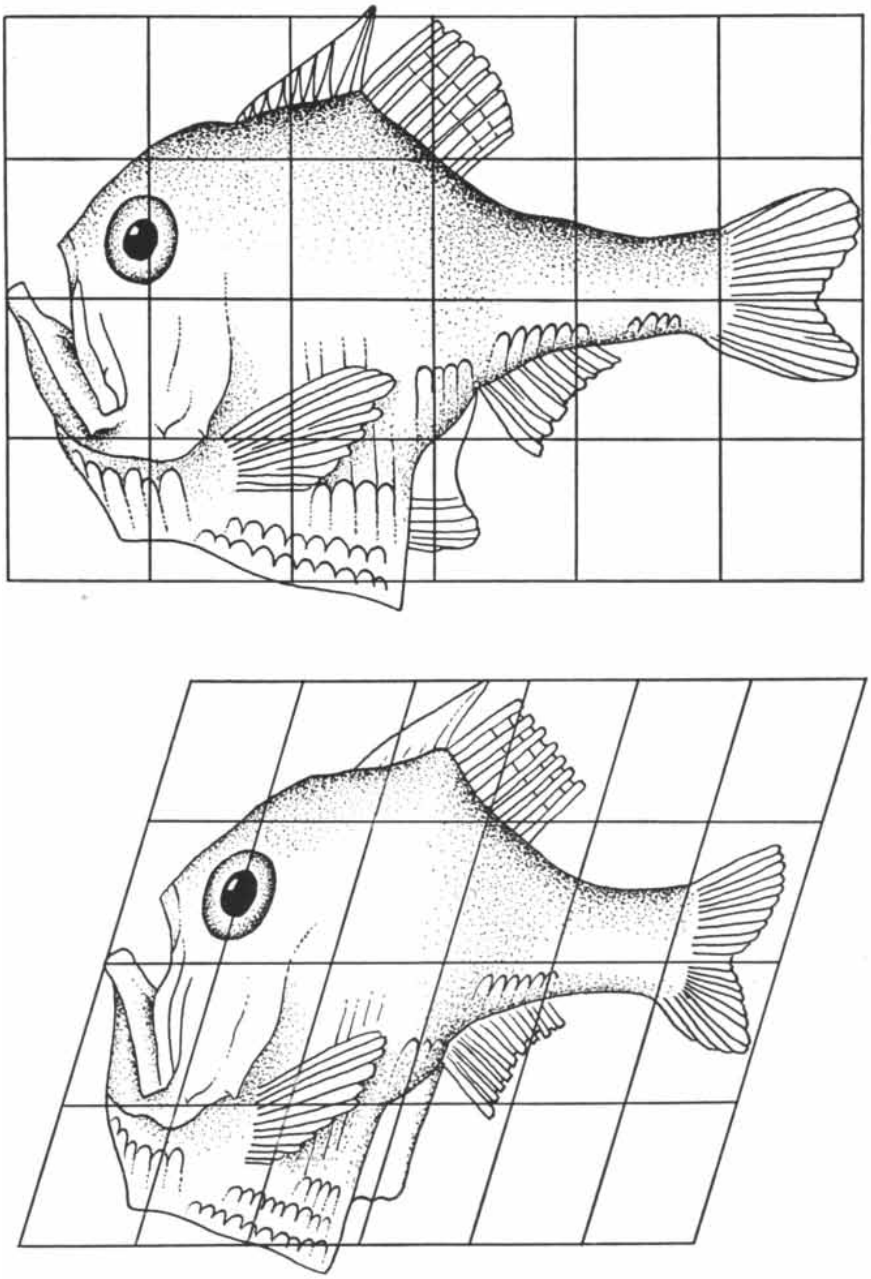
He put his ideas into practice in the education of his own son, D'Arcy. The boy's mother died soon after he was born, and the father had his upbringing to himself. D'Arcy received from his father what was for that time a most modern education. It was firmly grounded in Latin and Greek, but the classics were integrated at every point to the later discoveries, experiences and aspirations of man.



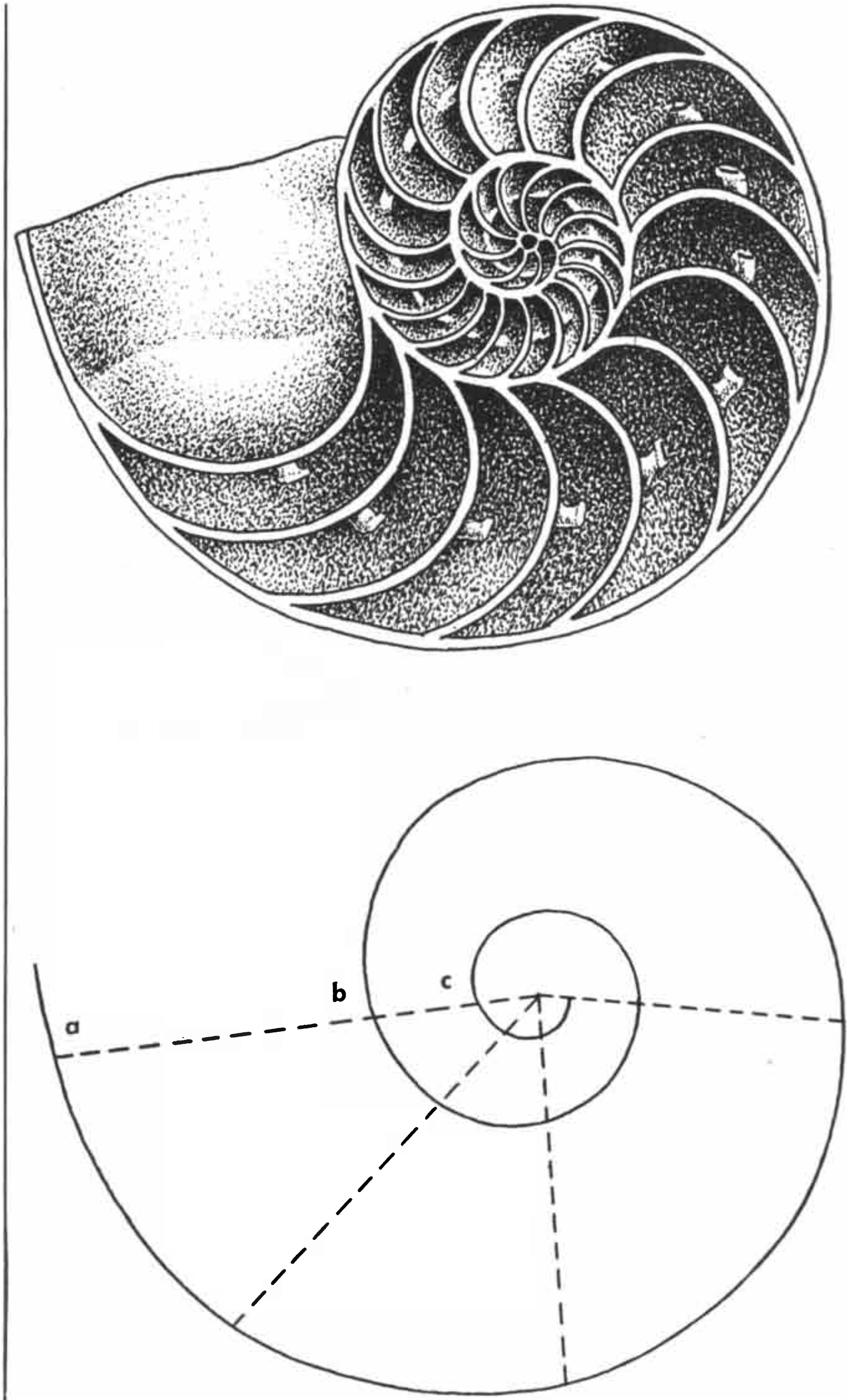
D'ARCY THOMPSON was born in 1860 and died in 1948. This photograph by Björn Soldan, reproduced through the courtesy of *Isis*, was made in 1946.

D'ARCY early showed a special interest in science. At 17 he entered the University of Edinburgh as a medical student, but he soon transferred to Cambridge to study zoology and natural history. In 1884, at the age of 24, he was appointed professor of biology at the University College in Dundee, Scotland. When, some years later, this institution was incorporated into the University of Saint Andrews, Thompson became professor of natural history. And there he remained on active status for 64 years. The policy of academic retirement was unknown in Thompson's day.

Thompson's first scholarly work, finished a year before he left Cambridge, was a translation from German of Hermann Müller's monumental *The Fertilisation of Flowers.* Charles Darwin, then an old man, wrote an introduction for Thompson's translation. From this ambitious beginning Thompson went on to produce some 300 other publications and to lead an active life in various fields, scientific and classical. For many years he worked on a translation of Aristotle's *Historia Animalium,* which was finally published in 1910. Two other great labors of love were a *Glossary of Greek Birds,* which came out in two editions, and a *Glossary of Greek Fishes,* published the year before he died. Into these works he gathered all the birds and fishes mentioned in Greek literature, and from his zoological knowledge illuminated the references and fused science with poetry. Not only a scholar and teacher but also a man of practical affairs, he spent a large part of his life helping to promote Scotland's fishing industry. This interest began when he settled a dispute with the U. S. over the fur-seal rights in the Bering Sea. For



TILTED COORDINATES show relationship between fishes in *On Growth and Form.* Top: *Argyropelecus Olfersi.* Bottom: *Sternoptyx diaphana.*



NAUTILUS SHELL, drawn in cross section at the top, has a spiral that may be precisely expressed. If a line is drawn from the center of the spiral, the distance from *a* to *b* will always be three times that from *b* to *c*.

41 years thereafter he served on the Fishery Board of Scotland, editing its periodic reports and writing papers on subjects of practical interest to the fishing fleets.

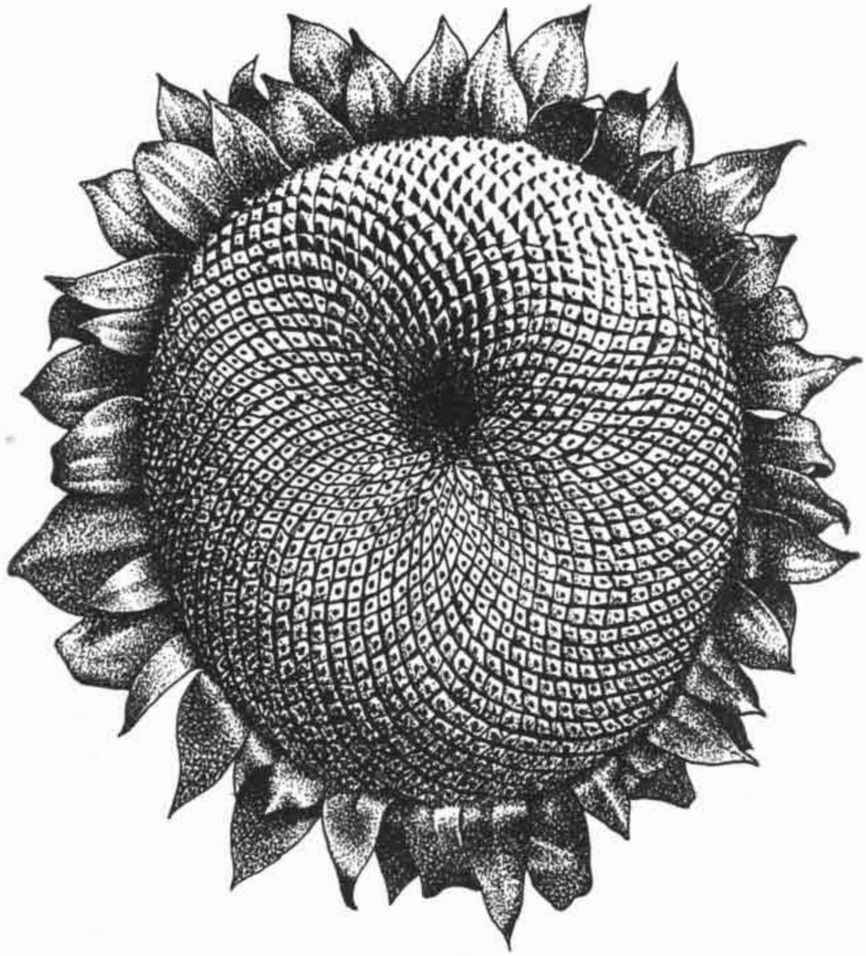
Thompson was a man of striking appearance and prowess on the lecture platform. He was a massive figure, with blue eyes and a fine spade-shaped beard, almost pink in his youth and later in life a pure white. His head was large, and he customarily covered it with a black fedora that was extra high in the crown and broad of brim. He made a trip to India shortly before he died (indeed, it was the trip that brought on his final illness) and while there spoke to a huge audience on the skeletal structure of birds. Throughout the lecture he held an angry hen tucked under one arm so that he could conveniently point out on a living specimen the salient features of his description. The remonstrances of his model disturbed not at all the easy flow of his speech.

THE KEY to Thompson's chief work, *On Growth and Form,* lies in his classical bent (he was at one time president of the British Classical Association). The classicists were preoccupied with form in every field of inquiry, and Thompson began early to seek form in nature. In particular, he wondered to what extent living shapes could be interpreted in physical and mathematical terms. Starting from the premise that all form is but a field of forces, he attempted to analyze these forces. This brought him to investigate cell shapes, tissue shapes, the shapes of all organisms. As an engineer understands the construction of a bridge, Thompson sought to understand the construction of living things. He was able to point out a number of instances in which the principles of engineering were duplicated by processes in nature.

Thompson's approach to the physical aspects of living forms is well illustrated by his analysis of the Radiolaria. These simple amoebas produce beautiful and varied shells which Thompson compared to snow crystals. He showed, however, that while radiolarian skeletons are made of silica and are crystalline in their fine structure, their over-all contours are not crystalline. That is, crystallization forces are not responsible for their general shape. He marshaled in support of this contention some simple and elegant proofs. He pointed out, for example, that one species of radiolarian is a regular dodecahedron (12 pentagonal faces) and another a regular icosahedron (20 triangular faces), and that these cannot be crystal shapes, for they do not satisfy the law of rational indices governing crystal symmetry.

A distinction often made between science and the humanities is that in science, a cumulative discipline, one need study only the latest paper on any subject to obtain all the background necessary for further investigation. Relatively few papers in a journal of bacteriology, for example, mention Pasteur or van Leeuwenhoek, even though every paper in the journal might be traced ultimately to the work of those men. In the humanities, by contrast, contributions to culture are important without reference to time or sequence, and we still read Shakespeare and study the political forms of the Greek city-states. *On Growth and Form* is written as though science were a humanity.

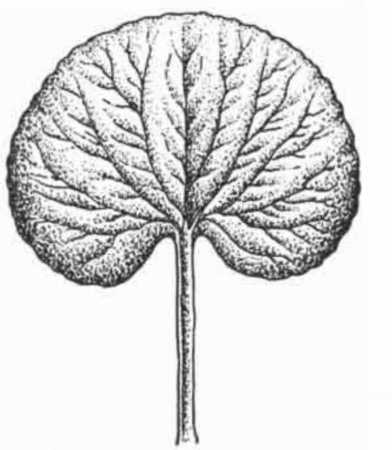
His manner of writing is less that of a scientist than of a man of letters. An admiring student of English literature, he produced a style of which he was justly proud. He once wrote to a friend: "To spin words and make pretty sentences is my one talent, and I must make the best of it. And I am fallen on

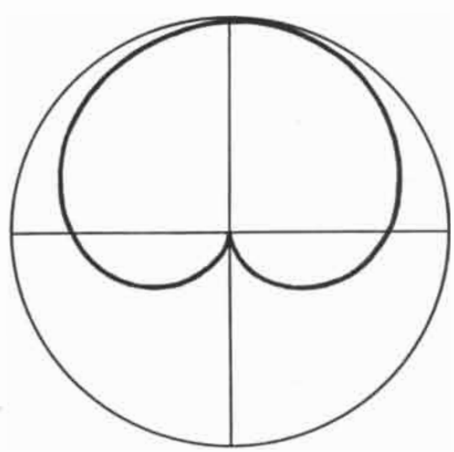


GIANT SUNFLOWER *Helianthus maximus* **has a composite head, the elements of which are arranged in rows according to a logarithmic spiral.**

an age when not one man in 20,000 knows good English from bad, and not one in 50,000 thinks the difference is of any importance." The following passage from *On Growth and Form* illustrates Thompson's style and attitude:

"How far even then mathematics will suffice to describe, and physics to explain, the fabric of the body, no man can foresee. It may be that all the laws of energy, and all the properties of matter, and all the chemistry of all the colloids are as powerless to explain the body as they are impotent to comprehend the soul. For my part, I think it is not so. Of how it is that the soul informs the body, physical science teaches me nothing; and that living matter influences and is influenced by mind is a mystery without a clue. Consciousness is not explained to my comprehension by all the nerve-paths and neurones of





VIOLET **has a reniform (kidney-shaped) leaf that may be described by a sine curve. The formula for the curve shown at the right is** $r = \sin \Theta/2$.

the physiologist; nor do I ask of physics how goodness shines in one man's face, and evil betrays itself in another. But of the construction and growth and working of the body, as of all else that is of the earth earthy, physical science is, in my humble opinion, our only teacher and guide."

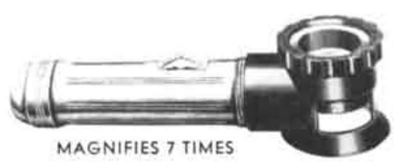
HOW has Thompson's extraordinary book affected biology? That it has had an influence there can be no doubt: Julian Huxley acknowledged a debt to Thompson in his book on *Problems of Relative Growth*, and a number of scientists paid tribute to him in a recent volume, *Essays on Growth and Form*.

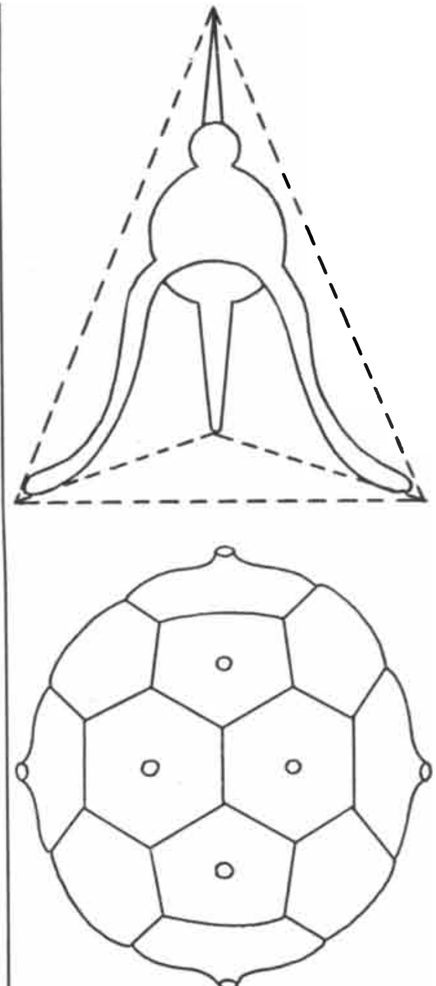
Thompson's most obvious contribution was his pioneering emphasis on the physical and chemical basis of life. He gave a great impetus to the notion that form in living organisms need not be explained entirely in terms of function, that physical and molecular considerations are at least as important. If one would know the cause of shape, he showed, one must seek physicochemical answers. Biology has been moving more and more in this direction during the past 30 years. The trend is evidenced by the fact that we have whole new fields such as "chemical embryology" and biophysics. To be sure, these developments would certainly have come even if Thompson had never written *On Growth and Form*, for the time was ripe. But it is fair to say that Thompson, in his unconventional way, was better prepared than anyone else to open the door on the new era.

Thompson's other contributions are less evident. He was interested in showing that many forms in nature can be described mathematically; further, that changes in form, either by growth or evolution, can be expressed by mathematical formulas. He devised a method, based, he tells us, on the work of Albrecht Dürer, that readily relates such changing forms to one another. This method of "Cartesian transformations" involves plotting an object, say a fish, on a rectangular graph or grid. Then if a grid is drawn through homologous points in a somewhat different fish, the deformation of coordinates will show at a glance the way in which the forms differ. It is a method of describing changes in form that helps one to appreciate the directions and magnitudes of change. Thompson applied the same kind of mathematical analysis to other problems, for example, to the spiral shapes of horns and snail shells.

The mathematics of growth is a rather specialized field where inquiry tends to remain on a descriptive level and does not seek causal explanations. Nevertheless, much of this work has been valuable, as for instance Julian Huxley's study of relative growth.

Research biologists today are apt to be impatient with Thompson's preoc-





RADIOLARIAN skeleton at the top has tetrahedral symmetry. Spines of radiolarian at the bottom are arranged as facets of an icosahedron.

cupation with formal relationships. He was content to define the nautilus or the snail in terms of a logarithmic spiral without concerning himself with mechanisms. To modern biology such mathematical description may be a clue to physical and chemical causes, but it cannot be an end in itself. The way of Thompson was the way of the Greeks; it was, as Joseph Needham of Cambridge University has recently pointed out, akin to Plato's search for the ideal in form and number.

ALTHOUGH *On Growth and Form* is out of harmony with the aims of present biological research—experimental, seeking causations and mechanisms—it represents a point of view which one would like to find more often in science. It gave breadth to biology. Science could use more men like Thompson, who served two masters, science and the humanities, and served both well.

John Tyler Bonner is a biologist at Princeton University.

What GENERAL ELECTRIC People Are Saying

K. H. KINGDON

Knolls Atomic Power Laboratory

MILITARY NUCLEAR POWER: Military considerations frequently demand that a vehicle shall be able to maintain high speed for a long time, and both these requirements are made available by using a concentrated fuel. The need for high speed makes particularly severe demands on the fuel supply. To double the speed of a ship requires an expenditure of eight times as much power. Nuclear fuel, with its million-fold concentration of energy over conventional fuels, is a natural for such military applications.

The most important features of a mobile military nuclear power plant are reliability, compactness, and light weight. A great deal of attention is being given to these features in the plants under development. The requirement for a biological shield to contain the dangerous nuclear radiations within the power plant of an inhabited vehicle makes the requirement of light weight a particularly difficult one to satisfy. This is especially so because there is nothing very smart that one can do about absorbing gamma rays, which can only be absorbed by relatively large thicknesses of heavy materials. These thicknesses are of the order of a few feet for materials like water and concrete, and of the order of a few inches for a very heavy material like lead. Fortunately, although the weight of shielding needed for an inhabited vehicle is awkward, it is not prohibitive.

The requirements of reliability and compactness are not unique to the nuclear power plant but are shared by any other mobile military power plant. The reliability requirement is made somewhat more difficult by the obvious problems which would attend maintenance or repair of any component of the plant which had become radio-active, and also because the nuclear requirements of the plant may demand the use of unusual coolants or structural materials with which there is little or no industrial experience.

There is also the question of the damage which may be done to the materials in the power plant by the intense nuclear radiations, damage which may be serious enough to cause failure of some component. Extensive investigations are being made of this radiation damage. It appears that neither the unfamiliar materials with which one has to work, nor the effects of radiation on the materials of the plant, is likely to prove to be a prohibitive limitation on the development of mobile military nuclear power.

Harvard Engineering Society
Boston, Massachusetts
April 17, 1952

★

T. TROCKI

Knolls Atomic Power Laboratory

HANDLING LIQUID METALS: Liquid metals have singular advantages as heat-transfer agents for certain high-temperature applications in our modern industrial economy. Water, although an exellent heat-transfer fluid and the most widely used medium for this purpose, has certain disadvantages above 500 F. These include high vapor pressure and a tendency to break down into hydrogen and oxygen. Metals, however, have much higher boiling points and consequently negligible vapor pressure at those temperatures. Furthermore, their very high thermal conductivity yields higher heat-transfer coefficients.

The basis for the successful handling of chemically active or personally hazardous materials is to contain them in an inert atmosphere and prevent leakage which might be injurious to personnel or result in fire or explosion.

Obviously, the success of any such system depends on the use of a structural material which will not be corroded by the contained liquid metal. It is, therefore, fortunate that many of the high-temperature structural materials are compatible with liquid metals as long as proper precautions are taken to purify the liquid metals initially and keep them clean.

Oxygen appears to be the principal contaminant affecting corrosion, and it must be kept to a minimum. The limit of oxygen contamination for boiler water is actually more stringent than it is for liquid metals. In boiler water the oxygen content is controlled by removing the oxygen at low temperature, when it is practically insoluble in water, and depending upon chemical "getters" at high temperature, when any remaining oxygen is released—and is most corrosive.

Oxygen solubility in liquid metals is also temperature dependent, and this is used as the basis for oxygen removal. Getters have also been investigated for liquid metals, but their effectiveness has not been established.

It can be seen from the foregoing that leak-tightness is the most important single requirement for a liquid-metal system. The difficulties resulting from leakage of liquid metal in such a system vary with the liquid metal concerned. Some of the metals—like lithium, sodium, and potassium—burn in air; others—like lead and mercury—are toxic.

Broadly speaking, the development leading to the successful handling of liquid metals has been devoted, first, to gaining an understanding of the limits and control of liquid-metal contamination, with the object of controlling corrosion; and, second, to developing leak-proof heat exchangers, pumps valves, and system auxiliaries.

G-E Review
May, 1952

You can put your confidence in—

GENERAL ELECTRIC

BOOKS

The chemistry of the planets as a clue to the beginnings of the solar system

by Otto Struve

The Planets, Their Origin and Development, by Harold C. Urey. Yale University Press ($5.00).

There is on the moon a large, flat, roughly circular area called Mare Imbrium. The area is not really a sea but a plain, about 600 miles in diameter. On its western edge it is bounded by several high mountain chains: the "Apennines" in the southwest, the "Caucasus" and the "Alps" in the west and northwest. Most of Mare Imbrium is flat, with a few slight undulations resembling sand dunes, but there are also a number of typical craters, which at first sight resemble the volcanic craters of the earth. A closer inspection shows that the mountain chains and the craters differ greatly from similar formations on the earth.

Despite the rugged appearance of the moon through a telescope (the effect is caused by the intensely black shadows), the slopes of its mountains are usually less steep than ours. Lunar mountains reach elevations of 26,000 feet, comparable with Mount Everest, but there is no indication of folded formations of the kind produced by terrestrial mountain-building processes.

Some of the craters on the floor of Mare Imbrium are perfectly shaped, with a circular wall, a depressed circular interior and a small cone in the center; others look as though they were partly flooded with lava. The large crater Archimedes is of this type. The small crater Wallace is almost completely submerged in the lava flow, and only a trace of its rim emerges from the surface of the plain.

No one who has observed the moon, even through a relatively small telescope, can forget this picture of tremendous catastrophe: a flood of molten lava that has engulfed an area roughly the size of all our states east of the Rocky Mountains and obliterated the craters and mountain ridges in its path.

Harold Urey began the inquiry that is the subject of this book by asking: How did the moon assume its present aspect and when were the craters, the mountain chains and the mares produced? The answers to these questions turned out to be related to chemistry—Urey's own special field. They, in turn, led him to inquire into the deeper questions of the origin of the moon, of the planets and their satellites and, finally, of the entire solar system.

Perhaps the most startling fact about the moon is that its appearance has changed little in the past two or three billion years. On the earth the forces of erosion and the gradual building of mountains have erased all recognizable traces of its early history. But neither mountain-building processes nor erosion are acting on the moon; it is truly a fossil world.

Urey strongly supports the hypothesis, advanced by several astronomers and defended ably by Ralph Baldwin in his recent book *The Face of the Moon,* that most of the surface features of the moon were formed by the impact of meteoritic or "planetesimal" bodies. The largest of these may have been some hundreds of kilometers in radius and may have grown out of the primordial dust from which the planets, comets and satellites also were formed. But the smaller objects, now recognized as meteorites, are probably the debris from the breakup of a larger planet. Urey shows convincingly that the impact of large bodies on the surface of the moon would generate heat sufficient to melt a large amount of material and cause the lava floods of the mares. Because of the tremendous pressure generated at the point of contact (about 170,000 atmospheres), the solid material of the moon began to flow like a liquid, and was pushed outward to form mountain chains.

The lava probably was soon covered with a layer of pumice or dust from small meteorites, and the layer went on accumulating over the millions of years. But the evidence indicates that the meteoritic rain has slowly declined. For one thing, the dust layer on the moon is too thick: it could not have built up to its present thickness if meteorites had been falling only at the present rate for three billion years. It is therefore probable that two or three billion years ago the moon and the earth were being pelted by meteorites and planetesimals much more violently than at present. On the earth these ancient scars have disappeared; we have only a few small meteor craters of relatively recent origin. On the moon nearly all the craters have been preserved, since the only process capable of destroying them is subsequent collisions. As a matter of fact, we can discern on the moon a number of ancient craters partly obliterated by fresher craters formed on top of them.

The floor of Mare Imbrium has fewer virgin craters than other regions of comparable size; hence we must conclude that the planetesimal which produced it struck comparatively late in the moon's history. There is evidence that the collision did not melt all the material in the planetesimal. Solid lumps or nodules seem to have been scattered for great distances over the moon's surface. Those that had low trajectories plowed through whatever obstructions they encountered, producing the peculiar "Alpine Valley" and the remarkable pattern of grooves in the "Apennines" which radiate from a point near the northern edge of Mare Imbrium.

Urey believes that these nodules must have been solid pieces of iron, either from the planetesimal or from the surface of the moon itself. The question arises: How were nodules of metal formed inside the more common silicates of which planets are mainly composed?

Astronomers have usually avoided discussion of the chemical processes that led to the present composition of the bodies in the solar system. It is reasonable to suppose that the composition of the original cloud from which they were made was similar to that of the sun and the interstellar gas today. Making certain assumptions about the rates of fall in density and temperature in the cloud outward from the center (where the sun is now), Urey is able to show that in the original nebula water and all the available ammonia condensed in the region between the belt of the minor planets and Jupiter. Methane would have condensed far beyond the present orbit of Pluto, and this fact may have aided in the formation of comets.

The recognition that water would condense in the region of Jupiter is one of the principal contributions of Urey's analysis. It explains why Jupiter grew to a much larger mass than the inner planets.

After the various protoplanets had been formed as condensations, local condensations of water, ammonia and methane in the several sections produced a sticky medium which greatly accelerated the process of accumulation. As Urey correctly states, without such a medium, colliding solid particles of dust or smoke would rebound or be shattered, rather than stick together. Hence, the slushy snow may have been an important factor in coalescing the protoplanets into solid planets.

At the low temperatures prevailing in the original nebulous condensations the common metals, especially iron, would have occurred in the form of oxides. But as density increased, the temperatures of the protoplanets would rise to the point where they reduced the oxides to pure metal, which could grow to form fairly large nodules.

Previous discussions of the formation of the earth's atmosphere have had trouble explaining why it contains so little neon, a relatively heavy gas, while oxygen and carbon, of lower atomic weight, are abundant. Urey believes that the original condensation of the protoplanets took place at about the freezing temperature of water. At this temperature the light gases hydrogen and helium could readily escape from a protoplanet. A heavier gas such as neon would not. As the temperature of the protoplanet rose, however, neon and other noble gases darted away; they did so because they could not combine with other elements to form heavier molecules. On the other hand, considerable amounts of oxygen, locked up in water, and nitrogen and carbon, similarly locked up in ammonia and methane molecules, were held in the protoplanet. The same was true, of course, of iron and other heavy elements.

The loss of gaseous constituents at the high-temperature stage resulted in a rapid cooling of the planets to approximately their present temperatures. Urey suggests that during this second low-temperature stage the planets continued to grow by the acquisition of planetesimals and meteorites, consisting mostly of silicates with iron nodules. In the cases of the moon and Mars the heavy iron-nickel nodules remained embedded within the magma of silicates where they happened to land, and produced a more or less uniform composition throughout, with a 30 per cent content of iron by weight. Mars has no iron-nickel core. The earth's core was produced by the gradual sinking of the heaviest iron-nickel nodules through the viscous medium of the predominant silicates. Urey believes that this process may be related to the convection processes which are thought to be responsible for mountain building on the earth.

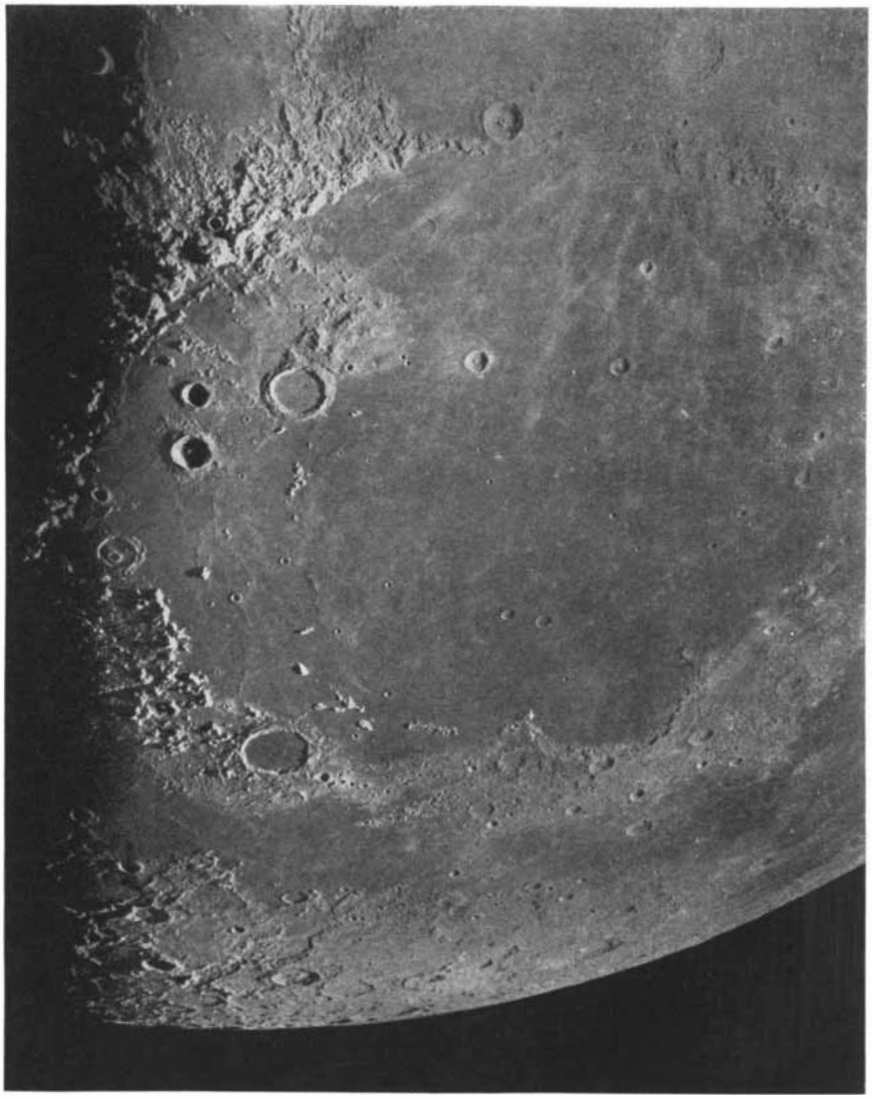
During the last stage of evolution, says Urey, "the earth had an atmosphere of water, hydrogen, ammonia, methane and some hydrogen sulfide. The hydrogen was lost and water was converted to oxygen and hydrogen by photochemical reactions in the high atmosphere; and as hydrogen escaped the atmosphere became oxidizing, ammonia was converted to nitrogen and methane to carbon dioxide. In the course of this change organic compounds occurred and life evolved."

On Mars "events moved more rapidly. . . . Life apparently evolved here as well as on earth."

On Venus "volcanic activity produced the carbon dioxide atmosphere which has not reacted with the silicates because of the absence of water at this stage. The presence of carbon dioxide in the planet's atmosphere is very difficult to understand unless water was originally present, and it would be impossible to understand if water were present now."

Urey has rendered a great service to astronomy by introducing modern chemistry into the planetesimal hypothesis of the formation of the solar system—a contribution comparable with that of another great chemist, Svante Arrhenius, who half a century ago advocated a cosmogony not unlike the one Urey now presents.

Urey states that his ideas "have been molded by current theories about the accumulation of the sun and stars from dust clouds, and of the planets from a dust cloud in the neighborhood of the sun." Most astronomers believe that the sun is an average star, of which there are a billion or more in our galaxy. There is every reason to believe that planet systems are just as common. Although no instrument today can detect a planet of Jupiter's size outside our system, we believe that such planets must abound. There appears to be no difference in principle between a planetary system and a double star of the 61 Cygni type, which has a companion



MARE IMBRIUM is the circular plain in this photograph made by the 100-inch reflecting telescope on Mount Wilson. In the lunar convention South is at the top, and West is at the left. The "Apennines," "Caucasus" and "Alps" run from upper left around the edge of the plain to its lower left.

with a mass halfway between that of Jupiter and that of the sun. Such an object may well be an exceptionally large planet!

If the solar system was formed from a cloud, should we not expect to see some traces of similar nebulae in connection with other solar-type stars? A nebula with an average density of one one-millionth of a gram per cubic centimeter would have 10^{18} atoms, mostly of hydrogen, in every cubic centimeter. If such nebulae are really numerous, there must be some whose planes are in our line of sight. We would then be observing their central solar-type stars through a screen 10^{14} centimeters thick. In other words, in front of every square centimeter of the star's surface there would be about 10^{32} atoms, mostly of neutral hydrogen, which absorbs and re-emits not only the discrete lines of the hydrogen spectrum but also the continuous spectra at the various series limits. We should be able to detect such a nebula. The fact that we have not done so yet indicates that it rarely occurs in our galaxy or, if it is common, lasts only a short time. Unfortunately, Urey's work provides no clue to the time required for the various processes of condensation and evaporation to produce a system of planets.

Urey adopts the current views of Lyman Spitzer, of Fred Whipple, and of Bart Bok and Edith F. Reilly in attributing the formation of the sun to a process of condensation in an interstellar "globule," consisting, at a temperature far below freezing, of solid particles of oxides of iron and other metals, some sulfides and silicates and gaseous hydrogen, helium and neon.

It is difficult to see how this process differs appreciably from the accretion mechanism suggested by Fred Hoyle and R. A. Lyttleton or that of C. F. von Weizsäcker. The latter has shown that "only a star which starts with a mass larger than that of the sun and which stays inside a very quiet cloud for more than 100 million years has a chance of increasing its mass considerably." Thus it would seem that to produce a star of the solar type out of an interstellar globule a more efficient process of accretion is required than the original one of Hoyle and Lyttleton. This does not invalidate the rest of Urey's discussion, but it introduces an assumption that might easily be mistaken for an established theory.

I have rarely read a book as stimulating as this one of Urey's. It is not easy to read, and it is more like a series of research papers intended for specialists than an integrated discussion for a varied audience. It contains many uncertain conclusions, and in places it arouses doubt and disbelief; there are occasional misprints (the name of Unsöld's star on page 189 should be Tau Scorpii!), and an astronomer may wince when he contemplates Urey's composite picture of the moon, made of two Lick Observatory photographs at complementary phases, or when he finds the genitive forms of Latin words, such as "imbrium" and "nectaris," used as proper names. But these details are unimportant.

Urey's book may well open a new branch of astronomy—astrochemistry—which should soon become as important as astrophysics.

Otto Struve is professor of astronomy at the University of California.

HISTORY IN EARTH AND STONE, by Jacquetta Hawkes. Harvard University Press ($3.75). Mrs. Hawkes is a British archaeologist whose beautifully written prehistory of Britain, *A Land*, brought her to the notice of a wide audience. The present book, more restricted in appeal, is an introduction to the prehistoric and Roman monuments of England and Wales. It is not a general history of prehistoric Britain—a subject covered by Mrs. Hawkes in another volume, *Prehistoric Britain*—but it offers a good deal of historical material as background for an understanding of canals, barrows, dykes, forts, roads, stone circles and rows, tombs, villages, caves and like antiquities.

RADIOCARBON DATING, by Willard F. Libby. University of Chicago Press ($3.50). Professor Libby, pioneer in the field, discusses the theoretical basis of the radiocarbon dating method and explains the various techniques of sample selection, preparation and measurement. He lists radiocarbon dates for samples obtained from various regions: wood from the deck of an Egyptian funerary ship, land-snail shells from Iraq, charcoal from the Lascaux Cave, pine cones from Denmark, beeswax from Bronze-Age England, conch shells from Ohio mounds, 10,000-year-old burned bison bones from Lubbock, Tex., corncobs from the debris in Bat Cave in New Mexico, basketry from Humboldt Cave in Nevada, sprucewood logs from Alaska, cattail roots from Peru, dung of a giant sloth from Chile, ancient lotus seeds (still fertile after 1,200 years) from Manchuria, charcoal from what is thought to be the oldest house site in Japan (circa 4,500 years old), and so on. Frederick Johnson, of the Robert S. Peabody Foundation for Archaeology, adds a final chapter appraising the usefulness and dependability of radiocarbon as a tool for dating.

WATER: A STUDY OF ITS PROPERTIES, ITS CONSTITUTION, ITS CIRCULATION ON THE EARTH, AND ITS UTILIZATION BY MAN, by Sir Cyril S. Fox. Philosophical Library ($8.75). This is an exceptionally interesting volume, simply and clearly written, by the former director of the Geological Survey of India. The author presents a mass of numerical data and other scientific details; nevertheless, the general reader is likely to find it absorbing. He discusses such subjects as the formidable eroding effects of land water, the action of underground water, the remarkable features of the hydraulic cycle, the distribution of the world's water, the deposition of sediments, the idiosyncrasies of great rivers, the building of dams and other aspects of water engineering. There are nine pages of excellent plates; even so, the price is exorbitant for a book of 150 pages.

Genetics and the Origin of Species, by Theodosius Dobzhansky. Columbia University Press ($5.00). An outstanding treatise in the Columbia Biological Series dealing with evolutionary theory in the light of modern genetics. For this third edition, Professor Dobzhansky has completely rewritten the text and has incorporated the developments of genetic science in the last decade—the "most fruitful decade," he says, since the appearance of Darwin's classic in 1859.

The Army Air Forces in World War II, Vol. III: Europe—Argument to V-E Day, edited by W. F. Craven and J. L. Cate. University of Chicago Press ($8.50). The third volume of this projected seven-volume history covers the period from January 1944 to May 1945 and relates in massive detail both the tactical and strategic bombing campaigns, the operations in support of the underground movement on the Continent, and, perhaps most interesting of all, the Crossbow attacks against the German rocket and guided missile installations along the Channel coast. The story of the confusion, the cross-purposes and the outright incompetence in high Allied councils in handling the countermeasures against V-weapons is one of the most revealing historical sequences yet to emerge from the last war. It is clear from this account that it was not Crossbow but the morale of the British civilian population and the fact that the Germans got their rocket offensive under way too late which prevented the V-bombs from bringing about a tragically decisive turn in the war.

The Enzymes: Chemistry and Mechanism of Action, edited by James B. Sumner and Karl Myrbäck. Academic Press Inc. (2 vols., 4 parts: Vol. 1, Part 1, $14.50; Vol. 1, Part 2, $13.50; Vol. 2, Part 1, $12.80; Vol. 2, Part 2, $14.00). An encyclopedic survey of the science of enzymology with contributions on every phase of the subject by 78 scientists in the U. S., Europe and Australia. The articles, each by an authority, treat, among others, the special chemistry of the various enzymes, enzymes in relation to genes, viruses, hormones, vitamins and chemotherapeutic drug action, enzymatic adaptation, enzymes and immunology, enzymes in luminescence, fermentations by bacteria, photosynthesis in green plants, bacterial photosynthesis, tumor enzymology, enzyme technology. It is scarcely possible here to offer general opinions of value on an enterprise of such magnitude and scope, yet even the most cautious scientist may safely commit himself to the opinion that whatever its weaknesses (some are inevitably attendant upon a cooperative venture) this is a high achievement in the literature of science. The editors have succeeded admirably in their attempt "to present as far as possible, every fact, either old or new, which has a bearing upon the general understanding of the problem in question."

An International Bibliography on Atomic Energy, Vol. 2: Scientific Aspects. Columbia University Press ($10.00). An invaluable reference work prepared by the Atomic Energy Commission group of the U.N.'s Department of Security Council Affairs. J. R. Oppenheimer has written a general introduction, and the individual chapters are accompanied by introductory essays as follows: Fundamental Nuclear Science, Pierre Auger; Nuclear Reactors, J. D. Cockcroft; Biological and Medical Effects of High Energy Radiation, R. E. Zirkle; Isotopes in Biology and Medicine, H. C. Urey; Radioactive Tracers in Non-biological Sciences and Technology, Otto Hahn.

On Dreams, by Sigmund Freud. W. W. Norton & Company, Inc. ($2.50); Totem and Taboo, by Sigmund Freud. W. W. Norton & Company, Inc. ($3.00). These well-known shorter works of Freud (the first appeared in 1901, a year after the publication of *The Interpretation of Dreams*, of which it is a popular summary, and the second in 1913) are reissued under most favorable auspices. Each study has been freshly and ably translated by James Strachey, who has also corrected inaccuracies, provided bibliographical references and performed other useful editorial chores. The four essays in *Totem and Taboo* discuss "some points of agreement between the mental lives of savages and neurotics." The studies continue deservedly to hold their place as classics of psychoanalysis, and even, in a sense, of general literature; *On Dreams* is an admirably lucid little essay, almost unknown to American readers.

Science for the Citizen, by Lancelot Hogben. W. W. Norton & Company, Inc. ($8.95). A third, revised edition, with numerous amendments of the earlier text, corrections, and an additional chapter on atomic energy. The treatment of the latter subject, described as "novel," is scarcely satisfactory, no attempt being made to carry the story beyond 1939. One may, in fact, question more broadly the merits of this book as a "self-educator." It covers a wide ground, is full of sound information and is strongly supported by James F. Horrabin's excellent illustrations; on the other hand it is much more difficult to read than its title would lead anyone to suspect, and the instruction is uneven, with disproportionate emphasis on details that Hogben considers essential to bringing out his theories of social and intellectual evolution. The result is a survey that, because of its gaps, falls considerably short of the requirements of a good textbook—though it contains valuable material not to be found in any school text—yet is very likely to overtax the ability of all but a few of the "alert" citizens to whom it is addressed.

JANE'S ALL THE WORLD'S AIRCRAFT, 1951-1952; compiled and edited by Leonard Bridgman. McGraw-Hill Book Company, Inc. ($22.50). Almost all sections have been substantially revised and hundreds of new illustrations added. Despite the fact that *Jane's* grows bigger and more inclusive every issue, information on the most interesting and important advances in military aviation, gas turbines, rocket motors, guided missiles, nuclear power plants for aircraft, pilotless carriers, convertaplanes (combining the lift and hovering features of a helicopter and the forward speed of a normal airplane) is so sparse as to provide very little enlightenment. It may, however, justly be said of this famous annual that it adheres to its "long-standing policy of eschewing all information that does not have the backing of authority, or at any rate the ring of authenticity."

KINCAID: A PREHISTORIC ILLINOIS METROPOLIS, by Fay-Cooper Cole and others. University of Chicago Press ($7.50). Kincaid is a large and important archaeological site located on the Illinois side of the Ohio River nearly opposite Paducah. There and elsewhere in the region extensive archaeological field projects have been conducted for a good many years with the purpose of reconstructing the civilization of the oldest known inhabitants of the Mississippi Valley (SCIENTIFIC AMERICAN, March). The present volume describes the work of a group of University of Chicago archaeologists who have succeeded in "integrating the evolution of the aboriginal culture at Kincaid with that of other Middle Mississippi settlements." A work of solid scholarship presented in a book of admirable design, illustration and manufacture.

MUSICAL ENGINEERING, by Harry F. Olson. McGraw-Hill Book Company, Inc. ($6.50). An unusual volume by the director of the R.C.A. Acoustical Laboratories, presenting an "engineering treatment" of the production and reproduction of music. Olson discusses musical scales, the mechanics of hearing, the characteristics of musical instruments, resonators and radiators, acoustics in theatre and studio, sound-reproducing systems and kindred matters.

YEARBOOK OF THE UNITED NATIONS: 1950. Columbia University Press ($12.50). The fourth in the series of these reference works, it reviews chronologically as well as by subject the activities of the UN, its major organs and specialized agencies. There is also a historical resumé covering the years 1946-1949. Numerous tables, maps and charts, some in color.

Also Noteworthy

THE BIRDS OF THE MALAY PENINSULA, SINGAPORE AND PENANG, by A. G. Glenister. Oxford University Press ($6.00). If you should happen to go bird-walking on the Peninsula, this volume, presenting meticulous descriptions of the shapes, colors, flight behaviors, calls, nests and eggs of the species one is likely to meet, would be an invaluable companion. In fact Mr. Glenister's carefully prepared and attractively illustrated guide to so many exquisite specimens should be welcome to any bird lover—from a fledgling Yosian to a seasoned ornithologist.

MECHANICS, by Stefan Banach. Hafner Publishing Company ($9.50). Lectures by a leading Polish mathematician on the "mechanics of a system of material points and a rigid body," appearing in the well-known series *Monografie Matematyczne* and translated into English by E. J. Scott of the University of Illinois.

COSMIC RAYS, by Louis Leprince-Ringuet. Prentice-Hall, Inc. ($6.65). One of France's outstanding physicists presents an attractive and well-illustrated account of the remarkable researches in this department of physics. The reader of average scientific training will not have an easy time, but this is a good book and one worth plugging at.

WHITEHEAD AND THE MODERN WORLD, by Victor Lowe, Charles Hartshorne and A. H. Johnson. The Beacon Press ($1.50). Three essays on Whitehead's philosophy of science, metaphysics and civilization. A thoughtful appraisal as well as an excellent introduction to the thought—often as difficult to grasp as it is profound—of this outstanding modern philosopher.

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THE AMATEUR SCIENTIST

Concerning (1) the life of the May fly; (2) the spectra of diffraction gratings

Conducted by Albert G. Ingalls

MAY FLIES have long come in for considerable attention from those who seek to tempt the trout or to tempt the pocketbooks of trout-fishermen by making artificial flies. Occasionally this purely utilitarian interest leads a man into the realm of amateur entomology. Such an individual is Richard Salmon, an artist whose off-hours are devoted to angling and to research into the life cycle, color variation and related phenomena of the May flies inhabiting the eastern U. S.

Salmon's interest in the May fly began when he turned to it for guidance and inspiration in constructing artificial flies for his fishing. He soon found himself deep in the study of aquatic entomology. Through the years he has read everything he could find on the subject and has spent much time on fishing trips digging under rocks and exploring riffles for varieties of May flies.

He has recorded his findings not only in writing but in the form of exquisitely fashioned artificial flies and in detailed paintings and in drawings such as those reproduced with this article. Last year he exhibited some of his work at the American Museum of Natural History in New York. The display comprised 100 outstanding examples of the fly-tyer's art. It included materials and standard colors used in making the imitations, a series of beautifully executed drawings of the natural insects and a description of their entomological background—all of which represented many years of field research along the streams and lakes of the East.

No one knows who invented the artificial fly. Perhaps some ancient cave-dweller lashed animal hair or feathers to a bone hook and, squatting on the banks of a Paleolithic river, became the first to cast a home-made fly into a stream. One of the earliest writings on the subject was by the Roman teacher Aelian, who recorded that the Macedonians used flies to fish in the river "Astraeus" between Messalonica and Borea. In the 15th century Dame Juliana Berners, Prioress of Sopwell Nunnery and an authority on hunting, hawking and "Fysshynge with an Angle," described "flyes with which ye shall angle to ye trought" which closely resembled the flies used by trout anglers today. Made of "donne woll, wyngis of the pertryche" and other materials common to the modern fly-maker, they simulated the May flies that dance over the English chalk streams in the spring and summer twilight.

May flies play an important part in the ecology of trout. Ordinarily during their season they constitute nearly 80 per cent of the trout's diet. They are most in evidence during a very brief period when they emerge from the nymphal state and swarm over the waters to mate and die. Like the Ephemerides of Greek mythology, May flies are said to live only one day; from this comes the insect order's technical name, *Ephemerida.*

Richard Salmon's studies have gone much further than the casual observations of the hobbyist; they encompass the whole life-cycle of the May fly from egg to adult. He collects the flies and nymphs "by hand," rather than with conventional tools of the entomologist such as the butterfly net.

"Catching the flies is not difficult," he explains. "The floating insects come to hand easily; those in flight travel slowly enough so that a vigorous wave of my hand carries them off their course and into the water where they may be picked up. In the nymphal underwater stage they are more difficult to catch. I take a small window screen to the stream, place it below the area I intend to search, and stir up the bottom. The current carries nymphs into the screen.

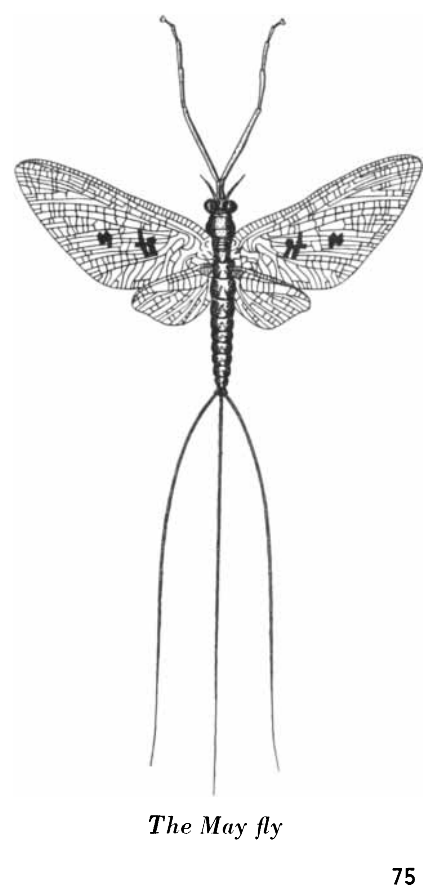
"I have a series of small clear-glass, wide-mouthed bottles in which I keep a solution of formalin and water: one part 50 per cent formalin to 20 parts water. To this I add a couple of drops of glycerin, which keeps the insects pliable. I use screw-top bottles and find it wise to keep them brim-full, because splashing in a partly filled container breaks their delicate bodies.

"I have never succeeded in keeping specimens in full color for any length of time. Their colors fade. When drawing and water-coloring, I find work should be done as soon as possible after collecting.

"It is advisable to carry a magnifying glass for identification purposes. The flies are easily distinguishable from all other insects by their remarkably large forewings and small hind wings, very short antennae, two or three long curving tail-filaments and entirely atrophied mouth parts. In this stage they are known colloquially as 'Drake,' 'Day Fly,' 'Sailor,' 'Lake Fly,' 'Shad Fly' and by other names. They are recognizable by nearly everyone who has found himself in the vicinity of streams where the insect breeds in astronomical numbers. In some towns along the St. Lawrence River the swarms of May flies are sometimes so dense that they stop traffic. They cover sidewalks with a slippery mess which pedestrians are unable to negotiate. May flies apparently mistake the black, shiny surfaces of macadam roads for stream surfaces. They often dip down and deposit eggs on road-tops as if they were rippling streams."

Although folklore gives the insect a lifetime of only one day, it really lives a great deal longer, most of the time under water.

"The life cycle is interesting and unique," Salmon reports. "Eggs are usu-



The May fly

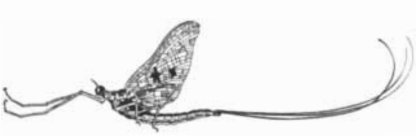
ally deposited in fresh water with a high oxygen content. A few species choose brackish water. In a short time the eggs hatch into minute nymphs, which are mainly herbivorous, living on diatoms and other minute water plants. They swim, crawl and burrow, according to their kind. Most species may be found under stones in or near swift water. The nymphs are quite active, with strong legs, distinguished by a single terminal claw.

"Physical idiosyncracies for the identification of ephemerid nymphs are few. In the main they have two shapes. Some are flat, their compressed bodies streamlined for the purpose of hugging the bottom. Their shape deflects the rapid current. Flat nymphs are usually the crawlers and the burrowers. Others are round-bodied. These are usually the swimmers. Some travel at remarkable speed and are almost impossible to catch by hand.

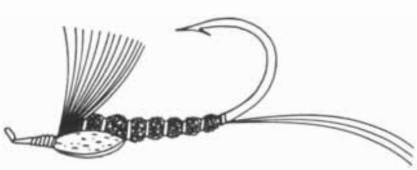
"During the insect's early growth there are several molts. The potential May fly grows faster than its skin, which quickly sloughs off to expose a new and larger shuck of similar pattern. The nymph's life-span usually lasts from one to three years. It may have as many as 20 molts. In one of the larger species (*Hexaga Variabilis*) the body of the pupa or nymph is an inch long in the final stage, with tail filaments extending half an inch more.

"As the nymph passes through the adolescent stage, it develops humps on its shoulders, where later the wings of the adult will emerge. When it is ready to transform, its wing-pads swell, giving it a hunchbacked appearance. It becomes very active, finally swimming or floating to the surface of the water. Then the skin of its back splits open and the winged insect flies out. In some kinds, such as the one known to fishermen as the 'Pale Evening Dun,' the transformation is so rapid that the fly seems to explode from the nymphal shuck. Time and time again I have observed the nymph rising to the surface; the next instant, without any perceptible struggle, it is in the air, flying rather awkwardly on its untried wings.

May-fly nymph



Male imago



The angler's nymph

"The rather large March brown, one of the *Stenonema,* is quite the opposite, and equally interesting to watch. The nymph swims to the surface in a zigzag series of spurts. It floats, wiggling in snapping convulsions, trying to crack through its shuck. I have followed the nymph downstream for a hundred yards watching its struggles. Finally the fly pulls itself from the burst skin and, apparently exhausted, sits upon its own skin while its wings dry. Then it tries to fly, and failure follows miserable failure until somehow it succeeds in becoming airborne. Because of its long period on the surface, trout find this fly easy to catch. The fish seem to go into a frenzy as they wait for the fly to emerge.

"Fishermen describe the transformation of aquatic flies as a 'hatch,' and a big 'hatch' is an exciting spectacle indeed. One moment the water will present a glassy surface without so much as a ripple; then suddenly the whole area becomes pock-marked—a frenzy of 'hatching' flies. Almost instantly the agitation spreads. The whole stream comes to life—charged with excitement. Swallows, flycatchers and other birds swoop over the water and gorge themselves on the sudden feast. And every trout in the stream, it seems, joins the party. At this point I cease temporarily to be an amateur entomologist, and my metamorphosis into a fisherman becomes as astonishing as that of the Ephemeridae!

"In the stage after transformation the May fly is known as a subimago, or, in the parlance of the fisherman, a 'dun.' The subimago may be distinguished from the true adult, or imago, by its direction and pattern of flight and by its cloudy, opaque color.

"Upon emergence it makes a beeline shoreward, where it conceals itself under a leaf or in some other inconspicuous place. It clings to its place of sanctuary, resting and calming down after its exciting experience. Then a curious phenomenon takes place, one not found in the life cycle of any other insect. There is a second molt. The skin of the subimago splits and the true adult fly emerges. At times I have seen this second transformation take place in mid-air.

"The life of the imago is extremely short. The fly begins to starve as soon as it leaves the nymphal shuck. It cannot eat because its mouth-parts are atrophied. The life span is usually longer, however, than the fabled 24 hours; some species live as long as four days if the air is dry and the atmosphere quiet. The 19th-century British entomologist John Curtis is said to have kept an adult May fly alive indoors for three weeks.

"The imago—called 'spinner' by trout fishermen—is a far brighter and more beautiful insect than the subimago. Its wings are glassy and finely veined. For a long time the order *Ephemerida* was classified under the *Neuroptera,* the nerve-winged flies, because of the finely laced veins of their wings.

"The males are easily distinguished from the females. In a female May fly the legs are too delicate to support the weight of the body, whereas in a male only the hind legs are weak.

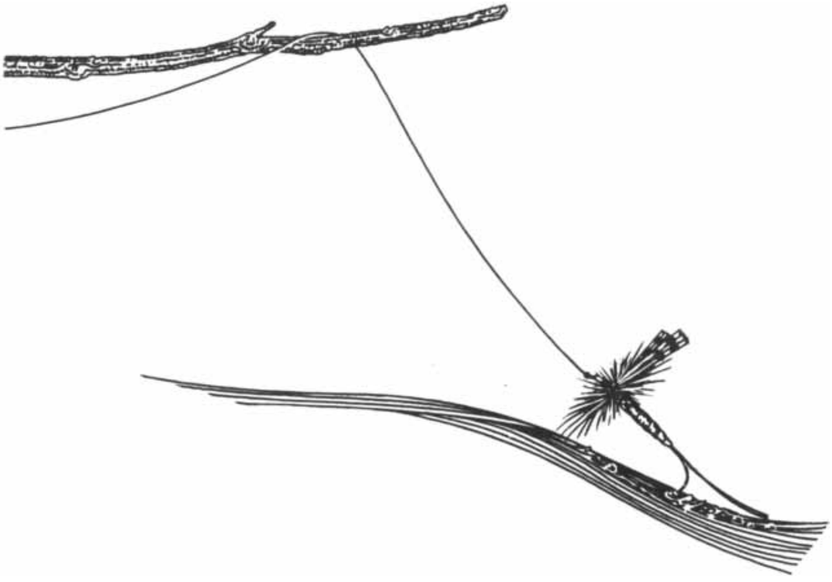
"May flies usually remain quiet during the heat of the day and fly in the cool of the morning or evening. They are attracted by artificial light and swarm around street lights or the headlights of automobiles. Sometimes the swarms are as thick as a dense snow-cloud.

"Most May flies couple during flight, the male clinging undermost. Egg-laying follows immediately. The male, spent, falls or flies off weakly to die, usually in a matter of minutes. Some May flies drop their eggs from mid-air. In most cases, however, the female proceeds in undulating flight, dipping down to the surface of the water to wash off loose clusters of eggs from her ovipositor. She rises to dip again and again. It is this undulating flight pattern that is known as the 'dance of the May fly.'

"During the egg-laying dance the insects continually work upstream. It has been suggested that this is a means of preserving the species. In swift water the eggs drift some distance before settling to the bottom. Thus if the flies merely dropped their eggs over the area where they themselves were hatched, each generation would hatch farther downstream than its predecessor, and conceivably the whole species might eventually be lost in the sea.

"In many once fine trout streams the numbers of May flies have sharply decreased, and in all too many they no longer exist at all. This lamentable decrease results from a combination of causes: pollution, flash floods that leave silt deposits, and the destruction of forests, which leaves streams unshaded and lets them fall in summer to low levels so that the water becomes too warm for the flies.

"The loss of May flies is of considerable concern to fishermen. During the latter part of the 19th century transplantations of English 'Drakes' were made successfully to America. Nymphs of the insect were planted in New York's Navesink River, where they propagated and continued to flourish. Some day, when industry stops dumping untreated factory-wastes into the waters, when the farmer and lumberman have at last adopted sound soil and timber conservation methods, we may see May flies clouding the air above streams in their



Dry fly floats in a swift current

former numbers—and let us hope there will be trout splashing for them as they rise from the foam-flecked pools and eddies as they did in the good old days."

TWO IMPORTANT recent books illustrate why diffraction gratings are increasingly used instead of prisms in research spectrographs. In *Practical Spectroscopy* George R. Harrison, Richard C. Lord and John R. Loofbourow of M.I.T. point out that a grating costing $800 will do the work of a quartz prism costing $10,000. In *Fundamentals of Physical Optics* Francis A. Jenkins and Harvey E. White of the University of California show that a quartz prism with resolving power comparable to that of a six-inch grating (of 15,000 grooves per inch) would have to be 30 inches wide—an impracticable size. It would be half as large as a pup tent, an object of similar shape.

The grating on the June cover, with 5 1/8-inch ruled width, rates in spectroscopy as a six-inch grating because the measure used is the diagonal, the diameter of the light beam.

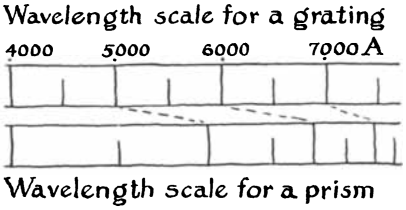
Diffraction gratings make spectra by an optical mechanism altogether different from that of prisms. According to classical theory, in a prism electrons vibrating in the atoms of the glass fall into resonance with the light waves and retard them. The resonance is greater for the shorter waves; hence the violet is retarded more than the red. This is what causes the differential bending that is responsible for dispersion of the colors in the light. In a grating the light reflected from a single groove is diffracted (deflected) over a wide angle. The light thus diffracted from many identical grooves then interferes, producing spectra.

With these wide differences in optical mechanism it would be remarkable if the spectra of prisms and gratings were alike. The illustration at the bottom of the next page shows how greatly they differ. The most striking difference is the fact that, while a prism spectrum is single, grating spectra are multiple. The lower part of the drawing shows the first four of many recurring pairs of spectra made by a grating. At the center is a white reflected image of the light source, the slit of the spectrograph. The same mechanism which puts light into a number of orders puts some of it into this zero order, but largely its light is reflected from the submicroscopically torn and burred edges and bottoms of the grating grooves, which cannot be ruled with geometrical perfection.

On both sides of the central image, in corresponding left- and right-hand pairs, are numbered "orders" of spectra. (R, G and V stand for red, green and violet.) Each pair is wider and fainter than the last. After the first order they overlap in apparent confusion. To a spectroscopist this is not as bad as it appears. From daily familiarity he comes to know his way about. He selects for use a single order on a single side, ignoring the others. Usually he removes the others with a filter. The chief advantage in the grating spectra is the fact that the resolving power is multiplied theoretically in proportion to the order selected. Practical reasons reduce this bonanza, so that the third order may no more than double the resolving power of the first, and with the fourth the gains begin to dwindle markedly.

There are other fundamental differences between prism and grating spectra. The upper part of the drawing shows a prism spectrum. The prism bends red rays the least, violet the most, whereas a grating does the opposite, the red rays falling farthest from the central image and the violet nearest.

Finally, a grating disperses the wave-



Rational v. irrational spectra

lengths almost uniformly. This is shown in the small drawing above, where the wavelengths are given in Angstrom units, from 4000 A. in the violet to 7000 and beyond in the red. In the grating spectrum (top) the spacing is even; in the prism spectrum (bottom) the wavelengths are increasingly crowded together toward the red. In the "rational" grating spectrum identification and measurement of wavelengths is much easier. This is what originally interested Henry A. Rowland in gratings.

Until recent years a serious drawback of the grating spectrograph was the fact that the total light was divided between the central image and many orders of spectra, so that the individual spectra were illuminated only faintly. A way was found, however, to make them brighter. Rowland had noted that gratings accidentally ruled with lopsided (not V-shaped) grooves sometimes gave a brighter spectrum in some single color than a prism did. Later the experimental physicist R. W. Wood described similar phenomena. The British physicist Lord Rayleigh investigated the theory of these anomalous gratings and proved that this special distribution of light was connected with the cross-sectional shape of the grooves, as suspected. Wood finally discovered that if he shaped the ruling diamond and set it at such an angle that the light reflected from one side of the groove coincided in direction with the diffracted light, most of the light could be thrown into the part of the spectrum where maximum illumination was desired. Today this is called the "blaze."

A chisel-edge diamond ground to shape and tilted for blazing a grating is shown in a drawing on the opposite page. Its keel is 1/16-inch long; the grooves shown are far out of scale in size. After the diamond has ruled about 10 miles of grooves (say three six-inch gratings), its leading corner will be rounded by wear. At the Johns Hopkins University the ruling engine technician Wilbur Perry expertly regrinds and repolishes worn diamonds on a lapidary's lap, removing about 1/10,000 inch of thickness in the process. The keel of the one that I examined under 700 diameters' magnification was too sharp to be seen; it was "visible" only as a diffraction line. Compared with its smooth edge, a razor's edge is a crosscut saw.

In 1916, when John A. Anderson went from Johns Hopkins to the Mount Wilson Observatory as an astrophysicist and ruling-engine consultant, he developed the "boat-bottom" diamond shown below the chisel-edge. Its curved edge is obtained by the intersection of two cones, one shallow, one deep. Only the shaded portion is used, set in metal. The curved edge presses the metal aside by plastic flow, also burnishing the groove. This form of diamond works wonderfully well on plane gratings, but poorly on the concave gratings that Rowland invented, in place of an added lens, for focusing the light.

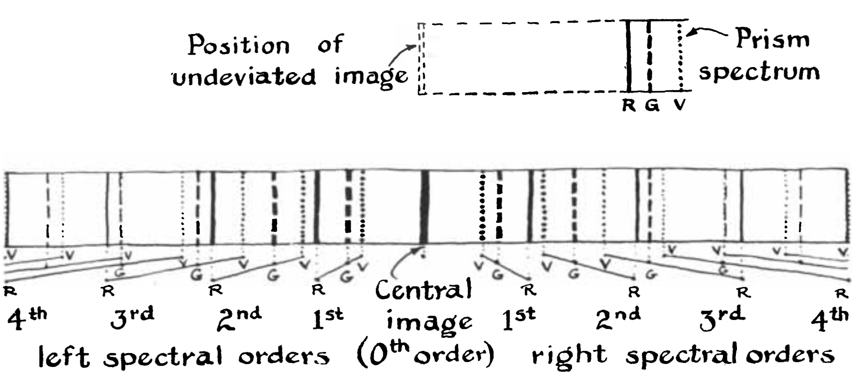
A grating may be blazed not only for a single order on one side of the central image but even for a definite part of that order. To a physicist this advance, little known outside the world of physics, is outstandingly significant and almost as important as more obvious advances such as larger gratings. Setting the diamond and checking the control of the blaze calls for patient fussing. Several gratings may be ruled before the correct angle is hit upon. David Richardson, in charge of the ruling engines at the Bausch & Lomb Optical Company, has been a leader in the art of blazing gratings, "doing a bang-up job on the control of the grooves," as a friendly competitor remarks. He accomplishes much of this control with a microinterferometer instead of a microscope, thus "seeing" the shape of the grooves in terms of interference fringes.

While it is easy to see the grooves with a high-power microscope, it is difficult to interpret their shape. Harold D. Babcock explains: "Every microscopist is familiar with the uncertainties of interpreting the appearance of a periodic structure when the limit of resolution is approached. Spurious details, delicately responsive to the slightest variation in the focal adjustment or in the illumination, are particularly troublesome in a field of parallel equidistant lines."

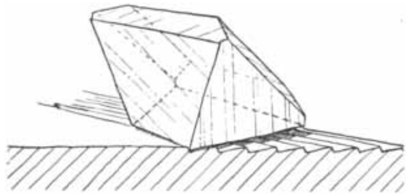
The pioneers Wood, Anderson and Babcock blazed gratings in hard, brittle, intractable speculum metal. Two decades ago John Strong, also Robley C. Williams, developed practical methods of depositing aluminum on glass. This metal is comparatively soft and tractable and has high reflectivity that lasts a long time. Its arrival greatly stimulated blazing, and thus the advance of the diffraction grating toward supremacy over the prism. Today a grating can concentrate more of the incident light in the blaze than a prism, with its large losses by internal absorption and surface reflection, can put into its single spectrum. Perry's gratings average 60 per cent of the light in one order, frequently reach 80 per cent and have reached 95 per cent.

John Strong remarks that it is just as wrong to discourage anyone from trying to build a ruling engine as to overencourage him. But the victim should be fully aware of the difficulties. Rowland's assistant and *alter ego*, the physicist J. S. Ames, listed Rowland's special combination of qualifications for ruling-engine work: 1) the scientist's grasp of fundamental principles, 2) the engineer's understanding of practical mechanics, 3) mathematical aptitude, 4) manual dexterity. Understanding of mechanics and high manual dexterity are not uncommon among amateurs with toolmaking skill. It is suspected, however, that some who have tackled the ruling engine and judiciously kept it a secret, or tried to keep it a secret from this department's elaborate spy network, have underestimated the importance of science and mathematics. Learning with surprise that most of the physicist operators of ruling engines do not themselves run the engines but make only occasional calls like a physician, while the technicians stay with the engines like a nurse, some have concluded that the "nurse" does the work while the "doctor" gets the credit. They do not realize how essential are the doctor's guiding judgment, diagnosis and treatment when things go wrong, as they usually do.

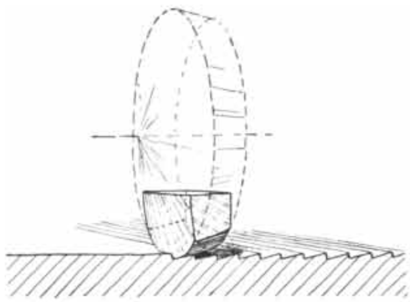
Rowland (who, by the way, pronounced the first syllable of his name to rhyme with doe and not with cow) acknowledged his technician Theodore Schneider but once in print, although Schneider made the screws and most of the working parts of the Rowland engines and superintended the ruling of every grating that left Johns Hopkins for a quarter-century. Today ruling-engine physicists are more careful to give public credit to their technicians in scientific



Prism and grating spectra



Chisel-edge diamond



Boat-bottom diamond

periodicals. Horace W. Babcock acknowledges contributions by his technicians C. Jacomini and E. D. Prall, and Strong praises the work of Wilbur Perry, John F. McClellan, Dave Broadhead, Howard Head, Robert Schreitz and William Koenig.

Some of the earlier ruling-engine operators were secretive. Today they are mutual friends who pool most of their findings in "family sewing bees." If any seem less communicative to new aspirants, the reason may be only that they are weary of hearing the same old proposals for engine designs advanced as new, often not without self-confidence. But their reticence may also be an act of mercy. After publication of the article on ruling engines in the June issue an enthusiastic mechanic informed me that he had made up his mind to borrow money from a bank to build a ruling engine and turn out 14-inch gratings "within six months." At the other extreme, the same article caused another fine mechanic, a doctor of science, to give up his long-smoldering ambition to build a ruling engine.

Scale drawings and a description of the Rowland engine were published in the *Physical Papers of H. A. Rowland*. This book is now rare, but photostatic copies of pages 691-697, on the ruling engine, and separate figures 1 to 5 may be purchased from the Library of Congress, Washington, D.C. No scale drawings of other engines have been published. The classic article of J. A. Anderson, "The Manufacture and Testing of Diffraction Gratings," occupies pages 30-41 of Volume 4 of Richard Glazebrook's *Dictionary of Applied Physics*. Anderson's article on "Periodic Errors in Ruling Machines," in *Journal of the Optical Society of America,* July, 1922, pages 434-442, also is basic to the understanding of the subject. Most of the literature on the ruling engine is cited by George R. Harrison in the same journal, June, 1949.

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BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful. The lists are not intended as bibliographies of source material for the articles. The references selected will provide supplementary information.

CHEMICAL AGRICULTURE

MANPOWER, CHEMISTRY, AND AGRICULTURE. Francis Joseph Weiss. Senate Document No. 103, U. S. Government Printing Office, 1952.

THE SPIDER AND THE WASP

TARANTULA VERSUS TARANTULA-HAWK: A STUDY IN INSTINCT. Alexander Petrunkevitch in *The Journal of Experimental Zoology,* Vol. 45, No. 2, pages 367-397; July 5, 1926.

THE RHIND PAPYRUS

THE RHIND MATHEMATICAL PAPYRUS, British Museum 10057 and 10058. Vol. I: Free Translation and Commentary by Arnold Buffum Chace. Vol. II: Photographs, Transcription, Transliteration, Literal Translation by Arnold Buffum Chace, Ludlow Bull and Henry Parker Manning. Mathematical Association of America, Oberlin, Ohio; 1927 and 1929.

ASTHMA

SOMATIC AND PSYCHIATRIC TREATMENT OF ASTHMA. Edited by Harold A. Abramson. The Williams & Wilkins Company, 1951.

MICROWAVES

THEORY AND APPLICATION OF MICROWAVES. Arthur B. Bronwell and Robert E. Beam. McGraw-Hill Book Company, Inc., 1947.

RUNNING RECORDS

THE A.A.U. OFFICIAL TRACK AND FIELD HANDBOOK. The Amateur Athletic Union, 1952.

ON THE ORIGIN OF GLACIERS

GLACIAL GEOLOGY AND THE PLEISTOCENE EPOCH. Richard Foster Flint. John Wiley & Sons, Inc., 1947.

ORIGIN OF THE ICE. George Gamow in *Scientific American,* Vol. 179, No. 4, pages 40-45; October, 1948.

VOLCANOES AND WORLD CLIMATE. Harry Wexler in *Scientific American,* Vol. 186, No. 4, pages 74-80; April, 1952.

D'ARCY THOMPSON

ON GROWTH AND FORM. D'Arcy Wentworth Thompson. Cambridge University Press, 1952.

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