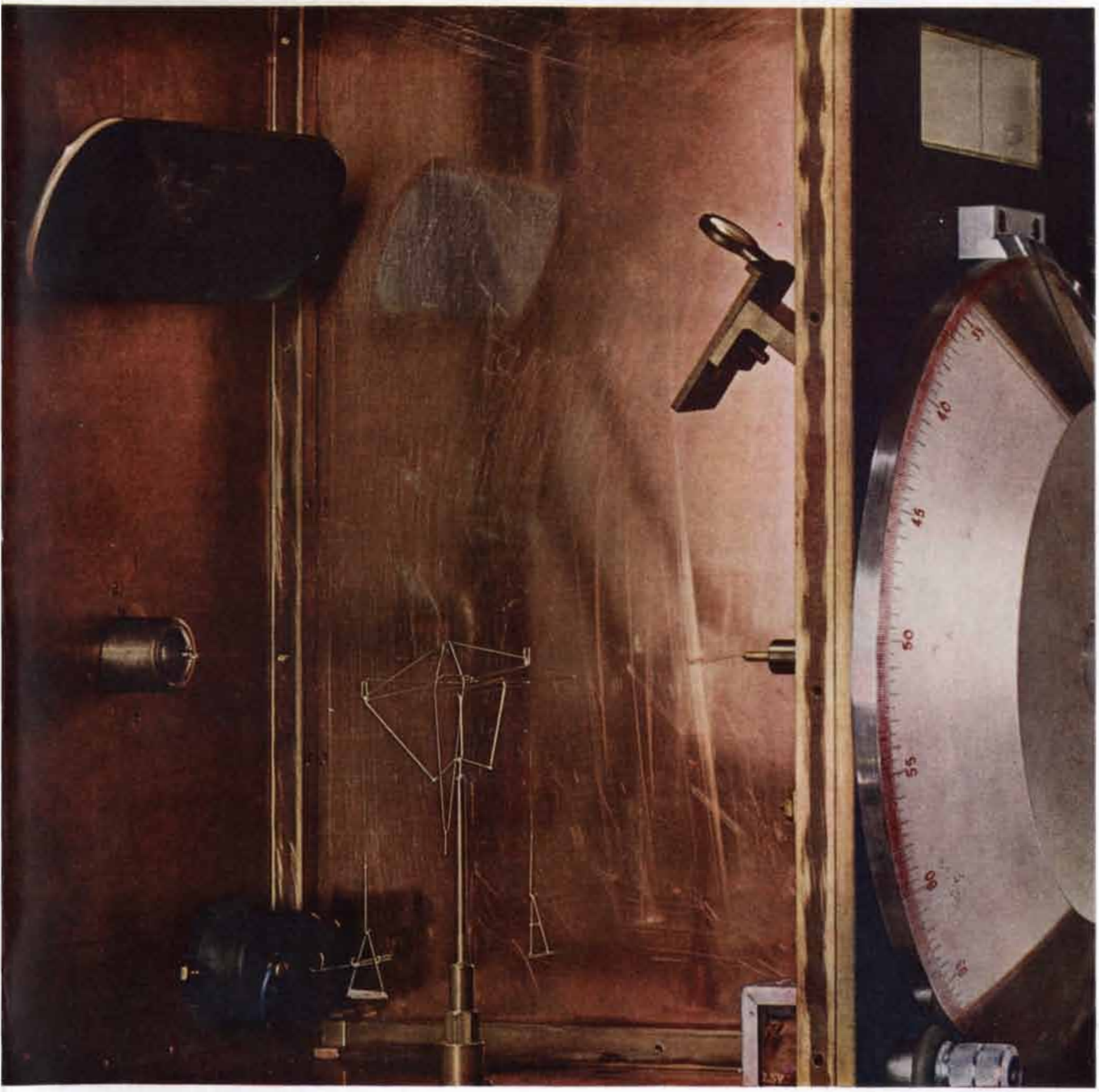
SCIENTIFIC AMERICAN



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February 1954

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One cubic foot of long-lasting AMBERLITE® IR-120 cation exchange resin has treated 8,000,000 gallons of water—enough for a family of four for 77 years—in one of the nation's largest municipal water-softening plants.

This resin is typical of those produced by Rohm & Haas Company, where the search for new ion exchange resins and techniques is as unceasing as man's quest for good water. In laboratory columns like the one above, industrial processes were developed for the preparation of high quality boiler-feed water, for the de-ashing and decolorizing of sugar syrups, for the recovery of precious or toxic metals from wastes.

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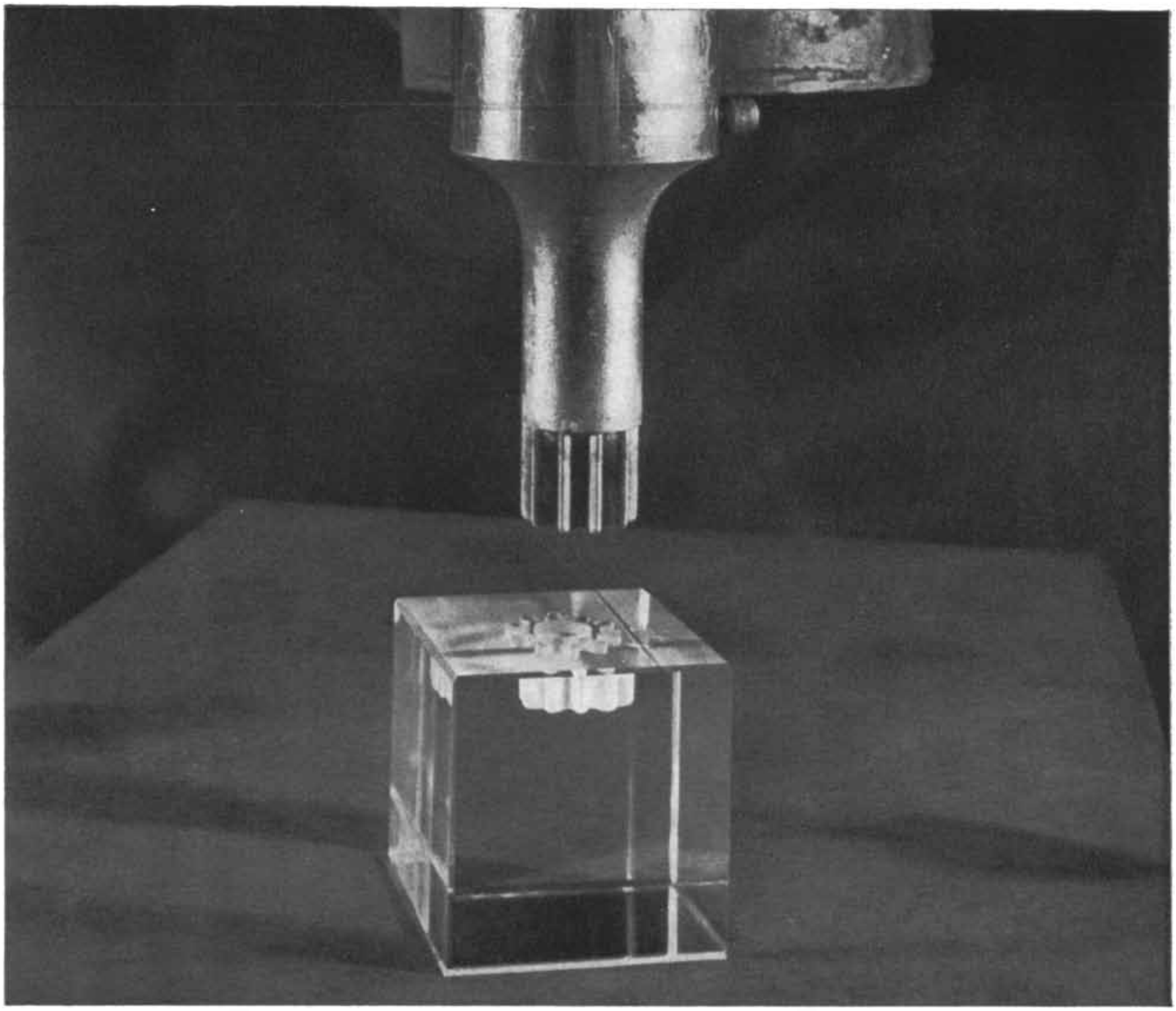

Using high-frequency vibrations and low-cost abrasives, the Cavitron Ultrasonic Machine Tool carves holes and patterns of all shapes in hard-to-work materials. Development of the tool climaxed more than 10 years of research and experimental work by the Cavitron Equipment Corporation, of Long Island City, N. Y.

How SILENT SOUNDS CUT HOLES you can't drill

This common steel gear bites its way into a glass cube as smoothly as it would mesh with its mate.

And that's *something*, for chiseling through glass is quite a trick, even with a tool designed for the job.

Yet, as you can see, it's being done right here. And the machine that does it can also sharpen the hard metal tools used to cut other metals. It can cut diamonds without the use of diamond powder. Some day, it may even eliminate the heat-generated pain caused by your dentist's whirling drill, or provide a vastly improved method for breaking up kidney- and gallstones.

Now how does this revolutionary tool work? *By ultrasonic vibration.* It vibrates 27,000 times a second! Every vibration pounds water-borne abrasive against the surface you're cutting, and steadily chisels away tiny particles.

It took time to produce and control these vibrations. Over 10 years of research and trial-and-error experimentation! Then—with the help of Inco Nickel — the successful method was perfected.

Pure nickel, when placed in an electromagnetic field, contracts much more than other commercial metals, and returns to its original length. (Physicists call this "magnetostriction.") It is this motion — stepped up a hundredfold — that produces the vibrations which give the tool its bite.

There are many similar useful qualities found in Inco Nickel Alloys. Between them, pure nickel and Monel provided the key to the problems of the ultrasonic machine tool. Another of our metals may help to open a door now locked to you. Let's get together and work out that problem of *yours* — soon.

THE INTERNATIONAL NICKEL COMPANY, INC.
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Inco Nickel Alloys

Monel® • "R"® Monel • "K"® Monel "KR"® Monel • "S"® Monel • Inconel® Inconel "X"® • Inconel "W"® • Incoloy® Nimonic® Alloys • Nickel • Low Carbon Nickel • Duranickel®

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LETTERS

Sirs:

In your department "Science and the Citizen" for October you refer to the speculations of Mr. Spencer Brown on the statistical basis of parapsychology and mention that many scientists feel uncomfortable about experiments in parapsychology, and feel sure that there must be something wrong. This discomfort should, however, put scientists on their guard against accepting a line of thought which promises to remove it.

Early controversy as to the statistical validity of parapsychological experiments was eased by the publication of an authoritative judgment by the president of the Institute of Mathematical Statistics that "the statistical analysis is essentially valid. If the Rhine investigation is to be fairly attacked it must be on other than mathematical grounds." It is, of course, possible (though not very likely) that Mr. Brown has detected a weakness that was not apparent to the Institute of Mathematical Statistics.

Careful checks have been made of the guesses made in successful ESP experiments against sets of targets for which they were not intended. Many such control experiments have been carried out. One of the most extensive is reported in the book *Extra-Sensory Perception After Sixty Years,* by Rhine, Pratt, Stuart, Smith and Greenwood. In this check the frequency distribution and other statistics of a 20,000-run series of guesses

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(half a million individual guesses) was made. The mean, the standard deviation, and other statistics were found, in fact, to be very close to those expected on the hypothesis of chance. Such observations rule out the possibility that the ESP experimental results are, as Spencer Brown has suggested, to be attributed to something being wrong with the laws of chance.

Mr. Brown is reported to have matched digits between arbitrarily chosen columns of a table of random numbers, and to have found that the total results differed from the mean chance expectation. There are obviously various possible explanations. Such a result might be due to: (1) something being wrong with the laws of chance; (2) the conditions of his experiment being such that something in the nature of extrasensory perception was at work; (3) the series of random numbers being not truly random but related in such a way that numbers in the same column are more likely to be alike than one would expect by chance.

Mr. Spencer Brown has chosen to adopt the first of these explanations; the third seems to be much more likely.

ROBERT H. THOULESS

The Parapsychology Laboratory
Duke University
Durham, N. C.

Sirs:

It is surprising to find in Dr. Thouless a critic who considers it "not very likely" that I have "detected a weakness that was not apparent to the Institute of Mathematical Statistics." This observation seems to miss the point in two ways. First, in the words "not very likely" Dr. Thouless has used a probability expression in assessing the value of an argument, whereas the usual procedure of people who understand arguments but disagree with them is to try to point out a flaw. Secondly, it is not in any case the validity of the mathematics but that of the axiomatics of statistical procedures that I have questioned. Anyone who draws a triangle between three points on the earth's surface, and then discovers that its angles add up to more than 180 degrees, does not thereby throw doubt on Euclid's geometry, though he might be led to question its axioms.

Dr. Thouless suggests that insignificant deviations in some control experiments *rule out* the possibility of there being something wrong with the laws of chance, in spite of the fact that he

knows other controls to have led to highly significant results. In this he is clearly guilty of a drastic and unscientific selection of data to fit his theory; using his argument, we might as well say that the insignificant results obtained by some people doing ESP experiments *rule out* the possibility of ESP.

Finally, I have not chosen to *adopt* the explanation that something is wrong with the laws of chance to account for the significant deviations in my random-number-matching experiments. An attentive reading of my paper (or its very clear review in your journal) will reveal that I did no more than suggest the possibility of this explanation as not inconsistent with the position I had reached after examining ESP data.

G. SPENCER BROWN

Christ Church
Oxford, England

Sirs:

I have read with interest the excellent article on scintillation counters by George B. Collins [SCIENTIFIC AMERICAN, November]. Your readers may be interested in some of the early background of the instrument in addition to that given by Dr. Collins.

The idea of recording scintillations with a highly sensitive, rapidly responding photoelectric device instead of the eye was first proposed in 1941. Krebs, describing his work in *Annalen der Physik,* combined a scintillation crystal with a highly photosensitive Geiger-Müller counter for the detection of polonium alpha scintillations. He used this technique to measure the diffusion of radium emanations and thorium emanations. In 1944 Curran and Baker introduced a form of the scintillation counter in which the eye was replaced by a photomultiplier tube. Kallmann published at a later date and applied the principle to both particles and quanta, using single crystals of various luminescent materials to produce the scintillations.

The years between 1947 and 1950 brought many improvements in the instrument by the impressive teamwork and cooperation of such workers as Broser and Kallmann; Bell, Coltman and Marshall; Deutsch, Hofstadter, Mandeville and Albrecht; Mandeville and Scherb, to mention only a few.

A. T. KREBS

Army Medical Research Laboratory
Fort Knox, Ky.

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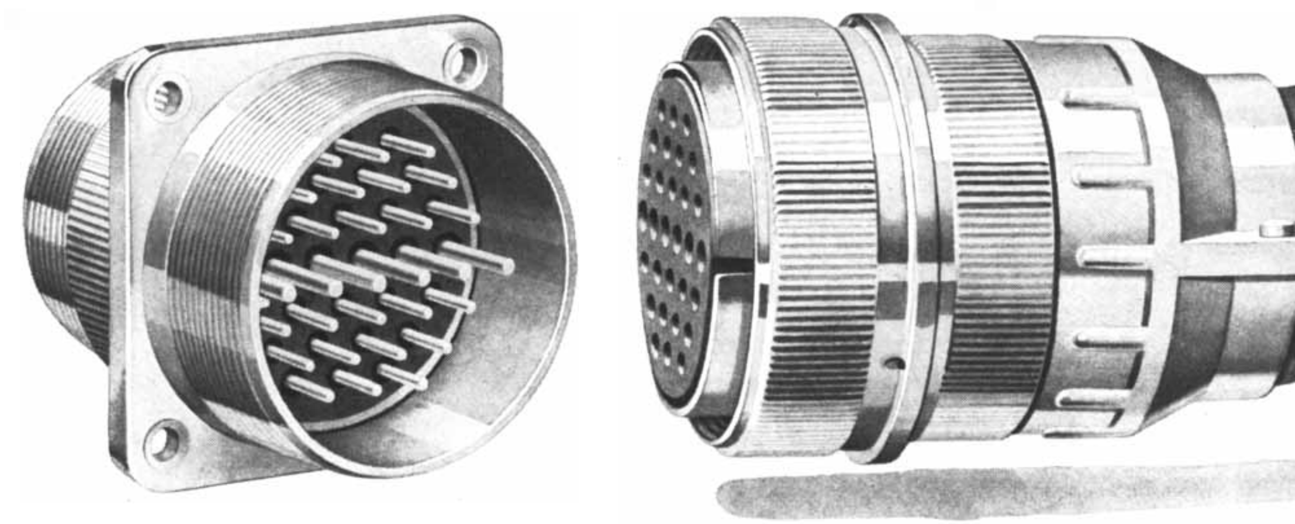

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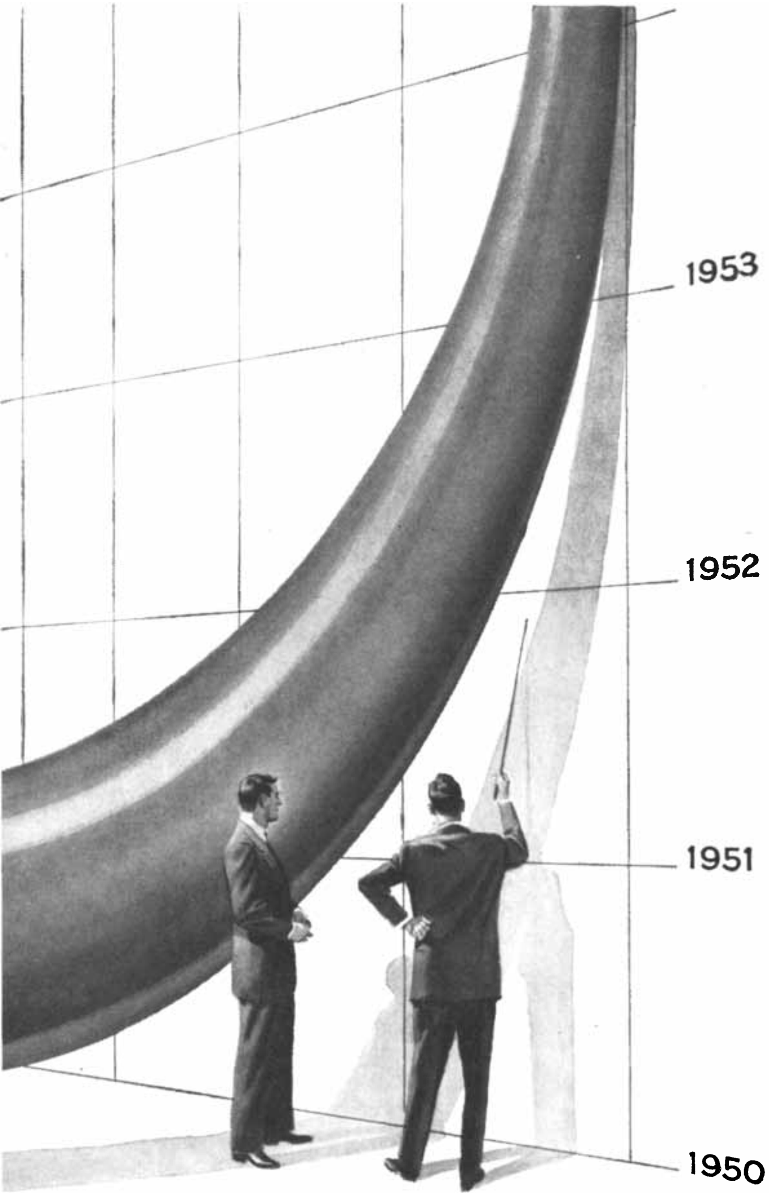

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

FEBRUARY, 1903: "Some further important evidence with regard to the suspected gradual conversion of radium or radium emanation into helium is furnished by Sir William Ramsay and F. Soddy. Radium emanation was condensed in a liquid-air tube, and the liquid air was then removed by the pump. The tube showed no trace of helium, but showed a new spectrum, probably that of the emanation itself. After standing for four days, the helium spectrum appeared, and the characteristic lines were observed identical in position with those of a helium tube thrown into the field of vision at the same time."

"Many ancient and historic buildings are now losing some of their antiquity by the introduction of the electric light, whose subtle encroachments apparently no hand can stay. Among the latest to succumb to the anachronistic illumination of electricity is no less a venerable pile than St. Peter's at Rome. The installation has recently been completed. Current is supplied at 2,000 volts alternating, and is reduced to a lower voltage by transformers situated in a chamber on the level of the main cornice round the dome."

"Sir Oliver Lodge has tried at Liverpool to disperse fogs, using for this purpose a Wimshurst influence machine which discharged by means of a bundle of points into the air. A very high potential is necessary and to increase the surface a large gas flame was used to supplement the points. On one occasion the discharge of electricity from the flame was sufficient to keep a clear space of fifty or sixty yards radius in a dense fog. Although these experiments were promising, the Wimshurst machine did not seem suitable for everyday use, and there was no other generator which would give a sufficiently high direct voltage to do the work."

"Prof. Curie has declined to accept the medal of the French Legion of Honor, despite the fact that the government offered it to him of its own free will,

and not because of the solicitations of any friends of the Curies. The refusal comes all the more as a surprise since Prof. Curie accepted the Nobel prize not so very long ago."

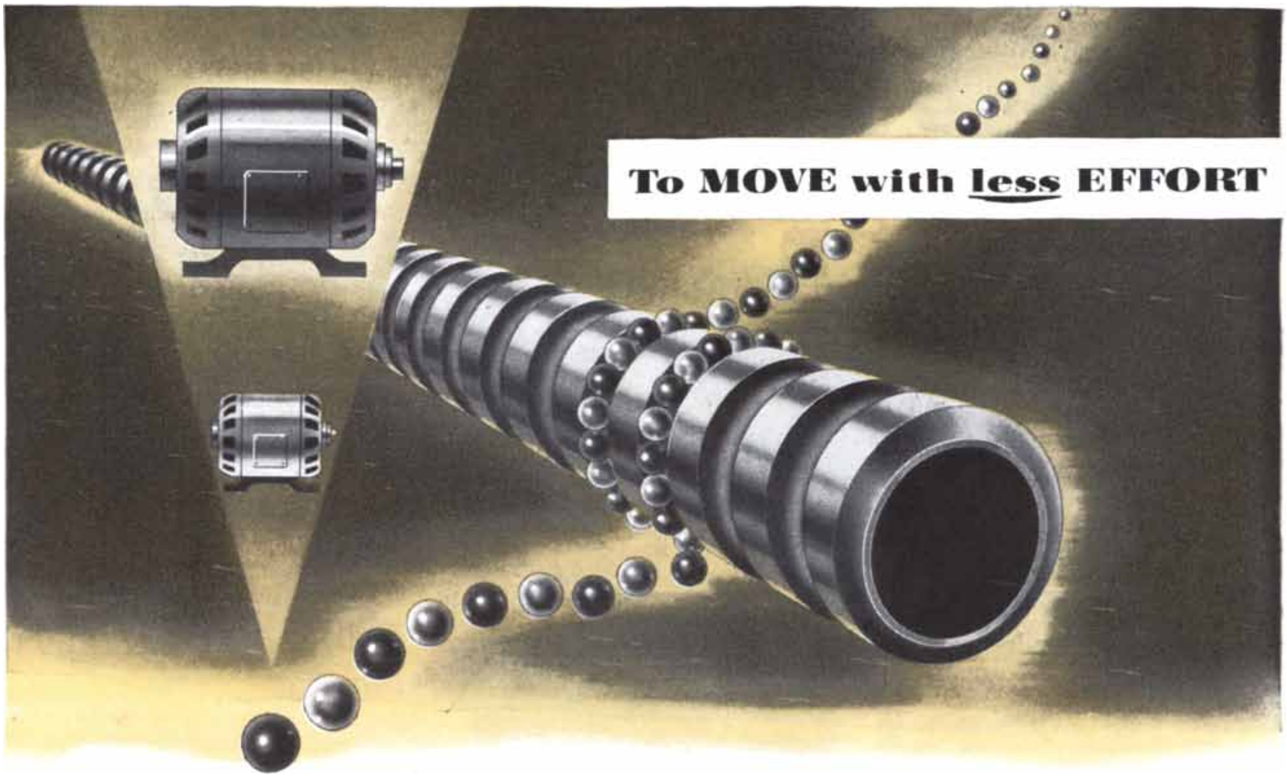
"An oxyacetylene blowpipe is described by M. Fouché in the Bulletin of the French Physical Society. The flame is formed by the combustion of a mixture of eight parts of acetylene to one of oxygen, and, in order that the explosion may not travel back into the blowpipe, a jet velocity is required equal to the pressure of a water column four meters in height. The flame melts most metals readily; it will solder iron and steel. Even silica and lime are melted by it."

"In the SCIENTIFIC AMERICAN of December 26 it was announced that the famous Eiffel Tower was about to be razed to the ground, for the reason that it displayed a marked toppling tendency. M. Eiffel denies the statement that the famous structure is to be torn down, and refers to the report of M. Mascart, president of the Academy of Sciences, in which it is said that 'the tower is in a perfect state of preservation, and that no change of position has been noted either in the foundation or in the framework.' Far from having sunk to one side, the tower seems to have preserved its position with all the constancy that could be desired. Every competent commission that has ever studied the tower has advocated the preservation of the structure, and has vouched for its scientific utility."

"The Technology Club of New York City recently held a radium banquet, in which the health of the Massachusetts Institute of Technology, whose alumni compose the association, was drunk in 'liquid sunshine.' A tiny tube of radium had been placed in water in a tiny cocktail glass. A magnesium wire was burned in a corner of the darkened room and in each glass there glowed a brilliant blue fluorescence. The toast to alma mater was then drunk standing."

SCIENTIFIC AMERICAN

FEBRUARY, 1854: "There are in Pittsburgh and its vicinity seventeen large rolling mills, twelve principal or large foundries, twenty glass manufactories, about twenty engine and machine shops, five large cotton factories, four



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We can also cut down friction in *your* designs and products . . . by shrinking the size of motors, easing the effort it takes to hand-actuate a device, making equipment move faster yet come to a more precise stopping point under any condition. Our Actuators operate smoothly under the greatest extremes of heat and cold.

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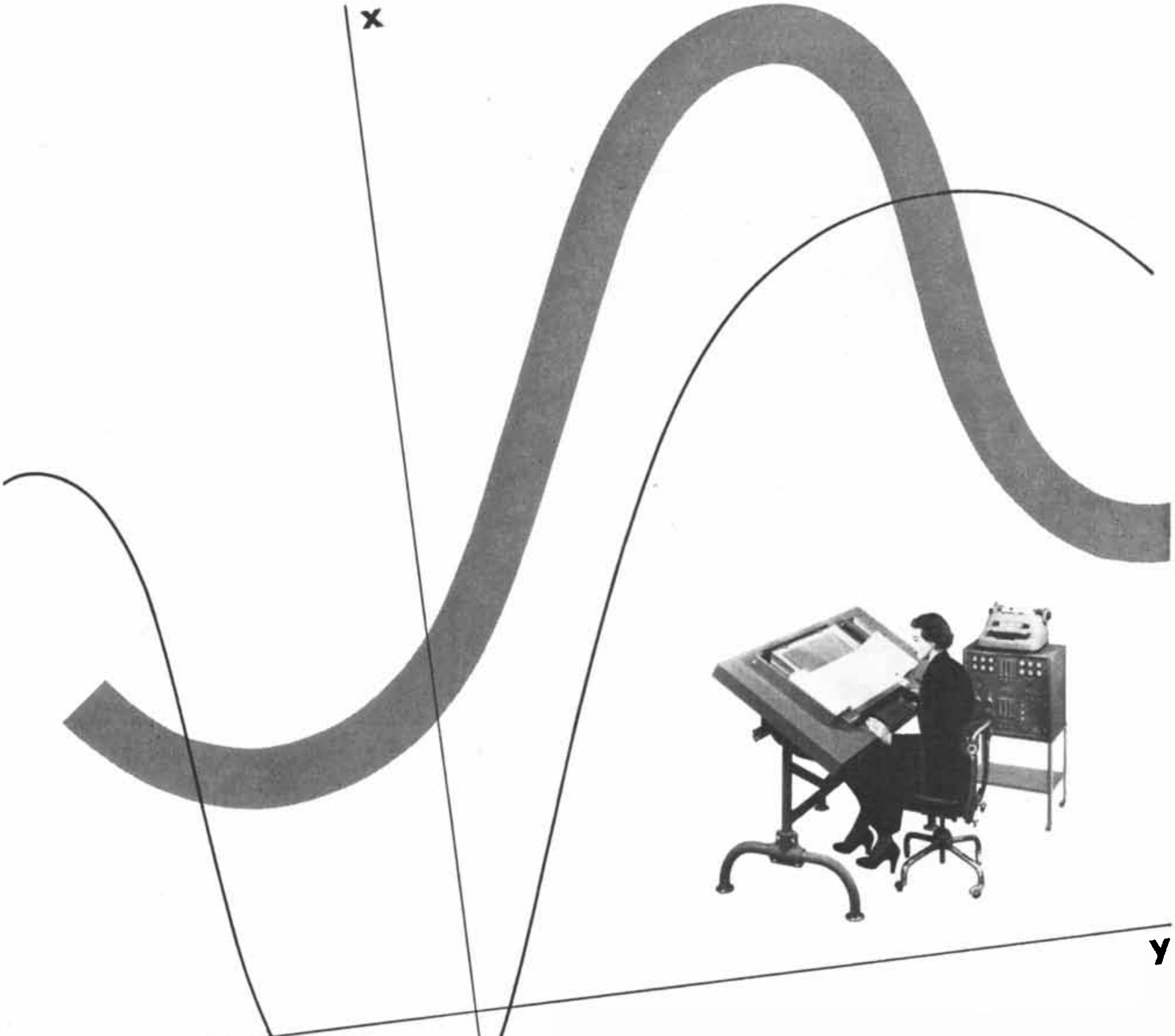
large flouring mills besides some smaller ones; and it is estimated that there are more than one hundred steam engines in operation in the city and vicinity."

"We see that Dr. Morton of Boston is now in Washington, hard at work to get friends and favor among the members of Congress in order that he may obtain an appropriation from Congress for the discovery of Etherization in surgical operations. A select committee of the House of Representatives presented a majority report in favor of Dr. Morton's claims, while an able minority report awarded the credit of the discovery to Dr. Jackson of Boston. In reviewing the claims of both applicants we took occasion to express our views upon the injustice done to Dr. Wells of Connecticut, now deceased, who had performed a surgical operation upon at least one person under the influence of ether two years before Dr. Morton obtained a patent."

"Since we published remarks a few weeks ago respecting the benefits that would be conferred upon the writing community by the invention of a *jet black pencil* to supersede pen and ink, we have received a number of letters about *fountain* pens, but we do not wish to have anything to do with these—their advantages and disadvantages being well known to us. The pencil and nothing but the pencil is the watchword and reply for us."

"Prof. Lovering, in his eighth lecture on Electricity, before the Boston Lowell Institute, said: 'Electricity will never be used generally for the purposes of mechanics or locomotion because of its expensive character, twenty-five cents expended in steam being as productive of power as two dollars expended in electricity.' This is also our view of the subject as it relates to expense, but there is a more fatal objection still to the use of galvanism as a motive power—we allude to the delicate nature of electro-magnetic conductors in machines, and the sensitiveness of the current to atmospheric influences. Steam is perfectly under the control of machinery, but the electric current is not, at least by any known appliances. An electro-magnetic engine of 10 horse power, by the simple disarrangement of one wire (not easily discovered) will not give out over one horse power. The management of the batteries, also, is difficult and troublesome, and not to be compared in simplicity to the furnaces and boilers of a steam engine."



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THE AUTHORS

FLETCHER G. WATSON ("A Crisis in Science Teaching") was trained as an astronomer but has shifted his interest to science education. Born in 1912 and raised in California, he graduated *magna cum laude* from Pomona College in 1933. He then joined the staff of the Harvard College Observatory, taking a Ph.D. in 1938. His principal research was on meteors, asteroids and comets, and he is the author of the well-known book *Between the Planets*. During World War II, as a lieutenant commander in the Navy, Watson worked on loran installations. Upon his release from the service he joined the faculty of the Harvard Graduate School of Education, where he is now associate professor. He collaborated with James B. Conant in planning several courses and summer programs, and is co-editor with I. B. Cohen of *General Education in Science*.

FRANK FENNER ("The Rabbit Plague") has been one of the chief scientific directors of the Australian campaign to eradicate rabbits by spreading myxomatosis. A microbiologist, he has had charge of the laboratory end of the work. Fenner was born in Victoria in 1914 and educated at the University of Adelaide, where he received an M.D. He spent six years in the Australian Army, where he specialized in malaria control. After the war he went to Melbourne to study animal viruses under Sir Macfarlane Burnet. He spent a year in the U. S. on a fellowship at the Rockefeller Institute for Medical Research studying tubercle bacilli. Upon his return to Australia he was appointed to his present position, professor of microbiology at the Australian National University in Canberra.

RICHARD M. SUTTON ("A Family of Solar Eclipses") has been called "one of the great masters" in the field of physics demonstration lectures. "The laws of physics," says a colleague, "simply jump out of his apparatus, and however abstract or subtle a physical principle may be, Dr. Sutton has constructed a piece of equipment or a model or a figure of speech to make it graphic and understandable." Sutton, who is descended from a long line of educators, was born in Denver in 1900. He attended Haverford College and the California Institute of Technology, where he took his doc-

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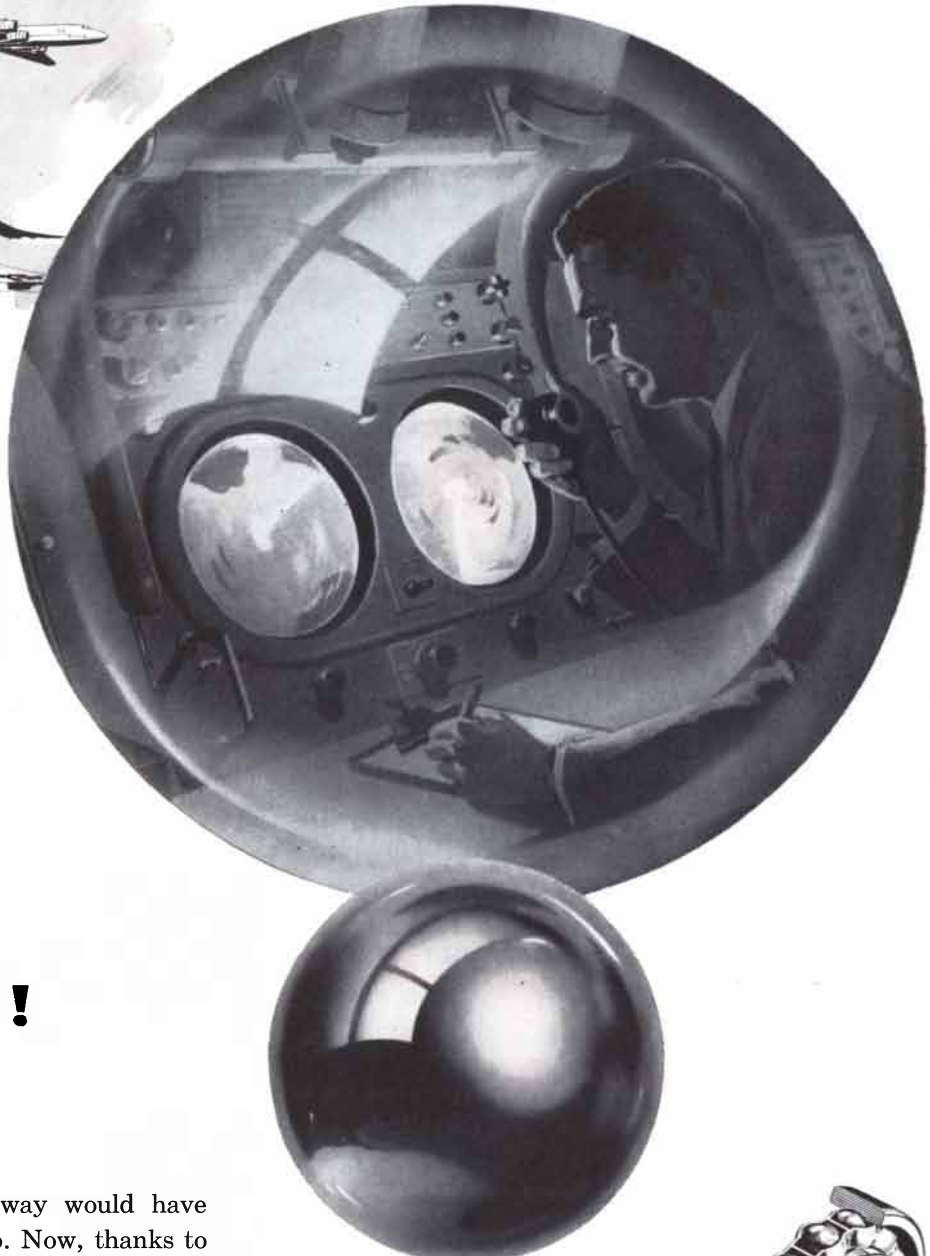

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tor's degree under the late R. A. Millikan in 1929. In 1931 he returned to Haverford and is now professor of physics and chairman of the department there. In recognition of his contributions to physics teaching Sutton was awarded the 1952 Oersted Medal of the American Association of Physics Teachers.

DOUGLAS SURGENOR ("Blood") is assistant professor of chemistry and associate member of the University Laboratory of Physical Chemistry Related to Medicine and Public Health at Harvard University. This laboratory grew out of the physical chemistry department at Harvard Medical School where, under the direction of the late Edwin J. Cohn, fundamental studies in protein chemistry were combined with wartime work on gamma globulin and other blood plasma fractions. Surgenor joined Cohn's group in 1946, having just taken his Ph.D. in organic chemistry at the Massachusetts Institute of Technology. His first studies were in the field of red blood cell fractionation. Later he played a major role in developing methods for fractionating tissues other than blood, particularly liver, and was one of the designers of the latest portable model of plasma processing equipment which is described in his article.

JAMES E. McDONALD ("The Shape of Raindrops") is currently a member of a large research team working on an Air Force-sponsored study of cloud physics at the University of Chicago. It was the raindrop problem, upon which he came almost accidentally, that stimulated his interest in cloud studies. This is his third appearance as an author in SCIENTIFIC AMERICAN; he has written articles on the Coriolis force and on the earth's electricity.

ROBERT A. BUTLER ("Curiosity in Monkeys") is a research psychologist at the Audiology and Speech Correction Center of the Walter Reed Army Hospital. He took up the study of psychology after the last war, receiving his Ph.D. from the University of Chicago in 1951. Before going to his present position he had taught at the University of Wisconsin, where he began his work on curiosity in the Primate Laboratory. He is continuing the research at Walter Reed. Butler is 30 years old.

BURRIS B. CUNNINGHAM ("Ultramicrochemistry") learned to work with small chemical samples while studying the metabolism of paramecia just before World War II. This experi-

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MODEL 390A **A medium duty model producing an alternating force of approximately ±25 lbs.**

Thrust	Force factor 4.7 lbs. per amp.
Max. Continuous Current Rating (R.M.S.)	2 amps. uncooled; 4 amps. with air cooling of approx. 5 lbs. per sq. in.
Stroke	0.5 in total excursion.
Impedance	8 ohms matching.
Frequency Range	Up to 10,000 c/s.
Weight of Moving System	0.16 lbs.
Stray Fields	Operating zone less than 100 gauss.
Flux Density	11,000 gauss.
Weight	26 lbs.

MODEL 790 **For Vibrating heavy components, and is capable of producing a force of ± 50 lbs.**

This unit has a force factor of approximately 9.2 lbs. per amp. and a total current capacity, with air cooling, of 4 amps. (R.M.S.).

Stroke	0.5 in total excursion.
Impedance	24 ohms matching (approx.)
Frequency Range.	Up to 5,000 c/s.
Weight of Moving System	0.5 lbs. (approx.)
Stray Fields	Operating zone less than 100 gauss.
Flux Density	11,000 gauss.
Total Weight (inc. trunnion)	70 lbs.

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MODEL 8/600

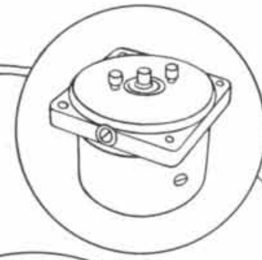
For the vibration of heavy loads or complete assemblies. Has a total force of approximately ± 300 lbs.

Stroke	1 in. total excursion.
Impedance	to suit driving equipment.
Frequency Range	Up to 3,000 c/s.
Weight of Moving System	6 lb. (approx.)
Stray Fields	Operating zone less than 25 gauss.
Flux Density	10,000gauss.
Total Weight (inc. trunnion)	4 cwt. (approx.)

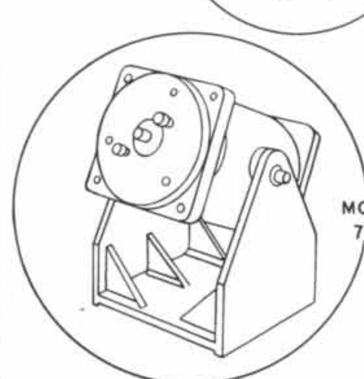
This unit can be fitted with (a) built in air cooling blower (b) switch to give high or low impedance armature coil and (c)pick-up unit for monitoring wave form and amplitude.

MODEL V47 **for the vibration of very light electronic components, optical-cell research, hair-spring torque testing etc.**

Thrust	Force factor 0.9 lbs. per amp.
Max. Continuous Current Rating (R.M.S.)	1.5 amps.; 2.0 amps. up to 2 min. duration.
Stroke	0.2 in total excursion.
Impedance	Varies with frequency and load between 3 and 10 ohms.
Frequency Range	Up to 10,000 c/s.
Weight of Moving System	6.5 grams.
Stray Fields	Operating zone less than 25 gauss.
Flux Density	11,000 gauss.
Weight	2 lbs.



MODEL 390A



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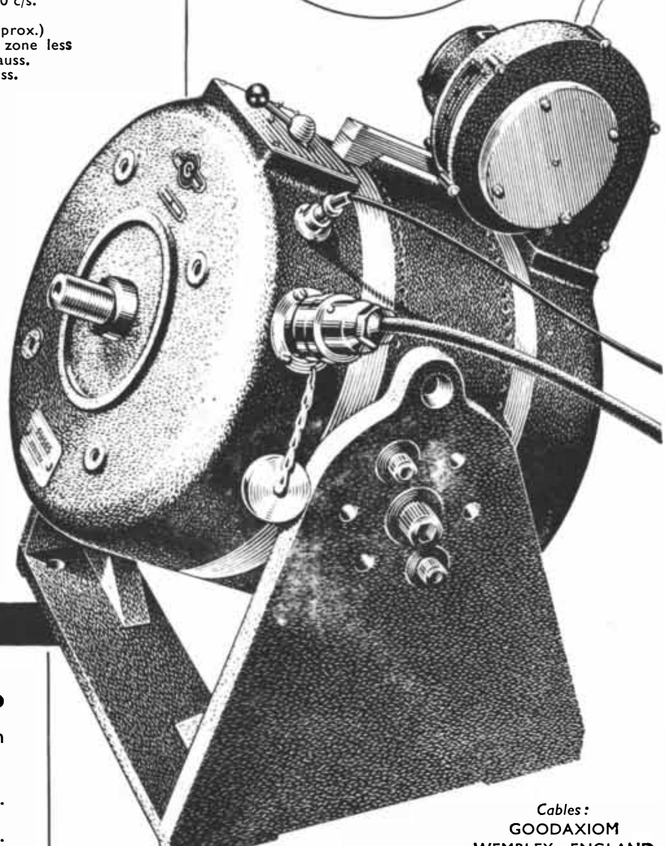

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ence led to an invitation from Glenn T. Seaborg to join the group working on plutonium at the University of Chicago. The only plutonium then existing was the tiny quantity manufactured in the University of California cyclotron. Cunningham and his associates were the first to see a pure sample of the metal; they isolated and weighed a microgram of it. When another transuranium element, americium, was discovered in 1945, Cunningham purified it also. "It was a rare thrill," he says, "to perform the final steps of this work, to observe the delicate pink color characteristic of solutions of this element, and to know that, for the moment at least, I was the only person in the world who knew for certain what the new element looked like." Cunningham was born in 1912 in the Territory of New Mexico a month before it became a state. Educated at the University of California, he took his doctorate in biochemistry and stayed in the field until his wartime work. After the war he decided to continue in inorganic chemistry and accepted a position at the Radiation Laboratory of the University of California, where he is now associate professor of chemistry. In his spare time he is an amateur geologist.

EDWARD S. DEEVEY, JR. ("The End of the Moas") is associate professor of biology and director of the Geochronological Laboratory at Yale University. He was born in Albany, N. Y., in 1914, and developed an early interest in nature studies and the outdoors which won him 41 Boy Scout merit badges and the Boy Scout Nature Prize in 1928. He studied biology at Yale, specializing in limnology, the study of lakes, and took his Ph.D. in 1938. After four years of teaching at the Rice Institute, Deevey went to the Woods Hole Oceanographic Institution to work on marine fouling for the Navy. Returning to Yale after the war, he has occupied himself primarily with the ecology of the Pleistocene epoch, with excursions into modern ecology. This year he is doing lake research in Italy and Denmark on a Guggenheim fellowship and Fulbright award. He finds his major relaxation in scientific field trips, but also enjoys reading and pre-Beethoven chamber music when forced to stay home. He is married to a former fellow student who now divides her time between the study of marine zooplankton and the care of three children—"a preschooler plus two comic-book collectors." Deevey has written several previous articles for this magazine, the most recent, "Radiocarbon Dating," appearing in February, 1952.

THE COVER

The balance on the cover can weigh amounts as small as 50 millionths of a gram (*see page 76*). Its beam hangs from a horizontal quartz thread linked to the large wheel at right. Atop the beam is a tiny mirror on which is focused a spot of light. When the beam tilts by twisting the thread, it moves the spot, reflected from the mirror and a larger one at upper left, on the glass screen at upper right. To weigh a sample, the vessel that will contain it is first placed in one pan and standard weights are placed in the other. The beam is made level by turning the wheel. Then the vessel is removed, the sample put in it, and the vessel put back. The added weight tilts the beam and deflects the spot on the screen; the amount of deflection is measured by turning the wheel until the spot is in the middle of the screen. The balance was made at the Socony-Vacuum Laboratories in Brooklyn, N. Y.

THE ILLUSTRATIONS

Cover photograph by Paul Weller

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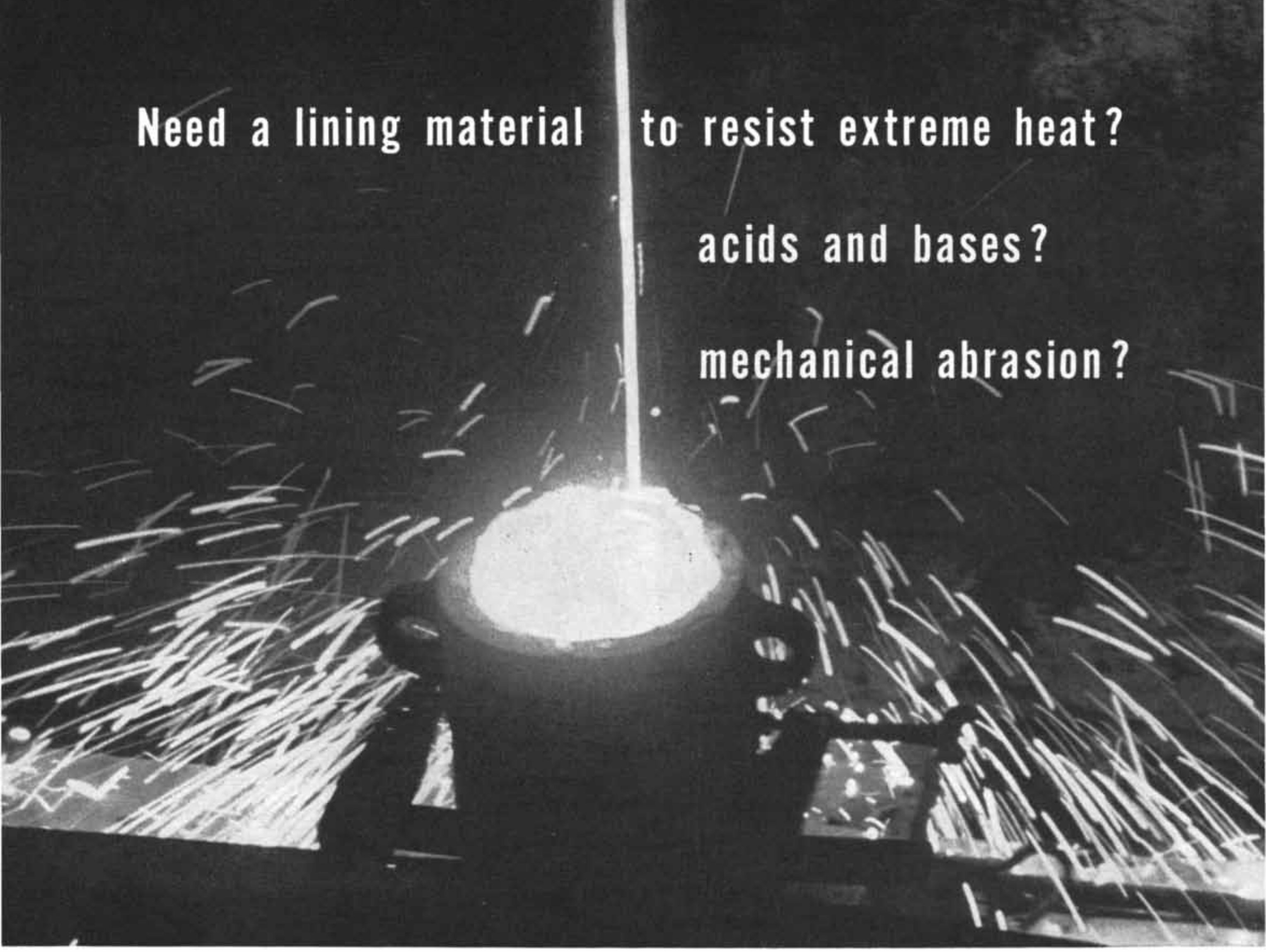

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CONTENTS FOR FEBRUARY, 1954 VOL. 190, NO. 2

ARTICLES

DEPARTMENTS

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FEBRUARY, 1954

SCIENTIFIC AMERICAN

VOL. 190, NO. 2

A Crisis in Science Teaching

In which the continuing shortage of scientists and engineers is traced back to the high schools. As their enrollments soar, the number of qualified science teachers actually decreases

by Fletcher G. Watson

Everyone knows about the shortage of scientific manpower. The need for scientists in industry, government and the military services is critical, and all indications are that it will become more critical in the coming years. The focal point of the problem is in the secondary schools, where the nation's youth take the decisions that shape our working force: what vocation to take up, whether to go to college, whether to enter engineering or the liberal arts or to major in a scientific field. Let us look at the situation there.

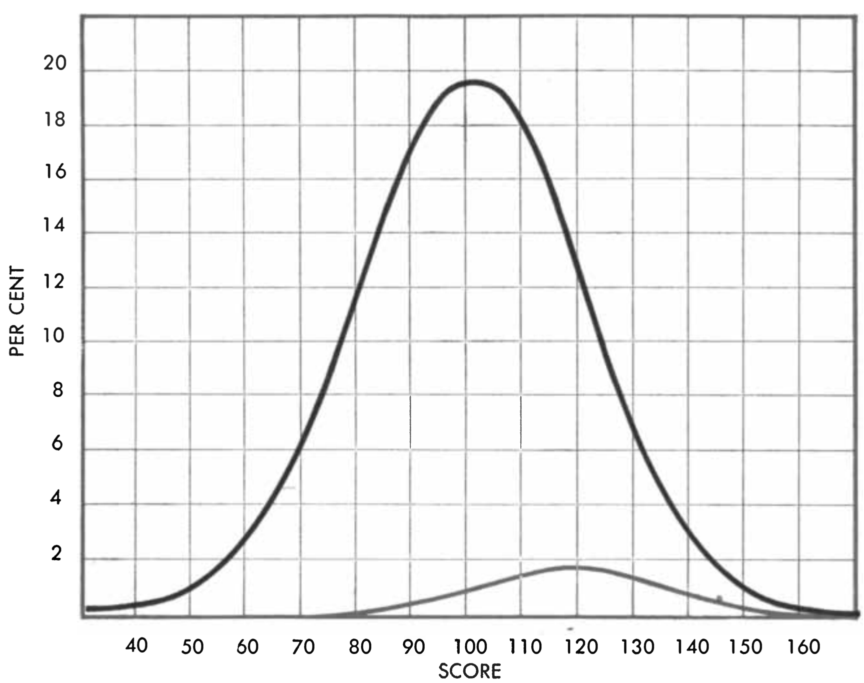
The U. S. has some 25,000 public and 3,300 private secondary schools, operated by nearly as many different school boards. The schools vary in size from a few score pupils to 5,000 or more. Half of the 6 million high school students attend schools which enroll less than 400.

So far as number goes, the secondary schools offer an immense and rapidly growing pool of human resources. In the past 80 years high school rosters have grown 18 times faster than the population. We now face an even sharper rise due to the soaring postwar birth rate. In the two years immediately after the war births jumped from 2.7 million to 3.7 million, and the trend is continuing: 1952 hit an all-time high. On the basis of these births and of a slowly rising percentage of teen-agers who go to high school, it can be predicted that high school enrollments will shoot to 9 million by 1960 and to over 11 million by 1966.

Where will the teachers be found to handle this increase? The 340,000 teachers in the high schools today are barely adequate to staff them. Within six years we shall need 418,000 teachers and by 1966 we shall need 520,000.

If we narrow this down to the specific case of science teachers, the picture becomes truly alarming. The requirement is expected to rise from 67,000 science teachers today to 84,000 by 1960 and 100,000 by 1966. Already some 7,000 new science teachers are needed each year. This demand, based upon replacements as well as new positions, will soon go to 10,000 a year. Altogether we shall require a total of 100,000 new science teachers between now and 1966.

In the face of this need the sources of teaching strength are drying up. College graduations have declined 30 per cent from the G.I. peak year of 1950. Because the colleges are still drawing from the low birth rates of the depression years, the current figure of 300,000 graduates



DISTRIBUTION OF INTELLIGENCE (in terms of scores on the Army General Classification Test) for the U. S. population is shown by the black curve; for college graduates, by the colored curve. The area between the curves at the right represents the part of the population which is intelligent enough for college work but which does not go to college.

a year is not expected to increase appreciably in the next five years. Furthermore, the number of persons qualified to teach has fallen off more than the number of college graduates. In mathematics the decrease is 41 per cent, in the other sciences 48 per cent. Last year fewer than 5,000 potential science teachers were graduated, as against the need of 7,000. Moreover, many of these potential teachers were lost to industry or to the military services. A recent study in Minnesota showed that only 41 per cent of potential science teachers were actually employed as teachers in the year after their graduation. Of all subject areas, science had the lowest yield to the teaching profession.

Just as serious as the shortage of quantity is the shortage of quality. There is no yardstick for measuring the quality of teachers, but at a minimum we must expect the teacher to know the subject he is teaching. We find in the first place that the state requirements are far from exacting. In 29 states a person can be licensed to teach science on the basis of study in just one science subject. Thirteen other states have rather specific course requirements. Only five states require study in comprehensive fields such as the physical or biological sciences.

There has been no nationwide survey of the actual backgrounds of teachers engaged in teaching science, but a consistent picture emerged from studies made in eight states and from a nationwide sampling of biology teachers. The states were Alabama, California, Massachusetts, Minnesota, Nebraska, Pennsylvania, Texas and Utah. A considerable number of the persons teaching science in secondary schools in those states were not certified to do so: about 20 per cent of all the high school teachers taught one or more science courses, but apparently only half of them were qualified in science. Of those certified in science, many had only meager training in it. A fairly large proportion had prepared in just one science. Teachers of general science tended to have less training than those teaching special subjects. At the other extreme, many of the science teachers in those states had done graduate work in science and education. In general, science teachers in large schools tended to be better prepared than those in smaller ones.

How do teachers with so little equipment to teach science as some of these have get into the classroom? One loophole is the "life certificate," which allows old teachers licensed many years ago to teach subjects in which they have had no college instruction. The other is the general secondary school certificate granted in a number of states, which permits an individual to teach in any subject area irrespective of his training. Athletic coaches and physical-training instructors are commonly used as part-time science teachers, though they often have less than the minimum background. Such makeshifts have been increased by the shortage of new science teachers, which has forced many school administrators to shift teachers from social studies or English, where replacements are available, to science classes. Although many of these teachers are acutely aware of their deficiencies, they have no escape.

For want of a few thousand competent new science teachers each year, science instruction in our schools must either be curtailed or become such a caricature of teaching as to bore or repel promising students. It is clear that if the shortage of scientists and technically trained people in the U. S. is to be solved, the first requirement is a joint effort of all concerned to encourage and train competent young people to become science teachers.

Certain myths need to be dispelled. One of the commonest, carried over from our memories of college instruction, is that a high-school science teacher teaches only science or only one science subject. Actually only half of the people teaching science in secondary schools do so full time. The other half teach at least one course in some other area of learning. Philip A. Johnson, formerly of the U. S. Office of Education, wrote in 1950: "Fragmentation of science teaching by the assignment of several teachers, each serving only one or two science sections, often results in the read-about, talk-about type of science teaching deplored by school leaders and tolerated by the pupils. . . . The large number of part-time science teachers . . . suggests that division of responsibility may be the most serious weakness of our science teaching enterprise." As school enrollments rise, administrators will have increasing opportunity to correct this by scheduling science teaching as the full-time responsibility of a few well-trained teachers.

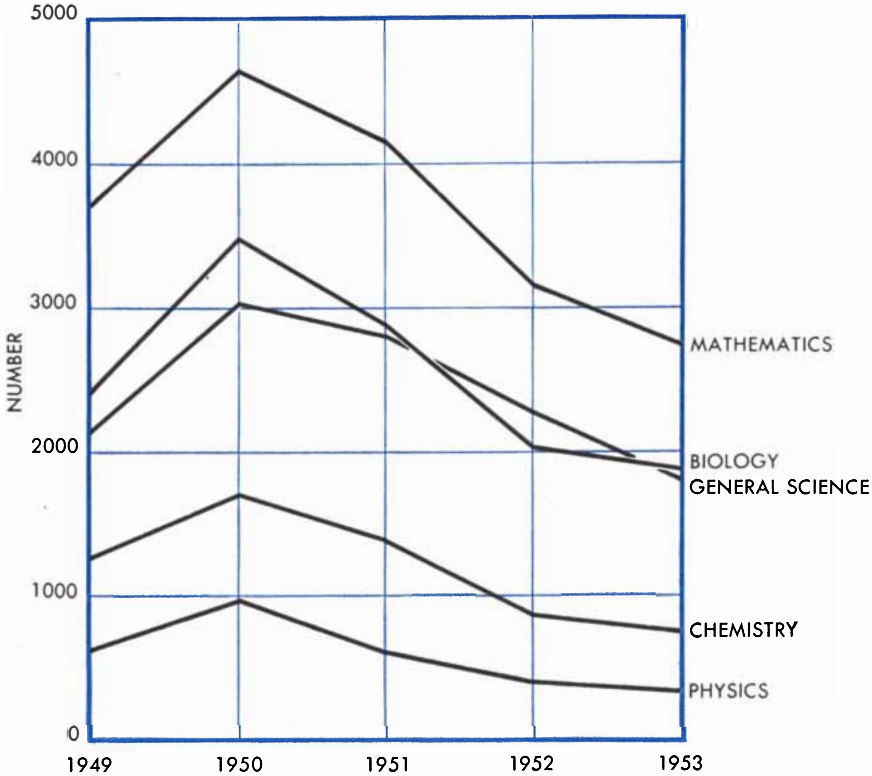
Most of the full-time science teachers today teach more than one science. A study in Illinois in 1946 showed that 61 per cent of biology teachers, 98 per cent of chemistry teachers and all physics teachers taught other subjects as well. Similarly, a study in New York found that 53 per cent of all science teachers had three or more different science subjects to prepare each day. Similar results were reported in Minnesota and Utah. Furthermore, the subject assignments often changed from year to year.

This means that science teachers should have at least some preparation in each of the major sciences. The narrow specialization often required by colleges is especially undesirable in the preparation of science teachers. Breadth of study must be obtained even if it means sacrificing so-called depth. Fortunately a growing number of states require five years of preparation for high school teaching, and future teachers may be able to obtain both breadth and depth in one or more fields. Already some five states require this longer preparation for the high-school certificate.

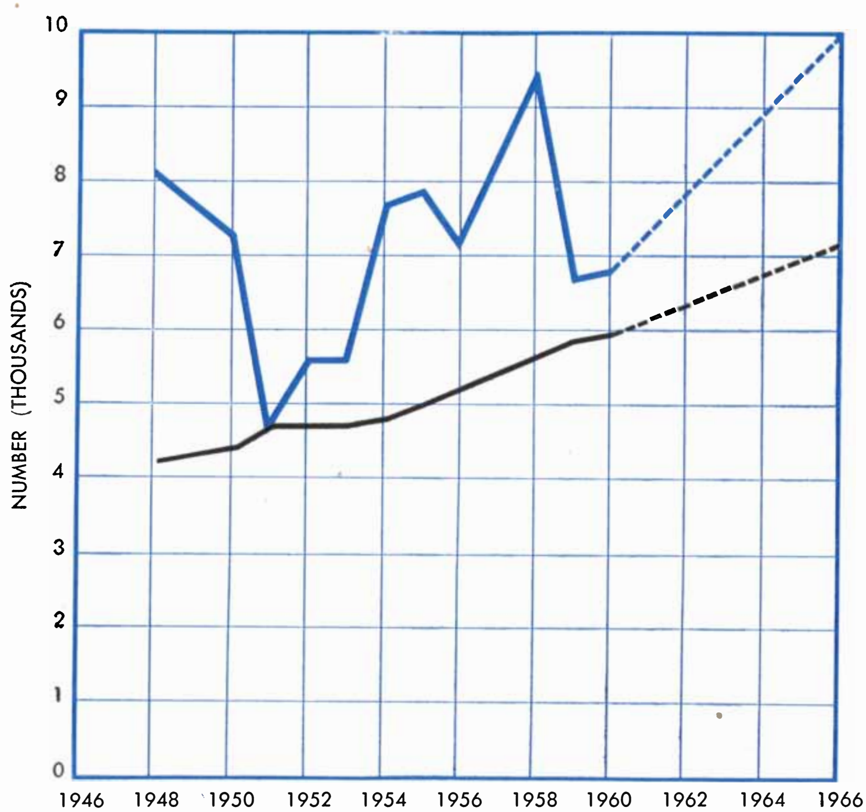
Another myth is that teaching is an easy job. Besides the 23 to 25 hours a week they spend in classes, teachers have a multitude of other school duties, including work with individual pupils, grading papers, taking care of laboratory equipment, preparing new instructional material and keeping informed in their fields. Up to 40 per cent of science teachers work under the handicap of having no permanently assigned room, so that they must move their material from room to room. A National Education Association study showed that the average teacher puts in 48 hours a week on school work. Only 21 per cent of the sample interviewed reported less than 40 hours, while 22 per cent reported more than 55 hours per week.

Considering the meager rewards of teaching, either social or financial, one wonders why anyone chooses to become or remain a teacher. Last year the average income of all teachers in the U. S. was $3,530 per year. In 1938 teachers were in the top third of the income groups of the country: by 1948 they had dropped into the bottom third. To make ends meet many teachers must carry extra jobs during the school year and take unskilled or semi-skilled work during the summer.

Fortunately there are competent people who "just have to teach," whatever the rewards, and they form the backbone of our educational system. But that is not enough. Teaching in science has become increasingly important as our society has become more technical and more wealthy through the fruits of science. It will take serious, thoughtful and cooperative efforts by all concerned—educators, parents, industry and government—to meet the needs in science education.



SUPPLY of qualified new teachers has steadily decreased since 1950. This chart shows the annual number of college graduates who are prepared to teach courses in various sciences.



DEMAND for teachers steadily increases. The colored line indicates the number of teachers needed; the black line, the number of new ones needed to maintain the present force.

THE RABBIT PLAGUE

It is the strange virus disease myxomatosis. In Australia, where the animals are destructive pests, it is a blessing; in Europe, where they are cherished game, it is a calamity

by Frank Fenner

In southern Australia there is a plant which in the spring clothes hillsides with a superb purple mantle. Known to botanists as *Echium plantigineum*, it was originally imported from the Mediterranean area. Australians have come to regard this plant with conflicting feelings. In certain arid areas where other fodder plants fail, country folk call it "Salvation Jane" (the flower looks like a Salvation lass's bonnet). In other areas, where it crowds out more valuable plants, it is called "Paterson's Curse."

It is with just such diametrically opposed feelings that different parts of the world now look upon the two-edged phenomenon which is the subject of this article—the deadly infectious disease of rabbits called myxomatosis. Introduced deliberately in Australia three years ago, it has swept rapidly over immense areas, causing great epizootics among rabbits. In Australia the disease is hailed as a measure of salvation which is ridding the continent of its major pest; in Europe, where it broke out in 1952, it is viewed as a malevolent killer which threatens to wipe out a favorite food, game and laboratory animal.

Myxomatosis gets its name from a symptom which identifies the infection: the word means slimy tumor. It is a virus disease, and a most peculiar one. The virus is dangerous to only one animal in the entire animal kingdom, but for that species it is nearly 100 per cent lethal. The vulnerable species is the common European rabbit (*Oryctolagus cuniculus*) which is so well known as a backyard pet, as the principal game animal of France, as a source of meat, furs and fur felt and as an experimental subject in biological laboratories all over the world.

To understand the origins and complex epidemiology of this disease, we need to consider first its rabbit hosts. Only two of the eight genera of the rabbit family concern us here. They are the genera called *Sylvilagus* and *Oryctolagus*. Sylvilagus is an American genus, and like the European rabbit it is subject to infection by the myxoma virus. But in this genus the disease is not at all lethal. The principal natural host of the virus is the Brazilian wild rabbit *Sylvilagus brasiliensis*; in this species the infection is wholly benign, producing tumors but no sign of any hampering illness. The cottontail rabbits of North America also are members of the Sylvilagus genus, and they too harbor the disease in a benign form. Very likely these rabbits serve as a permanent reservoir of myxomatosis in the West Coast states, where it occasionally breaks out among European rabbits in commercial rabbitries.

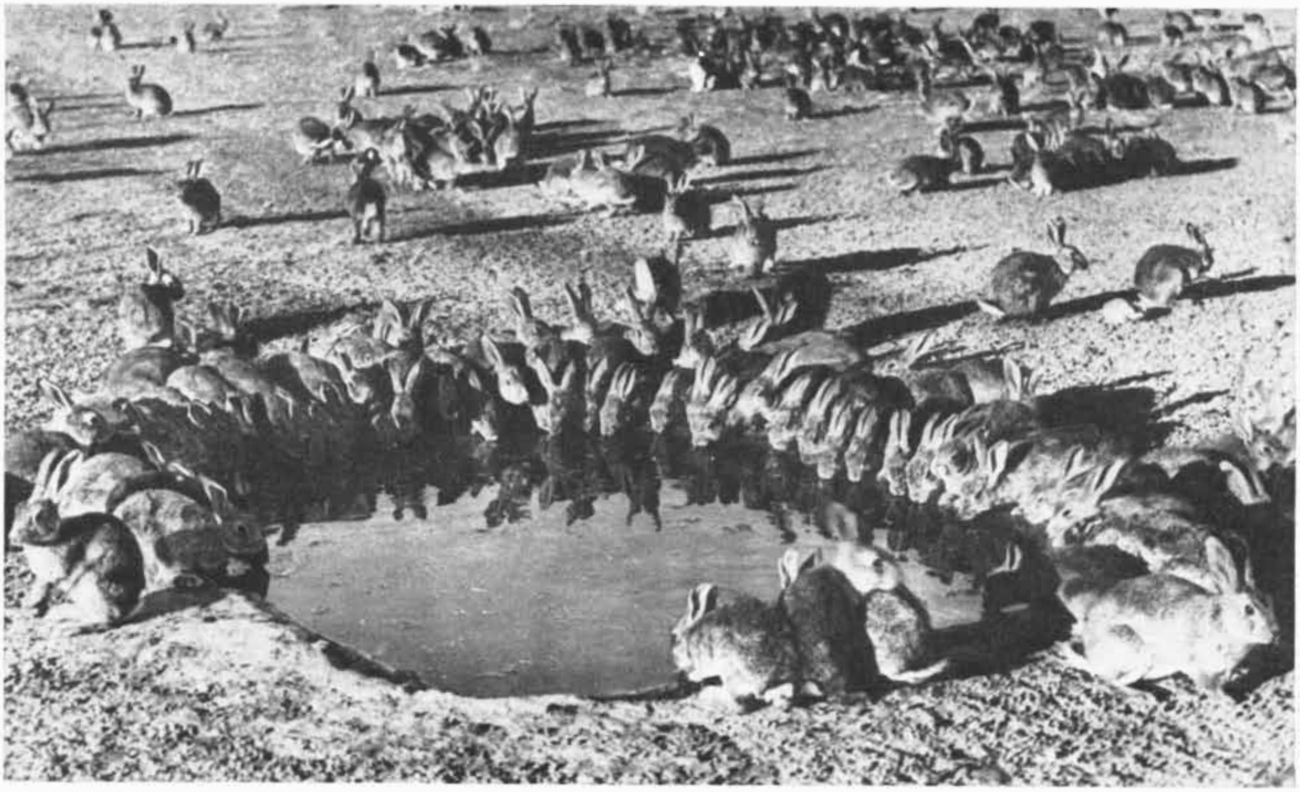
The disease was first discovered in Uruguay in 1896, when the Italian bacteriologist G. Sanarelli was beset by a strange new affliction which slaughtered his European laboratory rabbits at the Hygiene Institute in Montevideo. He described the disease and named it infectious myxomatosis. He also surmised correctly that it was caused by a virus. During the succeeding 50 years sporadic outbreaks of the infection were reported in several localities in Brazil, in Mexico, in San Diego, Calif., and in various other places on the West Coast where European rabbits were bred. Strange to say, in Uruguay, where the disease was discovered in 1896, it was not detected again until 51 years later.

In 1942-43 H. de Beaurepaire Aragão of the Oswaldo Cruz Institute in Rio de Janeiro established two important facts about the natural history of myxomatosis. He demonstrated (1) that the native Sylvilagus rabbit of Brazil harbored the virus, and (2) that mosquitoes could transmit the infection from these rabbits to European rabbits.

The myxoma virus has recently been isolated and observed under the electron microscope, and we have been struck by its close resemblance to the pox viruses—vaccinia, fowlpox and so on. The elementary bodies of both the vaccinia and the myxoma virus have a brick-like shape, are the same size and have a similar internal structure. It may be that just as the Sylvilagus rabbit is the New World equivalent of the Old World Oryctolagus rabbit, so the myxoma virus is the New World equivalent of the mammalian pox viruses of the Old World.

The effects of the infection upon European rabbits have been investigated by intradermal inoculation of them with a standard dose of about 10 infectious particles of virus—conditions which approximate the natural method of infection by a mosquito bite. Three or four days after the inoculation a small red, hard spot appears on the rabbit's skin at the site of the injection, and the spot daily increases in size. On the fifth day the rabbit's eyelids begin to redden and swell; eventually the eyes are completely closed, with a copious discharge running from the conjunctiva, and the whole face is swollen. Meanwhile the loose tissue in the anogenital region also swells rapidly, and if the animal survives long enough, the typical gelatinous tumors break out all over the surface of its body. Usually, however, the animal dies before the infection has spread that far. After the seventh day it becomes dopey and drowsy; its respiration and pulse rate slow down, and death commonly occurs on the ninth or tenth day.

The spread of the virus through the



SWARMING RABBITS drink from a waterhole in Australia. Their effect on vegetation may be gauged from the fact that in certain areas where the rabbit population was destroyed by myxomatosis, the production of wool increased from 10 to 15 per cent.

DEAD RABBITS are left in the open in Australia so that mosquitoes may propagate the myxoma virus among healthy rabbits. Sick rabbits can spread the disease to healthy ones by contact, but mosquitoes are the principal agent of transmission.

rabbit's body follows a regular course: from the site of inoculation to the regional lymph node, then to the blood, the spleen and the lungs and finally to the skin in parts of the body distant from the inoculation site. In other words, myxomatosis spreads in the same fashion as the pox diseases, except that in the late stages the rash takes the form of multiple tumors.

As for the transmission of the disease from one animal to another, there is no doubt that in nature the mosquito is by far the most important carrier. Rabbits can be infected with the virus, with some difficulty, through the oral or respiratory route, and they readily pick it up through intimate contact with infected rabbits, but the great epizootics of the disease have been disseminated mainly by mosquitoes.

Aragão concluded that mosquitoes do not incubate the virus but merely transfer it mechanically from one animal to another, as they do fowlpox. Our more detailed studies with M. F. Day at the Australian National University in Canberra have fully borne out his view. From the standpoint of its performance in transmitting the virus, the mosquito can be regarded as a flying pin. When it thrusts its proboscis into the virus-laden cells of an infected rabbit's skin, the "pin" picks up virus, and it passes on the disease when the mosquito probes or feeds on other rabbits. Since the virus does not multiply in the mosquito, the insect is most infective immediately after it has fed on an infected rabbit; as the virus becomes inactive or is wiped off the mosquito's proboscis on plants or animals other than rabbits, the power to infect declines. The fact that the virus can be transmitted in this mechanical fashion means, of course, that any insect which bites rabbits can spread the disease among them. Rabbits may, in fact, be bitten by other insects.

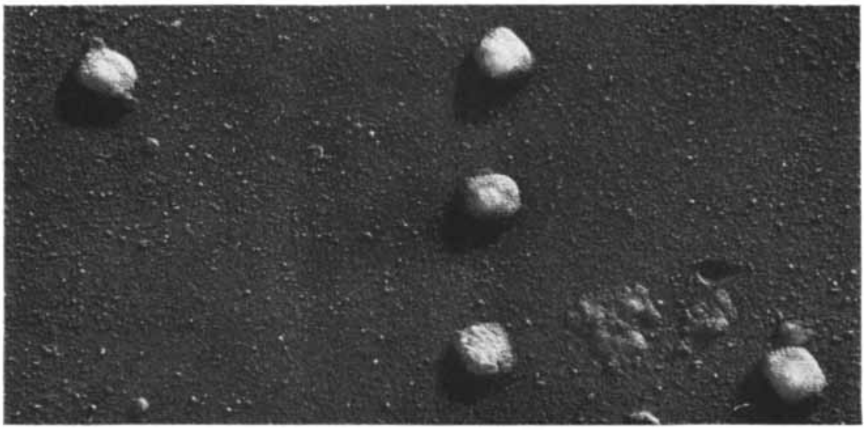
Two things made the myxoma virus an ideal instrument for controlling the rabbit nuisance in Australia. In the first place, this virus apparently does not harm any other animal. Extensive investigations have proved that it will multiply only in the two species of rabbits mentioned above—the common European rabbit and the wild Sylvilagus rabbit of Brazil—and in developing embryos of the chicken and the duck. In the second place, the disease is amazingly lethal to the European rabbit, *Oryctolagus cuniculus*. One investigator has said that every last rabbit of 2,000 he had infected in the laboratory died of the disease, and others have reported that only two or three of hundreds exposed in their experiments recovered.

The European rabbit, imported as a game animal, became established in Australia about 1860. Within the next 20 years it multiplied so prolifically and spread so widely over the continent that in 1887 the government of the colony of New South Wales offered a reward of 25,000 pounds for any method which would exterminate the rabbits. Louis Pasteur took an interest in the problem, and he proposed to attack the rabbits with the chicken-cholera bacillus. The Australian quarantine authorities vetoed the proposal, however, because the bacillus is pathogenic to domestic animals and birds.

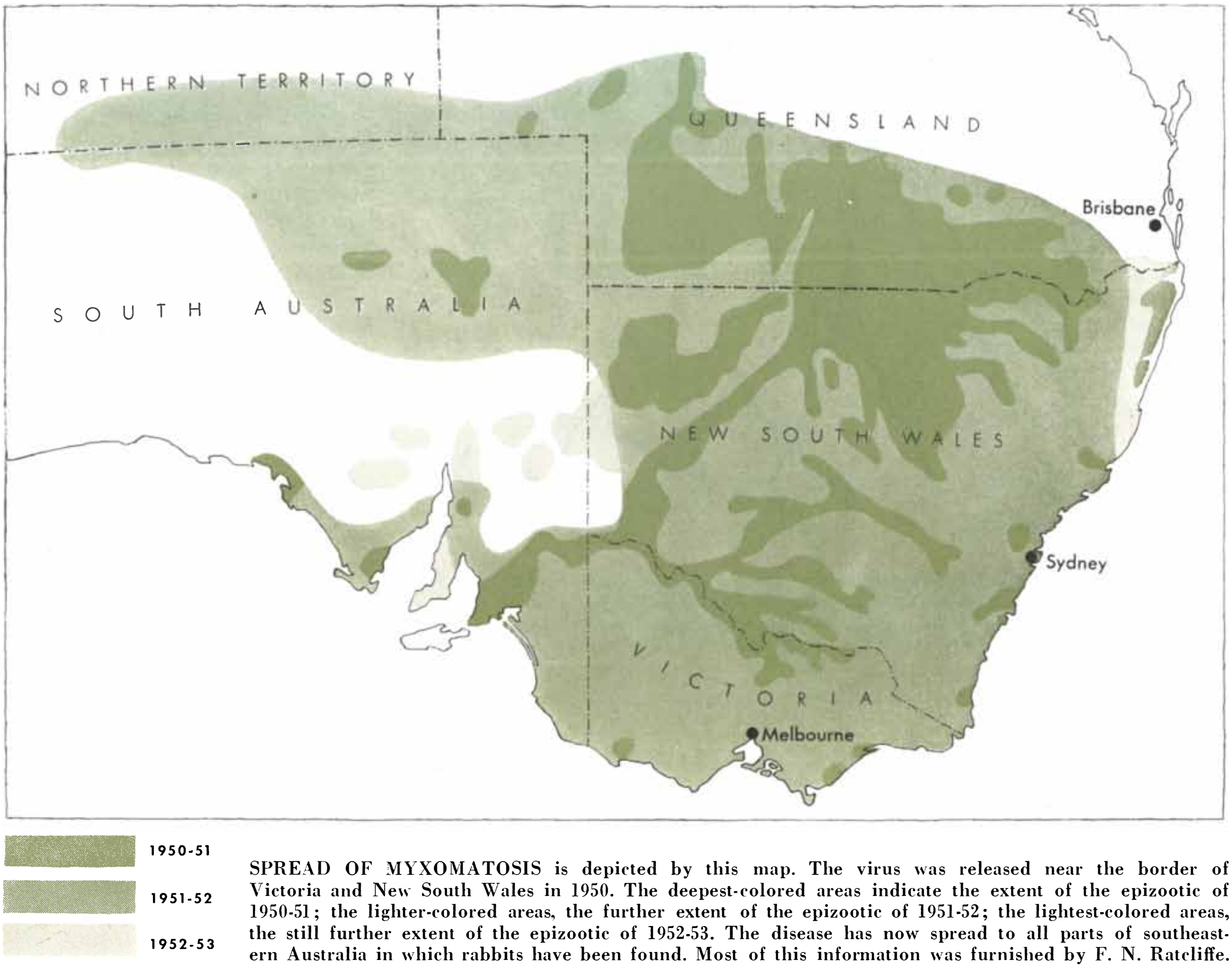
The first to suggest the myxoma virus was the Brazilian investigator Aragão; he put the suggestion forward in a paper on myxomatosis in 1918. The Australian authorities were interested and made a few preliminary experiments, but they deferred any extensive test of the idea until experiments should determine whether the virus would be harmful to other animals. Such experiments were carried out between 1933 and 1937 by Sir Charles Martin in England and by Lionel B. Bull in Australia. When they found that only European rabbits and developing chicken embryos were susceptible to the virus, it was tested in limited colonies of rabbits and then in several large-scale field trials in semiarid areas of South Australia. These proved that the virus was indeed exceptionally virulent for the rabbits, but the disease failed to spread among the rabbit populations and soon died out.

In 1950 a further series of trials was carried out in the well-watered Murray Valley, in three different sites, under the direction of F. N. Ratcliffe, the officer-in-charge of the newly created Wild Life Survey Section of the Commonwealth Scientific and Industrial Research Organization. These trials started in May, 1950, and were completed in December, 1950. Again the experiment seemed to result in failure; at the end of the trials the rabbit population in this locality was much larger than at the beginning. For example, at one of the sites, an area of 13 acres which a daily sight count showed to be populated by something of the order of 900 rabbits, 66 rabbits were captured, inoculated with myxoma virus, and released. A number of rabbits in the area caught the infection and died. But within a month and a half the disease appeared to have died out, and the population count had risen to 1,000.

The authorities in Australia were pretty well convinced at this point that the disease would not spread well enough under natural conditions to justify its employment in rabbit control. However, on December 20, five days after the rabbit population count just mentioned, a telephone call was received which completely altered the complexion of affairs. A farmer at Balldale, 15 miles from one of the trial sites, had seen many sick rabbits with greatly swollen heads on his property. In the next few weeks reports poured in from all over the Murray Valley, and by the end of March, when the summer outbreak was over, infected rabbits had been found over an area totalling some 500,000 square miles along the waterways of the Murray-Darling system. In the winter season between May and November, 1951, there were sporadic cases of myxomatosis over the whole of this area and a few localized epizootics. With the onset of hotter weather in November, another widespread series of outbreaks occurred,



MYXOMA VIRUSES are enlarged 33,500 times by this electron micrograph. The virus particles are shadowed with uranium. They resemble the pox viruses in structure.



SPREAD OF MYXOMATOSIS is depicted by this map. The virus was released near the border of Victoria and New South Wales in 1950. The deepest-colored areas indicate the extent of the epizootic of 1950-51; the lighter-colored areas, the further extent of the epizootic of 1951-52; the lightest-colored areas, the still further extent of the epizootic of 1952-53. The disease has now spread to all parts of southeastern Australia in which rabbits have been found. Most of this information was furnished by F. N. Ratcliffe.

this time extending to the dry country away from the rivers. By the summer of 1952-53 the disease had spread throughout southeastern Australia wherever there were enough rabbits to support an epizootic.

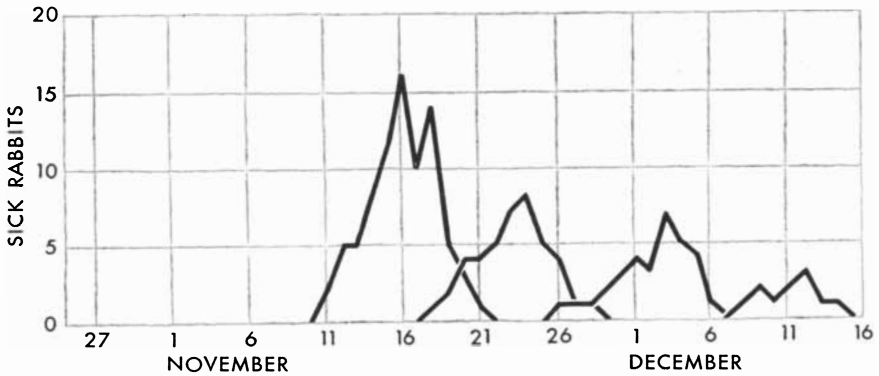
Obviously it is impossible to obtain accurate data over an area of half a million square miles, much of it uninhabited by man. But sampling surveys indicate that after the third summer an estimated original rabbit population of 500 million had been reduced to 10 or 20 per cent of that figure.

Officers of the Wild Life Survey Section of the Commonwealth Research Organization in collaboration with my laboratory have carried out precise observations at two sites. I shall describe in detail the results at one of these—Lake Urana, about 50 miles north of the Murray River. This lake of about 18,000 acres, usually dry, is surrounded by sandhills that have been extensively colonized by rabbits, for the lake provides them with an oasis. The first great epizootic of 1950-51 did not affect the rabbits at Lake Urana. During September and October in 1951 we inoculated hundreds of the rabbits in the sandhills with myxoma virus. In October the disease began to spread, and during the following month there was a catastrophic fall in the rabbit population, the counts in one sample area falling from 5,000 to 50. In the ensuing winter the small relict population commenced to breed, and by the following October there had been a natural increase from 50 to 550 in the sample area.

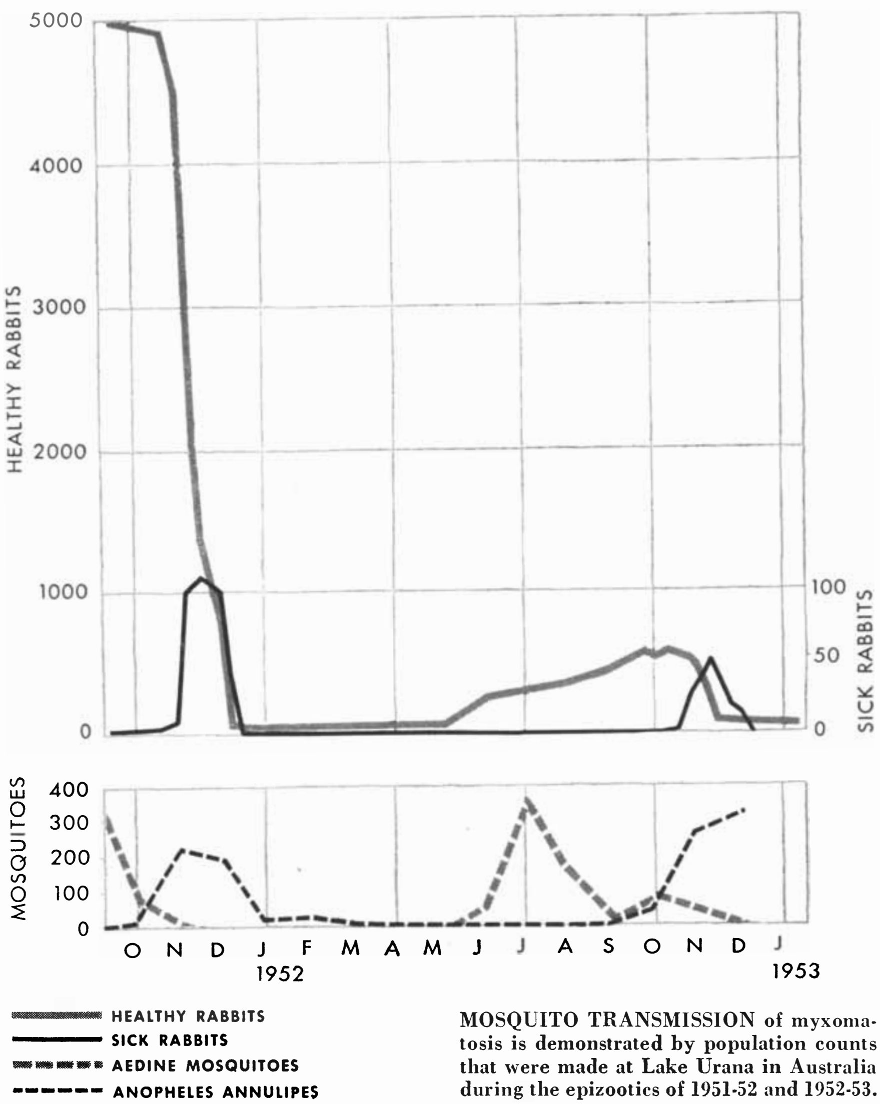
Analysis of the blood of survivors of the November, 1951, outbreak showed that among the survivors only 30 per cent had actually been infected. No serological evidence of infection of young rabbits born during the winter was found. In October, 1952, the population of 550 could be roughly divided into 500 young susceptible rabbits and 50 survivors of the previous outbreak. During this month another outbreak occurred, and there was once again a rapid fall in the population. All of the 70 to 90 survivors of this outbreak were found to have been infected. In other words, the mortality rate had dropped—from 99.8 per cent of those infected in the 1951 epizootic to 92 per cent of those in the 1952 outbreak. This seems to have been generally true of myxomatosis epizootics in southeastern Australia: in later outbreaks more rabbits appear to recover and those that die take longer to do so.

Since the effectiveness of this method of rabbit control depends primarily on the maintenance of a high mortality rate, it is important to try to understand the significance of the decline in the mortality rate observed at Lake Urana. It may be due to a number of factors, acting alone or in combination. We know that rabbits which have recovered from one infection have a high degree of immunity to a second, but this was of no importance at Lake Urana, because few survived. Laboratory studies have shown that maternal antibodies give young rabbits some immunization against myxomatosis, but again this was of little importance at Lake Urana, owing to the different times of the year during which breeding and epidemics occurred there.

Other possible explanations are being explored. One is that the hereditary resistance of the rabbit population may have been raised by the drastic selection of the more resistant individuals for survival. Another is that hot spells in the desert may fortify the rabbits' resistance, for it has been shown that prolonged exposure to high temperature makes the animals more resistant to myxomatosis.



MYXOMATOSIS DECLINES in the absence of mosquito transmission. In this Australian experiment 66 rabbits were inoculated with the myxoma virus. The first peak on the chart shows the first "generation" of sick rabbits. The succeeding three generations were infected by the first. The second, third and fourth peaks show the rapid decline of the disease.



MOSQUITO TRANSMISSION of myxomatosis is demonstrated by population counts that were made at Lake Urana in Australia during the epizootics of 1951-52 and 1952-53.

But there is no real evidence on these questions as yet.

So far the only factor that has been shown to be important in reducing the mortality rate among the Lake Urana rabbits is a loss of virulence in the virus. Most of the strains of myxoma virus isolated from infected rabbits in southeastern Australia have proved to be less virulent than the original laboratory strain. At Lake Urana the attenuation of the virus has been proved by the fact that the descendant viruses take longer to kill rabbits into which they are inoculated.

A summary of the position, then, is that some attenuation of the myxoma virus seems already to have occurred, but the virus is still fatal to 90 per cent of the infected rabbits. Changes in the genetic resistance of rabbits may be anticipated but have not yet been demonstrated. In certain circumstances we can expect active or passive immunity to become an important feature. Nevertheless there are good reasons, I think, for expecting the virus to control rabbits effectively in southeastern Australia for a number of years at least. In any case, long-term observations on the rabbit, the virus and the vector have been planned, and within a few years we should be able to get some idea of the rate and manner of evolution of a virus, its host and the disease.

I will now comment briefly on the recent epizootics of the disease in France. Control of the rabbit by microbial parasites has a long history in France, for Pasteur used the chicken-cholera bacillus to kill off rabbits on the estate of Madame Pommery in 1880. In 1952 microbiologists duplicated Pasteur's achievement, now using the myxoma virus. Unfortunately this time the microbial parasite failed to stay within the estate on which it was liberated. In the winter of 1952-53 myxomatosis broke out in a number of areas in France, and last summer the disease spread over the country with much the same rapidity and destructiveness as it had in southeastern Australia. It is, of course, unlikely that the disease will recognize political boundaries, and cases have already been reported in Holland, Belgium and England.

To check the disease investigators are searching for a vaccine against the myxoma virus. In 1932 Richard Shope of the Rockefeller Institute for Medical Research discovered a rabbit virus which produces a benign infection, characterized by the development of a fibrous tumor at the injection site, and which protects European rabbits against myxomatosis. But in vaccination tests with Shope's original strain we found that it gives complete protection for only one week and partial protection for only five months. Recently we have experimented with another strain of the same virus, the Boerlage strain, and this has given much better results: all but one animal in a group of rabbits vaccinated 12 months ago are still resistant to myxomatosis.

However, the immunizing virus will not be effective in protecting a wild rabbit population unless it is spread naturally among them by mosquitoes. There is some hope of this, for Lawrence Kilham of the National Institutes of Health in the U. S. has just reported that mosquitoes do transmit the harmless virus among cottontail rabbits; on the other hand, Day in Australia has been unable to transfer the Boerlage strain among European rabbits by mosquito bite except in very rare instances.

I do not doubt that hunting clubs in Europe will watch closely experiments now being conducted by the Animal Genetics Section of the Commonwealth Research Organization on the inheritance of innate resistance to myxomatosis among European rabbits. Or perhaps they might consider the possibility of importing to Europe the resistant American cottontail rabbit. If so, it is to be hoped that the Australian experience of the introduced animal becoming a pest would not be repeated, for there would then be no "Salvation Jane." And the establishment of a species such as *Sylvilagus brasiliensis* in Europe would ensure the permanent presence of enzootic myxomatosis which would escape every now and again from the wild to the domestic rabbit population.

The great current interest in myxomatosis may well stimulate virologists and epidemiologists in America to study some of the unsolved problems of the natural history of the disease in that continent. What, for instance, was the origin of the two outbreaks in 1896 and 1947 in Uruguay, which has no native rabbits? What is the natural reservoir of the disease in the western U. S.? It should be relatively easy to determine this by serological research. Has myxomatosis had any influence in limiting the spread of wild European rabbits in South America? The answers to these questions might allow reasonable forecasts of the future behavior of myxomatosis in both Australia and Europe.

RABBITS ARE INOCULATED in the field to spread myxomatosis in Australia. In the top picture the inoculation is prepared by mixing dried virus powder and saline solution. In the middle picture a rabbit is inoculated. In the bottom picture rabbits are released.

A Family of Solar Eclipses

On June 30 the moon will blot out the sun on a path from Nebraska to Pakistan. This eclipse is one of a series lasting for 13 centuries, thereby illustrating the complex motions of the earth and the moon

by Richard M. Sutton

On Wednesday morning, June 30, 1954, residents in parts of Nebraska, Iowa, South Dakota and Minnesota will awaken to see an almost black sun rising in the east. It will come over the horizon under total eclipse by the moon. In the U. S. the sight of the eclipse will be reserved for those in the shadow's path who are up at sunrise on the appointed day. For the moon's shadow does not linger, and the whole show will be over here before breakfast time. Racing over the earth at a speed far outstripping the fastest rocket plane, the great spot of the moon's umbra will dash eastward across Canada and Labrador, touch the southern tip of Greenland, just miss Iceland, sweep across the Faeroe Islands, Norway, Sweden, the U.S.S.R. and Pakistan, and swing off the earth into space just beyond the Khyber Pass. The shadow will have covered a course of nearly 9,000 miles in two and three quarters hours. In the successive time zones it will span all the terrestrial daylight hours: the Faeroe Islanders will get their eclipse at high noon, and the Pakistani will see a black sunset.

The moon and the earth each wears a long, black dunce's cap of shadow where the light of the sun never shines. When we ourselves enter the earth's shadow, we call it night. As this happens every evening at sundown, we are apt to overlook the fact that sunset is the beginning of a long total eclipse of the sun. In any case man has always been far more interested in the eclipse of the sun by the moon—one of the greatest spectacles that nature offers. During the short period of a total eclipse bright stars may appear in a dusky sky, and we get a look at the faint but impressive corona that extends for hundreds of thousands of miles from the sun. The corona is always there, but it is visible to the naked eye only when the sun's brilliant disk is obscured.

The coming eclipse is interesting in several ways. It will be the last opportunity during the 20th century to see a total eclipse of the sun over any substantial part of the U. S.; the only others that will touch this country will be one in Maine in 1963, a second in Florida in 1970 and a third that will flick the Pacific Northwest in 1979. This year's eclipse will be of more than average duration; in some places along the center line of the shadow path totality will last two and a half minutes. Residents of Minneapolis and St. Paul will see the total eclipse for 89 seconds, starting just before 5:08 a.m. Central Standard Time. The zone of totality will begin in Holt County, Nebraska, where the eclipsed sun will rise at 5:07 a.m. In Pakistan, where it ends, the black sun will set at 7:24 p.m. on this June day.

A point of special interest is that the coming eclipse is a member of a family of eclipses which in the 20th century has become very much a U. S. family—it will be the third total eclipse in this family to favor us with a visit since 1900. That eclipses run in families may not be widely appreciated, and it is both interesting and instructive to look into the family album of this particular eclipse.

The ancients imagined that eclipses were due to a dragon lurking in the sky which, at any time, might swallow all or part of the sun, fortunately to disgorge it again. To this day the symbols for the ascending and descending nodes of the moon's orbit (the points of intersection with the plane of the earth's orbit around the sun, where eclipses may occur) are ☊ and ☋, which are said to represent the jaws of this mythical dragon.

Seeking some way to predict eclipses, ancient astronomers looked for regularities or cycles in their arrival, and they

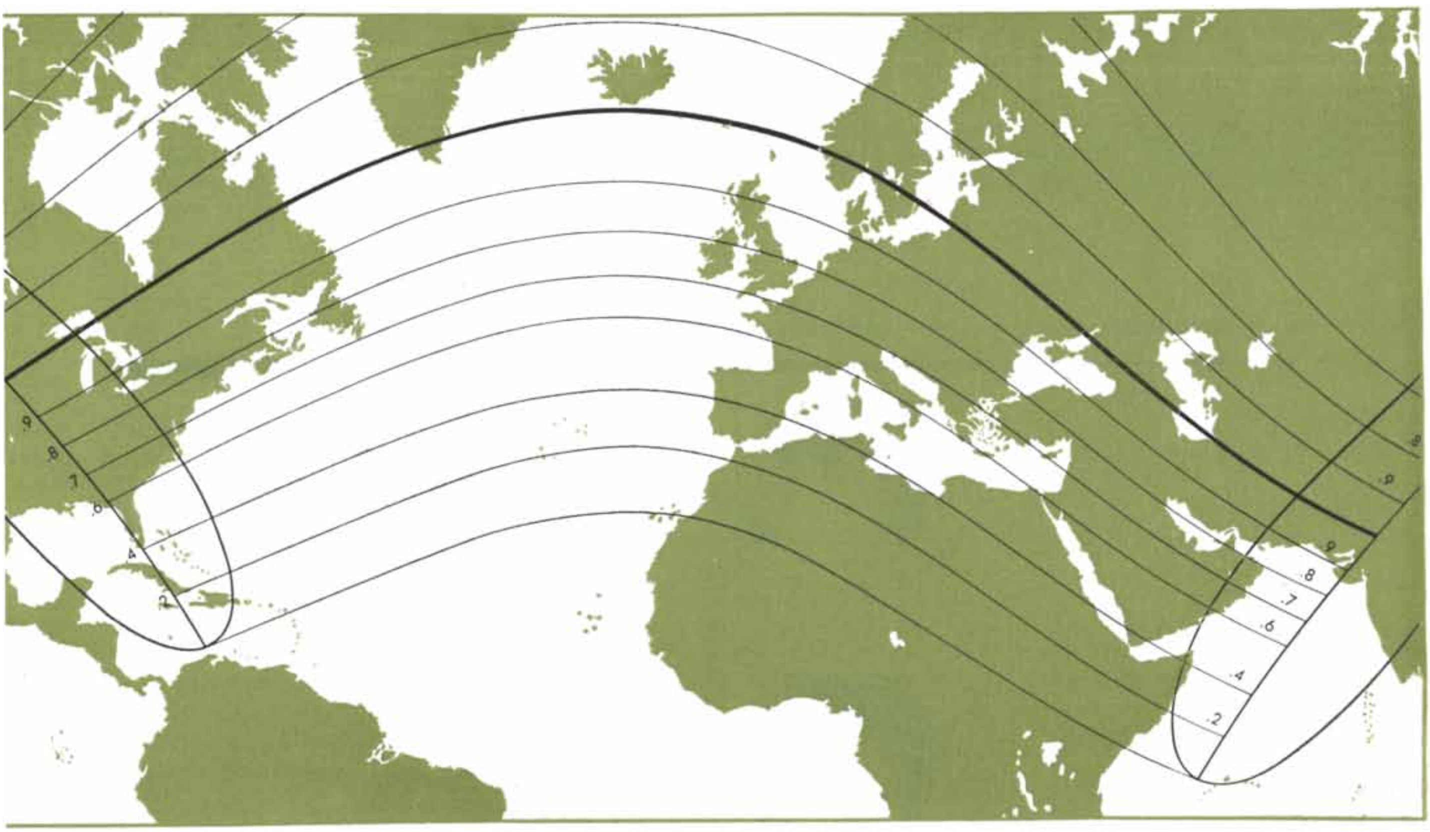
SOLAR ECLIPSE OF JUNE 30 will begin in the U. S. and end in India. The totally eclipsed sun will rise in Nebraska. Its path (*heavy black line*) will cross parts of Iowa, South Dakota, Minnesota, Wisconsin, Michigan, Canada, Greenland, Norway, Sweden, Poland, the U.S.S.R., Iran and Afghanistan. It will set in Pakistan. The first of the three

found only one that stood up in the long run. This cycle, probably known to the Chaldeans as early as 3,000 years ago, was called the saros. It is a period of 223 new moons, or 18 years and 10 or 11 days. After each such interval there is an unusually close repetition of the relative positions of the sun, earth and moon, assuring an eclipse. If an eclipse occurs on a certain day, it is virtually certain that a "related" eclipse will come at about the same latitude on the earth just 18 years, 10⅓ days later. The one third of a day beyond an even number means that the eclipse will start about a third of the way around the earth westward.

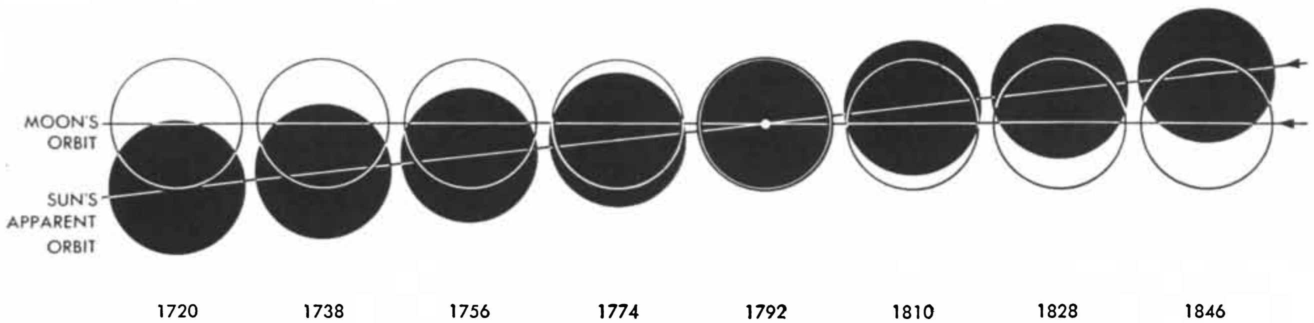
To see why all this is so we must consider the three conditions necessary for an eclipse. First, and most important, the moon must cross the line between the earth and the sun, and this can occur only at the time we know as new moon—the phase when we cannot see the moon because we face its dark side. It comes every 29.5396 days, and the period is called the synodic month: it measures the time of the moon's regular trip around the earth to overtake the sun.

If the moon's orbit were in the same plane as the earth's around the sun, we would have an eclipse of the sun every month. However, the plane of the moon's orbit is tilted about five degrees from that of the earth's orbit. The points of intersection of the two orbits are called the nodes. The second condition for an eclipse, then, is that the moon must be at or close to such a point of intersection. The moon returns to the same node every 27.2122 days, and this period is called the nodical month.

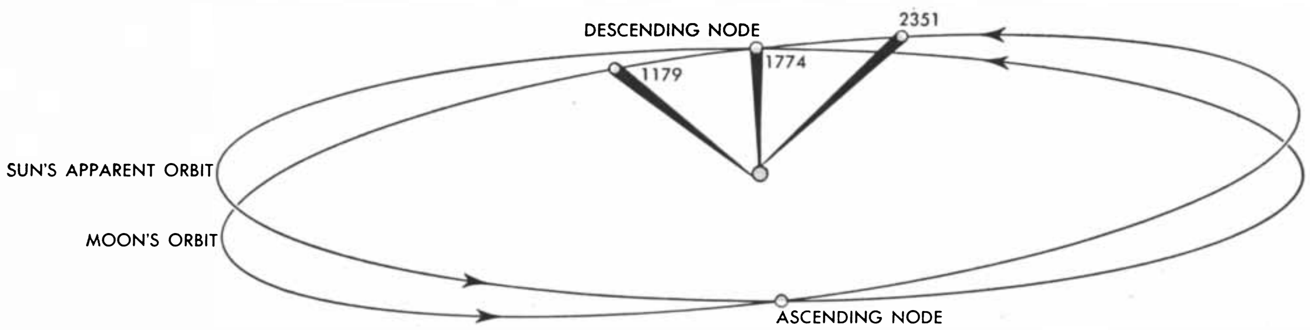
When new moon coincides with the moon's crossing of a node, we see an eclipse, provided we are standing at a spot on the earth where the moon is in our line of sight to the sun. But whether we will see a total eclipse or only an "annular" one (with the moon covering just the central part of the sun) depends on still a third condition, namely, the distances of the moon and sun, which govern the length of the moon's shadow. The chance that the shadow will be long enough to reach the earth rests upon a third kind of month and upon the time of year. Let us examine the effect of the time of year first. On January 1, when the moon and earth are farthest from the sun (93 million miles) the moon's shadow is 228,000 miles long; on July 1, when the earth and moon are closest to the sun (91 million miles) the shadow is 236,000 miles long. More important, however, is the variation in distance between the earth and the moon: it ranges from 218,000 miles to 248,000 miles. From this it is easy to see that the moon's shortest shadow may fall as much as 20,000 miles short of the earth's surface when the moon is at apogee (farthest away). Only about 40 per cent of all central eclipses of the sun by the moon are total. For a total eclipse the moon must be somewhere near perigee (its closest approach to the earth), and this



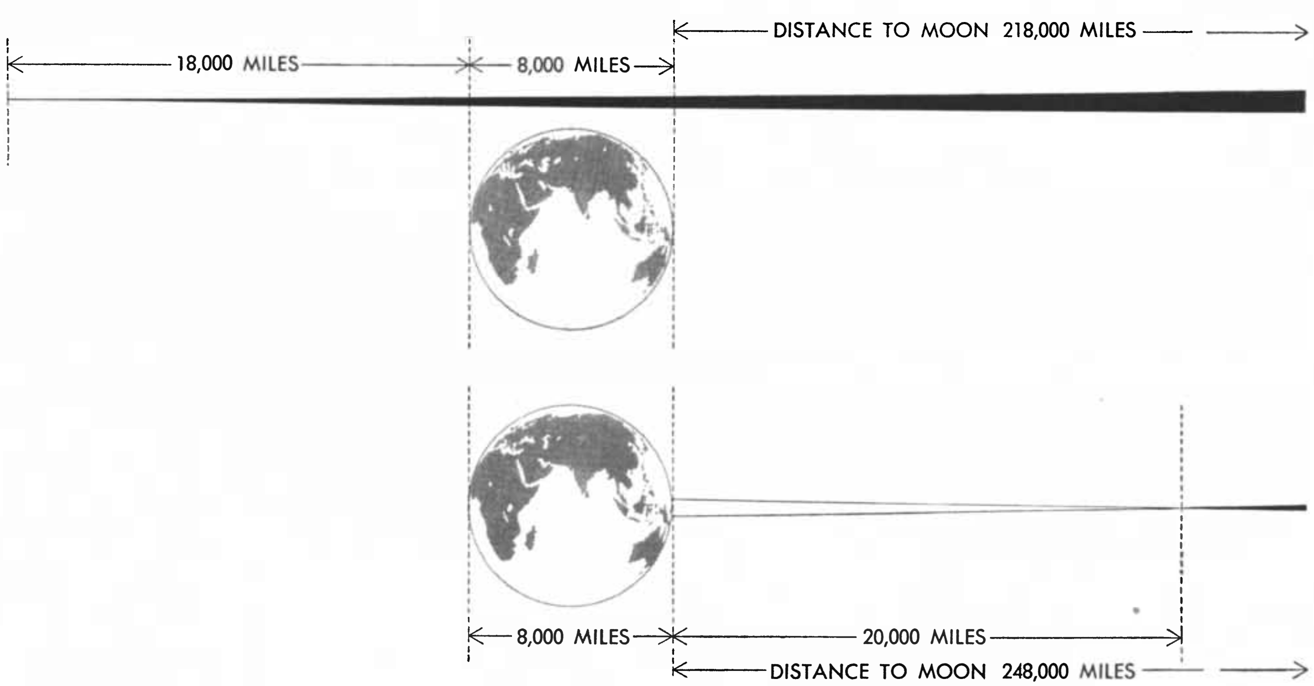
lines that loop down from the upper left indicates the points at which the end of the eclipse can be seen at sunrise; the second, the points at which the middle of the eclipse can be seen at sunrise; the third, the points at which the beginning of the eclipse can be seen at sunrise. Conversely the first of the three lines that loop down at the lower right indicates the points at which the end of the eclipse can be seen at sunset; the second, the points at which the middle of the eclipse can be seen at sunset; the third, the points at which the beginning of the eclipse can be seen at sunset. The lines running more or less parallel to the path of the totally eclipsed sun indicate the zones in which the sun will be only partly eclipsed; the numbers at the ends of these lines indicate the degree of obscuration. The northern limit of the partial eclipse is not shown. This map is adapted from the pamphlet "Total Eclipse of the Sun, June 30, 1954"; Supplement to the American Ephemeris, 1954; United States Naval Observatory, Washington, D. C.



ORBIT OF THE MOON is inclined to the apparent orbit of the sun at an angle of five degrees. The disk of the moon covers that of the sun only when the moon is close to the intersection, or node, of the two orbits. The sun and moon move eastward among the stars, but the moon overtakes the sun. The point of overtaking moves westward one moon diameter each saros, or about 18 years.



POSITION OF THE MOON regresses with each succeeding saros until it has crossed the node (*see illustration at top of page*). This causes the shadow of the moon to move from the Southern Hemisphere to the Northern. The family of eclipses discussed in this article began at the South Pole in 1179, crossed the Equator in 1774 and will last touch the earth at the North Pole in 2351.



DISTANCE OF THE MOON from the earth varies from 218,000 miles (*arrow at upper right*) to 248,000 miles (*arrow at lower right*). Shadow cast by the "largest" moon illuminated by the "smallest" sun may extend 18,000 miles beyond the earth's surface (*upper left*). Shadow cast by "smallest" moon illuminated by "largest" sun may fall 20,000 miles short of the earth (*lower right*).

comes at intervals of 27.5546 days, called the anomalistic month.

The saros marks a fortunate agreement between all three of these cyclic elements. Two hundred twenty-three synodical months are almost exactly equal to 247 nodical months and 239 anomalistic months: the three intervals amount to 6585.32 days, 6585.36 days and 6585.54 days, respectively. At this interval, century after century, the new moon arrives at the same node, and somewhere on the globe people can see an eclipse. A series of such eclipses, separated by the saros, is called a family. Old families eventually die, because the three cycles making up the saros do not coincide exactly, but new ones are constantly being born. It is impossible for the new moon to "sneak by" the nodes of its orbit more than six times in succession without obscuring at least part of the sun. For this reason there are never fewer than two solar eclipses in a year, and often there are three or four. Each belongs to a family: 18 years and 10 to 11 days later the new moon will come to the same node. This means that at any one period in history there are always more than 36 families of eclipses; over the centuries the number has not fallen below 39 and has risen as high as 48.

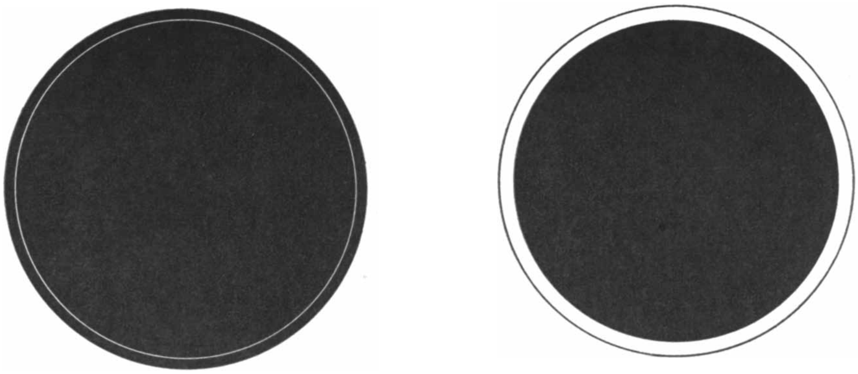
The family to which the eclipse of next June 30 belongs is one of 40 now periodically visiting the earth. We can follow this family from its birth nearly 900 years ago to its death four centuries hence. (How many human families can trace their genealogies through 13 centuries?)

The first member of the family made its appearance as a small nick in the sun, which would have been visible only near the South Pole, on March 10 in the year 1179—more than seven centuries before the first human exploration of Antarctica. Every succeeding saros the moon edged a little closer to dead center of the descending node of its orbit and took a little bigger bite out of the sun. Then in 1323 came the first member of the family which was in any sense an adult; perhaps it would be better to call it adolescent. In that year the moon came directly between the earth and the sun, but the tip of its shadow fell a few thousand miles short of the earth. If there were any prehistoric venturers on the wintry Antarctic seas, they may have been startled to see the annular eclipse on that June 4 of 1323. The sun was a brilliant ring surrounding a jet-black center.

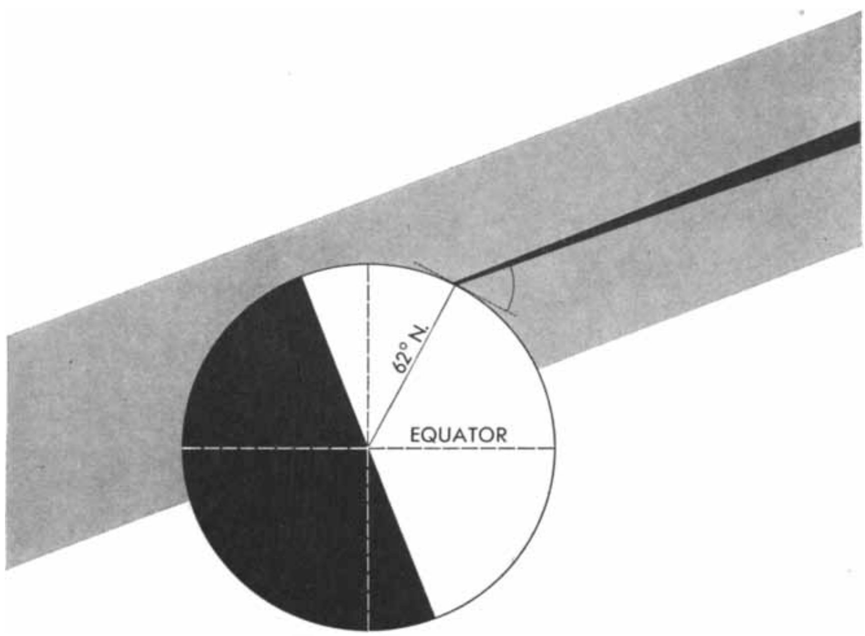
The annular eclipses continued saros after saros for nearly 500 years, and the family seemed to have settled down into mediocrity. Twenty-eight generations showed little change, except that each eclipse came a bit farther north on the earth. In 1774 it crossed the Equator and entered the Northern Hemisphere.

As time went on, the tip of the moon's shadow came closer and closer to the earth on each return of the family; the saros was approaching a coincidence with the perigee cycle. By 1828 the shadow had grown barely long enough to reach the earth and there was a total eclipse in part of its path. Since 1864 the shadow has painted a stripe of darkness across the earth from its beginning to its end, from sunrise to sunset. And each eclipse has lasted for a longer time as the shadow has covered a broader and broader band. The 1864 eclipse "wasted its sweetness on the desert air" of the Pacific Ocean from Borneo to Lower California; only a few islanders and voyagers in the Pacific saw it. The next one, on May 17, 1882, rode across the Sahara Desert, the Isthmus of Suez, Arabia and the breadth of Asia, ending in the Pacific not far south of Japan.

Then in 1900 the family paid its first visit to the U. S., sweeping across several southern states. It came again, racing over the country from the Northwest to the Southwest, in 1918. In 1936 the next of the family favored the U.S.S.R. The 44th member of the family will return to the U. S. next June. The family has passed maturity and is beginning to decline, but its old age will be triumphant. It will brush the earth with six



DIAMETER OF THE MOON from the earth varies by 13.5 per cent. Diameter of sun varies by 3.5 per cent. When "largest" moon is in front of "smallest" sun, a total eclipse occurs (*left*). When "smallest" moon is in front of "largest" sun, eclipse is annular (*right*).



SHADOW OF THE MOON in the middle of the eclipse on June 30 will touch the earth at a latitude of 62 degrees north. The angle of the shadow will be 51 degrees. The umbra, or shadow of total eclipse, is in black; the penumbra, or shadow of partial eclipse, in gray.

more total eclipses before the tip of the shadow swings off beyond the North Pole after 2044. Then a long series of partial eclipses will follow, and the family will finally die about the year 2351. But a century before that a new family will have been born near the South Pole and begun to pursue it northward up the globe, each member of the new family following just one month after a member of the dying family. (A family of eclipses which occurs at the descending node of the moon's orbit moves northward; at the ascending node, southward.)

The exact calculation of the path of an eclipse is tedious work, and it is generally done by skilled computers. Consider some of the factors they must take into account: the position of the earth in its slightly elliptical orbit around the sun, the position of the moon in its more eccentric orbit around the earth, the inclination of the moon's orbit to that of the earth, the closeness of the moon to a node at the time of new moon. As if that were not complicated enough, the tip of the conical shadow whips rapidly across a big spherical object, the earth, wiping a narrow path never more than 167 miles across, and the sphere over which the shadow moves is itself rotating on an inclined axis. The fact that the earth rotates toward the east fortunately helps to prolong every solar eclipse, because the moon's shadow also runs eastward. However, even under the most favorable conditions (a total eclipse at noon on the Equator on July 1) the period of totality cannot last more than seven and one half minutes.

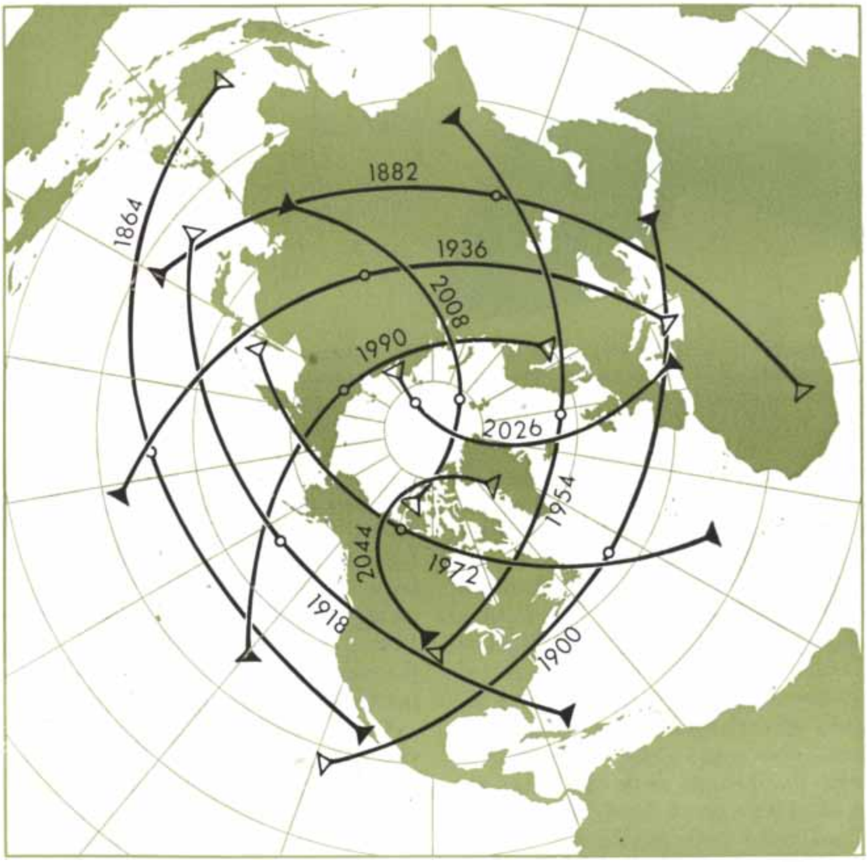
The U. S. Naval Observatory carefully calculates the path of each eclipse and prepares a special pamphlet with maps and tables. This booklet tells when the moon will first nick the rim of the sun, the times of the beginning and end of totality and the time of the moon's final departure from the face of the sun.

My own life became linked with this family of eclipses soon after I was born, for the eclipse of May 28, 1900, came in the year of my birth. I was favored to see the 1918 member as a working embryo astronomer. Stationed on top of the Continental Divide in Colorado at the small and now extinct railroad town called, believe it or not, Corona, three of us watched the great spectacle. We were there to make magnetic observations to discover possible changes in the earth's magnetic field during the eclipse. The party consisted of Louis A. Bauer, head of the Department of Terrestrial Magnetism at the Carnegie Institution of Washington, E. Waite Elder, a physics teacher at the East High School in Denver, and myself as chief porter and camp boy, not to mention scientific observer.

We set up a tent 500 yards from the Corona railroad station, mounted a sensitive magnetometer and set to work putting it into adjustment. On the day before the eclipse it was my task to observe the position of the magnetometer needle every minute for eight hours. The biggest magnetic disturbances were those caused by passing trains, sometimes with three engines. So sensitive was the instrument that I could "see" them coming 'round the bend while they were still two or three miles away. Then, on the day of the eclipse itself, the same regimen was followed. More memorable to me than any scientific results obtained was the very sore left eyelid that I suffered from squinting that eye hour after hour for two days as I read the instrument with my right eye. No one had told me what every microscopist knows —to keep the idle eye open and relaxed.

In beclouded Denver thousands of expectant watchers were unable to see the eclipse, but from our 11,660-foot perch we got a great view of it.

It is my hope to see the 1954 eclipse, which will take place within about one hour of exactly 19,756 days (three saroses) of the 1900 eclipse, so that the earth will be back in its turning to about the same place. Thus the coming eclipse will be shifted only slightly eastward and northward from the 1900 one. Perhaps I shall also be interested to go to northern Alaska or to Newfoundland to see the next member of the family on July 10, 1972. Mark Twain once wrote about his affectionate link with Halley's comet. He was born in 1835, when that infrequent visitor was near the earth, and he felt that he would depart with the comet in 1910 on its subsequent return. This he did. I should like to outdo Mark Twain and live to see the sixth return of my favorite family of solar eclipses when it passes through the land of the midnight sun in Lapland on July 20, 1990.



FAMILY PORTRAIT shows the paths of 11 successive total eclipses in the series of which the June 30 eclipse is a part. The paths are plotted on a polar projection. The beginning of each eclipse is indicated by a white triangle; the middle, by a white circle; the end, by a black triangle. Each succeeding eclipse is farther to the north, and about a third of the way around the earth to the west. The regular pattern of the lines is due to the fact that every third eclipse occurs approximately north of the one 54 years and 31 days earlier.

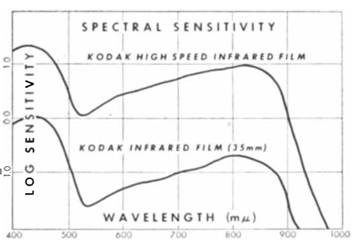
Kodak reports to laboratories on:

decupling the sensitivity of infrared film... making pH indicators easier to use... how 3 x 5-inch file cards turn into a library

High speed infrared

A close student of the course of photographic technology might surmise that some sort of photographic infrared barrier has been cracked within the past year or so. In a limited sense, he would be right. The photographic infrared still ends at about 12,200A (Kodak Spectroscopic Plates, Type Z), but the magnitude of the sensitizing effect to that point can now be greatly stepped up.

As one of the new products consequential to this development, we now announce *Kodak High Speed Infrared Film.* Although it only goes to about 9500A, its practical sensitivity for such purposes as pigmentation penetration, photography in



visual darkness, and heat-distribution studies is about ten times that of Kodak Infrared Film. Granularity is somewhat higher than that of Kodak Infrared Film. The effect of this on image sharpness tends to be offset in some applications by the fact that the higher sensitivity of *Kodak High Speed Infrared Film* permits the use of smaller lens openings.

Kodak High Speed Infrared Film *is supplied only in 16mm and 35mm perforated form as 100-foot rolls. It requires such extreme caution against fogging that we do not put it up in cartridge form. You can buy it from your Kodak Industrial Dealer. If you want the address of the one nearest you or more detailed information on the film, write Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.*

Indicator solutions

In the more orderly laboratories, it hangs on the wall; in others, you have to rummage for it under somebody's desk blotter. Ubiquitous on the scientific scene it is, though—the famous Eastman pH Indicator Chart with its array of bars that tell at a glance which of some 50-odd Eastman Organic Chemicals changes from what color to what other color over what pH range. The indicators themselves we have hitherto offered in dry form only—water or alcohol to dissolve them in is plentiful.

Now we have taken a second look at this policy, from the viewpoint of the business manager who knows that such laboratory drudgery as making up indicator solutions is still an expensive proposition. As a result, we report that nearly all the Eastman Indicators are now available as solutions in 500-cc bottles, with solvent, concentration, and pH range stated on the label. We continue to sell the indicators undissolved also.

Direct your inquiries and orders for Eastman pH Indicator Solutions to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company). Write to the same address if the Eastman Indicator Chart is still not quite ubiquitous enough for your convenience. (It's free.)

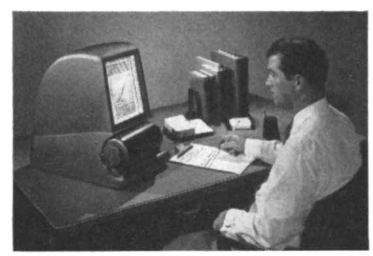
Microprint

The libraries are not going to explode after all. Libraries grow exponentially, of course, and any exponential process turns into an explosion unless something is done. Fortunately, something is being done.

It's the brutal truth that a man or woman is covering a narrow field indeed if he or she can honestly claim to be abreast of all that's set down on paper about it. A remedy—microprint cards—has been proposed by which a library card catalog can replace the library itself. Almost a decade of development has demonstrated its merit. Since it is based on photography, the time has come to state our position on it:

Before 1954 ends, you will be able to walk into dealers' establishments throughout the United States and be shown the *Kodagraph Microprint Reader.* This is an instrument, weighing less than a standard typewriter, for reading microprint cards with complete comfort. Microprint cards, usually the standard 3″ x 5″, look like the familiar library catalog card, carrying classification data, perhaps a brief abstract, etc., but, instead of having then to locate the item cataloged if it seems pertinent, it's right there on the back of the card in microprint—as many as 60 pages of the actual text.

"Complete comfort" is very important. Without it there would be no spreading of microprint readers from large libraries to smaller ones and on down to the individual user's office, desk, and even home. With large numbers of users to share the cost, microprint card literature will become vastly more extensive and intensive than it has already grown. Economic barriers to the development of automatic



subject-searching equipment will fall. New microprint publishing ventures will flourish—some for profit, some for the promotion of scholarship in fields too sparsely inhabited to support the cost of conventional publication. More industrial organizations will establish microprint systems for the debulking, speedy dissemination, and storage of literature and private internal data.

Our part is to work closely with everybody, supplying technical hints, *Kodagraph Microprint Readers, Kodagraph Micro-File Film, Kodagraph Microprint Paper,* and equipment to turn out microprint cards by the piece or by the peck.

If the possibilities of microprint interest you, we'd appreciate your dropping a note to Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y., to let us know the nature of that interest.

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

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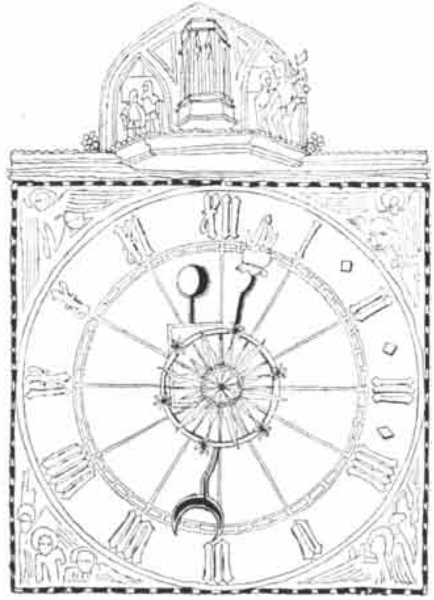


A.A.A.S Meeting

The American Association for the Advancement of Science, at its 120th meeting in Boston last month, appointed a new staff and took steps to realize objectives it adopted in principle two years ago in the Arden House resolution. As administrative secretary it named Dael Wolfle, a psychologist and director of the National Research Council Commission on Human Resources and Advanced Training. He succeeds Howard A. Meyerhoff, who resigned last March. As editor of its publications, *Science* and *The Scientific Monthly*, the organization appointed Duane Roller, formerly professor of physics at Wabash College and recently assistant director of research at the Hughes Aircraft Company. To the post of treasurer it appointed Paul A. Scherer, executive officer of the Carnegie Institution of Washington.

The A.A.A.S. elected George W. Beadle, director of the Kerckhoff Laboratories at the California Institute of Technology, as its president for 1955. Serving as president for the coming year is Warren Weaver, principal author of the Arden House resolution. His administration plans to proceed actively with the task of directing the energies of the A.A.A.S. to the "broad problems which involve the whole of science, the relations of science to government and indeed the relations of science to our society as a whole."

The broad problem that most concerned the 8,000 scientists attending the Boston meeting was the freedom of science. The topic was discussed not only at formal symposia but also in hotel corridors. In a luncheon speech E. U. Condon, outgoing president of the A.A.A.S., declared that the "critical, questioning attitude is an essential ingredient of the scientist's method of working" and not "just a kind of unruliness or bad-boyism which we perhaps have to tolerate in these eccentric fellows because they are the geese that lay the hydrogen bombs and many other great and good things."

The best-attended symposium of the convention heard four speakers on the same topic. Mark de Wolfe Howe of Harvard Law School observed: "Our laws and constitution do not secure the freedom of science but merely the freedom of scientists. Fortunately in our society there are other agencies of authority than government. All institutions dedicated to the pursuit of knowledge are able, if they choose to do so, not only to protect the scientists but to safeguard science. They may fulfill that high responsibility by recognizing and fully exercising their traditional powers of self-government."

Barry Commoner, biochemist at Washington University in St. Louis, won the $1,000 Newcomb Cleveland Prize for his paper on the reproduction of tobacco mosaic virus. He has worked out some of the steps in the complex process by which new virus particles are built in the infected plant cells. The viruses are formed from materials which would normally go into the cell's nucleoproteins, and Commoner found that they reproduce only in the cytoplasm.

The William Proctor Prize of $1,000, given by the Scientific Research Society of America, was awarded to David B. Steinman, New York bridge engineer.

The $1,000 A.A.A.S.-Westinghouse Science Writing Awards were won by Eric Hodgins, an editor of *Fortune*, and Nathan S. Haseltine, science editor of the Washington *Post*. Hodgins received the prize for an article titled "Power from the Sun" in the September, 1953, issue of *Fortune*. Haseltine's award was for a series of newspaper stories on prison medical volunteers. Honorable mentions went to Albert Q. Maisel and Norman John Berrill for magazine articles. A special citation was awarded to the science department of *Life* and to Lincoln Barnett for the series, "The World We Live In."

Some other reports at the meeting:

Peter M. Millman, of the Dominion

Observatory in Canada, said he had established by radar-tracking studies that meteors cannot come from outside the solar system. The maximum speed of those he has tracked is 45 miles per second, which is slower than the velocity they would need to escape from the sun's gravitational pull. Thus meteors must be permanent members of the solar system. Between 10,000 and 100,000 enter the earth's atmosphere every second.

A group of Cornell University zoologists headed by Marcus Singer reported that certain chemicals given off by nerve tissue are necessary for animal growth. They have been experimenting with regenerating limbs of salamanders. If the nerves are removed from the stump of an amputated leg, the salamander cannot grow a new one. To find out what substances are responsible for the effect, Singer devised an apparatus for continuously infusing chemicals directly at the growth site. He learned that substances which inhibit acetylcholine, a chemical important in nerve impulse transmission, also inhibit regeneration.

W. G. van der Kloot of Harvard University told of studies on the tiny brain of the silkworm, upon which he operates with delicate surgical methods. When the whole brain is cut away, the worm loses its ability to spin silk. Injury to some parts of the brain leaves the spinning ability unimpaired; when other sections are cut the worms spin a flat sheet rather than a cocoon. Van der Kloot has localized the spinning function in the corpora pedunculata.

The Pool Plan

The prospects for international control of atomic energy have been substantially improved, in the opinion of many scientists, by the new approach initiated by President Eisenhower in his December speech to the United Nations General Assembly. The President's suggestion that the UN members contribute to an international pool of fissionable materials and collaborate in exploring constructive uses of atomic energy was widely applauded as offering a promising beginning toward reducing the danger of atomic war. At its annual meeting in Boston last month the American Association for the Advancement of Science warmly approved the plan. Its resolution said: "Scientists throughout the world will welcome service in the interests of peace. . . . Science . . . knows no geographical boundaries. Hence it offers a particularly potent and valuable vehicle for promoting better understanding among the nations of the world."

Although past negotiations on international atomic energy control have yielded nothing but disappointment, the new approach seemed to offer some grounds for optimism: (1) the U.S.S.R., though reiterating its demand for immediate outlawry of atomic weapons, accepted Eisenhower's invitation to discuss his plan; (2) both the White House and the Kremlin agreed to informal, non-public negotiations; (3) Secretary of State John Foster Dulles said that the U. S. was prepared to discuss not only the pool idea but any measures "designed to end the danger of atomic warfare."

The New York *Herald Tribune* columnist Walter Lippmann saw an important concession by the Soviet Union. He observed that the Soviet note, in citing the deterrent effect upon Hitler of the Allies' possession of poison gas during World War II, seemed to offer the possibility that the U.S.S.R. would agree to the retention by the big powers of deterrent stockpiles of atomic weapons until they could negotiate an agreement to outlaw them.

Mare's Nest

The Fort Monmouth spy story fizzled out last month. Senator Joseph R. McCarthy concluded a series of public hearings, which he had said would "show that there was espionage" in the Fort Monmouth radar laboratory, with the statement: "It is not our function to develop cases of espionage." His parade of witnesses, some of whom invoked the Fifth Amendment, had failed to develop any testimony on spying. Of some 30 Signal Corps scientists suspended by the Army as a result of the McCarthy investigation, none was accused of espionage. They had been charged with such deviations as favoring "the leftist policies of Max Lerner," representing the Monmouth scientists in the Federation of American Scientists and failing to "take a positive stand on the issue of admitting Communists to the Monmouth County Chapter of the American Veterans Committee."

The New York *Herald Tribune* military writer Walter Millis, after investigating the results of the McCarthy investigation at Fort Monmouth, reported in his column: "This really vital and sensitive military installation has been wrecked—more thoroughly than any

Soviet saboteur could have dreamed of doing it. . . . The processes of witch-hunting, bigotry, cowardice, race prejudice and sheer incompetence have turned one of our top-level military-scientific operations into a mare's nest of exasperation, fear and futility. . . . The impairment of the national defense is something which no one whose life may one day hang upon the excellence of our radar screens can dare to disregard."

De Senectute

The 1950 census showed that one of every 12 Americans was 65 or older. In 1900 the figure was one in 25; in 1980 it will be one in nine. The problems raised by this rapid aging of the population were discussed by a number of experts in a recent issue of *The American Journal of Sociology*.

Robert K. Burns of the University of Chicago criticized the practice of retiring workers at the age of 65. He said that raising the retirement age to 68 or 70 would cut pension costs as much as a third and provide more nearly adequate pensions. The 65-year age limit is an anachronistic holdover from depression times, Burns said.

Preliminary findings of a cooperative study of aging and retirement in six Florida communities were reported in the *Journal*. L. C. Michelon of the University of Chicago, after close observation of a small group of retired persons in a Florida trailer camp, concluded that individual hobbies cannot take the place of work for those who have retired. During a man's working life such avocations provide a welcome escape from the daily bustle, but after retirement he needs a type of activity which will encourage and preserve his associations with others. Michelon found that laborers enjoy retirement more than professionals, married women more than men or single women.

Clark Tibbitts of the U. S. Department of Health, Education and Welfare suggested that retired persons could serve as consultants, members of survey teams, of commissions and advisory groups. He said that some retired businessmen have formed groups which offer consultation service to individuals or small organizations at little or no fee.

Seeding and Reaping

President Eisenhower has appointed a committee to look into the matter of cloud-seeding, and behind his action lies a serious disquietude. Texas cattlemen are convinced that last year's disastrous drought in their state was due to the large-scale cloud-seeding activities carried out in the West and Southwest during the past few years. They are supported in this belief by Irving Langmuir, director of the seeding experiments called Project Cirrus. In a report on the project Langmuir concluded that seeding in New Mexico caused an increase in rainfall as far as 2,000 miles to the east, and that it may well have deprived the Southwest of rain. The theory is that cloud-seeding under some conditions may draw moist Gulf air away from Texas to the Mississippi Valley region.

A Congressional act authorizing the appointment of the President's study committee warned that weather modification and control without sufficient information or safeguards "may cause catastrophic droughts, storms and floods." But it also pointed out that effective weather control could bring "far-reaching benefits to agriculture, industry, commerce and the general welfare and common defense."

The President's committee will try to assess the possibilities of large-scale modification of weather and to find out whether present unregulated tinkering by private rainmakers is doing harm. Its chairman is Howard T. Orville, who as a Navy captain was one of the chief weather advisers in the North African and Normandy landing operations. Among other members are Lewis W. Douglas, former Ambassador to Great Britain who is now establishing a cloud-physics department at the University of Arizona, and Alfred M. Eberle, dean of agriculture at South Dakota Agricultural and Mechanical College.

Better Transistor

A new type of transistor which "outperforms all transistors currently in use" was announced last month by the Philco Corporation. Called a "surface-barrier" transistor, it will replace vacuum tubes in important applications where the junction type will not work, the company says. It is claimed to be more stable and more exactly reproducible than junction transistors and to cover 10 to 100 times their frequency range; it operates reliably up to 70 megacycles.

In its manufacture two tiny streams of a liquid indium salt are directed against opposite sides of a small germanium slab. Electric current passed through the streams eats away the germanium until the slab is only a few 10,000ths of an inch thick. Then the current is suddenly reversed; the erosion stops and indium is deposited on both sides of the germanium wafer. The coating forms electrodes, to which wires may be attached. The whole assembly is then hermetically sealed in a metal container. The trick lies in precise control over the thickness of the germanium. The Philco engineers have devised a means of timing so delicate that they can attain an accuracy within 10 millionths of an inch.

Still unknown are the "aging" characteristics of the new transistor and what it will cost to produce.

Power from Wind

Great Britain and several other European countries are carrying on serious research on the possibility of harnessing wind power. The results of the British project to date are described in a recent issue of *Discovery.*

The major difficulty, of course, is the fickleness of the winds. But the British have found that over a period of a year the total wind energy delivered at a given spot is remarkably constant: it seldom varies more than 10 per cent from year to year. Thus a wind-driven electric power station could be counted on for a predictable annual output.

To find the best spots for these power stations a wind survey of England and Ireland has been undertaken. The most favorable sites turn out to be the tops of steep, smooth hills. Winds passing over these obstacles are speeded up five miles per hour or more.

In 80 British locations surveyed thus far the average wind speed ranges from 16 to 30 miles per hour. It is estimated that at any site with an average speed greater than 20 miles per hour wind could yield power as cheaply as coal. It would be used as a supplement to reduce the demands on coal-powered stations.

The most economical generating unit would be of 2,000 to 4,000 kilowatts capacity. Such a generator would require a windmill about 200 feet across. The giant mill would have to meet a number of difficult technical requirements: a minimum of maintenance, ability to operate in mild breezes and 100-mile-an-hour gales, and constant speed of turning, whatever the wind, in order to maintain the fixed frequency of the alternating current network. The British are testing some smaller-scale, 100-kilowatt prototypes.

Communicating with an Ape

Keith and Catherine Hayes of the Yerkes Laboratories of Primate Biology, who are raising a young female chimpanzee as a member of their family,

CORNING GLASS BULLETIN

FOR PEOPLE WHO MAKE THINGS

HOW the most remarkable glass in 4000 years was invented . . . Modern kitchen ranges are full of ideas . . . Do you know how glass conducts electricity?

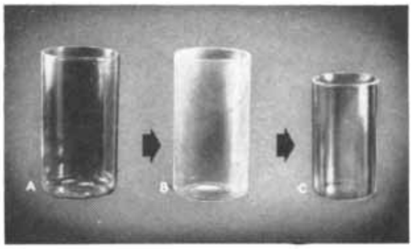
People are always looking for something new and better. You spend most of your time seeing that they get it.

We do the same, and want to tell you—quickly—of developments in glass that may suggest applications useful to *you.*

Hence this Bulletin, the first of a series which will talk briefly about new and unusual glasses—in the hope that you will let us send you more complete information. For your convenience, there's a coupon below.

most remarkable glass

In 1952 Philadelphia's Franklin Institute presented the John Price Wetherill Medal to Corning's Dr. Martin E. Nordberg and Harrison P. Hood for inventing the most fabulous of glasses—VYCOR brand 96 per cent silica glasses.



Evolution of a VYCOR jar: A—formed by conventional glass blowing; B—"thirsty glass"; C—finished product.

These two scientists discovered a composition that appeared to be a combination of two distinct types of glasses. One type could be dissolved out, leaving a skeleton of 96 per cent or more of silica filled with so many millions of holes that a one-inch cube contained some 60,000 square feet of hole surface.

This new child of research was dubbed "thirsty glass" because, just sitting around, it absorbed moisture right out of the air. But our researchers were on the trail of something even more exciting. They heated their "thirsty glass" and it shrank to two-thirds its original size. The millions of little holes vanished and left a vacuum-tight glass that looked like any other—except that you could take this new glass white-hot from a blazing furnace and plunge it into ice water without the slightest injury. It was a glass as ideal as fused quartz, but different since it could be melted, mass produced, and worked in its original state like ordinary glass.

The newest use for VYCOR brand 96 per cent silica glasses is in Sylvania's instant-heat lamp for electric ranges. *We'll tell you more in later bulletins about other uses these glasses have already found. If you'd like to know more NOW, just check the coupon below.*

ideas

Today's smart gas and electric ranges have wrought a kitchen revolution. And glass has made its contribution—designwise and utility-wise.

Some of the newest ranges include several kinds of glass items. PYREX brand oven door panels that let you see what's cooking; broiler plates, door handles, broiler shields, oven roundels to protect non-heat-resistant lamps. *Opal* glasses for decorative stove-top lighting. *Multiform* glass beads for electric surface units. Top-of-stove burner protection units made of VYCOR brand 96 per cent silica glass. Attractive designs and name plates permanently captured in *photosensitive glass* panels. (Photolay, we call this application. It gives a 3-D effect to anything that can be reproduced photographically.)

Sears-Roebuck's new Kenmore range with a Sylvania instant-heat lamp unit which has a VYCOR bulb and tinted cover plate.

Wonder if there might be an idea or two for you in what the modern stove designer is doing with glass? We'd be glad to tell you more.

conducting electricity

One of the interesting exhibits at the Corning Glass Center shows an electric light bulb mounted in the middle of what looks like an ordinary plate glass window pane. But push a little doorbell button beneath the pane and behold—the electric bulb lights up. The window pane isn't a window pane at all. It's a glass that conducts electricity—E-C (*E*lectrically *C*onducting) glass.

A transparent film on one side of a PYREX panel acts as a resistance heater with power ratings as high as 10 watts per surface square inch. Switch 115- or 230-volt alternating current through it and you get up to 650° F.—enough to char but not ignite a piece of paper.

E-C glass is being used successfully today in portable and wall-mounted space heaters and in industrial heating and drying equipment, especially where *even heat distribution* is needed.

Our engineers have collected a good deal of information about E-C glass. We'd be glad to share it with you. For preliminary action, just put your mark on the coupon after E-C glass.

Flick a switch and this electric bulb mounted on a glass panel lights up. Magic? No—this glass conducts electricity.

If the items listed below don't seem to bear on your problem, we may have what you need at our fingertips. We'd like to hear from you.

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bring their account up to date in a recent issue of *The Journal of Comparative and Physiological Psychology*. Their chimp, Viki, is now five years old. The Hayes's report has to do with her progress in communication.

From the age of 18 months Viki has been interested in leafing through magazines and catalogues. When she was three she put her ear to a picture of a wrist watch, and she learned to repeat the action when told to "listen." She frequently points to illustrations in beverage advertisements, says "cup" and runs to the kitchen to be given a drink.

To find out how much pictures actually convey to the chimpanzee, the Hayeses tried a number of controlled experiments. In one series Viki had to pick out an automobile from other pictured objects. In a second she was asked to select pictures to match sample objects. In a third she was tested on nonsense designs. In all the trials she scored substantially higher than she could have by chance. The more realistic the picture, the better her performance, but even with line drawings she chose correctly 80 per cent of the time. She discriminated pictures of real objects much more easily than nonsense designs.

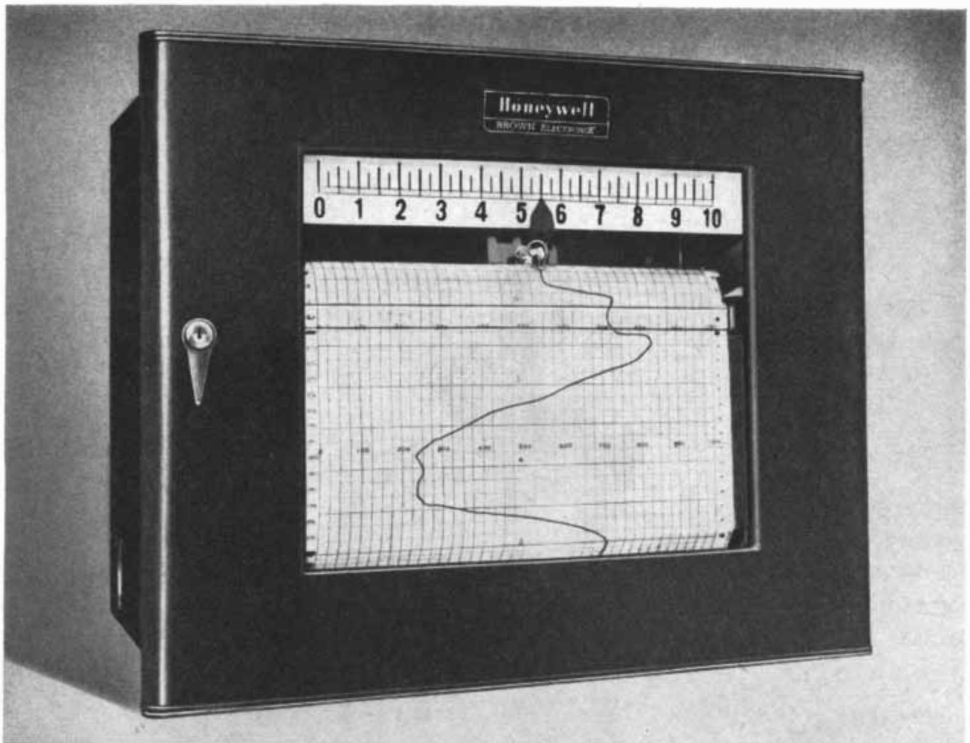
Concluding that "pictorial representation is a usable channel of communication from man to chimpanzee," the authors point out that the channel works only one way. Although their "daughter" does a lot of scribbling, she has yet to produce anything they can recognize.

Fish Story

Sea serpents not only exist but will one day be caught and photographed, according to Anton Bruun, eminent Danish oceanographer. Bruun told the recent International Zoological Congress in Copenhagen that he had once actually seen a baby monster. Dredged up from the deep sea, it was a Leptocephalus (the larval form of an eel) six feet long. Since it had 450 rudimentary vertebrae, three times as many as the largest known eel, Bruun judged that when fully grown it should make a respectable monster.

Bruun, who directed last year's *Galathea* deep sea expedition, has learned not to be surprised at anything that comes from the depths. He pulled up a giant angler fish in whose mouth were lights like neon tubes. "We simply do not know what exists in the abyss," the Danish scientist said.

To catch a monster he proposes a direct attack. He would bait a hook, attach it to a cable a few miles long and troll from an oceangoing ship.



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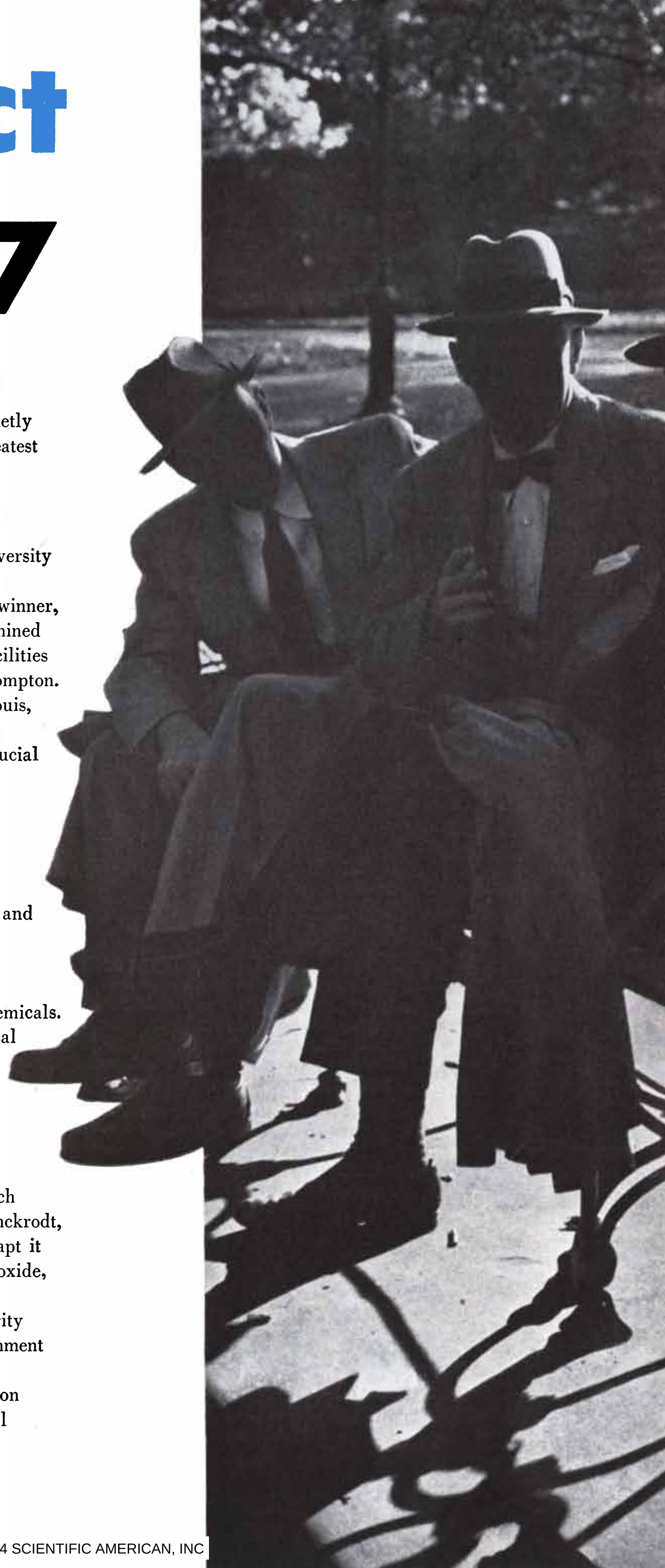

April 1942. Big things were being done quietly in those days. Shrouded in secrecy the greatest brain trust in history had undertaken to release the enormous energy of the atom for the defense of the free world.

Under the trees on the campus at the University of Chicago, three men sat quietly talking. One, an eminent physicist and Nobel prize-winner, was a leader of a group of scientists determined to marshal the nation's highest technical facilities for this purpose. His name: Arthur Holly Compton. He told his companions, just in from St. Louis, that he and his colleagues faced a problem of vital importance to the war effort. The crucial requirement was for pure uranium oxide, far purer than it had ever before been prepared except in test tubes. Moreover, his people would need tons of it, first for experimentation, later for its ultimate use.

The visitors from St. Louis, Henry V. Farr and John R. Ruhoff, were chemists from the Mallinckrodt Chemical Works, a firm with a long-established reputation for more than ordinary skill in the manufacture of fine chemicals. Edward Mallinckrodt had asked his technical managers to give his friend Compton whatever he wanted, if humanly possible.

Scientists working under the sponsorship of the N.D.R.C., Compton explained, had developed an ether extraction process for the purification of uranium nitrate which worked on a laboratory scale. Could Mallinckrodt, with long experience in handling ether, adapt it for use in tonnage production of uranium oxide, and achieve the necessary high purity? The specifications were rigid. Extreme purity was required. Time was short; but the assignment did not differ greatly from many others undertaken by Mallinckrodt chemists, also on a highly confidential basis, for the chemical and pharmaceutical industries.

Back in St. Louis, these men quietly, secretly put Mallinckrodt's technical organization to work. Less than 15 weeks later the primary problems of commercial production had been solved, a new plant had been designed, built, put into operation, and Dr. Compton's scientists were getting their uranium oxide.

After it was all over, the Smyth report recorded: *"Delivery started in July 1942 at a rate of 30 tons a month . . . it was a remarkable achievement to have developed and put into production on a scale of the order of one ton per day a process transforming grossly impure commercial oxide to oxide of a degree of purity seldom achieved even on a laboratory scale."*

By the fall of 1942, the need was for uranium metal—and lots of it. The Manhattan Project had been created, and a chain of supply had been set up in the country, starting with normally available uranium products and going on, through the oxide step, all the way to metal. DuPont, Harshaw, Electromet, Linde, Iowa State College and many other organizations had been working on various phases of uranium production. But still more output was needed. Some of these companies built new plants for oxide production. Mallinckrodt's operations were expanded to include uranium metal production. Technical information was freely exchanged among these cooperative groups, with the result that their combined production supplied the uranium needed for the atomic energy program.

V-J Day left us with a miraculous achievement, a great and threatening secret—and hope for a bright new future with atomic energy as a peacetime ally. But the job was still unfinished. To ensure an adequate supply of uranium, the United States must be able to process any uranium-containing raw material—domestic or imported, crude or refined—in the amounts needed. This meant the development of new processes, the designing of new equipment, and the construction of new plants. A challenging engineering problem loomed on the horizon.

With the war over, production of uranium metal was centralized, and it fell to Mallinckrodt to apply the accumulated experience, that of others as well as their own, to the development and integration of processes for producing pure metal from ores. Leading engineering and construction firms were called in. In cooperation with Mallinckrodt chemists and engineers, and under the sponsorship first of the Army, later of the Atomic Energy Commission, new facilities were designed and built by such firms as Singmaster & Breyer, Wigton-Abbott, Blaw-Knox and others—facilities that have since been operated continuously by Mallinckrodt at ever lower cost, and have been the prototypes for others subsequently built.

This is an important part of America's atomic energy story, *and the story of a Mallinckrodt assignment*—Project 42-17. Its significance to American industry is this: Mallinckrodt was given a tough job of critical importance—the job of supplying tonnages of highly purified materials, regularly, and at a reasonable cost. The job was done, on time, with superlative results. Much of the research and process development was a product of Mallinckrodt's own team, drawing whenever possible upon the experience of others engaged in similar problems. The engineering and construction became a joint enterprise which brought together a wealth of know-how and experience.

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Blood

The red fluid of the human body is a rich mixture of cells and molecules. New methods of fractionating and preserving these many constituents increase their usefulness to medicine

by Douglas M. Surgenor

In 1665 the English anatomist Richard Lower performed the first successful transfusion of blood from one living animal to another. Later he also transferred lamb's blood into a human being. But he was preceded in this by the French physician Jean Denis, who, having learned of Lower's experiments, had hastened to be the first to make the human experiment. The importance of these experiments was not underestimated at the time. The newly formed Royal Society of London announced Lower's achievement with a flourish in 1666. Samuel Pepys was quick to comment on the medical and social implications of the discovery: "This did give occasion to many pretty wishes, as of the blood of a Quaker to be let into an Archbishop." The diarist noted the opinion of doctors that transfusion "may, if it takes, be of mighty use to man's health, for the amending of bad blood by borrowing from a better body."

Unfortunately the new discovery did not "take" at the time. After several successful transfusions, Denis had the misfortune of having an important patient die. The strong public reaction to this event stopped further experimentation for over a century. Not until the 20th century did investigators learn enough about blood to make transfusion a safe practice. They had, first of all, to discover that the blood of one species of animal is not compatible with that of another, and in 1900 the Viennese immunologist Karl Landsteiner finally removed the major obstacle to safe transfusion when he identified the incompatible blood groups among human beings.

Today blood and products derived from it are used in every hospital in the world. The handling and processing of blood is a multimillion-dollar enterprise. This invaluable human tissue is a uniquely convenient healing agent: it is easily withdrawn, is speedily replaced by the body and performs a host of vital functions. Even more important and exciting is the fact that investigation has begun to identify the individual blood components that carry out these various functions, so that we can look forward to mining from this great raw material a whole catalogue of "drugs"—substances which can be preserved for long periods, will treat various diseases and will multiply the usefulness of the blood taken from donors.

Blood is not the simple fluid it was once thought to be. More than 70 different proteins have been identified in it, not to speak of the various formed elements—the red cells, the white cells and the platelets—of which it is composed. And the body is constantly manufacturing new supplies of these products to replace the old: even in the case of the long-lived red cells (average lifetime: 120 days) a human adult produces about 140 million new cells per minute.

Functions of the Blood

To appreciate the wide range of usefulness of blood as a therapeutic agent we must review its main functions in the body. The first is to carry raw materials to the tissues and remove waste products therefrom. The essential raw materials include oxygen, food elements, vitamins and minerals. The blood also transports internally formed chemicals such as hormones. Of the waste products it carries to the elimination outlets, one of the most important is carbon dioxide.

The blood's transport function is performed by methods of varying intricacy. Consider one or two examples. Oxygen is carried by the red cells, which make up about 45 per cent of the blood volume. A red cell contains mainly hemoglobin, the iron-containing protein that readily combines with oxygen. Whether the molecule will take up oxygen or release it depends on the oxygen gas pressure in the place where it happens to be. Thus in a region of relatively high oxygen concentration, as in the lungs, hemoglobin attaches oxygen to itself and becomes oxyhemoglobin—a scarlet-red substance. When this molecule reaches the hungry tissues, where oxygen concentration is lower, it delivers the oxygen and becomes dark-red hemoglobin again. Practically all of the transportation of oxygen in the body is accomplished by means of this simple reversible reaction. In a similar manner the hemoglobin of the red cells carries carbon dioxide away from the tissues to which it has delivered oxygen.

Most of the chemicals carried by the blood are small molecules, like oxygen. If they were left free, they would be lost through the walls of the blood vessels; moreover, some of them are toxic or otherwise incompatible with other elements in the blood. Nature has taken care of this by providing each with a special protein carrier which seizes the small molecule, locks it to itself and prevents it from diffusing through membranes or reacting with other substances. An excellent example is the transport of iron. In the plasma (the cell-free, fluid part of the blood) there is a certain large protein which can bind iron tightly to itself—the only plasma protein with this ability. Each molecule of the protein can take on one or two atoms of iron, and it is this protein that provides the means of transport of the iron in the body to its various destinations, including the tissues where the iron is used to build hemoglobin. Similarly specific plasma proteins serve as carriers for other small molecules. The albumins, the most common proteins in the plasma, can transport many kinds of compounds, including metals, dyes and drugs.

The second important function of the blood is to fight infection. The primary line of defense is held by the white cells, which rush to engulf and render inactive any invader. They number only one for every 750 red cells, and their life span is very short. Any injury that impairs the production of white cells (*e.g.*, severe exposure to radiation) greatly increases susceptibility to infection. Another line of defense is provided by antibodies; these proteins, produced in response to invasion by viruses, bacteria or foreign proteins, are concentrated in the blood as gamma globulins.

The blood's third main function is to maintain its own composition and integrity. For this nature has developed most ingenious and elaborate mechanisms. The blood halts its own escape from the body by a self-starting series of reactions, still imperfectly understood, which involves calcium, the platelets and a number of plasma proteins, all in trace amounts. The process leads to the formation of thrombin, which in turn converts the protein fibrinogen to the blood-clot material fibrin. The internal composition and viscosity of the blood are controlled mainly by osmosis, which regulates its water content. This is no simple matter, for parts of the circulatory network, notably the capillaries, are permeable to water. The control of the water balance between the blood and the tissues with which it is in contact is exerted to a large extent by the concentrations of the large protein molecules on the two sides of the capillary wall.

Preservation

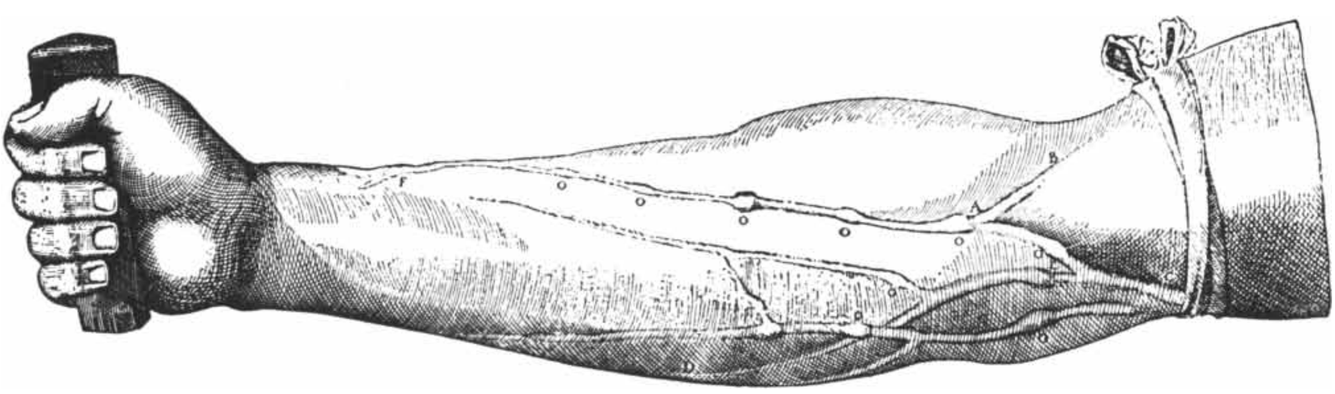
Detailed understanding of the functions of the blood, and of the surprisingly large cast of actors that play their parts in this versatile fluid, has come only within the last 15 years. We now know that besides antibodies against various infections the blood contains at least 10 substances involved in clotting, 20 different enzymes, fat-containing proteins, carbohydrate-containing proteins, metal-containing proteins, hormones, albumins and doubtless other still unidentified substances. All this has compelled a completely new outlook on how blood should be used in medicine. It becomes plain that to administer whole blood to a patient who needs only one of its components—a common practice today—is grossly wasteful. As more and more components are separated from the blood and made widely available, each pint of blood should multiply in value. And since the demands are steadily increasing, there is more and more need for strict economy and maximum efficiency in the use of the blood supplied by the voluntary donations of the public.

It is a most fortunate fact that the discovery of the various useful components of blood has gone a long way toward solving the most troublesome problem in using it—the problem of preserving it. Whole blood is an extremely perishable material. Since late in World War II it has been kept in a solution (citric acid, sodium citrate and dextrose) which is popularly supposed to preserve it for 21 days; actually what is preserved is not the whole blood but primarily the red cells. As soon as blood is removed from the body, it begins to degenerate. Its enzymes go on breaking down the proteins, and no fresh ones are manufactured: within a few days the blood has declined in ability to clot, the white cells have begun to die and the red cells to lose their integrity. The introduction of the citrate solution took care of the red cells (for 21 days), and the development of the freezing and drying method made it possible to preserve plasma. But these methods can only be considered temporary expedients, for it is not economical to store whole blood just for the red cells or to destroy valuable proteins in plasma just to keep the plasma. For treating shock the albumin in plasma is fully as effective as the whole plasma.

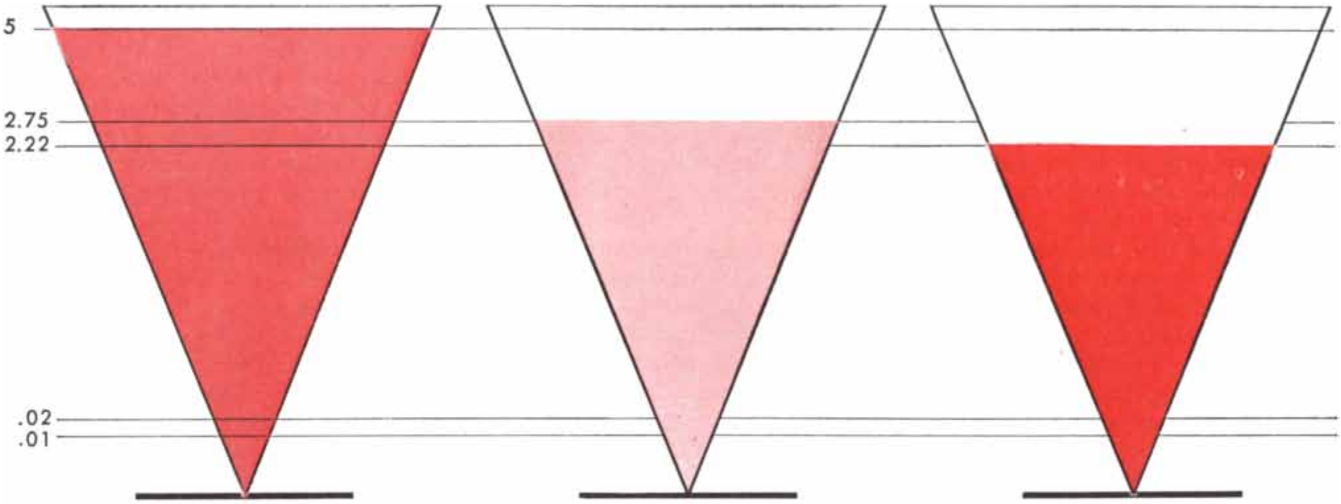
The problem of preserving blood is vastly simplified when it is reduced to the preservation of individual components, for it is easier to meet the environmental requirements of a single material. The red cells, white cells and platelets can be kept in a viable state far longer if they are separated from the plasma and from each other, and the plasma proteins that have been isolated have proved to be almost unbelievably stable when treated individually.

The Components

The first feasible process for the separation of the proteins of plasma on a large scale was developed in the laboratory of the late Edwin J. Cohn at the Harvard University Medical School. Dr. Cohn had made great strides in this work even before Pearl Harbor, and some material that had been produced at the Harvard pilot plant was actually used for casualties of the Pearl Harbor attack. The U. S. military services' first demands were for the serum albumins, which had proved exceedingly effective in the treatment of shock. But Cohn insisted that the other protein fractions in plasma also should be saved, and in 1943 he urged the Red Cross to establish a civilian blood program, predicting that the antibodies in plasma would be valuable for controlling measles and perhaps other infectious diseases. The fractions later isolated have indeed proved more important than albumin in civilian medicine. Besides the antibodies, known as gamma globulins, they include thrombin (the enzyme that



VEINS OF THE ARM, tapped for the blood used in medicine, were depicted by Fabricius of Aquapendente (1537-1619), who first described their valves. Fabricius was a teacher of Harvey, and this engraving was the basis for similar ones in Harvey's book.



PRINCIPAL FRACTIONS OF THE BLOOD are depicted in proportion by these schematic beakers. The average human body contains 5 liters of blood (*first beaker*), which consists of 2.75 liters of plasma (*second beaker*), 2.22 liters of red cells (*third beaker*),

converts fibrinogen into fibrin), fibrinogen itself and the antihemophilic globulin, extremely effective in the control of the bleeding tendency in hemophilia.

Pure albumin was found to be so stable that it could be kept in solution, without refrigeration, for more than five years. In emergencies concentrated solutions of albumin have a great advantage over dried plasma, which has to be dissolved in sterile water before use. Purified fibrinogen, which is extremely unstable in solution, proved to be stable indefinitely in the dry form, and in combination with thrombin was used for the control of surgical hemorrhage, as an aid in the removal of kidney stones and to control *post partum* hemorrhage. A protein that separates with fibrinogen is active in producing a normal clotting reaction in persons suffering from hemophilia.

The antibody proteins were concentrated in another fraction from which they were isolated in a purified form suitable for clinical use. The gamma globulins have been kept for 11 years, six in the dry state and an additional five in solution. When gamma globulin is prepared from a large pool of plasma (in commercial production a pool often contains plasma from 1,000 to 5,000 donors) the antibody content is of course representative of the immune status of a population. The measles antibody fraction was found after wide clinical trial to be extremely effective in the control of measles. Injection of a small amount of gamma globulin into a person known to have been exposed to measles completely prevents the disease. This is a passive immunity, however, because it persists only as long as the injected gamma globulin remains in the bloodstream—some 30 to 40 days. Use of the preventive dose would be dangerous in the long run, because it would tend to produce a population highly susceptible to measles. It is better to use a smaller dose, which reduces measles symptoms so that they are barely noticeable and at the same time allows the patient to produce his own antibodies and thus acquire active immunity. This dosage policy is being aimed at in the use of gamma globulin against poliomyelitis.

In certain diseases the patient retains very little antibody after recovering from the infection. Mumps is such a disease. Ordinary gamma globulin provides no protection from mumps. But gamma globulin from persons convalescing from mumps has proved to be very effective in modifying the severity of the disease. This suggests that convalescent plasma might have great potential value in various infections, but so far only limited efforts have been made to make such plasma available.

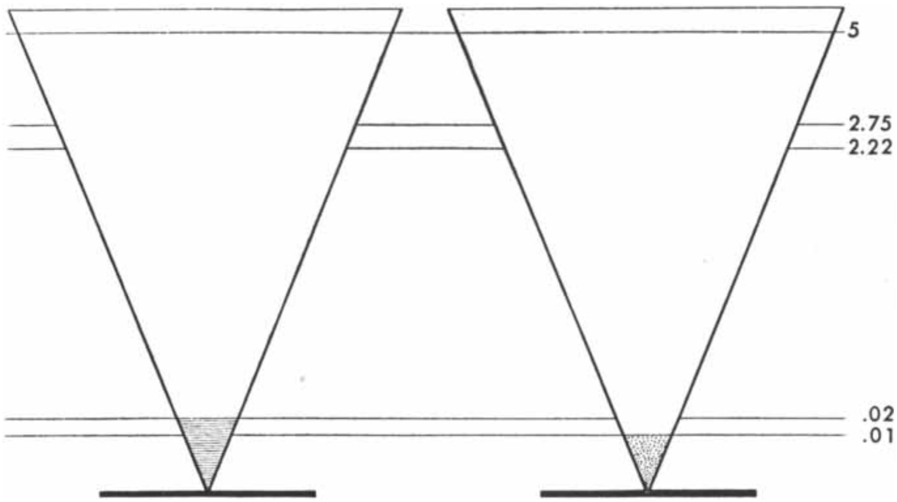
In 1944 Cohn called attention to another promising opportunity. He pointed out that periodic sampling and analysis of the pooled plasma of a population might make it possible to follow the course of epidemics, "much as the course of a comet may be followed by the photographic records of the skies."

Blood may carry microbes as well as antibodies, and the operation of transfusion services on a large scale of course heightens the danger of the spread of disease. During World War II a virus disease known as serum hepatitis was transmitted through plasma to many persons in the armed forces. The risk was known, but it was taken because the need for plasma in military medicine was so great. Fortunately no virus diseases have accompanied albumin and gamma globulin, which have been given to immense numbers of people. Possibly the reason is that viruses, like other complex proteins, are removed when these two blood derivatives are prepared. There are additional safety factors in the fact that gamma globulin is dispensed in solution, in which the hepatitis virus seems to be much less stable than in the dry state, and that all albumin is heated for 10 hours at 140 degrees F. before being released. Fibrinogen, on the other hand, may be contaminated with the hepatitis virus, but it seems likely that this fraction, too, can be rendered safe from virus transmission.

There is every reason, therefore, to press on with the separation of the blood into its parts. Fractionation kills three birds with one stone: the separated components make the limited blood supply go much farther, they can be preserved longer and they reduce the risk of the spread of virus disease. Since the war a great deal of research has been done on the fractionation of blood, not only in Cohn's laboratory at Harvard but in a number of other laboratories as well. This program was given coordination and considerable impetus by a 1949 conference of workers on the problem, arranged by Cohn at the request of the National Military Establishment's Research and Development Board.

Handling Blood

Essentially the problem is to reduce interactions among the components by rapid cooling and to separate them in a



.02 liter of platelets (*fourth beaker*) and .01 liter of white cells (*fifth beaker*). The height of the fraction in each of the beakers is an accurate representation of its relative volume.

way that will not damage them, thus bringing them to a stable condition before they have begun to deteriorate. Under wartime conditions it was impossible to process the blood rapidly: often the plasma had to be shipped hundreds of miles to the processing plant, and this sometimes meant a delay of 72 hours or more. Moreover, the processing methods themselves were time-consuming and damaging to the protein components. Much of the postwar research has been devoted to the problems of handling and speeding up the processing of blood.

In handling blood the first requirement is to prevent it from clotting. A glass or rubber surface promotes the coagulation of blood, apparently because such a surface is wetted by it and breaks down the platelets, initiating the coagulation reactions. Furthermore, a wettable surface damages the white blood cells. Hence at the beginning the tubes used in blood transfusions were coated with a non-wettable substance such as paraffin. The chemist Eugene G. Rochow, discoverer of the silicones, had devised a silicone coating which later proved very effective in preventing the clotting of blood in glass bottles, and he also helped develop a treatment which made metal surfaces non-wettable. For tubing an inert plastic was used instead of rubber, and the surgeon and inventor Carl Walter developed a new intravenous needle through which blood could flow in almost laminar fashion.

In the chain of reactions that causes blood to clot the most vulnerable link is the reaction involving calcium. Sodium citrate prevents clotting by incorporating calcium in an imprisoning compound. But the use of citrate as the anti-coagulant provides a false security, for it is highly toxic to the white cells. To help find another anti-clotting agent, Cohn turned to Dr. Walter and John G. Gibson, hematologist at the Harvard Medical School. They learned that an Army researcher, Dr. Arthur Steinberg, had found a cation exchange resin effective for this purpose. Passed over the resin, the blood yields its calcium to the resin in exchange for sodium. The process is just like the softening of water; indeed, Steinberg used standard water-softening exchange resins in his experiments. Drs. Gibson and Walter, aided by Gibson's brilliant young colleague, the late Edward S. Buckley, Jr., soon determined that the resins did no damage to blood cells and removed calcium rapidly enough to be useful in the collection of blood from donors. Almost all the blood used in the researches at Harvard during the past three years has been collected over an exchange resin.

The next problem was to find ways to cool the blood as rapidly as possible. It is not a simple task to cool a bottle of blood quickly to the temperature of ice. Even if the bottle be immersed in a bucket of ice and shaken constantly, the time required is too great to make the operation practical in a donor center. A small, extremely efficient heat exchanger was developed to do the trick. Made of a thin-walled plastic tube six feet long, coiled in a refrigerated bath, the unit greatly increases the length of time the flowing blood is in contact with the cold walls and effectively reduces the temperature of the blood within seconds after it leaves the donor's circulation.

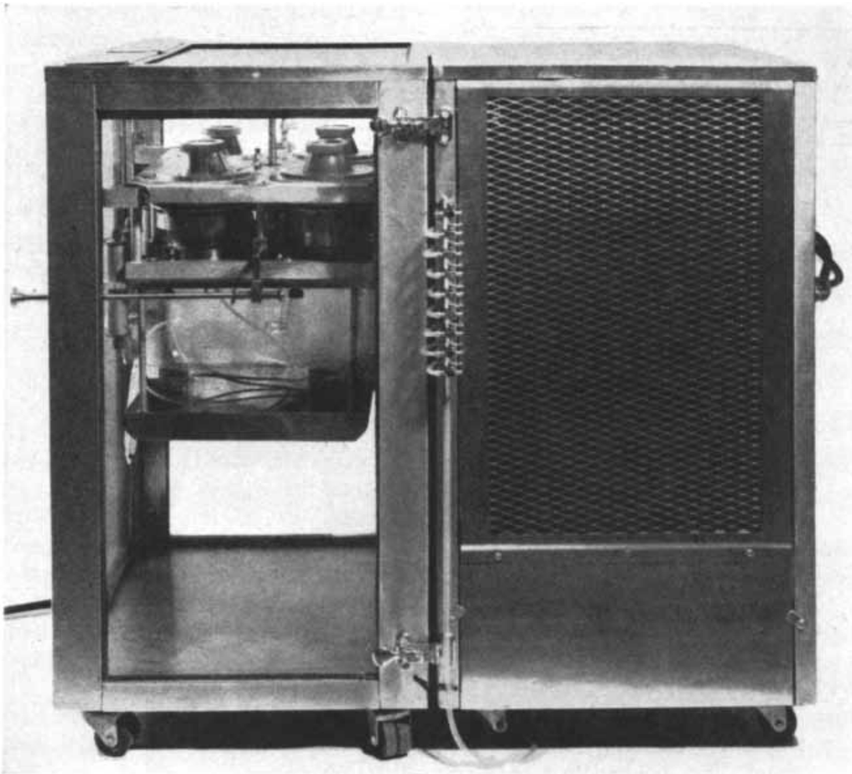
There remained the formidable problem of separating the blood components. Plasma was then and still is separated in a high-speed centrifuge, which throws the formed elements (cells and platelets) to the bottom of the bottle and leaves the clear, straw-colored plasma at the top. This procedure does no harm to the plasma, but it irretrievably damages the delicate white cells and platelets. There was, in fact, no practical method of separating white cells or platelets in a viable state.

Separation

A major break in the problem came in 1948. It had long been known that when blood is allowed to stand, the cells slowly sink to the bottom of the fluid. The Swedish investigator Robin Fahraeus had shown that the red cells have a tendency to pile up, much like a stack of coins, in what he called *rouleaux*, and he discovered further that an increase in the concentration of fibrinogen in the plasma speeded up the rate of the red cells' sedimentation. In 1948 A. H. Minor and L. Burnett at the Sloan-Kettering Institute observed the striking fact that however rapidly the red cells sedimented, the white cells always remained suspended in the fluid. Gibson and Buckley at Harvard quickly recognized the value of this clue. By adding fibrinogen, which promoted the formation of rouleaux and accelerated the sedimenta-

FRACTION	PER CENT
SERUM ALBUMIN	52
γ- GLOBULINS	11
β_1 LIPOPROTEIN	5
FIBRINOGEN	4
α_1 LIPOPROTEIN	3
β_1 LIPID-POOR EUGLOBULIN	3
β_1 METAL-COMBINING PROTEIN	3
α_2 GLYCOPROTEIN	1.2
ACID GLYCOPROTEIN	.5
α_2 MUCOPROTEIN	.5
COMPLEMENT	.4
COLD INSOLUBLE GLOBULIN	.15
α_2 PROTEIN	.1
PROTHROMBIN	.1
BILIRUBIN GLOBULIN α_1	.05
β_1 PROTEIN	.05
ISOAGGLUTININS	.03
CHOLINE ESTERASE	.005
ALKALINE PHOSPHATASE	TRACE
AMYLASE	TRACE
CAERULOPLASMIN	TRACE
β GLUCORONIDASE	TRACE
HYPERTENSINOGEN	TRACE
IODOPROTEINS	TRACE
PEPTIDASE	TRACE
PLASMINOGEN	TRACE

PRINCIPAL FRACTIONS of the plasma are also given. They consist of proteins.



BLOOD IS FRACTIONATED by one of several machines recently developed at Harvard University. At the right is a compact refrigeration system. At the upper left are four small centrifuges. The donor lies on a cot beside the machine so that his blood runs directly into it through a thin tube. The fractions are collected in small plastic bags beneath the centrifuges.

tion of red cells, they were able to recover, after about an hour, a suspension containing 80 per cent of the white cells and platelets in the blood. How fibrinogen promotes the aggregation and sedimentation of red cells is not yet clear; the action appears to be related to the asymmetric shape of the fibrinogen molecule. A large number of otherwise unrelated substances have the property of causing red cells to form rouleaux; these include polyvinyl pyrrolidone (PVP) and certain polysaccharides related to starch. The accelerated sedimentation process has now become one of the best methods for separating red cells, white cells, platelets and plasma.

After removal of the red cells, the suspended white cells and platelets are separated from the plasma by a so-called "falling film" centrifuge: they are centrifuged out of a shallow, flowing stream of the fluid. Recently another way of separating platelets has been found. Platelets are held by the exchange resin over which the blood passes, and some can be recovered by washing them off the resin. James L. Tullis and W. H. Batchelor of the University Laboratory discovered that the resin could capture more platelets if a little of it was saturated with calcium beforehand.

The successful development of methods for separating the formed elements of the blood opened new vistas. For the first time white cells and platelets were available for research into their nature and also into their preservation. The preserving of white cells and of platelets presented two quite different problems.

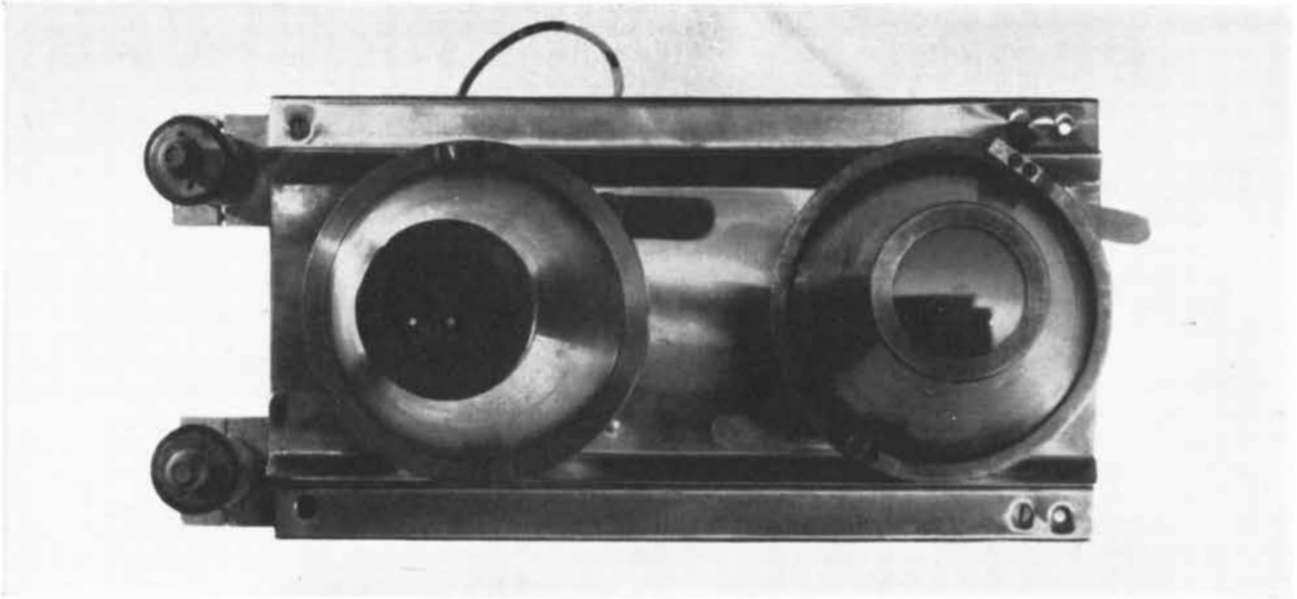
Of all the formed elements, the white cells are the most active metabolically. Under the microscope fresh white cells are seen to be in constant motion, continually changing their form like amoebae. Their metabolic activity is so great that white cells do not survive more than a few hours after removal from the body; they can be saved only if they are placed in a properly controlled environment. The maintenance of the white cells in a quiescent state for preservation is a difficult task, and the problem still remains far from solution. Space does not permit more than a brief account of the progress that has been made. Working on a chance observation, Tullis, who is in charge of the investigation, tried using a gelatin-containing medium which, on chilling, forms a gel and keeps the cells separated from one another. When the gel suspension is liquefied by warming up to body temperature, the cells are found to have survived remarkably—a matter of weeks instead of their normal lifetime of three or four days in the body or a few hours in bank blood. Despite these gains in the preservation of white cells, their succcessful transfusion is a hurdle not yet surmounted, partly because the problem of typing them is intricate but primarily because their life span is so short that large amounts would have to be transfused at frequent intervals.

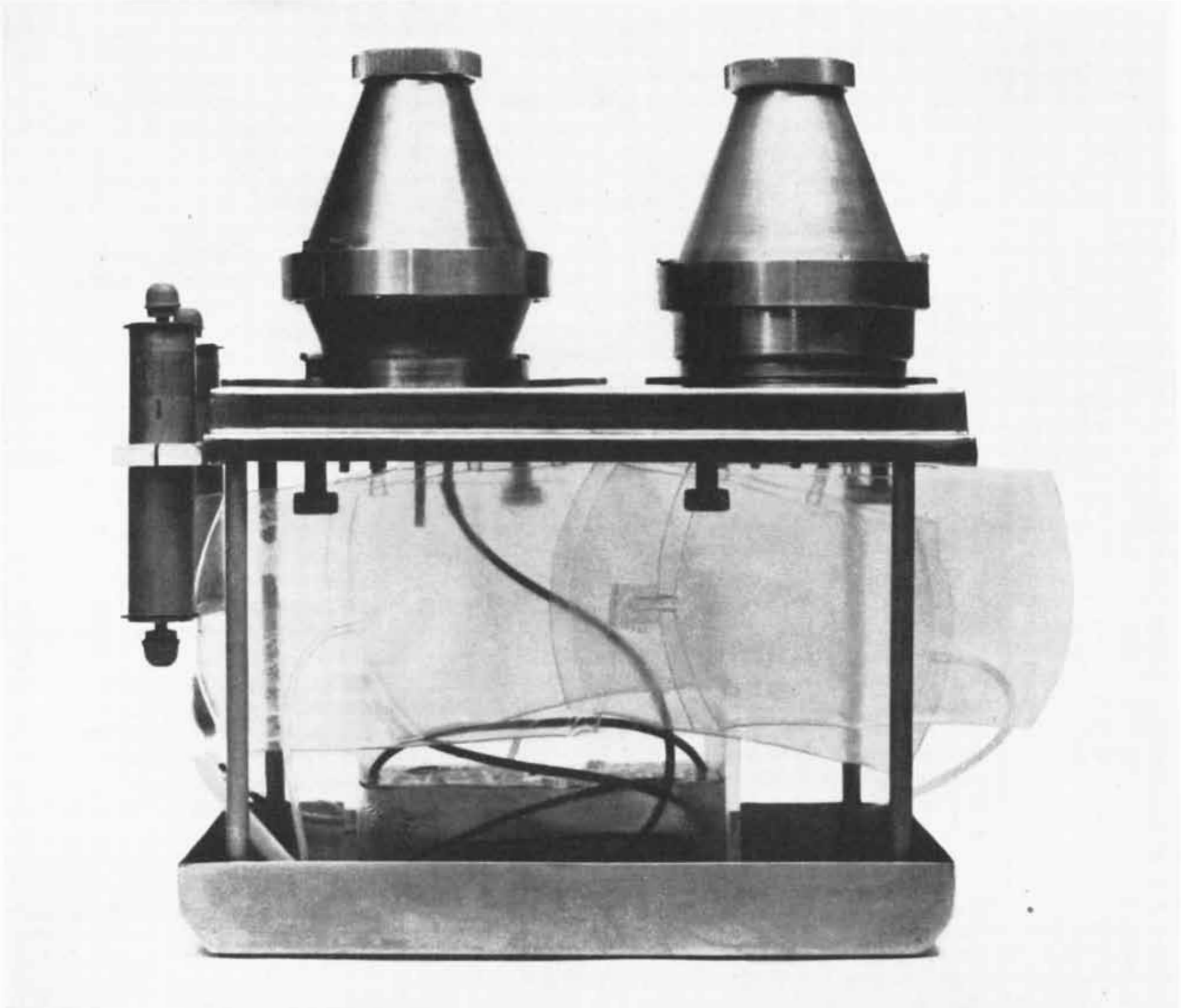
The platelets, in contrast to the white cells, have very little metabolic activity. But they cannot withstand exposure to wettable surfaces or packing together too tightly. However, if carefully handled and stored in a gelatin-containing medium similar to that used for white cells, they retain their clot-promoting activity for months and can be successfully transfused.

Proteins and Metals

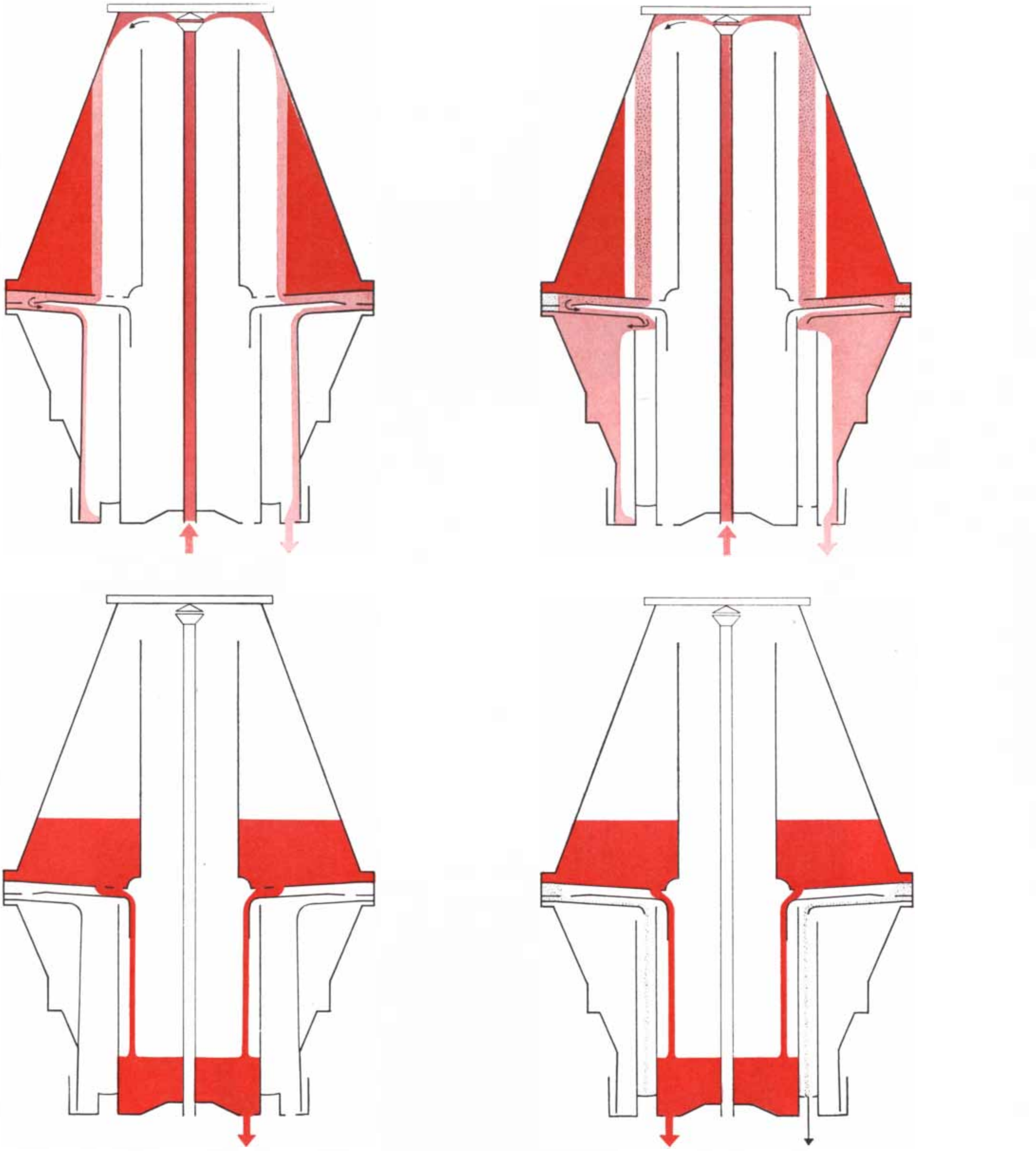
As for the plasma proteins, much of the research has focused on their interesting reactions with metals; indeed, these reactions have become the basis of a whole new field of chemistry. Proteins unite with metallic ions (calcium, magnesium, manganese, copper, cobalt, iron, zinc) with various degrees of vigor. At one end of the spectrum are proteins to which the metals are so firmly attached that the molecule must be broken up to release them. The iron-containing protein, hemoglobin, falls in this group. Then there are enzyme proteins which require a metal ion for their activity and can take on the metal or shed it. At the other end of the spectrum are proteins which form only loose associations with metals. The proteins that bind calcium are representative of this group; they readily give up their calcium to simple exchange resins.

Let us look at the reactions of proteins with zinc ions as an example. The addition of a zinc ion to a protein often produces a pronounced change in the solubility of the protein, and the reaction is completely reversible: when a reagent which removes the metal is added, the insoluble compound passes back into solution. The addition of zinc to human plasma precipitates roughly one third of the proteins. The precipitate contains all the fibrinogen and immune globulins, the fat-containing proteins known as beta-lipoproteins and a number of others, especially the more labile proteins. This is highly convenient, because it makes easy the separation of the immune globulins and the clotting proteins, which can be extracted from the precipi-



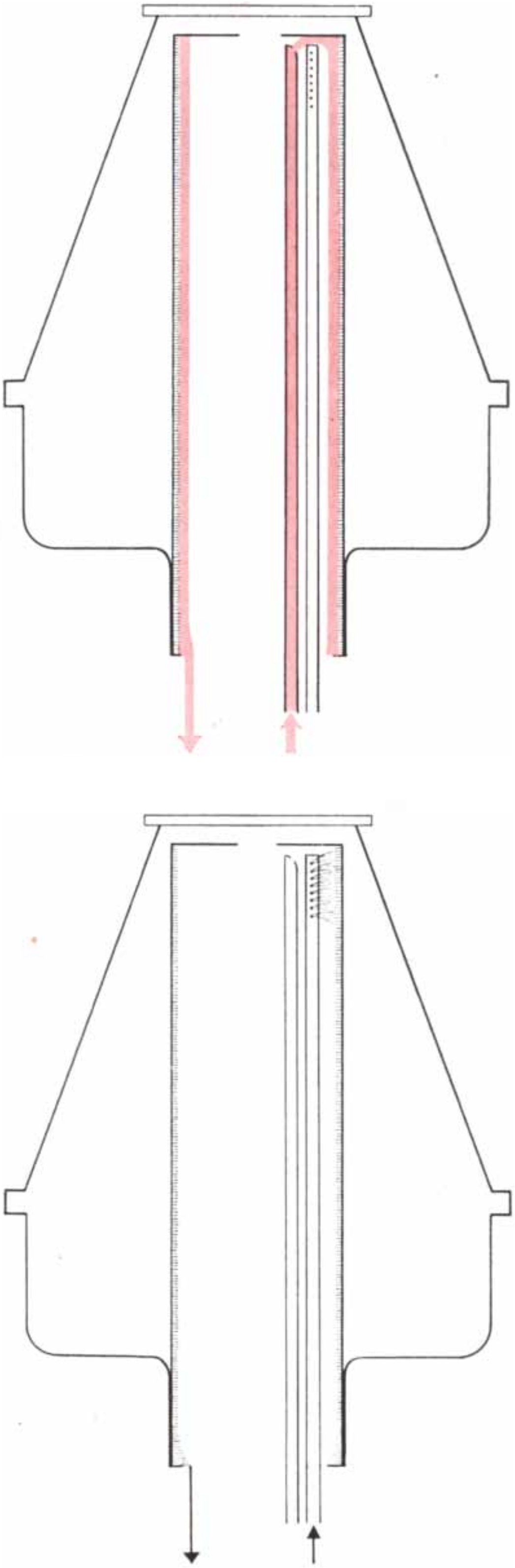


TWO CENTRIFUGE ROTORS of the four in the machine on the opposite page are shown from the top (*upper photograph*) and side (*lower photograph*). The rotors turn at 2,000 revolutions per minute, fractionating blood as shown in diagrams on next two pages.



BLOOD CELLS AND PLASMA are separated by centrifuge. At the top is a cross section of a spinning rotor; at the bottom the rotor is stopped. The blood enters the rotor from the bottom and flows down the inner wall of its upper chamber. Because red and white cells are heavier than plasma, they move outward, leaving the plasma behind. As the chamber fills, the plasma overflows through a ring of holes and empties into a stationary collecting chamber. When most of the plasma is separated in this manner, the rotor is stopped (*bottom*) and the red and white cells drain out together.

RED CELLS, WHITE CELLS AND PLASMA are separated in an alternate rotor. Here a small quantity of high-density solution is placed in the upper chamber of the spinning rotor. As the blood flows outward, the heavier red cells penetrate the high-density layer, leaving the white cells and plasma behind. As the chamber fills, the white cells and plasma fall through a ring of holes. The plasma pours into the lower chamber, while the white cells collect in the space between the two chambers. When the rotor is stopped (*bottom*), the red and white cells drain out separately.



PLATELETS are separated in a "falling-film" rotor. Here the platelet-containing plasma flows downward in a thin film on the inside of a spinning tube. Though only slightly heavier than plasma, the platelets need only traverse the thickness of the film to be removed from the flowing stream. The plasma discharges from the bottom of the tube. The platelets are then washed out.

tates in purified form by chemical and simple ion-exchange processes.

The plasma proteins left after removal of those that go off with the zinc include all the albumin, the iron-binding globulin, most of the carbohydrate-containing proteins and the so-called alpha-lipoprotein. These proteins are responsible for more than 80 per cent of the osmotic efficiency of whole plasma. With part of the water removed this solution could be quite as effective as whole plasma or concentrated albumin solution for the treatment of shock and burns. Moreover, it is remarkably stable—considerably more stable than plasma. It has therefore been named Stable Plasma Protein Solution (SPPS). The solution requires no refrigeration during storage; preparations stored for two years are still crystal clear. Furthermore, SPPS can be pasteurized by heating at 140 degrees Fahrenheit for 10 hours without harm. This kills the virus of serum hepatitis and makes the solution safe.

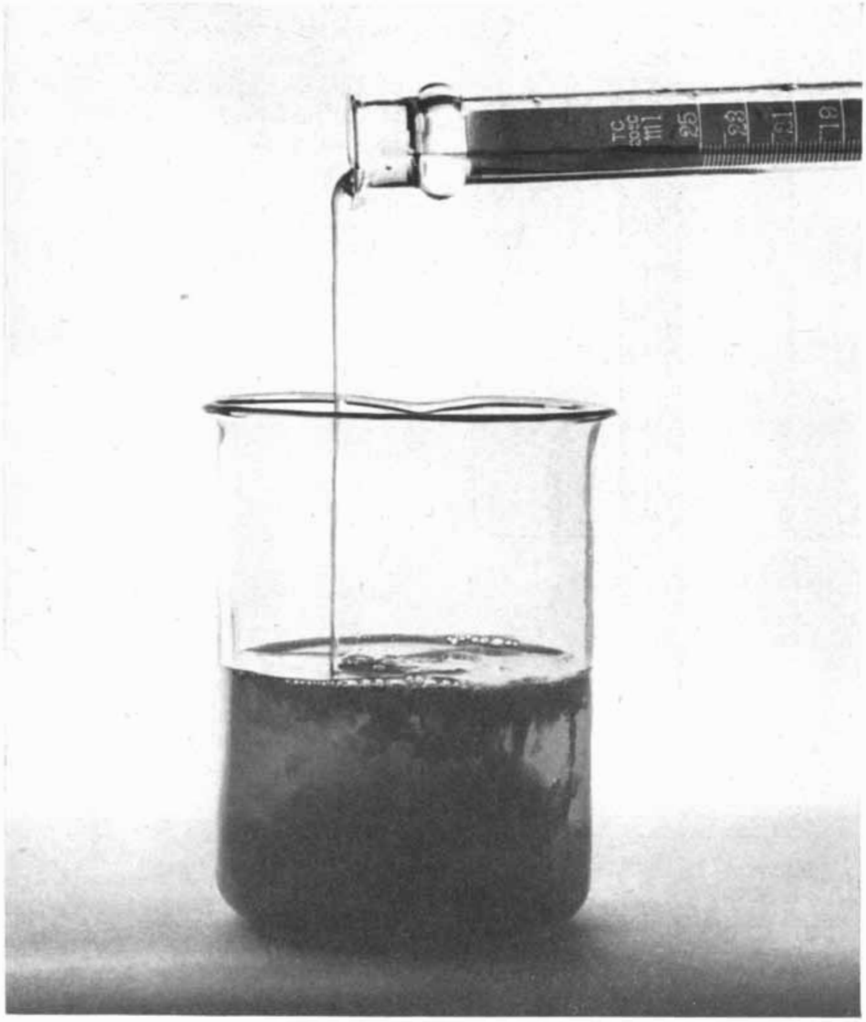
The almost unbelievable stability of the products prepared by this method is without precedent in protein chemistry; doubtless it is a result of not exposing the proteins to the harsh conditions of acidity which obtain in all older methods. The metal treatment method has greatly simplified the preparation of the gamma globulins and has made possible for the first time the isolation in undamaged condition of many physiologically important proteins. Already it appears, for example, that the important proteins involved in blood coagulation, as well as a number of other protein components of the plasma, can be made available for clinical evaluation and use.

Besides zinc, metals such as calcium, magnesium and even lead and mercury are being used as reagents; the latter two metals, generally regarded as poisons, can be removed by ion exchange resins, but so far they have been used only experimentally. In the broad program at the University Laboratory Frank Gurd has put the metal reagents to work in investigating the nature of the groups on the protein molecule with which the metals react. The new tools are also being utilized in the study of tissues other than blood—the proteins of milk and several viruses.

Processing at Bedside

What are the practical implications of this vast new store of knowledge about blood? Aside from the fact that it has made available for scientific study supplies of white cells, platelets and the labile proteins of plasma, it has already borne medical fruit in the form of new equipment for the virtually automatic processing of blood. This apparatus, called Biomechanical Equipment for Blood Collection and Processing, has been under development in Cohn's laboratory for over three years and is now essentially completed. The current model is a portable three-foot cabinet, one half of which houses a compact refrigeration system, the other half a mechanical driving unit and centrifuge. The unit is placed near the cot on which the donor lies. Just before use, a sterile cartridge, taking the place of the blood bottle, is inserted into the machine. This engages the driving mechanism and couples the cartridge with the circulating refrigerant. The nurse then has only to prepare the donor and insert into the vein of his arm a specially coated needle connected to the cartridge by plastic tubing. The blood flows first through an ion-exchange column, which removes the calcium and may be used to collect platelets, then through the heat exchanger, which lowers its temperature to just above freezing. After this it flows into the heart of the machine, a complex multichambered bowl rotating at approximately 2,000 revolutions per minute.

As the blood spurts into the uppermost chamber of this bowl, it is caught in the centrifugal field and thrown outward along the curved wall of the chamber. Here it comes into contact with a layer of solution of a certain density, such that the heavy red cells go through it and the lighter plasma and white cells float inside it. The red cells, the "high density solution" and the suspension of plasma and white cells thus form three separate layers. As blood continues to flow in, the volumes of the red-cell and plasma layers increase until the chamber is filled. This occurs approximately halfway through the donation. Thereafter the white cells and plasma overflow through small openings at the inner surface into a second chamber, which concentrates the white cells precisely as the upper chamber concentrates the red cells, leaving only the plasma to overflow into a separate container. When the nurse removes the needle from the donor's arm, the separation of cells and plasma is complete: the platelets are in the ion-exchange column, the red cells in the centrifuge's upper chamber, the white cells in the lower chamber and the plasma in its container. The centrifuge is then stopped; the red cells and white cells fall into separate containers, and the platelets are washed out of the



A THIRD OF THE PROTEINS in plasma are precipitated by the addition of zinc. These include fibrinogen and gamma globulin. The components are then separated by other means.

column. Alternatively, the platelets and the white cells may be left with the plasma, to be removed later by centrifugation from a falling film.

This ingenious new centrifuge was designed by Cohn and his mechanical experts, including Charles Gordon, Fred Gilchrist and Robert Tinch, specifically for centrifuging blood. All processing is carried out in a closed, sterile system. The centrifugal force to which the cells are exposed in the new machine need be only 200 times gravity—a fraction of the force employed in the standard equipment now in use. And the equipment is flexible. For example, the operating cycle can be varied to meet the requirements of the user. The simplest operation might be that of a blood bank that wanted to salvage the plasma and red cells from whole blood which had been stored for three weeks and from which the white cells and platelets had long since disappeared. For this operation only the upper red-cell chamber would be needed, to separate the red cells and other remnants of formed elements from the plasma.

A more unusual application for which the new equipment is being adapted is called immunophoresis. This technique was suggested by the virologist Joseph Stokes, Jr., of the Children's Hospital in Philadelphia, as a means of solving the shortage of gamma globulins for poliomyelitis protection. Stokes proposes to collect the blood of selected donors who are hyperimmune to polio, separate the plasma and precipitate the globulins therefrom and then reinject the cells and remaining plasma proteins into the donor. This would be a globulin donation rather than a blood donation. Since about 93 per cent of the proteins in a pint of blood would be returned to the donor, the burden of a donation would be slight and a donor might be able to give globulin as often as once a week.

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They are not handsomely tapered but often resemble a small hamburger bun. This unpoetical form, frozen by high-speed photography, is analyzed to reveal the forces that mold it

by James E. McDonald

One of the few predictions that a meteorologist can make with confidence of almost 100 per cent accuracy is that if you ask an illustrator or cartoonist to draw a falling raindrop, his picture will be dead wrong. Without fail he will give it the streamlined shape commonly known as the teardrop. Meteorologists have known for many years that a real raindrop bears no resemblance to this drawing-board impostor. As pictured by high-speed photography, the usual small-sized drop (less than a millimeter in diameter) is almost perfectly spherical, and a larger drop is a squat object resembling nothing so much as a hamburger bun.

While this real picture is esthetically less satisfying than the teardrop fiction, it is of considerable interest to meteorologists. Just why the large raindrops take the deformed shape that they do has been a puzzle for half a century. I became interested in the problem in a casual way which seems to illustrate how the non-systematic approach in science can sometimes bear fruit. While browsing through a work on surface physics, I came upon a general equation which described the internal pressure in any fluid object, whatever the shape of its surface curvature. A slightly different equation, applying only to a spherical shape, had previously been tried on the drop problem without complete success. This more generalized relation was immediately recognizable as the key to an understanding of the deformation of large raindrops. It took only a few minutes to formulate the general outlines of a new hypothesis for raindrop shape. But to obtain an adequate check on this new hypothesis and to expand it in certain necessary details required several months' work. The results seem to show that one can, in fact, give a fairly good account of the way in which oversized raindrops develop their hamburger-bun shape. They also bring out that a falling raindrop is the seat of some surprisingly complex physical processes.

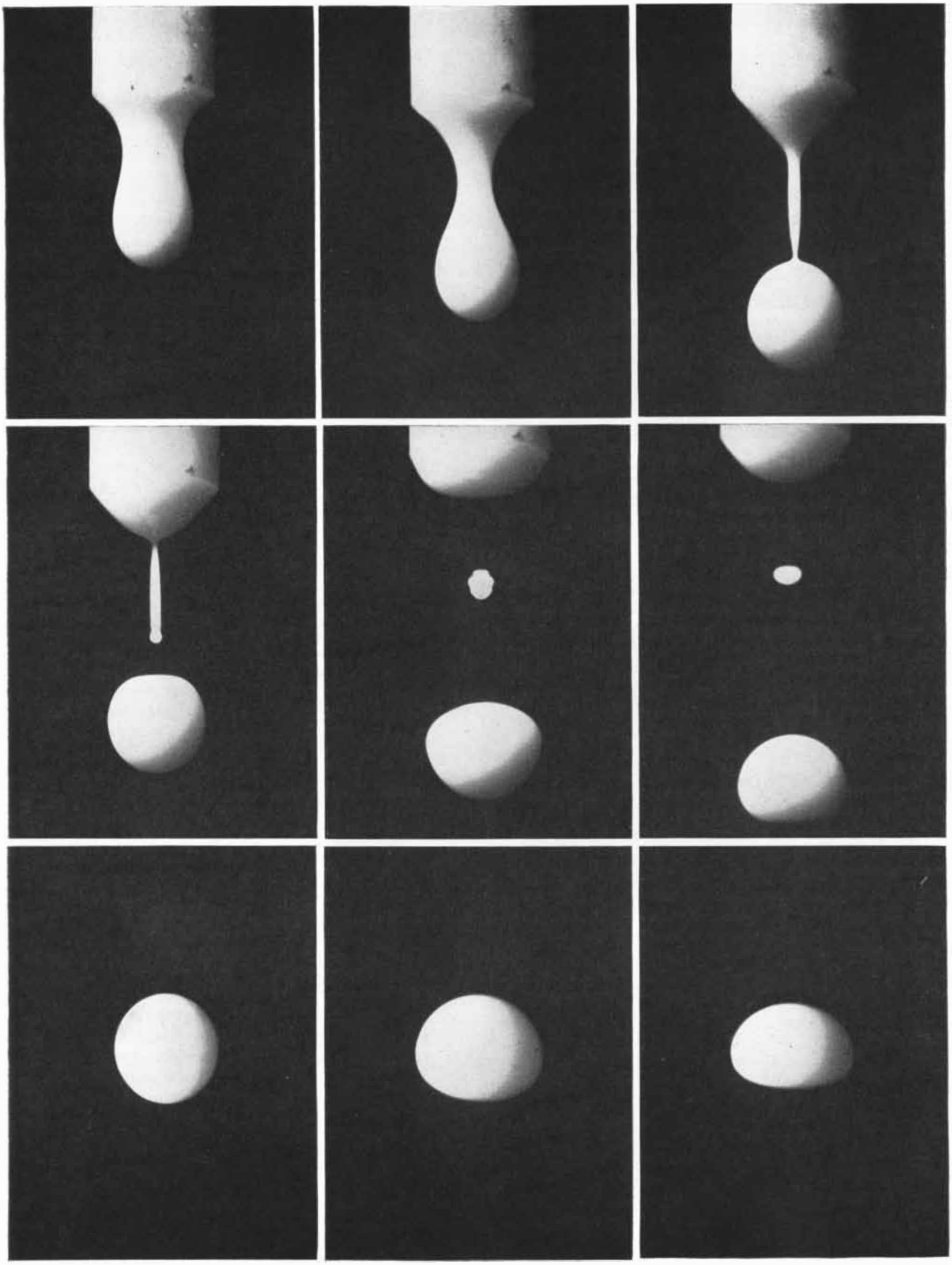
One might begin by asking why a drop of water should bear any resemblance to a sphere at all. The answer is that surface tension always tends to reduce the surface of a free mass of liquid to the smallest area it can achieve. The smallest possible surface area is that of a sphere, and an isolated drop of liquid not distorted by external forces is pulled by its surface tension into a spherical shape. In terms of thermodynamics, it adjusts itself to the spherical shape to minimize its surface free energy.

The question can also be considered in terms of pressure. The internal pressure just inside the convex surface of a drop is higher than the external pressure prevailing in the surrounding gas. The smaller the radius of curvature, the greater is the pressure difference between the two sides of the convex surface. (For example, a cloud droplet of one micron radius has an internal pressure of more than two atmospheres.) If our isolated drop should momentarily assume some shape other than that of a sphere, its surface would have different radii of curvature at different points, and the internal pressure just below the surface would momentarily be dissimilar at these various points. The consequent pressure gradients within the drop would tend to force liquid from the regions of sharp surface curvature to those of more gentle curvature. This is equivalent to saying that surface tension, through its control of internal pressure, reshapes the drop into a sphere whenever it happens to become slightly deformed. When the drop is finally brought into the shape of a perfect sphere, the uniform surface curvature makes the pressure difference uniform at all points of its surface, and the internal pressure within the drop also is uniform, provided that the external pressure field around the drop remains so.

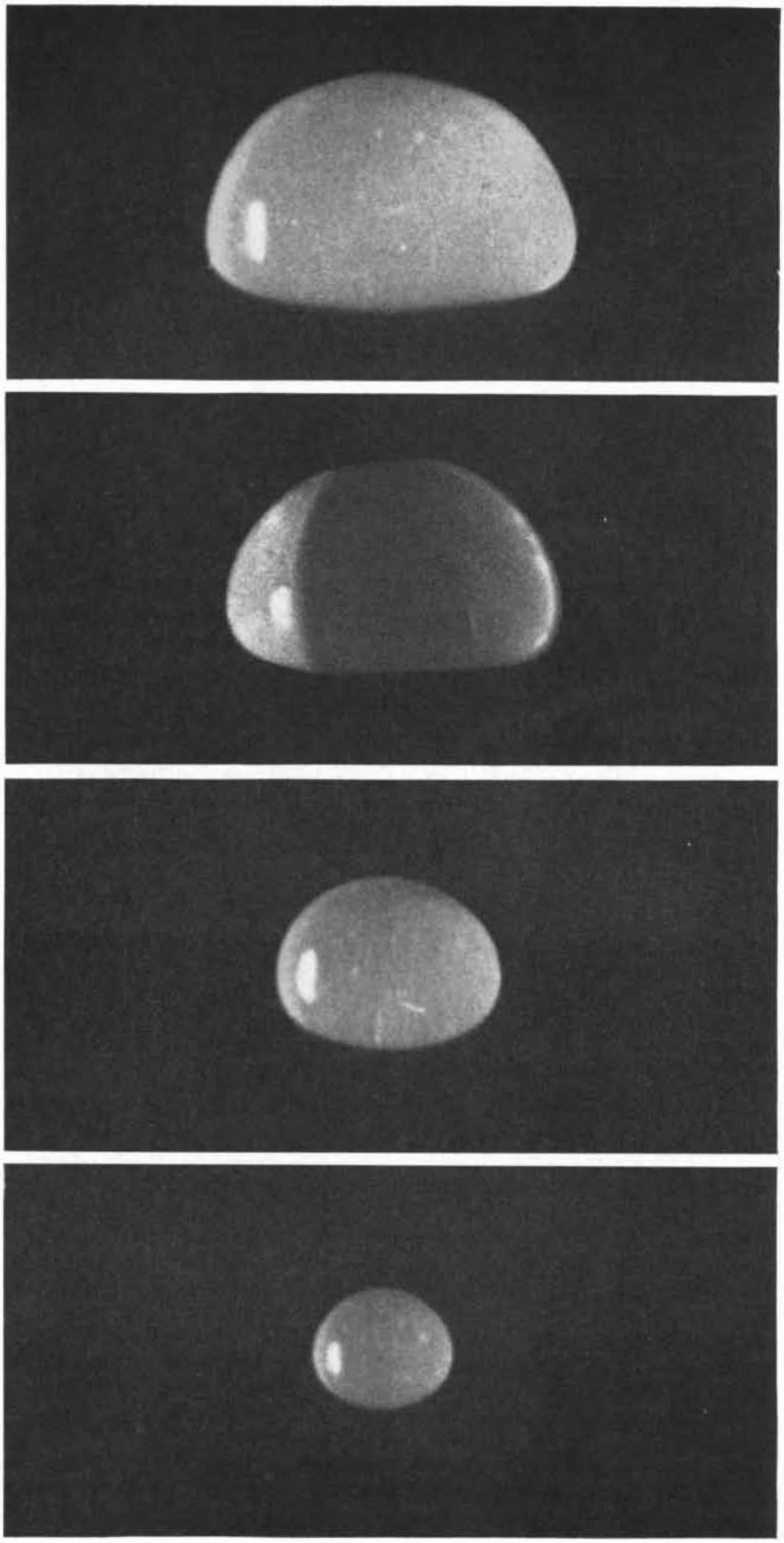
Such a uniform pressure field actually exists in an ordinary fog or cloud, and, sure enough, photomicrographs of cloud and fog drops show that these tiny particles are indistinguishable from perfect spheres. Doubtless precise measurements would disclose that they depart slightly from perfect sphericity, because of the weak gravitational and aerodynamic forces acting on them, but a manufacturer of precision ball-bearings would be very happy to turn out bearings as close to perfection as these drops.

The disturbing effects on drop shapes that appear as one considers larger and larger drops seem to be due almost entirely to aerodynamic and gravitational forces. A. F. Spilhaus, now at the University of Minnesota, was the first to call attention to the role played by aerodynamic forces in shaping raindrops. As drops grow larger and their falling speed increases, the disturbance of the air sets up momentary non-uniformities in the air pressure around them. The big drops that pelt down in a summer thunderstorm plummet through the air so fast that they continuously create about them their own shape-deforming pressure fields as they fall.

Now it is well known that when a body falls the air pressure just under the body becomes higher than average and the pressure around its sides lower than average. This means, of course, that the internal pressures within a large falling



FALLING DROPS OF MILK, used instead of water because of their high visibility, were photographed with high-speed flash by Harold E. Edgerton of the Massachusetts Institute of Technology. In the third, fourth and fifth pictures the shape of the drop briefly oscillates. In the sixth it is spherical. In the last picture the drop has attained an almost stable configuration after a fall of 14 feet.



FALLING DROPS OF WATER were photographed by Choji Magono of Yokohama National University. The volume of the drop at the top is equivalent to that of a sphere 6.5 millimeters in diameter; its velocity is 8.9 meters per second. The corresponding numbers for the other drops are as follows. Second drop: 6 mm. and 8.8 meters per second. Third: 4.8 mm. and 8.3 meters per second. Fourth: 2.8 mm. and 6.8 meters per second.

raindrop must change accordingly; the drop develops an excess of pressure near its bottom and a deficiency of pressure all around its waist. And if we momentarily assume that the air flow is that of a perfect fluid, there will be an excess of internal pressure near the top of the drop as well as near the bottom.

At this point we obtain a vivid notion of how a drop takes care of its own shape. The gradients of internal pressure drive water from near the base and top out into the regions around the waist, thereby tending to flatten the drop and increase its horizontal diameter. Even more intriguing is the fact that the resultant modification of the drop's surface curvature is of just the kind required to help the drop restore a uniform internal pressure and achieve an equilibrium. The sharpening of the curvature around the waist adjusts the surface tension effects to make up for the deficiency of external pressure there, while the flattening of curvature near the base and top tends to cancel the effects of the excessive external pressures in those regions. Together the joint action of surface tension and aerodynamic forces deforms the drop continuously until it reaches a stable internal pressure distribution.

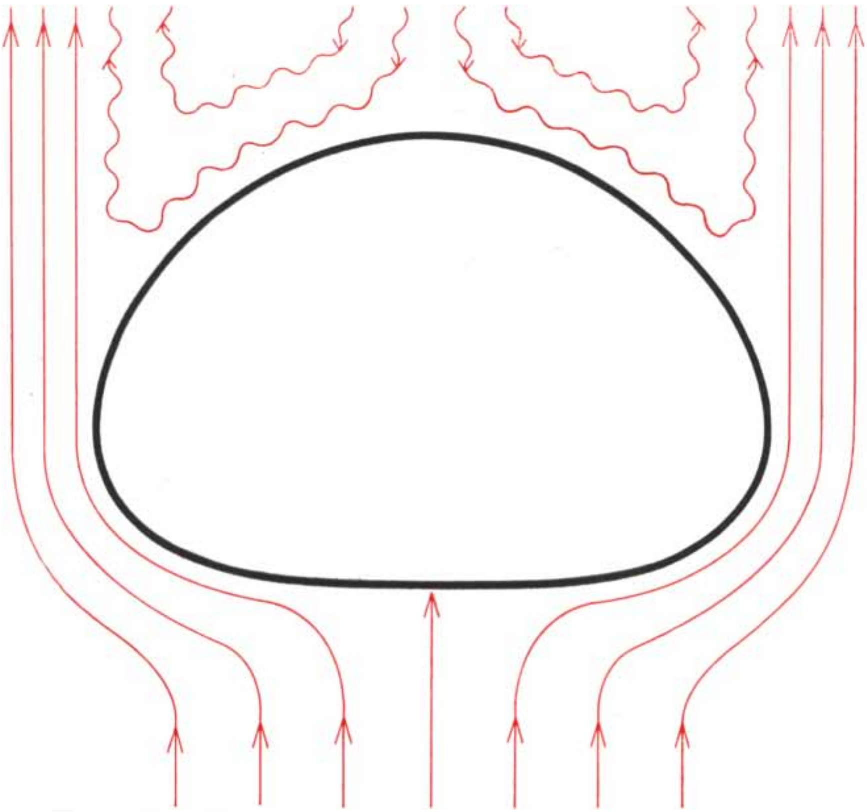
But clever as a raindrop may now seem in managing its affairs, one must ask whether a large drop has truly brought itself into complete mechanical equilibrium when its internal pressure is uniform. The answer is that it has not, for it must still meet an important demand of the laws of gravity: that is, it must develop a vertical pressure gradient just sufficient to permit the lower strata of the drop to hold up the upper ones in the gravitational field. Briefly, a liquid drop falling at terminal velocity can be in full mechanical equilibrium only when its internal pressure, instead of being uniform throughout, varies vertically in such a way as to satisfy the familiar hydrostatic equation relating liquid density, liquid depth and the acceleration of gravity. If the drop were accelerating freely in the earth's gravitational field, this hydrostatic requirement would not appear. But raindrops reach a terminal uniform velocity after only a few yards of fall; hence small but important hydrostatic pressure gradients must exist within them.

In the tiny droplets of clouds the hydrostatic gradients are not important, because the difference in internal pressure from top to bottom of these microscopic globules is negligibly small compared to their internal pressure increase due to surface tension. The top-to-bottom hydrostatic pressure differential varies directly with drop size, while the surface pressure increment varies inversely with drop size. Consequently, by the time a cloud droplet has grown into a large raindrop hydrostatic effects have become about equal in importance to surface-tension effects—a point which appears to have been overlooked by those who have examined the raindrop-shape problem in the past.

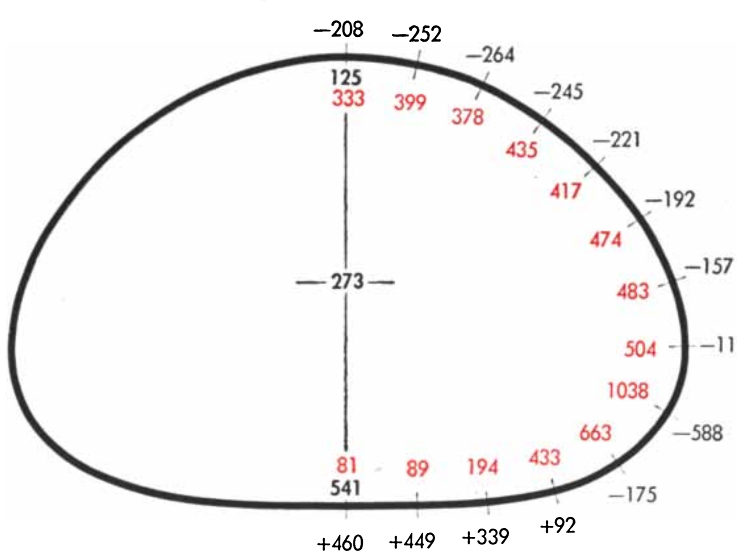
Combining the hydrostatic principles with the aerodynamic principles, one next obtains a curious result. If we demand that drops deform in such a manner as to yield an internal pressure field satisfying the hydrostatic equation, we find to our embarrassment that the drop must be flatter on its upper side than on its lower—which is just the reverse of the shape that falling raindrops actually take.

An aerodynamicist would spot the difficulty very quickly. We have assumed so far that the drops are falling through a perfect, non-viscous fluid. Actually air has some viscosity, enough to have a significant effect on an object of raindrop size (one to five millimeters in diameter) and falling speed (five to eight meters per second). Around a large raindrop the air must behave essentially as it does over the wing of an airplane in a stall: the boundary layer of air just next to the object (raindrop or aircraft wing) separates from the object and leaves a turbulent wake. In such a wake region the air pressure is always lower than it would be for perfect fluid flow in which the streamlines neatly close in behind the object. Thus the lower air pressure in the wake of a falling drop forces a greater curvature of its upper surface than of its underside.

When the drop has accomplished this adjustment, it is at last in full equilibrium with all of the important forces that play upon it as it cleaves through the air. It seems almost unfair that the fate of so cleverly equilibrated a little system may be no more glorious than to splatter down on some dusty road at the beginning of an August thundershower.



FLOW OF AIR around a large falling raindrop is indicated by the red lines in this diagram. The boundary layer streamlines follow the curve of the drop until they reach the "separation point." Above the drop and enclosed by the separating boundary layer is a turbulent region. The low pressure of this region is responsible for the shape of the drop.



DISTRIBUTION OF PRESSURE is given for a 6-mm. drop falling 8 meters per second. The numbers outside the drop give the difference between the pressure around the drop and that of the atmosphere. The red numbers inside give the difference in surface pressure; the black numbers, in internal pressure. The units are dynes per square centimeter.

The role of boundary-layer separation came to light only after I had computed pressure profiles from measurements made on an actual photograph of water drops provided by Choji Magono, now of Yokohama National University. The method used to deduce the aerodynamic pressure distribution over the surface of a drop hinged upon the use of certain relationships concerning the differential geometry of surfaces of revolution obligingly worked out by my colleague J. M. Keller at Iowa State College. The falling speed and size of the photographed drop were known, and its curvature at every point could be accurately measured on the picture. The first step in the analysis was to determine the pressure at a single point. Fortunately the pressure at the center of the underside of a falling body can be calculated even if nothing is known about the rest of the airflow pattern. This, added to the pressure due to surface tension which was computed from the curvature at the bottom, gave the total pressure just inside the lowest point of the drop. Since the drop was in hydrostatic equilibrium, the internal pressures at all the other levels could be calculated. The surface tension pressures at other points were calculated from curvature measurements and subtracted from the internal pressure. This gave the outside air pressure all around the drop. The pressure pattern thus deduced turned out to be much like the patterns observed in wind-tunnel work on separating boundary layers.

The idea that there was a separation of boundary layers around raindrops agreed with observations. Ross Gunn of the U. S. Weather Bureau had reported a curious sideslipping of falling drops of about one millimeter diameter, and he had shown rather convincingly that this odd behavior must involve eddies. Eddies can be shed only from a wake region enclosed by a separating boundary layer. Later a more quantitative type of evidence for the shape hypothesis was obtained by means of a calculation of the total pressure drag acting on a falling drop. In the case of a drop falling with uniform velocity, this pressure drag plus the drag of friction (which is very small) must be equal to the weight of the drop. It was found that the drag was in fact equal to the weight to within the limits of precision of the methods employed in the pressure calculation. It now appears reasonably safe to conclude that the queer shape of a large raindrop results in an understandable way from a conspiracy among the forces we have here examined.

Of what use is the result? First of all, it is always pleasant to acquire some understanding of even a minor peculiarity of nature. Then also, the study yielded information which may be useful for solving the vexed problem of why and how raindrops break into fragments in the turbulent regions of clouds. Finally, the clear recognition of the role of boundary-layer separation in the aerodynamics of raindrops will almost certainly help to clarify the nature of heat and vapor transport at the surface of falling raindrops.

But, to end on a note of dark pessimism, it seems quite improbable that any amount of progress in exploring the drop-shape problem will persuade cartoonists and commercial artists to alter the shape of their peculiar brand of raindrops.

Curiosity in Monkeys

Some amusing experiments of the psychological laboratory indicate that this trait of primates may be an even more fundamental part of their make-up than previously thought

by Robert A. Butler

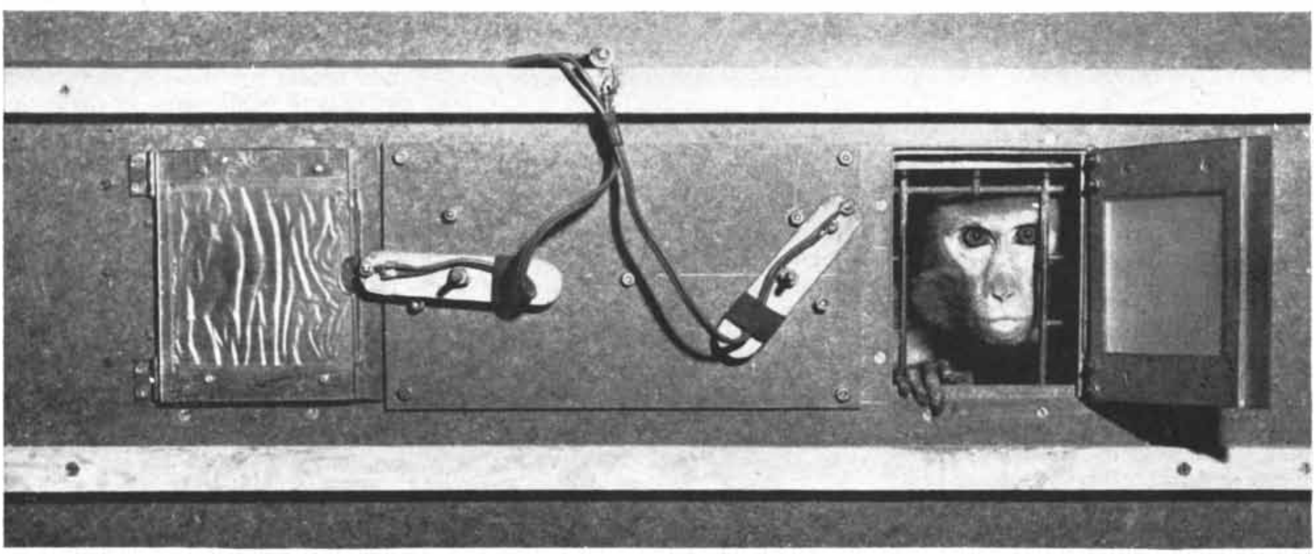
Curiosity is certainly one of the strongest motives in human behavior. Children begin very early to explore the world around them: they are excited by new sights and sounds, continually manipulate and investigate their toys or other small objects, and in general are extremely responsive to new things and events in their environment. Indeed, severe deprivation of environmental stimulation may permanently retard a child's development.

Until recently little or no research has been conducted on the curiosity motives, for reasons which are not hard to discover. A current theory in psychology has reduced human motivations to the biological drives of hunger, thirst and sex and the conditioned drive to avoid pain, and it has maintained that all learning is based on these drives. Curiosity was dismissed by the behaviorists as an "instinct," beyond the scope of experimental investigation. But in recent years psychologists have found a great deal of experimental evidence that the behavior of human beings and other primates cannot be explained adequately in terms of biological or pain-avoidance drives. Some experimental study has been given to the curiosity motives in monkeys, and this article will review those studies.

The everyday behavior of monkeys seems plainly to be motivated in considerable part by something akin to curiosity. Monkeys, not unlike children, persist in examining things in their immediate environment by close inspection and manipulation. Every object presented to a monkey is at one time or another handled, fondled, scratched, rubbed, bent, picked at, bitten and pulled apart before finally being discarded. A monkey will tamper with the lock on his cage door and will invariably confiscate any objects left on accessible shelves. In short, a monkey spends a considerable portion of his life "monkeying around" with anything he can get his hands on.

To prove that monkeys have a fundamental curiosity drive, or drive to manipulate, we must demonstrate three things: (1) that they will work for long periods with the manipulatory behavior itself as the sole reward; (2) that the manipulation drive will produce learning, in the same way as the hunger or pain-avoidance drives, and (3) that no drives other than curiosity are significantly influencing the experimental results.

Harry F. Harlow and his associates at the University of Wisconsin were the first to investigate manipulatory behavior in monkeys. Their experiments were designed to determine whether monkeys can learn how to solve a me-



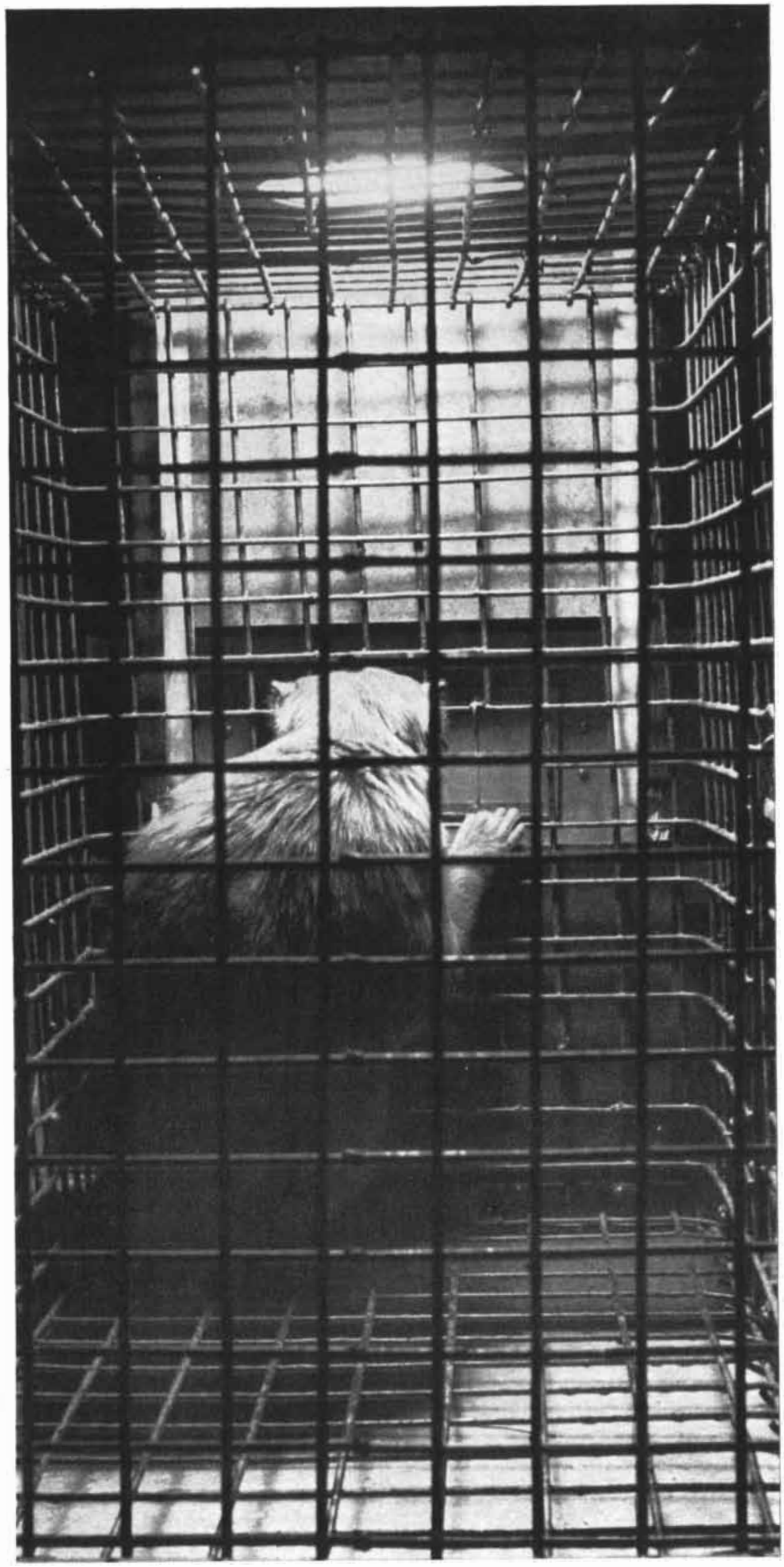
CURIOUS MONKEY stares out into the busy laboratory. Tirelessly the monkey in this experiment would push open the door with the blue card on its back when it learned that this and not the adjacent yellow door afforded a glimpse from its cage.

chanical puzzle with no reward other than the working of it. The puzzle consisted of three interlocking devices—a metal pin, a hook-and-eye and a hasp. The three items could be disengaged if the monkey first removed the pin, then took the hook out of the eye and finally lifted the hasp. If the monkey touched any of the items out of order, it was counted as an error. After a few training sessions the monkeys' score was nearly perfect. Then the puzzle was made harder by adding more devices, but it was just as readily solved. Another study investigated the persistence of this behavior. Every six minutes the puzzle was reset. The monkeys went on disassembling it repeatedly for 10 hours, at which point the experimenters, rather than the subjects, had had enough.

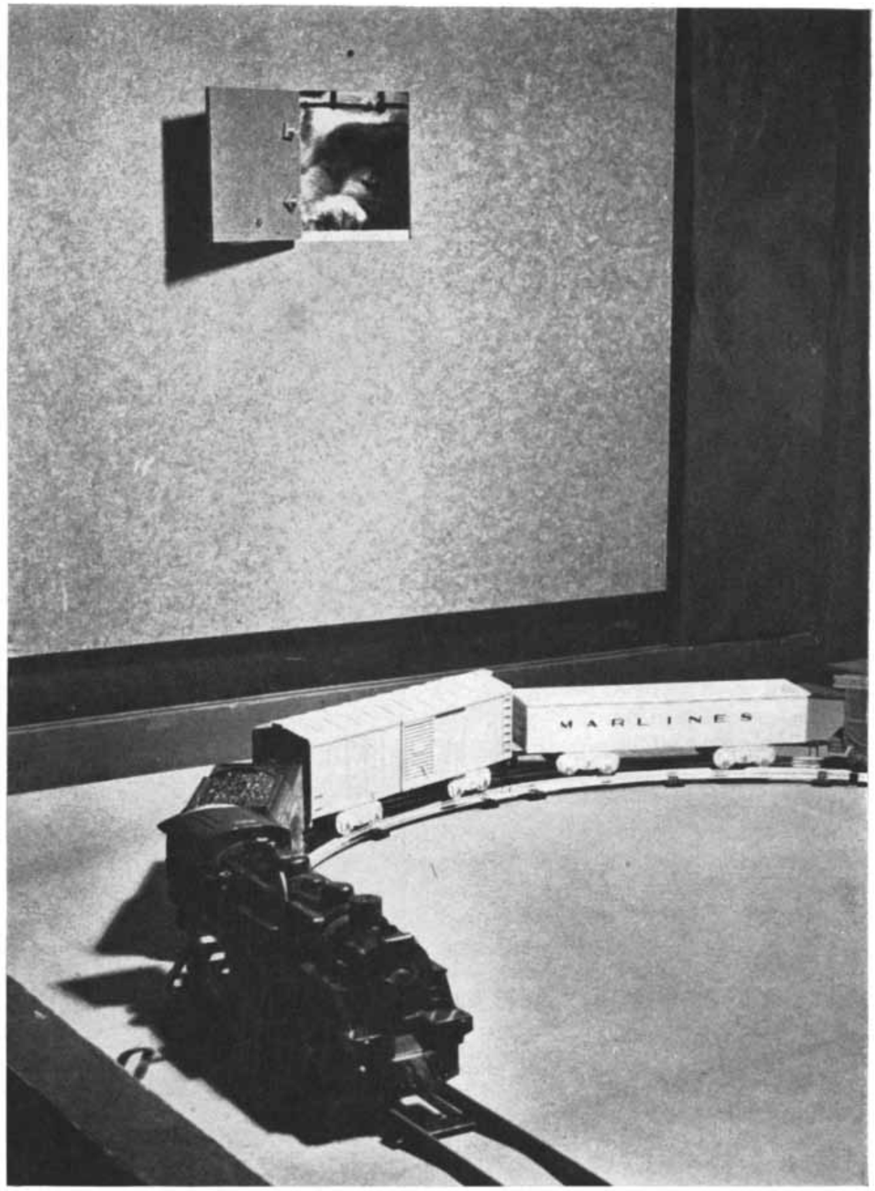
Recently Wisconsin's Primate Laboratory devised a puzzle that involves learning to discriminate between stimuli. The usual procedure in such a test is to give a reward, such as food, for the correct response in a choice between two different stimuli. But in this experiment the only reward was the opportunity to manipulate objects. Ten screw eyes were mounted in two vertical rows on a metal panel. Five of them, colored red, were removable; the other five, colored green, were firmly fixed. The screw eyes were randomly placed so that the only clue to whether they were removable was color. The monkeys soon learned that the red screw eyes could be removed to play with, and they almost unerringly touched only those.

These experiments yielded two important findings: that the opportunity to manipulate objects is reward enough to motivate monkeys to learn, and that an external stimulus, like an internal, biological one, can evoke a drive. The curiosity motives apparently are initiated by external stimuli.

What kinds of stimuli are most effective in eliciting the manipulation drive? Wallace Welker of the Yerkes Laboratories of Primate Biology has just completed experiments on chimpanzees which bear directly on this problem. On a table before the chimp's cage he placed a pair of objects. One of the pair would be movable and the other fixed, or the handling of one would produce a sound and the other not. Like monkeys, the chimpanzees showed a strong preference for movable objects over fixed ones and for objects that produced a sound or triggered a light over those that yielded no change in the environment. After 30 minutes with a pair of objects the animals became bored and stopped han-



EAGER to peer out of its cage, the monkey shown from without on the facing page is about to open the blue door. All these photographs were made at the University of Wisconsin.

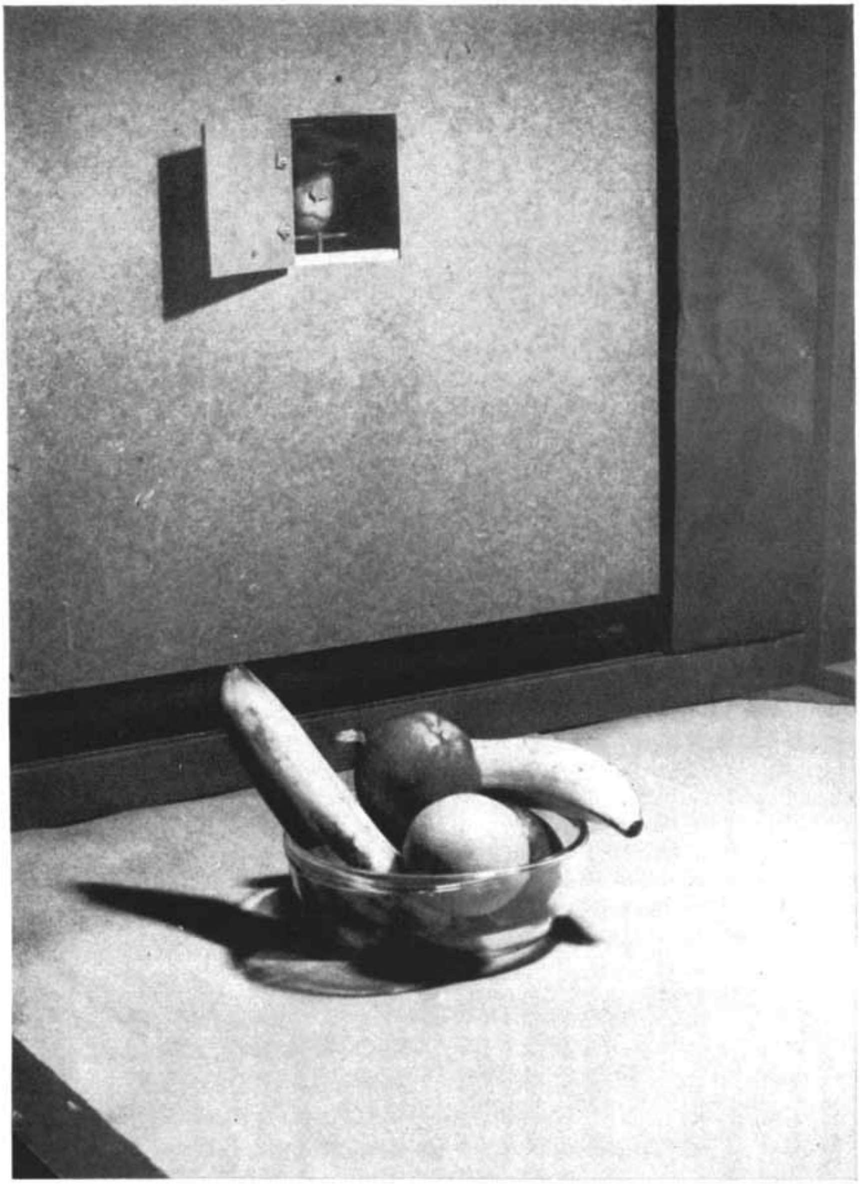


TOY TRAIN proved to be a strong visual incentive for monkeys to open the door repeatedly in order to be able to view it. An even stronger one was the sight of another monkey.

dling them, but their interest could be maintained if new stimuli were introduced periodically. Young chimpanzees consistently displayed more manipulatory behavior than older ones.

Monkeys and apes watch closely everything that goes on around them. Perhaps this expression of curiosity in monkeys accounts for their popularity with man. At the zoo or in the laboratory, man and monkey seem to observe each other with great interest. Which one derives more information from the experience remains an enigma. It is as if man as an observer meets his first real competitor in the monkey. Sometimes this competition becomes rather unnerving. I had such an experience during the course of a series of experiments at the Wisconsin laboratories. I was testing monkeys on a food-rewarded problem. The monkey worked behind a screen where it could not see the experimenter. By the same token, the experimenter could not see the monkey, and there was a great temptation to peek to find out what the animal was doing. I first made a small peephole in the panel, but the monkey quickly discovered it and thereafter spied on me as often as I did on him. I next tried placing a small mirror in a position that enabled me to watch the animal constantly. The monkey turned the tables by dropping its work and watching me through the mirror!

Taking advantage of this lead, we designed an experiment to investigate monkeys' visual exploratory behavior. The apparatus was essentially an enclos-



BOWL OF FRUIT turned out to be less of a stimulus for the monkeys than either the toy train or another monkey as an inducement to push open the door of its cage to view it.

ure with a built-in color discrimination problem. Monkeys were rewarded by a view of the surroundings outside the enclosure, provided they responded correctly on the problem. The monkey was placed in a large box with two doors. The animal was given preliminary training to familiarize it with the apparatus: first it was given a look through the open doors into the laboratory, where considerable activity was going on, and then the experimenter closed the doors. Soon the monkey learned to open the doors within a few seconds.

Then the main part of the experiment began. One door was locked, and it was identifiable by a yellow card on the inside. The other door, marked by a blue card, was unlocked. The experimenter raised a screen that had been lowered between the monkey and the doors, exposing the two doors with their differently colored cards. If the monkey pushed against the door with the blue card, the door opened and it could look outside. After 30 seconds the experimenter lowered the screen and the trial was over. If the animal pushed against the door holding the yellow card, it automatically flashed on a light which signaled its error; the experimenter immediately lowered the screen, denying the subject a glimpse of the outside world. Twenty trials a day were given for 20 days, and each test session lasted from 25 to 45 minutes. The experimenter recorded the number of correct responses and the length of time that elapsed between the raising of the screen and the monkey's attack on one of the doors. The speed of response provided a measure of the strength of the monkey's motivation to look outside.

The results of the experiment left no doubt about the strength of the monkeys' curiosity or its power in promoting learning. Throughout the 20 days of testing the animals worked away eagerly at the problem (the colored cards were shifted at random from door to door). Without tiring of the game, they went on pushing the doors enthusiastically to get a look at the people working in the laboratory outside the box. In a second study that ran for 57 days and presented various color-discrimination problems, the subjects worked just as unflaggingly.

These data strongly suggest that the drive to explore visually is indeed a fundamental drive in monkeys. To measure its strength and persistence further, two monkeys were tested for four continuous hours each day for five days. The animals worked as fast on Day Five as they did on Day One. A second experiment yielded still more surprising results. Three monkeys were put to the door-opening test hour after hour, with 30 seconds between trials, until they quit. One monkey performed for nine continuous hours, another worked for 11 and the third for more than 19 hours! The response time of this marathon performer was actually shortest during the final hour of the test.

That monkeys would work as long and as persistently for a food reward is highly unlikely. The tenacity and rapidity with which these subjects performed on the task of opening a door in order to see outside clearly indicated that the activities in the laboratory were extremely effective in exciting their curiosity.

To find out what specific kinds of visual stimuli excited them, we presented to the monkeys three different sights: a fellow monkey, an operating toy electric train and an array of fresh fruit and monkey chow. As a standard for comparison the test was arranged so that the monkeys would sometimes see nothing but an empty room. The apparatus was the same as before except that this time the box had only one door. Upon opening the door, the monkey saw a large chamber which contained a monkey, the running train, the array of food or nothing at all. The monkeys were allowed a five-second view, and the trials were repeated at 10-second intervals. Eight monkeys were tested 30 minutes a day, five days a week for a period of four weeks. Each week the visual incentive was changed. The strongest incentive turned out to be, not surprisingly, the sight of another monkey; the electric train ran a close second.

PUZZLE SOLVING indicates the extent of the curiosity drive in monkeys. Learning to discriminate, monkey pulls only red, removable screw eyes (*left*). In another test with no re-

We next investigated the relative effectiveness of different sounds. A highly vocal monkey and the noise of the electric train were the incentives. Sometimes the subjects, after opening the door, could see the source of the sound, sometimes not. Ten of the youngest monkeys in the colony participated in the study. All of them opened the door frequently and rapidly, through five weeks of testing, irrespective of which sound they heard or whether they were rewarded with the sight of the sound-maker. Although the experiment failed to show any clear-cut differences among the incentives, it provided valuable evidence on the strength of the curiosity drive in young monkeys.

These researches with monkeys and apes are the beginnings of what promises to be a most fascinating and important area of investigation. The strong tendency of monkeys and apes to explore all things and situations provides an extremely serviceable mechanism for acquainting these animals with the intricacies of their environment. That this tendency is most marked in the younger animals suggests that the curiosity motives are largely responsible for the early and extensive learning which unquestionably contributes to the biological success of the primates.

ward other than doing it, monkey repeatedly works puzzle of pin, hook and eye, hasp.

ULTRAMICROCHEMISTRY

The early study of plutonium, when only microscopic amounts of the metal were available, stimulated a kind of chemistry that deals with quantities measured in millionths of a gram

by Burris B. Cunningham

In 1943 engineers of the atomic bomb project decided the design of chemical processing plants costing hundreds of millions of dollars on the basis of a few experiments carried out with quantities of plutonium so small as to be scarcely visible. The information gained from these tiny samples helped to shorten by months the time needed to produce plutonium in militarily useful amounts. This case is an example of the utility and importance of the new field of chemical investigation known as ultramicrochemistry. With its techniques the writer and his associates, L. B. Werner and M. Cefola, had isolated microscopic quantities of plutonium in pure form, and chemists at the University of Chicago Metallurgical Laboratory had performed the necessary experiments to determine its chemical properties.

At the time only a few chemists in the U. S. had any acquaintance with ultramicro methods. They are now somewhat better known and have been put to work in various areas, notably biochemistry.

Ultramicrochemistry is an invasion of a world almost unbelievably small with unbelievably delicate instruments. It is the daughter of microchemistry, but a thousand times more refined. To have obtained the needed information about plutonium the methods of classical microchemistry would have required about a hundred times as much plutonium as was available. An ultramicrochemist works with amounts of material a million times more scanty than in conventional chemistry: his samples are measured not in grams (about the weight of a fly) or even milligrams but in micrograms—a millionth of a gram!

The objectives of the ultramicrochemist are the same as those of any other chemist: to weigh and measure substances, determine their melting and boiling points, measure the amount of heat absorbed or liberated in their chemical reactions, observe their interactions with various kinds of electromagnetic radiation, follow their chemical behavior, and so on. But to devise reliable techniques for doing all this with the minuscule samples available is a problem of great technical difficulty.

Research on extremely small quantities of material can be done with the methods of tracer chemistry [see "Tracers," by Martin D. Kamen, SCIENTIFIC AMERICAN, February, 1949]. Tracer work is restricted, however, to situations in which the substance is highly diluted. The microchemist and the ultramicrochemist work with substances in the pure state or in relatively concentrated solution.

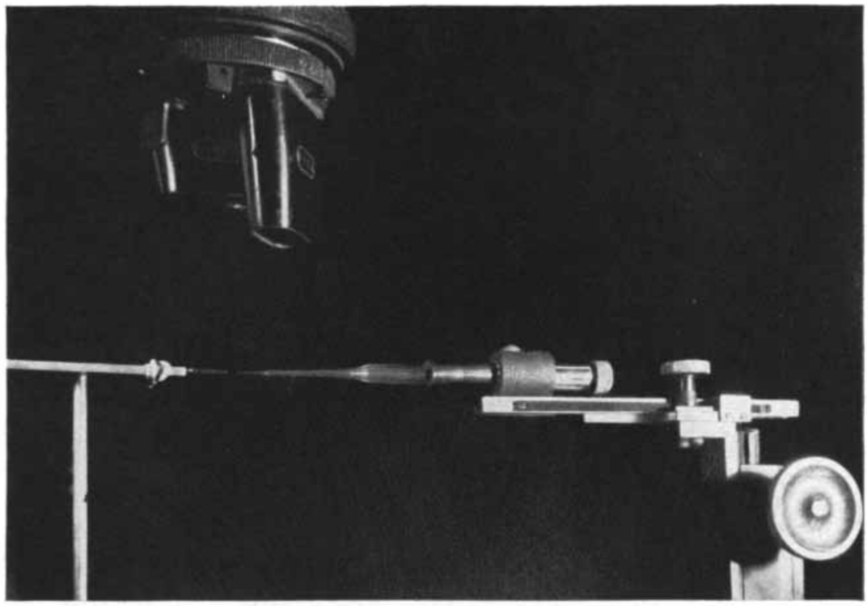
Ultramicro methods did not originate with the atomic bomb project, although they were greatly expanded under its impetus. Long before World War II systems of ultramicroanalysis had been developed by the pioneering efforts of such men as P. L. Kirk and Roderick Craig at the University of California, A. A. Benedetti-Pichler at Queens College in New York, K. U. Linderstrom-Lang at the Carlsberg Laboratories in Denmark, P. F. Scholander at Swarthmore College and E. J. Conway at the University of Dublin. Their methods were designed primarily to meet a single technical problem: the exact measurement of very small volumes of liquid, of the order of a hundredth of a milliliter—about one 3,000th of a fluid ounce. Of course other operations, such as filtering, stirring and so on, also had to be developed for this small-scale work, but the problem was primarily one of measurement.

Two devices for making such measurements were developed. One of them, simply a refinement of the familiar kitchen measuring cup, is a graduated vessel of very small diameter—hardly more than an upright capillary tube. The error involved in reading off a volume from a graduated tube is equal to the error in matching the liquid surface to the reference line times the cross-sectional area of the vessel. Using the best equipment, it may be taken as a rough rule that the uncertainty in adjusting a liquid level to a reference line is about five thousandths of an inch. If the volume to be measured is a microliter, say, and the error is not to exceed half of 1 per cent, the diameter of the measuring tube cannot be more than a hundredth of an inch. With so small a diameter, irregularities in the bore would produce large errors in volume. Therefore the volume of these measuring tubes is usually determined directly, by weighing them empty and when filled with mercury. Another difficulty arises if the measured liquid is to be transferred out of the measuring tube, because a considerable and variable portion of the liquid will stick to the tube walls. This can be overcome by coating the walls of the tube with water-repellent material.

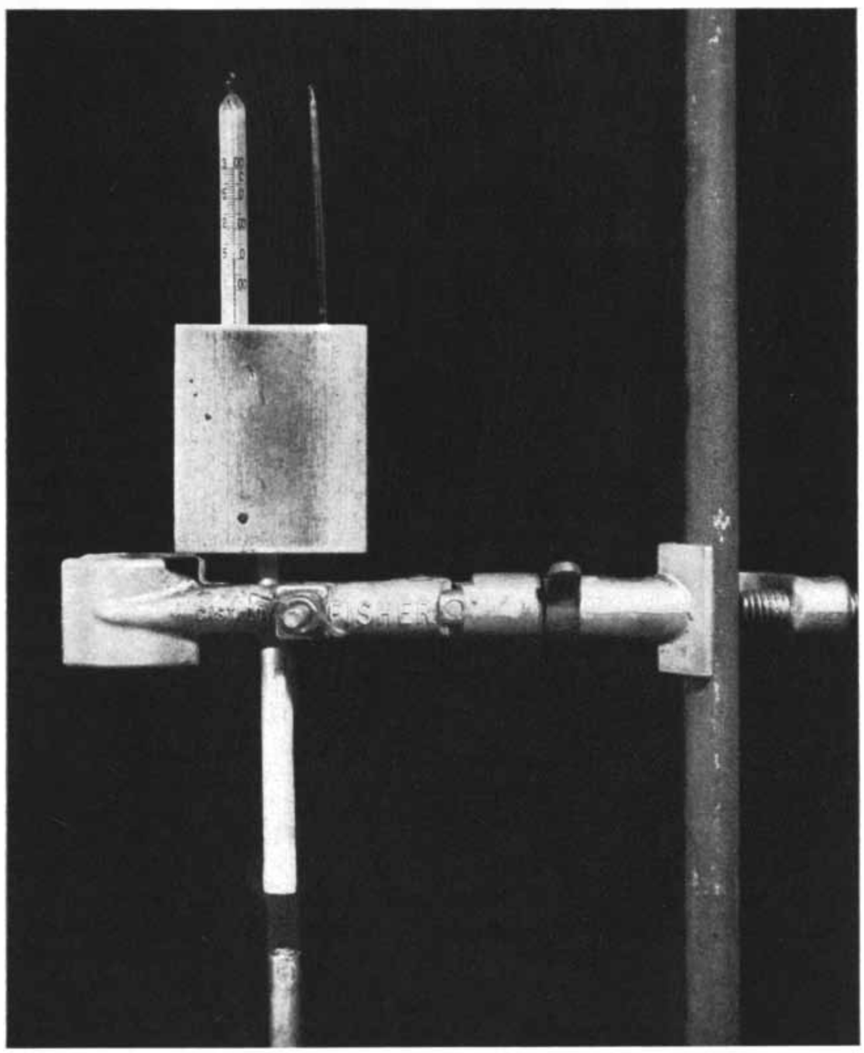
The second principle of small-scale volume measurement, applied a number of years ago by Scholander, avoids both difficulties. In Scholander's system the liquid to be measured is put in a hollow cylinder of metal or plastic which connects at one end to a very fine glass capillary tube. The other end of the cylinder is drilled to admit a closely fitting cylindrical plunger of small and precisely known diameter. The plunger is pushed into the cylinder by means of a precision micrometer screw which measures its advance very sensitively. If the cylinder and glass tube are filled with the liquid to be measured and the plunger is advanced, some liquid will be pushed out of the capillary. The volume escaping will be precisely equal to the volume of plunger entering the chamber. This volume can be calculated from the diameter and the distance the plunger has been moved. Scholander's setup, which used a plunger no thicker than a small sewing needle, achieved a precision of about one 10,000th of a microliter.

The techniques of small-scale volume measurements have found a number of important applications in biochemistry. Certain blood chemistry studies that used to require large, expensive experimental animals to provide enough material for analysis can now be done with mice. Ultramicro methods can determine where and under what circumstances insecticide accumulates in the body of an insect. Embryologists have found many uses for the techniques. An interesting example is the work of the British investigator N. G. Heatley, who has been able to show that in salamander eggs the regions destined to develop into the back part of the animal have an extra amount of the starchlike substance glycogen. By implanting a little glycogen in other parts of the egg he was able to cause a primitive spinal tube to develop there.

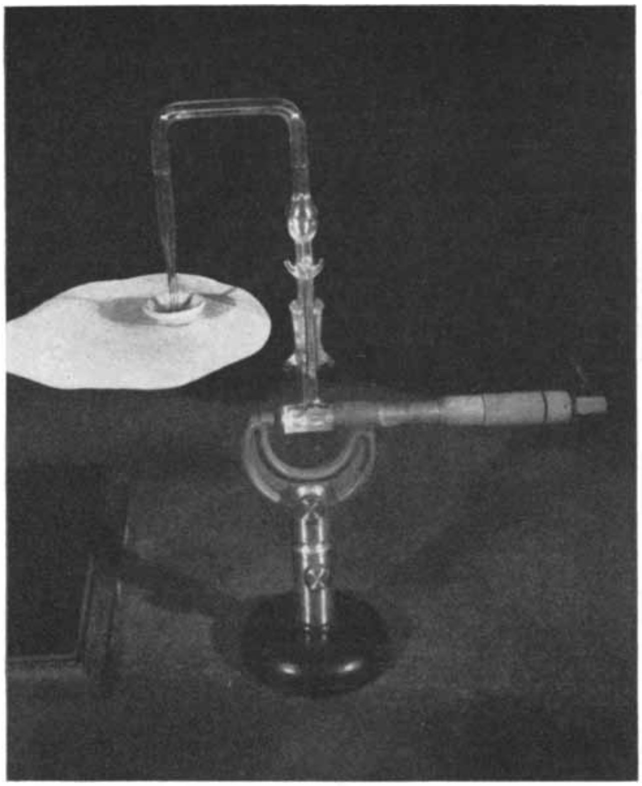
Linderstrom-Lang has been one of the most active workers in applying ultramicro methods to biochemical research. In addition to small-volume measurements he used two other delicate techniques. He adapted the familiar little toy known as the Cartesian diver to measuring small quantities of gas. A homemade diver usually consists of a small open medicine bottle that is partly filled with water and floated upside down in water in a larger wide-mouth container, such as a milk bottle. A sheet of thin rubber stretched across the mouth of the larger bottle makes an air-tight seal. When you push the rubber sheet down with your finger, compressing the air in the milk bottle slightly, the increase of pressure is communicated through the water to the air inside the smaller bottle, or "diver." Since this air is compressed, more water enters the diver. Eventually so much water is forced in that the diver loses buoyancy and sinks to the bottom of the milk bottle. If you remove your finger, allowing the air to expand, the diver rises to the surface again. There is a definite pressure and volume of air that will just keep the diver afloat, and any internal change in the gas pressure inside the diver can be measured by the amount of pressure adjustment that must be made from outside to keep it just floating. Thus a chemical reaction taking up



MANIPULATION of the minute vessels required for ultramicrochemical procedures is often done with a micromanipulator under the microscope. Here a tiny volumetric cone (*left*) is filled from a pipette before it is weighed on an ultramicrobalance (*see cover*).



DISTILLATION on ultramicro scale can be accomplished with a simple device. A capillary tube filled with liquid is inserted in an aluminum block. The block is heated until vapors have condensed in the cool upper portion of the tube, which is then simply broken off.



SCHOLANDER BURET employs a micrometer. Handle advances plunger into mercury well, displacing it and liquid in capillary.

KIRK BURET also operates on mercury displacement system, but the mercury does not touch liquid in calibrated region.

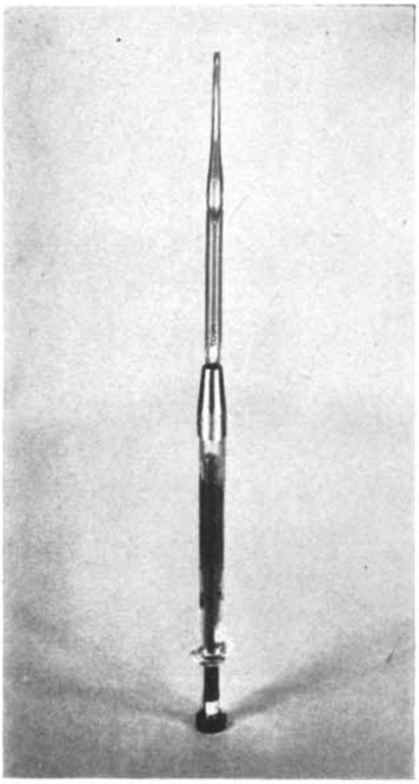
oxygen inside a diver can be followed by noting the changes in pressure. Linderstrom-Lang's divers, containing only a few microliters of air, were used in this way to study such things as the utilization of oxygen by small bits of living tissue.

The second technique developed by this Danish biologist also depends on a flotation principle. A tall glass cylinder is partly filled with one organic liquid and then filled the rest of the way with a second, which is miscible with the first but slightly lighter. Care is taken to minimize mixing of the two liquids until the vessel is all filled. Then it is stirred gently so that mixing takes place near the dividing line between the liquids. This gives a region in which the density is graduated more or less uniformly from the lower to the higher value. A drop of water solution, not soluble in the organic liquids and having a density greater than the lighter but less than the heavier one, is put in at the top of the vessel. The droplet sinks until it comes to rest in the region where the density of the surrounding liquid is the same as its own. If the drop of solution contains substances which are reacting chemically in such a way as to change the density of the solution, it will seek a new level and the progress of the reaction can be followed from the drift of the drop. In this way Linderstrom-Lang studied the action of isolated enzymes on proteins. (As proteins break down, the density of the solution increases.)

The water-drop trick is an indirect method of weighing small quantities of liquid. Let us now consider how ordinary weighing operations are done in ultramicrochemistry. Early in this century the Australian chemists B. D. Steele and K. Grant built the first balance that could operate in the microgram range. They made the apparatus entirely of fused silica, a precedent that has been followed by nearly all later makers of ultramicrobalances. Their instrument consisted of a beam of fused silica rods balanced on a prism-shaped lump of silica with a fine knife-edge which rested on a small plate of polished quartz. It was so sensitive that the English chemist Sir William Ramsey could use it to weigh about a hundredth of a cubic inch of radon—the gaseous decay product of radium. By this measurement Ramsey was able to determine the atomic weight of radon and thus to verify Lord Rutherford's hypothesis of radioactive decay. Rutherford had suggested that the first step in radium disintegration should be the emission of a helium atom, whose atomic weight is four. Ramsey obtained an atomic weight for radon just four less than that of radium.

A serious drawback to the Steele and Grant balance was the fineness of its knife-edge; the slightest particle of dust under the edge rendered the balance useless. The difficulty was overcome by the Swedish chemist Hans Pettersson, who put an axle through the center of the beam and suspended the axle by fine silica threads from an overhead frame. Pettersson's balance was remarkably accurate (to about six 10,000ths of a microgram). In fact, it has been exceeded in accuracy only by a balance built recently in the author's laboratory. Fine as it was, however, it was not good enough to enable Pettersson to realize his hope that he might detect the weight gained by a body as its temperature is increased, in accordance with Einstein's then novel equation $E=mc^2$.

Neither the Pettersson nor the Steele and Grant balance was well adapted to general chemical experimentation, and they are no longer used. The first ultramicro weighings on pure plutonium compounds were carried out with a very simple balance, which was a refinement of the one invented in 1901 by E. Salvioni, an Italian biochemist. His instrument consisted of a thread of glass about



CAPILLARY PIPETTE holds 100 microliters, upper limit of ultramicrochemistry.

three times as thick as a human hair and about four inches long, bent at one end to form a small hook. The straight end was fastened to a support so that the fiber stuck out like a tiny fishing pole. The object to be weighed was hung from the hook, and its weight was calculated from the amount of bending in the fiber. Using silica fibers instead of glass, a high-power microscope to observe the bending and tiny weighing pans of very thin platinum foil, my associates and I were able to weigh plutonium compounds with an accuracy of a hundredth of a microgram. The Salvioni balance obviously cannot support much weight, however, and manipulating the minute weighing pans is inconvenient.

A more generally useful balance for routine ultramicro weighings has been devised by Kirk, Craig, J. E. Gullberg and R. Q. Boyer at the University of California. Its beam is a plane triangular framework of fused silica fibers, weighing but 15 milligrams altogether. The beam is supported at its center by a horizontal fiber, which tends to twist as weight is added to one end.

As a crude analogy to this balance, imagine a thick rope stretched taut between two trees. A thin rod of iron is thrust horizontally through the strands

VOLUMETRIC FLASK with a capacity of 200 microliters (*left*) is used to develop solution for colorimetry in the spectrophotometer. The solution is removed from the flask with a pipette and put in an absorption cell (*right*). All the apparatus depicted in this article was photographed at the Socony-Vacuum Laboratories in Brooklyn, N. Y.

of rope near its center. An object hung at one end causes the rod to rotate, twisting the rope, until the torque (turning force) due to the weight is equaled by the tendency of the rope to untwist. If we know how much torque is necessary to produce the observed twist in the rope, we can figure out how much the object weighs. In the actual balance a fiber of fused silica, an almost perfectly elastic material, serves as the "rope."

In the setup thus far described computation of the weight would be unnecessarily complicated. The torque due to the weight depends not only on the weight and on its distance from the supporting fiber but also on the angle through which the rod has turned. (If it were to turn through 90 degrees, for example, so that the weight hung straight down, there would obviously be no torque.) It would be more convenient if we could keep the rod horizontal, so that the weight exercised its maximum torque throughout the weighing. To accomplish this we untie one end of the fiber and clamp it to the hub of a vertical wheel supported in a rigid framework and left free to turn. Now when a weight is hung from the bar we can turn the wheel until the counterbalancing twist in the fiber restores the bar to the horizontal position. We note the amount of turning required to restore the beam to the "null" position, and, knowing the elastic torque of the twisted fiber, we can compute the weight of the object with a high degree of accuracy.

Using a torsion fiber about a thousandth of an inch in diameter and two inches long, a torsion wheel accurate to a minute of arc and twin microscopes focused on a small section of the fiber at each end of the beam to observe its rotation, weighings accurate to a hundredth of a microgram can be carried out as rapidly and as easily as weighings on the macro scale. Because fused silica is very strong, we can place as much as 25 milligrams on each side of the balance, or more than two million times as much mass as the balance will detect. Naturally the balance system must be shielded from all disturbing air currents. The silica must be plated with a thin coating of gold to make it conducting. Otherwise, electrostatic charges could build up on the silica and produce forces many times greater than the small forces we are attempting to measure in the weighing process.

The elastic properties of silica torsion fibers are not actually known with sufficient accuracy to calculate weight directly from the amount of twist; the instrument has had to be calibrated with a small amount of residue from an evaporated solution of precisely known weight.

Various models of ultramicrobalances have been tested in the last few years and the instruments are beginning to be available commercially. Weighings ac-

curate to a hundredth of a microgram are now routine. More sensitive balances have been built, but they demand more elaborate techniques for obtaining precision measurements.

Torsion ultamicrobalances are useful for measuring not only weight but magnetic and other forces. A sample of material is suspended from the beam and counterbalanced. Then the instrument is placed between the poles of a magnet in such a way that any force between the sample and the magnetic field will be in an upward or downward direction. The change in weight measures the effect of the magnet on the material.

While we have been concerned here mainly with the measurement of volume and weight, which is the core of ultramicrochemistry, we should also mention some of the ultramicro devices for determining other properties. For chemical analysis there is paper chromatography, which can separate and identify extremely small amounts of substances in a complex organic compound. Tiny samples can also be analyzed by X-ray, microwave and infrared spectroscopy. A new addition to the arsenal of ultramicro methods is coulometry, which measures tiny amounts of material in a solution by the current required to deposit it electrochemically or to produce some other chemical change in the material.

For the ultramicro measurement of heat there are as yet no truly precise techniques. Microcalorimeters, capable of measuring heat down to a few tenths of a calorie, have been known for some time. But an ultramicrocalorimeter, which would have to detect a few 10,000ths of a calorie, does not exist. However, such small quantities of heat can sometimes be measured indirectly by the laws of thermodynamics. For example, the heat of solution of microgram quantities of transuranium elements has been determined by measuring the effect of temperature on their solubility.

Ultramicrochemistry, then, already has at its disposal a wide variety of methods for studying matter. But it would be misleading to give the impression that chemists can deal with matter on the microgram scale as expeditiously and conveniently as in the familiar macro world. Human anatomy is simply not built to manipulate matter on so fine a scale as this. To come to grips with the ultramicro world at all the ultramicrochemist must resort to precision manipulators, lenses and other ingenious mechanisms which inevitably stand between him and his samples.

The End of the Moas

A swamp filled with bones indicates that these enormous wingless birds lived in New Zealand when knighthood flowered in Europe. Then they vanished. Were they exterminated by aboriginal man?

by Edward S. Deevey, Jr.

Any biogeographer would cheerfully suffer shipwreck on a land as interesting as that of the Swiss Family Robinson. The peccary, ostrich, hyena and walrus disported there with the jackal, buffalo and wild ass, while honey guides and swifts which built edible nests darted among the vanilla and euphorbia trees. In the world of real life there is an island that can vie with the Robinsons' fictional wonderland. It is New Zealand, where three quarters of the plants are peculiar specimens that live nowhere else on earth, where cycads and tree ferns, refugees from Paleozoic coal swamps, grow in sight of active glaciers; where astonishing varieties of flightless birds scurry through the underbrush like rabbits and not long ago grazed the plains like herds of antelope. Indeed, because there are no mammals to prey on them (the only mammals on the island are bats), even geese and perching birds in New Zea-

WASHING OF THE BONES was a laborious task necessary to remove the clinging lake sediment from the moa remains excavated at the site in New Zealand's Pyramid Valley. The immature bones will float for some time; often such bones are found widely scattered.

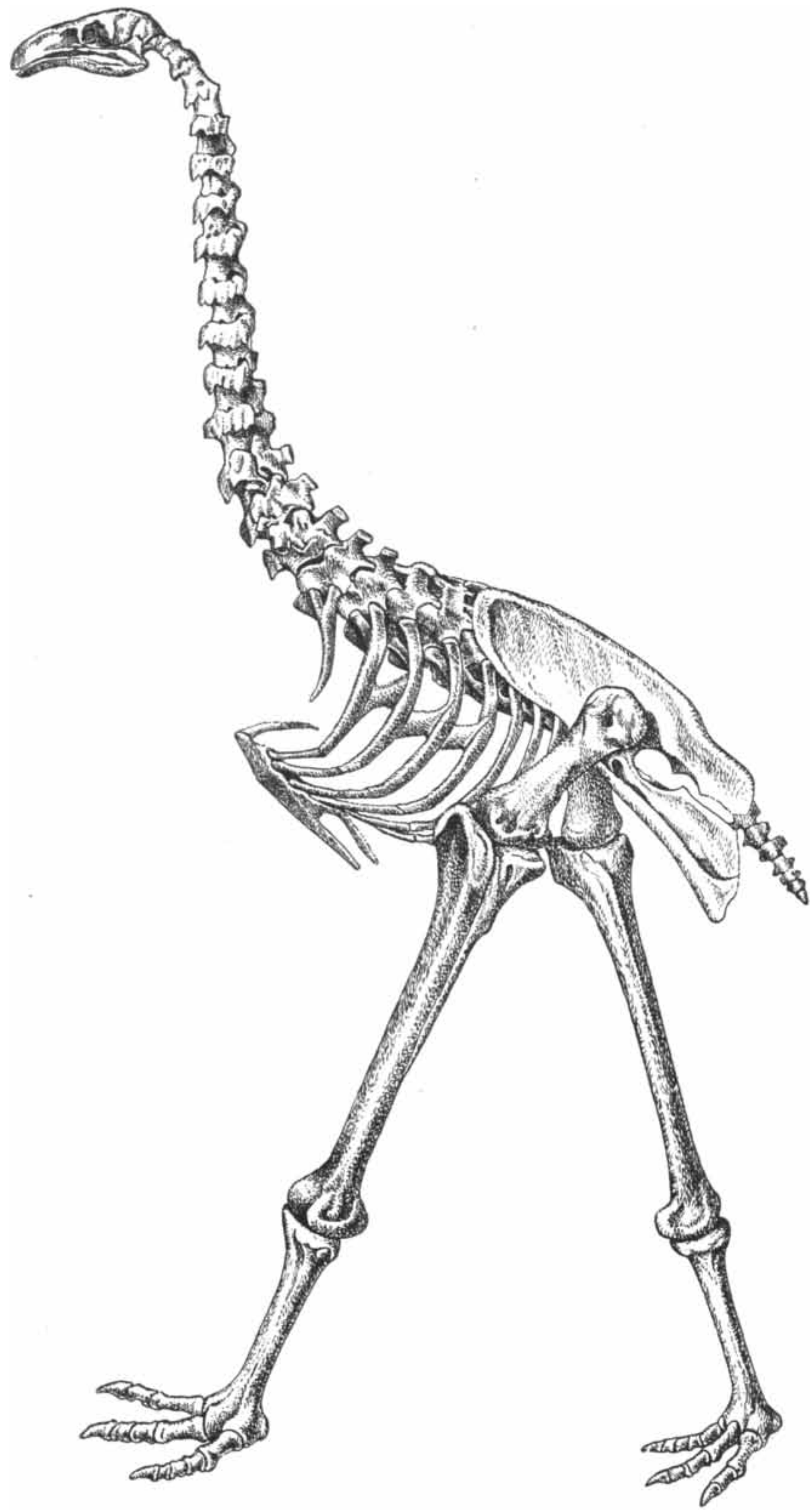
land have forsaken the use of their wings.

The weirdest of all the flightless birds of that island were a now extinct kind called moas, which lived in New Zealand for so long a time that they lost their wings entirely. All of them were large and some were gigantic; one variety, *Dinornis*, was a giraffe-like creature 10 feet tall. Probably they were not fierce, for they were grazing animals. Mystery surrounds their disappearance. Moa bones and feathers today are found lying on the floors of caves or only a few inches below the surface in swamps. Obviously their extinction was not a remote event.

When, in 1840, the great English anatomist Sir Richard Owen first described these "struthious birds," Europeans assumed that such spectacular creatures must have been known to the aboriginal Maori. Their leading questions to the natives about the birds brought the answers the Maori thought were desired. By 1870 New Zealand folklore was full of circumstantial accounts of moas—how they buried their heads in the sand, how they flapped their wings when they ran, how the female sat on a clutch of 30 eggs while the male stood guard, how the birds were ambushed as they left the caves where they lived.

Sophisticated modern anthropologists, among them Roger Duff, director of the Canterbury Museum at Christchurch, do not believe all they are told by elderly and compliant Maori. That the aborigines knew fossil moas there is no doubt, for they used the bones for artifacts, and the word *moa* itself before 1840 seems to have meant only "a stone; also the name of a person or a place." But apart from a few vague allusions to events which antedated the arrival of the Great Fleet from Tahiti about 1350 and which probably refer in any case to other kinds of birds, there is no authentic record in Maori folklore of their having had any personal acquaintance with living moas. This only deepens the mystery. The moas were there in abundance not more than a few thousand years ago, and had been there for at least 12 million years; if the Maori didn't exterminate them, who did?

Archaeological studies, most recently at Wairau on the northeast coast of the South Island, have supplied a partial answer. Diggings directed by Duff have shown that there was a pre-Maori people who hunted moas. Not only are the birds' great bones found in profusion in mid-

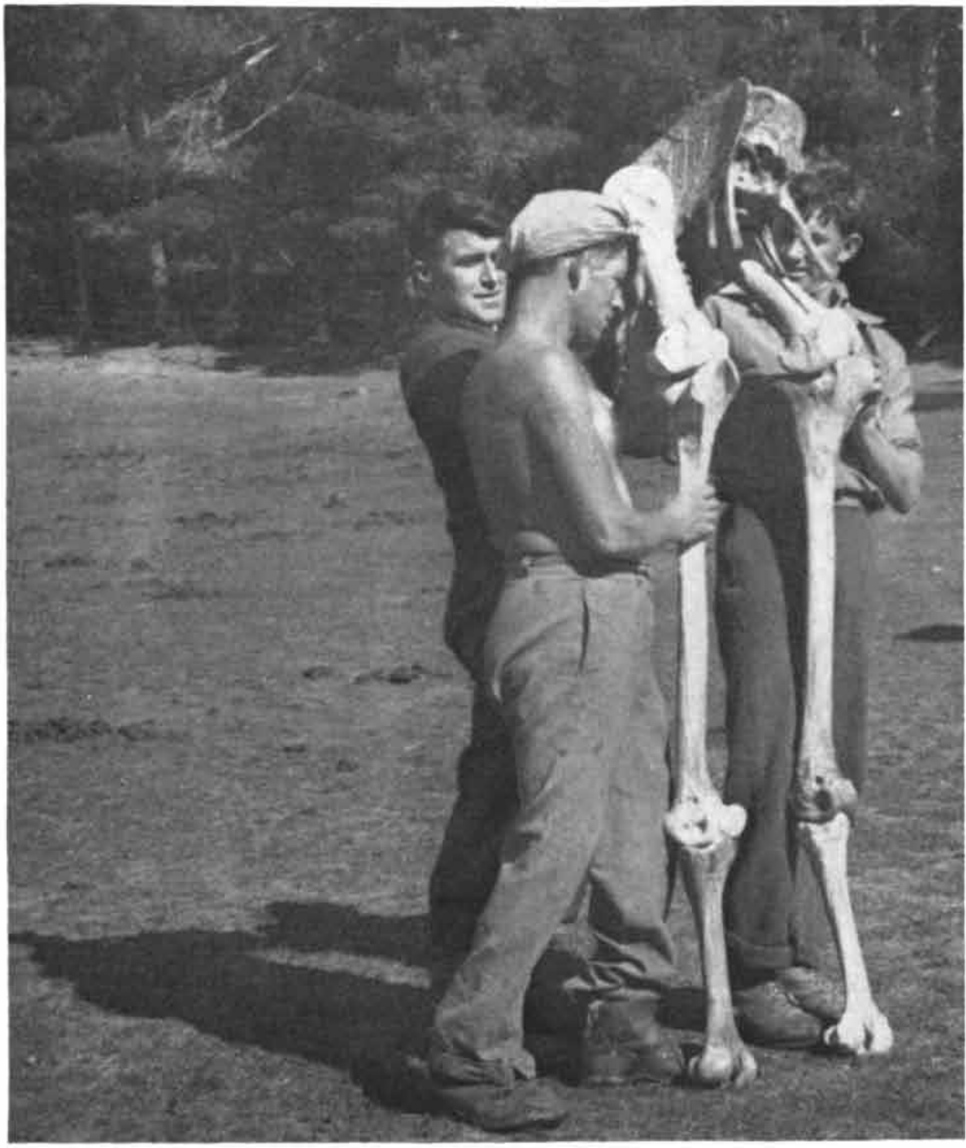


LARGEST MOA was *Dinornis maximus*. It was 10 to 12 feet tall, depending on whether it stood erect or bent its neck like a swan's. Sir Richard Owen reconstructed these bones.

dens, but moa eggs, perforated at one end, were buried intact with the dead. No doubt the eggs were used as water bottles, as the South African Bushmen use ostrich eggs, and they were interred with other cherished property of the dead for the journey to the hereafter.

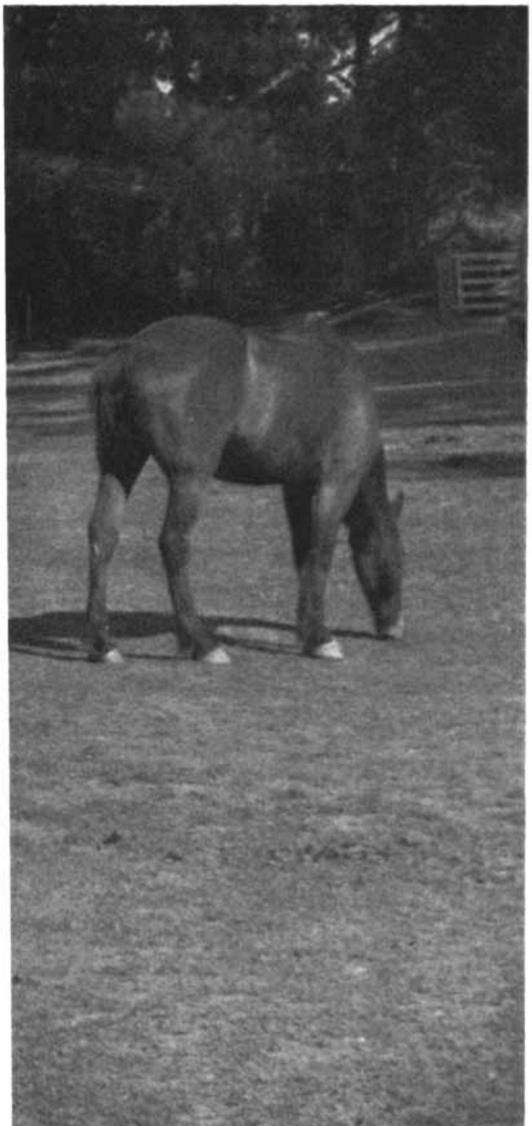
These moa hunters of the South Island may have been the people who exterminated the moas. Certainly they killed the birds in large numbers. Their camp, which was situated at the end of a peninsula, was admirably suited as a cul-de-sac for rounding up moas. Yet this can be only part of the story of the end of the moas. The principal genus found in the camp, *Euryapteryx*, seems to have been designed by nature to become extinct—the savages must have found it a veritable schmoo. Constructed with a slender head and neck and an incredibly massive body below, it was a cross between a hogshead and a gazelle—four times as tall as a domestic chicken and probably 10 times as stupid. A few fossils of two other kinds of moas, of about the same size, have been found in the moa hunters' camps. But of Dinornis, the avian giraffe, there is not a trace. Yet Dinornis and Euryapteryx were contemporaries, at least as the geologist views time, and their remains are found together in swamps. The puzzling question changes slightly then: instead of asking "Who killed the moas?" we wonder "Where did Dinornis go?"

The answer is not in yet, but it is within sight as a result of geologic studies at the latest and most important of the moa-bearing swamps to be discovered.

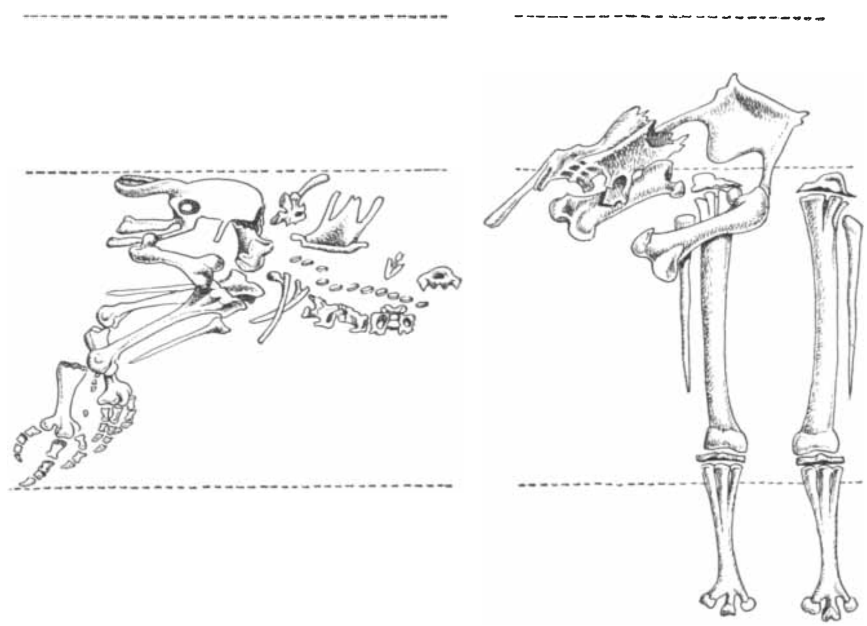


SIZE OF DINORNIS may be measured against these members of a digging party holding up the leg bones and pelvis of an average specimen. *Dinornis* stood higher than any pres-

This is in Pyramid Valley, about 100 miles inland from Wairau on South Island. Here the moa-trap was an old lake deposit, exceptionally sticky and treacherous. Today it is covered with sedge tussocks and is used as pasture, but when the moas flourished it was a swampy forest into which the ponderous birds were tempted while feeding. Once they broke through its deceptive crust of black forest humus, they were irretrievably mired in the sticky clay beneath, which went down for five or six feet. The long legs of Dinornis were not quite long enough to reach firm bottom, and the smaller species never had a chance. As they floundered, sinking deeper with every struggle, the moas were attacked from above by the giant harpy eagle—so one infers, at least, from the fact that the



ent mammal save the giraffe and elephant and probably ate as much grass as a steer.



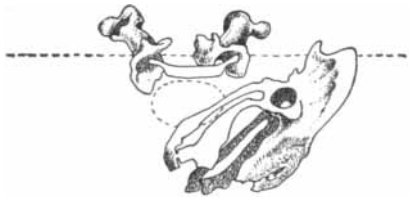
BONES OF TWO MOAS are depicted as they were found in the swamp. The top layer of earth is peat; the middle layer, yellow lake sediment; the bottom layer, blue clay. At the left are the bones of the smallest moa, *Emeus;* at the right, the heavier bones of *Dinornis.*

heads and necks are usually missing from otherwise complete skeletons. Moreover, a few of the eagles themselves were trapped, along with some 30 other kinds of smaller birds.

Excavations in the Pyramid Valley swamp led by Duff and the ornithologist Robert Falla had by 1949 dug out more or less complete skeletons of 140 moas, representing four of the six genera and six of the 20 species found in New Zealand. Forty-four of these skeletons were Dinornis and only 12 Euryapteryx. There were no chicks among them, but one five-foot hen was caught carrying a fully-formed egg with a capacity of more than half a gallon.

Dating the Pyramid Valley swamp is a complicated process. New Zealand bogs, like bogs in other countries, preserve a time-scale in the form of varied assemblages of pollen grains, originally airborne from plants in the neighborhood and fossilized in the accumulating bog sediments. The scale is purely relative, telling the comparative but not the absolute ages of the deposits. Pollen times, established by counting different kinds of pollen in successive layers of bog mud, are converted to climatic times by inference from the nature of the vegetation they record. Because changes of climate operate over wide areas, it is comparatively easy to match up pollen records from bogs a few miles apart. This has been done in great detail in areas in western Europe and eastern North America, where the plants and the climate are fairly uniform. It is not so easy to carry pollen times with any assurance across the North Atlantic Ocean, or from the Northern Hemisphere to the Southern, for purposes of comparative dating.

New Zealand's pollen time-scale was worked out by Lucy Cranwell in collaboration with the inventor of the pollen dating method, Lennart von Post of Stockholm. Applied to Pyramid Valley, it suggests that the marly lake deposit in which the moas were entombed corresponds to the latest of three climatic stages. It was a time when southern beechwoods spread at the expense of coniferous forests, which means that the period was cooler and at first moister than the one that preceded it. A layer of peat containing sedges underlies the marl, and this can be dated to the coniferous-forest period itself. In terms of the Northern Hemisphere time-scale, it can be guessed that the southern-beech time was the same climatic period that saw the expansion of beeches over western Europe at the expense of oaks and lime trees. This happened at the end of the Bronze Age, so that a date of 600 B.C. for the laying down of the marl deposit seems reasonable. The overgrowth of the Pyramid Valley lake by swamp forest should then correspond to one of the later times of dry climate in western Europe, of which the best known fell in the fifth and the 13th centuries. If pollen dating is possible over such enormous distances, the moas of Pyramid Valley met their sticky end



UNLAID EGG *(dotted line)* was found among other *Emeus* bones. Trapped by the bones, the egg was kept from floating away.

some time between the fall of Rome and the rise of Italian painting.

If pollen dating is possible over such enormous distances—geology and the other historical sciences are bedeviled by such questions. Geologic happenings are dated in terms of each other, and one can get just so far by matching independent sequences; sooner or later the method fails. It is for this situation that radiocarbon dating seems to be made to order, for its scale of time is measured in absolute terms of centuries or years [see "Radiocarbon Dating," by Edward S. Deevey, Jr.; SCIENTIFIC AMERICAN, February, 1952]. In this method the age of a fossilized animal or plant is measured by the decay of radioactive carbon 14 in its tissues since its death.

The most interesting radiocarbon date for Pyramid Valley, as measured in Yale's Geochronometric Laboratory, is not the age of a moa, but that of the peat that underlies the lake deposit in which the moas drowned. This peat proves to be 3,700 years old, a figure which seems about right if the coniferous forest time in New Zealand was the dry time of the European Bronze Age. In other words, pollen dating *can* be carried across enormous distances, and when a few more such dates are measured in both Northern and Southern Hemispheres, we may say that the relative pollen time-scale has been "calibrated." The marly lake deposit itself is older than the moas and younger than the peat, but its radiocarbon dates are mainly useful in proving what had been suspected—

GIZZARD STONES from the remains of a single *Dinornis* weigh 5 pounds. They are rough, indicating that the bird vomited or excreted them before they became too smooth.

that dates based on the carbon of marl (a clay containing calcium carbonate) are less reliable than those for peat.

And what about the moa? The last meal of a large Dinornis consisted of about a bushel of seeds and twigs, found buried in the lake mud along with the skeleton (and a peck of gizzard stones, some as large as a hen's egg). The food remains are woody; when burned and analyzed for radiocarbon, they gave an age of 670 years. Thus we learn that Dinornis roamed New Zealand as recently as about 1300, in company with Euryapteryx. The moa hunters of Wairau may not have exterminated Dinornis, but it certainly seems likely that the people who did wipe out the moas lived not long before these hunters.

Until Dinornis remains are actually found in middens alternative hypotheses may be preferred by some. Perhaps, like Friedrich Barbarossa, the greatest of the moas is not extinct but merely sleeping. Or perhaps Dinornis, maddened with grief at the death of Euryapteryx, sought Ophelia's melancholy fate. Once a hen Dinornis ventured into Pyramid Valley,

". . . long it could not be
Till that her garments, heavy with their drink,
Pull'd the poor wretch from her melodious lay
To muddy death."

PRIMITIVE HUNTER was buried near Wairau with a water bottle consisting of a pierced moa egg (*right*). These pre-Maori people slew moas of one species in large numbers.

BOOKS

An account for the general reader of how mathematics influences our whole culture

by James R. Newman

MATHEMATICS IN WESTERN CULTURE, by Morris Kline. Oxford University Press. ($7.50).

Morris Kline, a professor of mathematics at New York University, has written a stimulating and readable book on the cultural influence of mathematics in the Western world. He has dealt not only with its effects upon science, technology and philosophy but also with its much less obvious connections with religious doctrines, social opinion, economic and political theories, literature, music and other creative pursuits. His work has, it seems to me, serious shortcomings, but it is nonetheless a considerable achievement, deserving attention as the first full-scale attempt to survey a uniquely important branch of cultural history.

The method of the account is a chronological presentation of the principal mathematical ideas that have shaped the modern world, from Babylonian arithmetic and Greek geometry to the theory of relativity. Many of the episodes selected by Kline to illustrate his theme—that mathematics is a prime "fashioner" of civilization—have been made familiar by other popularizations. But Kline's version even of well-known periods and events has special merit. He is unfalteringly clear in explaining mathematical ideas; he is learned but not pedantic; he has historical discernment, a sympathetic social outlook and a nice sense of fun and irony. Unfortunately he is inclined to be eloquent; in this vein he is tiresome, but when he does not try to be eloquent he is interesting and persuasive.

The story begins in the Near East. The Babylonian and Egyptian mathematicians, though incapable of the soaring imaginative flights of the Greeks, were not exclusively a grubby lot of tax collectors, mortgage makers, money lenders and surveyors, as several esteemed historians have contended. Mathematics in Egypt and Babylonia, says Kline, was used not only for bookkeeping and measurement but in astronomy, calendar reckoning, the building of the great ziggurats and pyramids, the digging of canals from the Tigris and Euphrates rivers to irrigate the land. Priests fastened on the occult science of numbers for conjuring, divination and the interpretation of man and the universe. Geometrical forms were a dominant motif in painting and other works of art. The mathematics of the Egyptians and the Babylonians was an invaluable tool; it was also an expression of wonder, longing, loneliness, fear and delight.

The Greeks were the pupils of the East, but as the noted historian Michael Rostovtzeff has said, "they refashioned all they received and stamped a fresh character upon it." They had an endless curiosity, a passion to discover "the rule of law in nature." The Greeks asked not "How?" but "Why?" Their answers were at first "childishly simple," no doubt, but scientific rather than mythological. They founded scientific geography and astronomy, they created mathematics "in the sense in which we understand the term today." Kline's summary of the achievements of Euclid, Archimedes, Apollonius, Hipparchus, Eratosthenes is very good; he has the knack of selecting perfect examples, of explaining them in an original way, of searching out and answering obscure little points that we have always been embarrassed to ask about though we have never understood them. I must confess, however, to growing weary of being told that the qualities of Greek geometry—simplicity, clarity, orderliness, perfection—reflected the dominant characteristics of the Greek mind. For Kline Greek culture is epitomized by Myron's statue of the Discus Thrower, who, though "about to make a tremendous physical effort, is as calm and unruffled as the proverbial Englishman drinking tea." I venture to say that this piece of sculpture no more demonstrates that the Greeks were ruled by a love of static perfection than the passionate conflicts of Aeschylus' *Eumenides* show that they were an overemotional people incapable of objective reasoning.

Kline is so eager to press the argument that mathematics is the "arbiter of thought and action" that he indulges in extravagant claims. Did mathematics shape Greek culture, or was it the other way around? The question is absurd: causes and effects were intertwined. Everything in mathematics is an effect as well as a cause of the surrounding culture. Rationalism, an insistence on deductive methods of proof, a preference for the abstract, a penchant for generalization, a search for what is permanent amidst what is transitory—all these were deeply ingrained habits of Greek thought. They help to explain the Pythagorean theorem, the Parthenon, the philosophy of Plato and the plays of Sophocles. But they do not completely explain these creations, much less define the whole of the civilization that produced them.

Kline is at his best in describing the rise of mathematical concepts, the application of mathematical methods to physical problems and the interpretation of nature. He delights and instructs us with his discussions of the work of Kepler, Copernicus, Descartes, Galileo and Newton. There are occasional errors of fact; for example, he calls the gambler-mathematician Jerome Cardan a "murderer." Cardan certainly was a full-fledged rogue, and he had a son who disliked his wife and disposed of her with an arsenic pie, but even in these times imputing the son's crime to the father is carrying guilt by association too far. The chapters on painting and perspective and on the invention of projective geometry are ably handled. It is interesting to see how geometry was wedded to painting and how the painters in turn repaid their debt by introducing new geometrical ideas. Projective geometry was "the most original mathematical creation of the 17th century." Its inventor, Gérard Desargues, was impelled to his researches by the desire to help his colleagues in engineering, painting and architecture.

Galileo has been called the first of the moderns, I think rightly. His primary interest was to discover how things work, not why they work as they do. In this important respect he differed from the Greeks, but in an even more important respect he shared their beliefs. "The history of 17th-century science," wrote Alfred North Whitehead, "reads as though it were some vivid dream of Plato or Pythagoras." Galileo insisted on the supremacy of the "irreducible and stubborn facts," but he was not primarily an experimenter. He said: "Philosophy is written in that vast book which stands forever open before our eyes, I mean the universe; but it cannot be read until we have learnt the language and become familiar with the characters in which it is written. It is written in mathematical language and the letters are triangles, circles and other geometrical figures, without which means it is humanly impossible to comprehend a single word." The chief purpose of experiments was roughly to verify or refute the mathematical models of reality. As Kline points out, Galileo valued "a scientific principle, even when obtained by experimentation, far more because of the abundance of theorems which flowed deductively from it than because it afforded knowledge in itself."

The mathematical achievements of the 16th and 17th centuries included the invention of analytic geometry and the calculus, and the application of the abstract concept of periodicity to the orbital motion of the planets, the vibrations of the pendulum, the behavior of light and sound and various other phenomena. These spectacular triumphs not only achieved a revolution in science but profoundly influenced philosophy, religion, literature and esthetics. I should like to consider briefly Kline's treatment of the Newtonian influence on this heroic period.

The setting is well known. No man before or since his time attained the intellectual prestige of Isaac Newton; no man's scientific theories commanded such universal assent. He modestly described himself as a boy playing on the seashore, "now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me." But the opinion of his contemporaries regarding his accomplishments is more accurately portrayed in Pope's familiar lines:

Nature and Nature's laws lay
hid in night:
God said, Let Newton be! and
all was light.

The Newtonian system of motion and gravitation stirred the hope that all phenomena might be reduced to cases of matter in motion and thus made amenable to strict mathematical treatment. A dozen different programs were launched to convert this hope into reality. In physics and astronomy the researches of d'Alembert, Clairault, Lagrange, Laplace and other leaders brilliantly supported the belief that the universe was a machine. In chemistry many quantitative laws were discovered, and the basis was laid for the modern ideas of chemical structure. In the biological sciences it was believed that studies of the flow of water in pipes would explain the circulation of the blood, that researches on light would elucidate how we see, researches on sound how we hear. Julien de la Mettrie, the celebrated French physician, wrote a book called *Man a Machine*, and claimed to have discovered the "calculus of the human mind." François Quesnay, the economist, formulated economic and social equations. The Marquis de Condorcet applied the theory of probability to the administration of justice. Baron d'Holbach, the arch antireligionist, explained consciousness and "all human thoughts and actions" in terms of matter and motion.

The influence of mathematics on philosophy is particularly noteworthy. Since the time of Aristotle mathematics had played a negligible part in speculative thought. But in the 17th century philosophy derived fresh inspiration from the triumphs of the mathematical sciences. Leibnitz conceived the idea of a universal language for science and a calculus of reasoning. He hoped to decompose complex ideas into simple, distinct, non-overlapping elements, represented by ideograms, which could then be manipulated according to the rules of the logical calculus. Mathematical procedures would make it possible to solve every problem, from the nature of the universe to the ideal recipe for a soufflé. The execution of the program turned out to be more difficult than Leibnitz had anticipated, but modern symbolic logic is based upon the foundations he laid.

Spinoza, Hobbes, Locke and Kant each expressed in his philosophy the dominant position of mathematics. Spinoza's *Ethics* was composed in the Euclidean style, with definitions, axioms and deduced theorems. Hobbes emphasized the purely physical character of mental processes and regarded mathematics as the sole means of gaining genuine knowledge of the outside world. Locke, by far the most popular philosopher of his time, accorded first place to mathematical knowledge, and his philosophy "is an almost perfect reflection of the contents of Newtonian science." In Kant's system of thought mathematics held a central position: the Euclidean postulates, for example, were represented as in effect built into the human mind; thus they determined the only possible mode of spatial apprehension.

Two philosophers moved against the Newtonian current. Bishop Berkeley argued persuasively against the prevailing belief in the supremacy of matter and matter's laws; for him mind and mental events alone were real. Moreover, he attacked the logical validity of fundamental concepts of the calculus—the most spectacular of the new mathematical tools. It must be admitted that his criticism was justified. More than a century was to pass before the calculus was placed on a rigorous and secure footing. David Hume carried Berkeley's radicalism further: he denied the existence of the mind itself. He wrote: "We cannot penetrate into the reason of the conjunction" of cause and effect. Mathematics was not spared in the sweep of his skepticism. He asserted that the statements of arithmetic were trivial and tautological: 2×2 is "simply another way of saying or writing 4." And so for the theorems of geometry, which are mere elaborations of tautological axioms. Thus he "destroyed by reasoning what reasoning had established while, at the same time, he revealed the limitations of reason." Bertrand Russell has said of Hume that by making self-consistent the empirical philosophy of Locke and Berkeley, he succeeded in making it incredible. His metaphysic, it may be observed, has not been refuted, despite many attempts. Indeed, modern science has in a sense vindicated both Berkeley and Hume. Matter is not, as was once supposed, material; space and time are today joined in a relative and personal concept, each observer having his own "here-now" which is just as valid as the here-nows of others; neither differential equations nor neat causal relations suffice to explain the universe.

The mathematical and scientific works of the 17th and 18th centuries challenged religious thinking. Newton, to be sure, saw the hand of God in the design and operation of the universe, a God "very skilled in mechanics and geometry." But in an age of reason, faith, except in reason, gradually fell into disfavor. The concept of the soul was denounced as meaningless; the Christian promise of eternal bliss in the after-life as reward for good behavior here below was adjudged a hoax devised to entice the credulous. Determinism brushed aside free will as pure nonsense. Voltaire summarized this view in a famous aphorism: "It would be very singular that all nature, all the planets should obey eternal laws, and that there should be a little animal, five feet high, who, in contempt of these laws, could act as he pleased, solely according to his caprice." And if man was bound by mechanical laws he was thereby excused for his sins.

Various attempts were made to accommodate religion to the current temper. The most successful of these was Deism, a kind of antiseptic Christianity whose followers, it was said, regarded Reason as God, Newton's *Principia* as the Bible and Voltaire as their Prophet. The Deists believed that the study of nature would provide them with ethical principles and answers to the problems of life. The movement was immensely popular. Thomas Jefferson and Benjamin Franklin were Deists, and "so great was the influence of this rational religion that no one of our first seven Presidents professed Christianity, though of course many made references to the Christian God in political addresses." Although Deism faded as a formal movement after the 18th century, Kline remarks that it remains to this day the essence of the prevailing religious attitude among educated persons. I am not fully persuaded that this is true. In the last decade there has been a powerful upsurge of primitive religious belief; tragically this has been accompanied by a decline of the tolerance and free thought which were characteristic of the Deist outlook.

One of the most interesting effects of Newtonianism manifested itself in literature and esthetics. "Just as the successful businessman in 20th-century America has become the authority in our time, so mathematicians, successful in revealing and phrasing the order in nature, became the arbiters of the language, style, spirit and content of 17th- and 18th-century literature." This is another of Kline's unfortunate oversimplifications; the 18th century was not all "calm serenity." Yet it is certainly true that it was a far more comfortable and secure age than ours. Much of its prose and poetry reflected a confident belief in the mathematical order of the universe and celebrated the value of science. This assurance took many forms. It appeared in the writings and critical principles of Samuel Johnson, in the attempts of Jeremy Bentham and others to attain precision of language, in the rationalistic poetry of Dryden and Pope, in the prolific outpouring of verse permeated with ideas and images of color and light inspired by Newton's work in optics. A linguistic reform committee of the British Royal Society urged members of the Society to reject all "amplifications, digressions, and swellings of style" and to use a "close, naked, natural way of speaking; positive expressions, clear senses, a native easiness; bringing all things as near the mathematical plainness as they can; and preferring the language of artisans, countrymen, and merchants before that of wits and scholars." Descartes, Pascal, Huygens, Galileo and of course Newton were held up as literary models because their writings were clear, neat, orderly, "elegant." Le Bovier de Fontenelle, the most famous scientific popularizer of the century, was convinced that "a work on ethics, politics or criticism, perhaps even a work of eloquence, will be finer, other things being equal, if it is done by the hand of a geometrician." The painting, architecture, landscape gardening and even furniture design of the 18th century exhibited their own brand of Newtonianism. Symmetry and adherence to simple geometrical forms were the ideals. According to Sir Joshua Reynolds: "It is the very same taste which relishes a demonstration in geometry that is pleased with the resemblance of a picture to its original and touched with the harmony of music. All these have unalterable and fixed foundations in nature."

It was a marvelous age. Its legacies are imperishable. But its triumphs were its undoing. The belief that the methods which had achieved successes in astronomy and mechanics and mathematics could be extended to the solution of all man's problems had a stifling effect upon thought. "The ambition of the 18th-century systematizers," writes J. Bronowski in his excellent volume *The Common Sense of Science*, "was to impose a mathematical finality on history and biology and geology and mining and spinning. It was a mistaken ambition and very dangerous." Modern science is more modest in its ambitions. It believes in studying processes as if they were machines, but in two crucial respects it has abandoned the 18th-century position. The machines we regard as models of natural processes are no longer thought to be simple affairs constructed of levers and pulleys and springs; they are machines capable of making random choices. This means that we are limited in our ability to predict what the machines will do, except in a statistical sense. Scientific thought has rejected the cause-and-effect sequence as the inexorable rule of process. "We can be quite clear," said Max Planck, "about one very important fact, namely, that the validity of the law of causation for the world of reality is a question that cannot be de-

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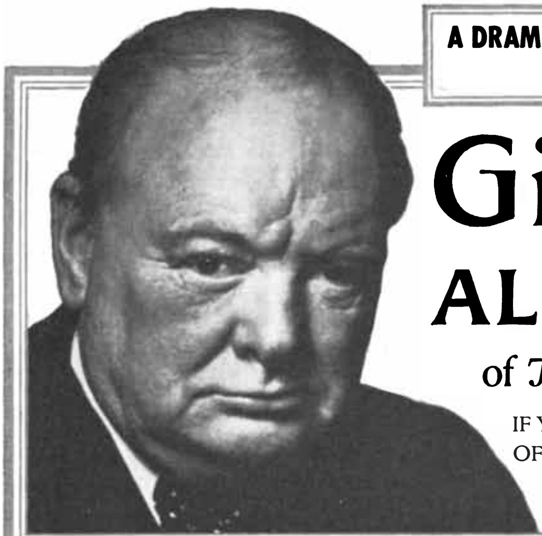

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cided on grounds of abstract reasoning." The uncertainty principle, the quantum theory, the concept of time in the Special Theory of Relativity—each contributes to undermining our belief in causality. It is not only that we do not know enough about any process to predict with certainty its future state; in principle it is impossible to gain all the needed information. We have come to realize that there is no clean cleavage between the observer and the observed; our plight is like that of the hapless biology student who saw long, curved black lines in every object which he examined under his microscope because his eyelashes always got in the way.

The profound consequences of the abandonment of the mechanical philosophy are admirably described in the later chapters of Kline's book, dealing with electromagnetic theory, probability and statistics and the theory of relativity. He enables us to see very clearly the trend in mathematics which has created the new concepts of science. Physics, the best example of this development, has "passed from a mechanistic to a mathematical foundation. Whereas mathematics served previously to represent, study and advance the mechanical analysis of phenomena, today the mathematical account is fundamental." Meanwhile mathematics itself is steadily becoming more abstract. It might be supposed that, moving in this direction, it will gradually lose contact with the physical world. Yet "the paradox is now fully established," said Whitehead, "that the utmost abstractions are the true weapons with which to control our thought of concrete fact." The relationships which seem to underlie phenomena at the deepest level are best described by the most abstract mathematical disciplines.

Kline's book makes some surprising and disappointing omissions. His treatment of the paradoxes of mathematics and foundation problems is trivial. He makes no reference to the work of Kurt Gödel, whose dazzling proof may well be as important for the future of mathematics as the work of the non-Euclidean geometers. Topology and the theory of games are not mentioned; quantum theory is brushed off in a sentence or two with the strange excuse that the subject is too difficult to explain in a popular book. Kline has shown that he can handle such subjects better than anyone else around, and I hope he tackles them in another book. In any case he has made a genuine contribution to our understanding of the nature of mathematics and its relation to western civilization. The beauty and fascination and rare excellence of mathematics emerge from his story. It is an exciting, provocative book.

Short Reviews

LOCKE'S TRAVELS IN FRANCE, edited by John Lough. Cambridge University Press ($8.00). The philosopher John Locke spent four years during his middle 40s traveling in France, mainly for his health. During the last two years of his stay he had charge of the son of Sir John Banks, with whom he intended making a trip to Italy—"but old father winter, armed with all his snow and iseicles, keeps guard on Monsenny and will not let me passe." Locke kept a voluminous journal in which he recorded all he said, heard and saw on his tour, as well as miscellaneous data on the weather, lists of coins, weights and measures, medical notes, comments on the Old and New Testaments and so on. Professor Lough has eliminated material of minor interest, added pertinent information contained in Locke's correspondence and papers and here offers an admirable edition of his journals. Locke was a diligent diarist, and many of his jottings are pretty tedious—for example, descriptions of expenditures, minute details about the fountains of Versailles, measurements of aqueducts and public buildings. On the other hand he had a lively curiosity, was as eager to talk to a "poore paisant's wife" as to a noble lord, and was a wonderfully sharp observer. His entries give fresh, vivid impressions of France at the height of the reign of Louis XIV. In Paris he broadened the education of his pupil by attending a public execution for which he had to pay to get good seats; at Poix his lodging furnished every conceivable discomfort, not excluding "6 legd creatures"; at Versailles the sights included an elephant and the *Roi Soleil* devoutly praying at his bedside; at "Tholouse" he was told that the Church of St. Sernin boasted among its "reliques" the "bodies entire of 6 of the Apostles and the head of a 7th." He noted the dreadful poverty widespread in France, the amusements, the agriculture and manufactures, the Roman ruins, the fine wines, the great cost of wigs, silk stockings and hats. He witnessed the conferring of a degree of "doctor of physic," a high affair which included speeches, "interludes of musick, much kissing and imbracing, & soe the ceremony ended with the inceptor making legs to each of the professors. . . ." A delicious book.

REASON AND NATURE, by Morris Raphael Cohen. The Free Press ($6.00). This notable book by the late

Morris Cohen, regarded as a leader in American philosophic thought, is republished in a revised edition. Edited by his son Felix, who died in 1953, the volume includes detailed corrections that the author incorporated in his own copy during the 16 years in which he had opportunity to reconsider his outlook. *Reason and Nature* is a lucidly written, thoughtful and exciting analysis, combining a scientific approach to philosophic problems with a philosophic approach to scientific problems. The distinguishing mark of Cohen's thought was "a profound faith in philosophy itself." The task of philosophy, he said in summing up his views, "is too complicated to be solved by simple magical formulae. . . . Let not philosophy, therefore, deal in false comforts or gratify those who crave from it confirmation of established prejudices. It has a far higher function—to give men strength to envisage the truth. Vision is itself a good greater than the perpetual motion without any definite direction which modernists regard as the blessed life. Cosmic vision ennobles the pathetic futility of our daily crucifixions." Since some lovers of philosophy are not wealthy, it will please them that they can now acquire for a reasonable price a book whose original edition was in such demand that secondhand copies sold for $25.

SPACE TRAVEL, by Kenneth W. Gatland and Anthony M. Kunesch. Philosophical Library ($4.75). FLIGHT INTO SPACE, by Jonathan Norton Leonard. Random House, Inc. ($4.50). Anything you could possibly wish to know about the prospects of visiting the moon—indeed a good deal more than most persons would wish to hear—is contained in these two volumes. Gatland and Kunesch, two British technical experts, give a straightforward account of the history of rockets and discuss current problems of space flight, including the danger of collisions with meteors ("meteor bumpers" will be used), landing procedures ("hydraulic legs" are in vogue at present), the construction of an artificial satellite (the military value of which the authors pooh-pooh). In spite of the many scientific and engineering details the average reader will have no difficulty in following this story, which appears to give as calm and dependable a report on the subject as has yet been published. The Leonard book is somewhat breathless. It makes a subject whose plainest facts bristle with terrors and fancies seem unreal and even a little absurd. In his 25 chapters (of which a sample title is "Into the Black Yonder") Leonard covers much of the same ground as Gatland and Kunesch, but his version is less informative and less interesting. On one point, at least, both books agree: The most palpitating ideas about space travel emanate from Wernher von Braun, the well-publicized astronaut who helped develop the Nazis' V-2 and is now with the U. S. Air Force. Dr. von Braun, known as "the Prophet of Space," means to get to the moon if he has to walk there. The latest and gaudiest of his plans is to build a plastic satellite from which we can keep tabs on earthly foreign powers and on the moon. The cost: $4 billion.

JANE'S FIGHTING SHIPS: 1953-54, edited by Raymond V. B. Blackman. McGraw-Hill Book Company, Inc. ($23.00). The 55th edition of *Jane's* is as fascinating and revealing a survey of our bloodthirsty little planet as ever. The three main trends of naval development are atomic propulsion, ship specialization and guided missiles. A philosopher might suggest that each of these trends not only reflects the adaptability of navies but foreshadows their inevitable extinction. Specialization has reached the point where no ship would dare stick its nose out of port without a corps of bodyguards. Great Britain is building four different types of frigates for anti-submarine, anti-aircraft and aircraft-direction duties; U. S. aircraft carriers are divided into attack, support, hunter-killer and escort types; submarines fall into several sub-categories, such as attack, hunter-killer, radar picket and guided-missile vessels. Surface-to-surface guided missiles, now in the experimental stage, will open up "new horizons." With atomic warheads and accurate target-finding capabilities of several hundred miles, these missiles will make the big warship as useful and as wieldy a military weapon as a dinosaur with glanders. A 75,000-ton, $200-million aircraft carrier, requiring more than five years to build, may be vaporized in five seconds by a guided missile costing a few hundred thousand dollars, launched from a small ship costing less than the officers' mess on the carrier. Nevertheless the U. S. and Great Britain are still pushing building programs involving huge ships. The U. S. Navy now has so many ships that, if they were strung end to end, one could walk halfway across the Atlantic over them. They include 36 fleet aircraft carriers, 66 escort carriers, 15 battleships, 2 battle cruisers, 29 heavy cruisers, 44 light cruisers, 352 destroyers, 250 destroyer escorts, 201 submarines, 365 mine craft, 162 patrol vessels, 900 amphibious craft, 678 fleet auxiliaries and 1,800 service craft. The Soviet Navy has no aircraft carriers and three rather moldy battleships, but it has 370 submarines—a setup which may be quite important if the main purpose of a navy is to sink the other fellow's navy.

THE STUDY OF CULTURE AT A DISTANCE, edited by Margaret Mead and Rhoda Metraux. The University of Chicago Press ($5.00). This is a manual based on researches inaugurated during the last war by the distinguished anthropologist Ruth Benedict. They were supported by a grant from the Human Resources Division of the Office of Naval Research, and their purpose was to study the cultural features of societies which, because of the war, were inaccessible to direct observation. Japan and Germany then belonged in this category. Today the U.S.S.R. and Communist China are barred to most students, and among other societies whose culture is inaccessible to them are the small Jewish towns in eastern Europe which were extirpated by the Germans and countries changed by revolution, such as Indonesia and Thailand. Various ingenious methods have been devised for interpreting these societies at a distance. They include extensive interviews with "living and articulate individuals whose characters was formed in the inaccessible society," and the study of books, newspapers, periodicals, films, works of popular and fine art, diaries, letters and the like. A good deal of the reporting in these pages is high-flown, pretentious and couched in the repellent argon of social scientists. But some of the contributions are of compelling interest: among them Rhoda Metraux's interviews of 10 people of various nationalities, several scholars' analyses of literature and films and projective test of representative individuals. One gets a sense from this book of how abundant, and how dangerous, is our ignorance of the thinking, habits, motivations and values of societies whose relations with us may well determine the issue of human survival.

INSTINCTS OF THE HERD IN PEACE AND WAR, by Wilfred Trotter. Oxford University Press ($5.00). Trotter was a noted British surgeon and student of social psychology who died in 1939. He first published this famous essay in 1916 and reissued it in 1919 with a postscript using the lessons of the First World War to reinforce his thesis. It is now republished in a handsome format incorporating final corrections based on the author's manuscript. Trotter's study is concerned both with the good uses to which the herd instinct may be put when intelligently directed and the limitless evil it causes when uncontrolled or deliberately manipulated by unscrupulous men.

CEILING UNLIMITED, by Lloyd Morris and Kendall Smith. The Macmillan Company ($6.50). The authors review the 50 years of U. S. aviation which began with the Wright brothers' epochal 12-second flight at Kitty Hawk on December 17, 1903. Their book succeeds in giving a vivid, anecdotal account of the men and machines who made the history of flight and in explaining clearly some of the theoretical and practical problems of aerodynamics that had to be solved along the way.

Notes

HYDROCARBONS FROM PETROLEUM, by Frederick D. Rossini, Beveridge J. Mair and Anton J. Streiff. Reinhold Publishing Corporation ($18.50). This massive volume, an American Chemical Society monograph, summarizes a 25-year research project of the American Petroleum Institute on the fractionation, analysis, isolation, purification and properties of petroleum hydrocarbons.

SCIENCE IN PROGRESS, edited by George A. Baitsell. Yale University Press ($6.00). Eighth of the series, this book covers the Sigma Xi National Lectures of 1951 and 1952. Among the lectures are one on the origin and evolution of the universe by George Gamow, on the evolution of insects by F. M. Carpenter, on sensory physiology and the orientation of animals by D. R. Griffin, on luminescent organisms by E. N. Harvey, on cooperation and conflict among primitive organisms by P. R. Burkholder.

THE THEORY OF METALS, by A. H. Wilson. Cambridge University Press ($8.50). Second edition of a monograph reviewing the basic physical principles of the theory of metals and reporting on researches of the past 15 years.

NATURAL HISTORY, edited by Charles Tate Regan. John de Graff, Inc. ($12.50). This immense reference work, edited by the director of the natural history department of the British Museum, has more than 1,000 photographs and articles by experts on species from the lowest unicellular organisms to the highest and most complex forms. On the whole, as good a one-volume survey as you are likely to find.

THEORY AND APPLICATIONS OF DISTANCE GEOMETRY, by Leonard M. Blumenthal. Oxford University Press ($10.00). On metric topology, concerned with mappings or transformations in which distances are preserved. Many of the topics are treated in English for the first time.

RADIOACTIVE ISOTOPES, by W. J. Whitehouse and J. L. Putman. Oxford University Press ($10.00). A manual by two Harwell scientists on the preparation, handling, measurement, radiochemistry, uses and properties of radioisotopes.

MATHEMATICAL METHODS FOR SCIENTISTS AND ENGINEERS, by Lloyd P. Smith. Prentice-Hall ($13.35). Lectures on the application of the more important and useful mathematical methods to problems of theoretical and applied physics.

METHODS OF MATHEMATICAL PHYSICS, Vol. I, by R. Courant and D. Hilbert. Interscience Publishers, Inc. ($9.50). This is the first English translation of a celebrated German treatise.

THE PROTEINS, edited by Hans Neurath and Kenneth Bailey. Academic Press Inc. (Part A, $12.00; Part B, $13.00). For advanced students, presenting an "integrated account of the chemical, physical, and biological properties of the proteins."

SQUARING THE CIRCLE AND OTHER MONOGRAPHS, by E. W. Hobson et al. Chelsea Publishing Company ($3.25). Four well-known essays on problems of geometry: "Squaring the Circle," by E. W. Hobson; "Ruler and Compass," by H. P. Hudson; "The Theory and Construction of Non-Differentiable Functions," by A. N. Singh, and "How to Draw a Straight Line: A Lecture on Linkages," by A. B. Kempe. An intriguing, meaty little book.

THE WORLD BENEATH THE SEA, by Otis Barton. Thomas Y. Crowell Company ($3.50). A singularly colorless account of the colorful adventures and deep-sea descents of Otis Barton, who invented the bathysphere and benthoscope.

A SURVEY OF MODERN ALGEBRA, by Garrett Birkhoff and Saunders MacLane. The Macmillan Company ($6.50). For this revised edition of their admirable text the authors have added several important topics: equations of stable type, dual spaces, the projective group, the Jordan and rational canonical forms for matrices.

THE AMATEUR SCIENTIST

Two astronomical matters: electronic light meters and "off-axis" reflecting telescopes

Conducted by Albert G. Ingalls

The next time you visit the station of an advanced radio ham take a look around his basement and back yard. The chances are better than even that you will find a well-made telescope. Many hams have two avocations, astronomy and electronics. The way things have been going in recent years, the two may soon merge into a single hobby.

Apollo Taleporos, whose eclipse pictures of the moon appeared in this department last September, explains: "Astronomy has borrowed so many of radio's techniques, and the aims of electronics have become so closely identified with those of astrophysical research, that you have to stop and think today before you can decide in which field you are working. I enjoy physics, particularly the electromagnetic part of it. So I do a lot of playing around in both electronics and optics. The only thing that keeps me out of the ultra-ultrashort waves is the cost of cyclotrons and sounding balloons."

Until 1946, according to Taleporos, most radio hams stuck closely to the communication side of radio. Back in 1912, when a government official was asked what part of the radio spectrum he would assign to the amateurs, he replied: "We'll stick 'em on 200 meters and below; they'll never get out of their back yards with that." As history records, in little more than two decades the hams made a back yard of the whole world, one now largely occupied by the multi-billion-dollar communications industry. But by the end of World War II amateur radio as such held few remaining challenges and the hams were ripe for something new.

It came suddenly, not with a bang but a squeal. Shortly after the Federal Communications Commission lifted the wartime ban on ham activity, some of the amateurs began to hear eerie squeals on the 14-megacycle band. The squeals were heard only at night, after the band had closed down for long-distance communication. An amateur would be idly scanning a portion of his dial between two active local stations in the hope of making one last distance contact before turning in for the night when suddenly a strange "woweeee" would almost shock him out of his chair. It was unlike anything heard on the longer waves. Some evenings it would come a dozen or more times at the same point on the dial. On others it would not be heard at all.

Word passed around quickly and before long almost everyone with a supersensitive receiver equipped for tuning in continuous wave telegraph signals was listening to the mysterious wails. Then someone discovered that they came from meteors.

Meteors leave in their wake ionization trails—mile-thick cylinders of charged gas which reflect 14-megacycle waves efficiently. During the brief interval that a meteor's trail persists, a favorably located receiver can pick up the carrier wave of a transmitter which would otherwise be beyond range, for at night the ionosphere loses some of its charge and becomes less efficient in reflecting signals. Thus in effect the hams were hearing shooting stars. The discovery opened the era of radio astronomy for them.

The flood of surplus optical and electronic gear that was put on the market after the war was a big help. Much of it was sold "as is" in the form of complete units, and amateurs often had to buy a large piece of apparatus in order to get the particular meter, lens or gear train they wanted. So the whole thing was carted home and the useless parts stored away against the day when they might come in handy. Some of this "junk" consisted of parabolic antennas, photomultipliers, recording meters, prisms, filters and other odds and ends which were destined—with the help of sweat and imagination—to become priceless possessions.

Today many hams are seen more often than they are heard. Amateurs are busy tuning in celestial objects on radio telescopes, bouncing waves off the moon, tracking meteors and recording their paths automatically, detecting and measuring disruptions on the sun's surface, plotting the orbits of eclipsing binaries and measuring the apparent magnitudes of variable stars with a speed and precision which would have startled professionals in the days when Harlow Shapley suggested that the cepheid variable might make a good yardstick.

Just as meteor observing attracted the radio hams to astronomy, so the photoelectric cell made electronic addicts of many optical men. For more than four decades members of the American Association of Variable Star Observers have been looking at these stars through their small telescopes. They have made more than a million and a half observations of some 600 variable stars. But the job takes good eyesight. Now electronics can do it much better. With the variety of sensing tubes now on hand, electronic gadgets can see farther, faster and more sharply and keep at it longer than the human eye. Moreover, electronic eyes can "see" in invisible parts of the electromagnetic spectrum and can tolerate blinding intensities.

One of the first amateur astronomers to go all out for electronics was John Ruiz of Dannemora, N. Y. After several years of mixing vacuum tubes and lenses, he recently said, with only slight exaggeration: "Whatever you can do mechanically you can do better and cheaper electronically." Whereas in mechanical amplification accuracy to one part in 100,000 is considered very good, in electronic amplification accuracy to one part in 100 million is routine. It takes high craftsmanship to make a telescope objective that yields a magnification of 300 diameters with good resolution, but a beginner can build on his first try an electronic gadget capable of amplifying a million million times with equally good "resolution."

Electronics has also taken a load off the amateur astronomer's pocketbook. For example, $25 will equip an amateur to pick up from the National Bureau of Standards' Station WWV time signals accurate to two parts in 100 million. How much would a pendulum clock of comparable accuracy cost, assuming, of course, that the market afforded one? The effect of the merger between astronomy and electronics has been to bring the amateur of modest means to a more nearly equal footing with his professional colleague in equipment.

A photoelectric photometer which Ruiz built for taking the guesswork out of variable star observing illustrates how simply optics and electronics can be combined to make an instrument of extraordinary power. As Ruiz says, you can hitch a photometer of your own make to a star.

"Of course, the star that you select should be one showing some action, *i.e.*, a variable star. Some variable stars go through a complete cycle in the course of a few hours (*e.g.*, the Beta Canis Majoris type), and you can make a full set of measurements for a complete 'light curve' in one night, weather permitting. Other stars of the eclipsing type have periods of a few days or longer. These are more difficult to follow and may require many nights of observing for a complete light curve. In the northeastern U. S. a series of observations on a single star may span two years or more, because nights ideal for photometry are rare.

"As an example of what an amateur can do with relatively modest equipment consider the light curve of No. 12 Lacertae, a short-period star of the Beta Canis Majoris type [*see upper illustration at right*]. This curve was taken in the course of one night. Ten curves like it were taken in the summer and fall of 1951 and they proved of value to the Dutch astronomer C. de Jager in making a new determination of the 'beat period' of the light variation. This star exhibits fluctuations both in amplitude and period, or, as radio hams would say, it exhibits both AM and FM.

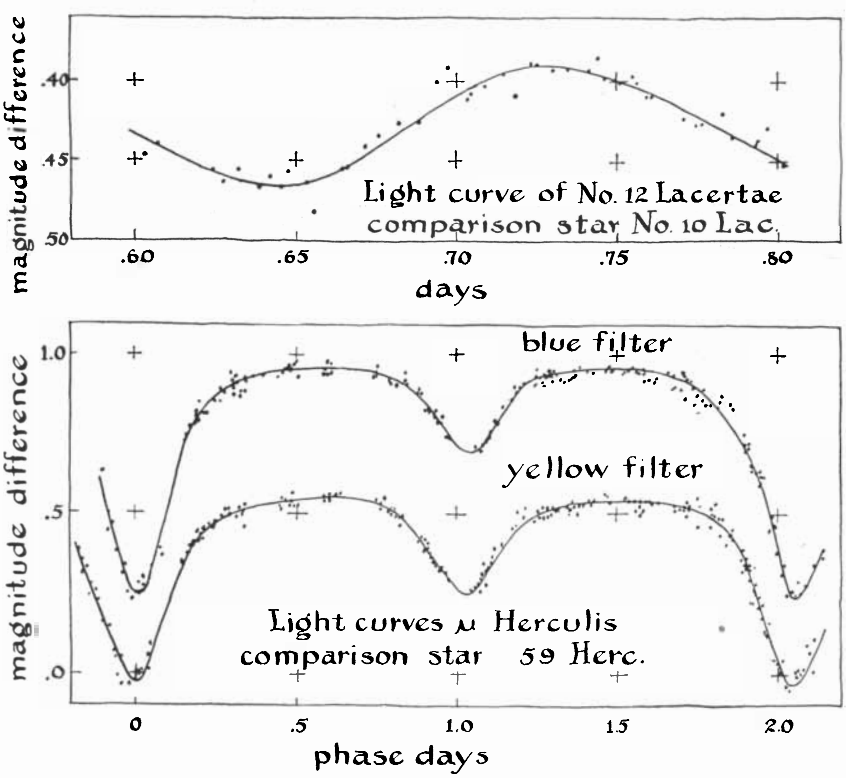
"Another type of variable is illustrated by the complete light curve of Mu Herculis, an eclipsing variable with a very short period—two days and one hour. The curves were taken in two colors, blue and yellow, corresponding roughly to the respective photographic and photovisual magnitudes. These curves promise to be of value in a more accurate determination of the orbital elements of this system.

"As some astronomers have recently pointed out, visual observation of variable stars is now outmoded, at least for those of short periods and narrow range. The photoelectric method is at least 10 times as accurate and far more objective, particularly in ascertaining the brightness of stars of different color or spectral class.

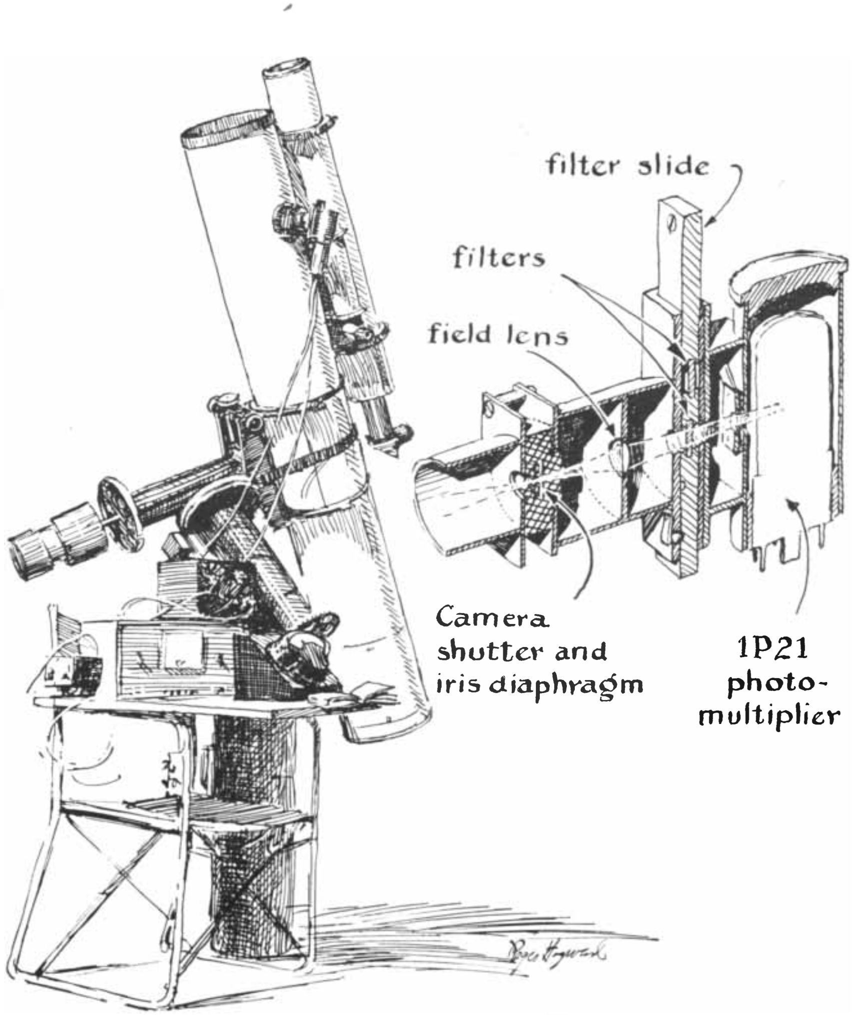
"To make graphs like these, you must have, first of all, a telescope solidly mounted in the manner advocated by Russell Porter. My setup is shown in Roger Hayward's illustration [*see next page*]. The telescope should be provided with an accurate clock drive and slow motions in both declination and right ascension. A reflecting telescope is preferred to a refractor, because violet and near ultraviolet light, to which the cesium-antimony photocell is most sensitive, is reflected by the aluminum surface of a mirror more effectively than it is transmitted by a refractor. Incidentally, the prism of a Newtonian should be replaced by an aluminized flat for the same reason. For the conventional eyepiece and eye we substitute a photometer head, or light box, which consists mainly of a holder for filters and the photomultiplier tube.

"In principle the stellar photometer is little more than a glorified exposure meter of the type used in making photographs. Like *omnia Gallia*, it consists of three parts: the photometer head, which corresponds to the light cell of the exposure meter; a direct current amplifier to build up the faint energy received from the stars, and an indicating device, usually a milliameter, which is read by eye, if possible by the eye of an assistant.

"The construction of the photometer head calls for no special tools and is easy if the amateur can lay hands on a small junk camera. Mine was made according to suggestions from William A. Baum of the Mount Wilson and Palomar Observatories. It is built around a camera shutter provided with an iris diaphragm [*see inset in illustration on next page*]. Note the use of the 'field lens,' which serves the double purpose of forming an enlarged image of the star (centered on the iris diaphragm) and of projecting on the photocathode an image of the fully illuminated mirror rather than a pinpoint image of the star under observation. This compensates for the granular structure of the photocathode, which is not equally sensitive at all points. You may compute the focal length of this field lens to give an image of your object glass or mirror about five millimeters in diameter, using nothing more than the elementary optics you learned in high school. Note that the gate holding the multiplier can be swung to one side when centering your star on the diaphragm. It is provided with an automatic shutter to cut off all light to the tube when this is done, for if strong light strikes the energized photocathode, it



The light curves of two variable stars, as plotted by electronic photometer



How an electronic photometer is affixed to a telescope, and a detail of the photometer

"To meet the present high standards of professional observation, an amateur must apply to his readings certain corrections which were of no consequence in the era of visual work. These have to do with atmospheric extinction, reduction of time to the sun and non-linearity of the meter and amplifier. But a serious worker will find many a helping hand among his kind both in amateur and professional circles. The dividing line between a professional and an amateur is very dim indeed, for only an 'amateur' would ever become a professional. James Stokley of the General Electric Company once said that the difference between an amateur astronomer and a professional is that the amateur is sorry when it is cloudy."

may become temporarily unstable or even permanently damaged.

"My photometer uses a nine-stage 1P21 photomultiplier which works on the secondary emission principle, as explained in this department last March. Each stage amplifies the signal by a factor of four or five, so that the over-all gain in signal strength is enormous.

"The energy we receive from a faint star is so small that even after immense amplification by the dynode stages of the 1P21 tube it may amount to no more than 10^{-9} amperes. Minute currents of this order of magnitude can be measured by ultrasensitive galvanometers and electrometers. But these instruments are costly, require rigid mounting and are delicate. The output of the photomultiplier tube is usually amplified.

"Two properly chosen vacuum tubes in a well-designed circuit will provide amplification of a million and permit the use of a meter which is driven to full-scale deflection by one milliampere. Many of these rugged little meters are on the market and can be purchased for less than $5.

"Gerald E. Kron of the Lick Observatory has designed a two-tube, direct-coupled amplifier specifically for photometric use which is about as simple and foolproof as the instrument can be made. The complete circuit, together with instructions for building it, a list of the parts and full operating information, comprises a chapter in *Amateur Telescope Making, Book Three.*

"With these three units completed, all that remains is to hook them together, substitute the photometer head for the eyepiece, select a star and have fun. If you have both a persuasive personality and a kindly disposed wife, she can take readings while you do the guiding with the auxiliary telescope. Of course you may choose to buy a Brown potentiometer for about $600 as an alternative—but I could not induce the director of the budget in my household to approve this expense. So most of the time I do all the work myself. As is evident, stellar photometry is an ideal project for two amateurs, one a gadgeteer to build the apparatus and the other a researcher who enjoys the role of chief observer.

Obstructions in telescope tubes, such as diagonal and secondary mirrors and their mechanical supports, not only cut off light but also cause injurious diffraction. Horace E. Dall has pointed out in *Amateur Telescope Making—Advanced* that diffraction vitiates the image and reduces contrast of fine detail, such as lunar and planetary features. The radial spikes that project from images of bright stars on some photographs are evidence of diffraction caused by telescopic obstruction. In general, reflecting telescopes, most of which have central obstructions, give images with lower contrast and slightly poorer definition than those of high-quality refractors.

The late planetary astronomer William H. Pickering described a diffraction experiment which emphasized the impairment of seeing by obstructions. First he deliberately increased the diffraction effect by enlarging the obstruction area of the diagonal mirror with a paper mask extending beyond the mirror. Then he entirely eliminated the obstruction of the diagonal mirror and its supports by another device—a mask which let the incoming rays of light reach the mirror only through a relatively small off-center opening. In spite of the reduction in the amount of light that reached the mirror, the seeing was greatly improved. Adopting this working principle, A. E. Douglass, another planetary astronomer, masked the aperture of a 36-inch telescope in such a way as to leave uncovered only an off-axis circle 13 inches in diameter [*see drawing at upper left in illustration on page 104*]. The result was a net gain in visibility of fine detail despite the loss of brightness.

Astronomers have noted these evil effects of central obstruction for many years, but it is not easy to build large off-axis telescopes to avoid them. In recent years advanced amateur observers of the planets and moon who have exhausted the fullest powers of conventional obstructed telescopes have been inventing new telescope designs for reducing diffraction effects. One of these is J. S. Hindle of England, son of the late amateur astronomer J. H. Hindle. He writes:

"When conventional types of reflecting telescopes are used visually on planets, especially with large apertures, the finest detail is usually best seen by using an off-center diaphragm to cover the secondary mirror and its supports, as described by Pickering. However, the arrangement is far from perfect, as the large block of glass in the primary mirror is rarely in a state of thermal equilibrium and definition consequently suffers. An alternative for obtaining an off-axis section of a paraboloid is to coat a spherical mirror with an uneven layer of aluminum. Excellent in theory, this is open to the objection that the thickness of the aluminum deposit must be extremely accurate to get optimum results. The Herschelian reflector, used with a meniscus correcting lens in the return beam [*see drawing at upper right in illustration on next page*], seems to offer an answer. Moving the lens to or from the mirror gives under- or over-correction for spherical aberration. Although the scheme gives remarkably good results with moderate apertures, it proves cumbersome with large instruments, the observer perforce being perched high on a ladder or platform in the dark. The same dangerous and uncomfortable situation arises when an off-axis paraboloid is used.

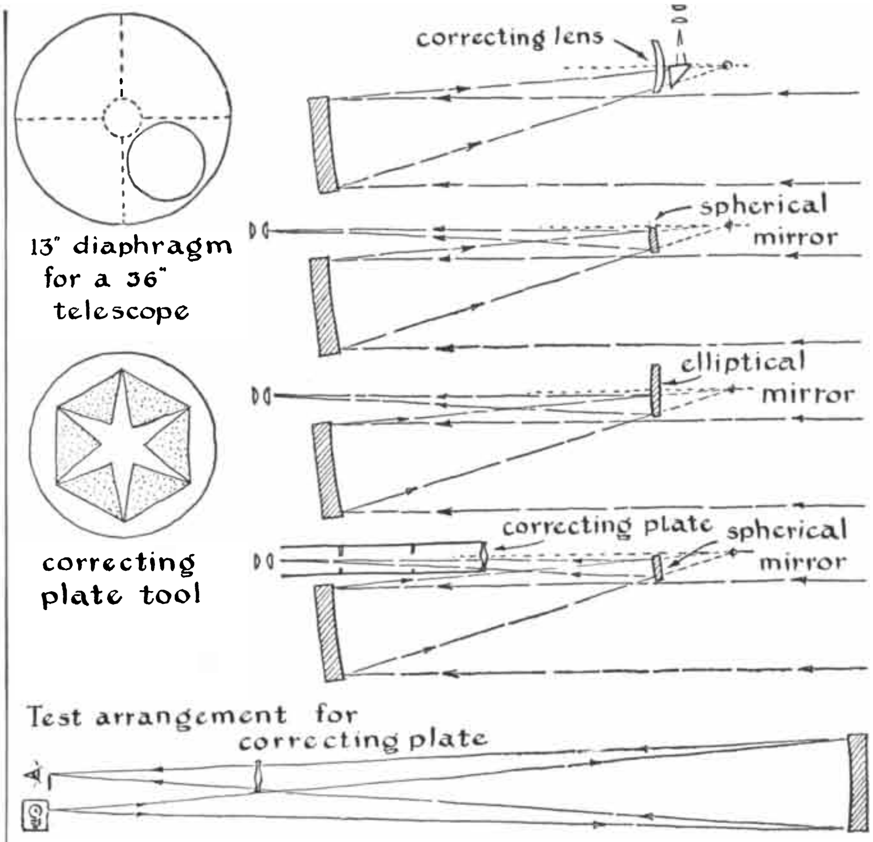
"The skew Cassegrain was first used to avoid central obstruction by Karl Fritsch of Austria, who made many small ones about six inches in diameter, and A. A. Common of England, who made a 12-inch from which he claimed to get good visual results. These instruments used two spherical mirrors [*see cross section second from top in illustration on next page*]. Although the aberrations of the secondary tend to cancel the spherical aberration of the primary, the method fails when tried on large apertures, the residual spherical aberration being such that critical detail is unobtainable under high magnifications. Tilting the secondary tends to minimize spherical aberration but introduces astigmatism, which causes star images to appear as short straight lines.

"Another modification which at one time looked promising was an elliptical secondary about two thirds the diameter of the primary [*see cross section third from top*]. This large secondary was necessary because only an off-center section of it was used. The scheme failed on large sizes, due to flexure of the secondary, which could be supported only at the edge. The elliptical secondary also is very difficult to test and figure.

"To dispose of these defects of the off-axis telescope I have designed and constructed a Cassegrain-Schmidt combination [*see cross section fourth from top*]. It has two spherical mirrors and a small correcting plate similar to a Schmidt plate to cure spherical aberration. In sizes larger than about eight inches this type will give far sharper detail and stand far higher magnification than the conventional Newtonian and Cassegrain types. My 12-inch will stand 600 diameters on most nights and still give an image nearly as sharp and crisp as when using only 60 diameters. Tested against three different 12-inch reflectors and one 15-inch, it has easily outclassed the performance of them all when planetary detail was being observed. The data for a 12-inch telescope of this type are as follows: Focus of primary, 10 feet or more. Diameter of convex, 3 inches. Radius of curvature for convex, 62 inches. Cone cut off by convex, about ⅕ focus. Diameter of correcting plate, 3 inches; thickness, about ¼ inch.

"If these proportions are approximated, the primary mirror may be used for testing the figure of the correcting plate. The angle of the return cone of rays, when an illuminated pinhole is placed at the center of curvature of the primary, will be identical with the angle of the cone from the secondary when the finished instrument is used at infinity. The amount of deviation from flatness that must be imparted to the correcting plate can be calculated from the familiar formula r^2/R, with one important difference. The r in this case does not refer to the semi-diameter of the primary; it refers to the distance from the optical axis of the system to the farthest point on the circumference of the primary.

"When testing the correcting plate the spherical primary is set up as usual for the Foucault test but using about six inches' separation between the pinhole and knife-edge [*bottom drawing*]. The plate is then placed between the primary and knife-edge, at such a distance that it just fills with light when viewed from the center of curvature, without any of the mirror being visible outside the plate. In the example given the plate must be figured until the primary assumes the appearance of a hyperboloid,



Concerning reflecting telescopes with unobstructed tubes

with the outer rays coming to a focus about ⅞ inch longer than the central rays. It will be necessary to attack both sides of the plate to obtain this deviation, if the plate is made from polished plate glass. It is advisable to cut several square pieces and test for astigmatism in the return cone of rays from the primary at center of curvature. The best shape of polisher for the plate is shown in the illustration. If the plate is mounted on a rotating spindle, it may be quickly roughed to shape with the ball of the thumb, and afterward finished off with the polishing pad.

"If the plate shows traces of astigmatism when finished, do not scrap it but rotate it in different positions when in the telescope, as only half of the plate will be in use and a good diameter usually can be found.

"The best test for the convex is King's, but a fair idea of the figure may be obtained by placing the pinhole at four times the focal length of the primary away from the primary and intercepting the return cone of rays with the convex, so as to reflect the cone back to the edge of the primary. On passing a knife-edge across the apex of the cone, an even darkening of the light should be observed. The big snag to this method, of course, is that a long testing room is required. The primary should be aluminized for the test, because there are two reflections.

"A slightly positive meniscus lens may be substituted for the correcting plate, but it will give a rather curved field of view. The chromatic aberration caused by the correcting plate is so small as to escape detection with quite high powers.

"The stops shown between the eyepiece and the plate are very important, as objectionable sky flooding will occur if they are missing or imperfectly positioned.

"Moving the correcting plate nearer the convex increases correction for spherical aberration, and moving it away has the reverse effect, hence good definition will not be attained until this adjustment has been made perfect.

"To collimate the instrument it is necessary to place a button or small circular object exactly in the center of the primary, at the open end of the tube. Both mirrors are then adjusted until the reflection of the mirror and the button are seen concentric in the convex, looking from the eyepiece drawtube with the eyepiece removed."

The off-axis Cassegrain shown in the second drawing from the top was invented in 1876 by I. Forster and Karl Fritsch of Vienna and was known as the

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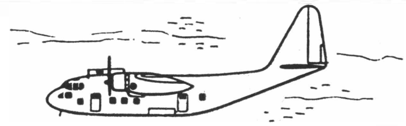

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brachyte. In the December 1, 1952, issue of *The Strolling Astronomer*, organ of the Association of Lunar and Planetary Observers, Guenter Roth and E. L. Pfannenschmidt described a modern German variation called the neobrachyte. Roth's $f/20$ "neo-bra" has an eight-inch spherically concave $f/12$ primary mirror, its axis tilted to an angle of 3 degrees, 16 minutes and 30 seconds of arc with the incoming light. The four-inch $f/24$ spherically convex secondary mirror has the same radius of curvature as the primary and is tilted to an angle of 12 degrees, 56 minutes from the new or deflected axis of the primary (though the three axes involved are not in the same plane). The secondary is separated from the primary by a distance of seven times the diameter of the primary. Astigmatism is eliminated by deforming the secondary to a slight cylindricality with a screw pressing against its back along one diameter. This subterfuge, which avoids the necessity of figuring an aspherical correcting plate, is the secret of the neo-bra.

According to the authors an eight-inch neo-bra will show perfectly round, concentric star images at powers of 300 to 450. Larger sizes require a shorter focal ratio, ray tracing and a Dall-Kirkham primary. Excellent star images were given by a 12-inch neo-bra at a power of 500.

Roger Hayward, who made the illustration from Hindle's sketches, comments: "I recall J. A. Anderson (who had charge of the optical parts of the 200-inch Hale telescope) saying that the ideal size of telescope for visual observation was around 10 inches. In a smaller telescope the image suffers from too little resolving power, in a larger one the seeing deteriorates. This is because atmospheric waves that mess up the air commonly are of such dimensions as to make the image from a 10-inch disk wobble about at a rate which the eye can follow. At twice this size or larger the image will go in and out of focus as the light from two sides of the disk is refracted together or apart. I feel that this, more than the absence of obstruction, is likely to have been one reason why the 13-inch diaphragm opening improved the seeing with the 36-inch telescope."

Anderson has described a simple method for observing atmospheric waves that impair good seeing. These waves are believed to be ripples at the interfaces between moving layers of warm and cold air high aloft. Anderson points a small low-powered telescope—for example, with one-inch aperture, eight-inch focal length and a low-powered eyepiece—at a bright star, holding the eye end with one hand, the objective end with the other. Then he swings the objective end in a circle about a quarter inch in diameter at the rate of four or five revolutions a second. Due to the persistence of vision, the star image is drawn into a nearly complete circle if the rate of rotation is correct. You soon learn to judge the state of the seeing by the number of bright patches in the circle. The bright patches correspond to the moments when the concave crest of the wave is in line with the telescope so that it refracts the sides of the interrupted disk together, and the darker portions correspond to the convex trough of the waves, which Anderson assumes from experience are about six inches in length. In good seeing the frequency of the bright patches with this scintillometer ranges from a few to 25 or 30 a second, while in bad seeing there are often 150 a second.

Much has been written about the evil effects of central obstructions on visual observation, but there is no agreement about the effects. Laboratory experiments which exclude the effects of the turbulent atmosphere do not agree closely with tests at the eyepiece out-of-doors. The laboratory tests seem to prove that there is no serious impairment of image quality until 20 to 30 per cent of the diameter of the aperture is obstructed. On the other hand, E. K. White of British Columbia found at the eyepiece that even the 17 to 25 per cent obstruction in the typical Newtonian telescope caused pronounced diffraction effects on the images of planets. With a reduced diagonal which obstructed but 10 per cent of the aperture diameter, he found that the image quality was greatly improved. The editor of *The Strolling Astronomer*, in which the experiment was described, remarked that White had observed little-known delicate features on Saturn about as well with a nine-inch telescope as he had been able to do with an 18-inch telescope.

Does the factor described by Hayward—the length of the atmospheric waves high aloft—have anything to do with this equality? David W. Rosebrugh, a veteran observer, believes that it does. He thinks that the maximum useful aperture for visual use is six inches, because larger telescopes are more sensitive to the atmospheric waves.

After reading a score of articles on the subject, as I have just done, you may come to feel that only two facts have been isolated: (1) unobstructed telescopes are better than obstructed ones; (2) the effects of obstruction are confused by the effects of size of aperture.

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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.

A CRISIS IN SCIENCE TEACHING

CRITICAL YEARS AHEAD IN SCIENCE TEACHING. REPORT OF NATION-WIDE CONFERENCE ON PROBLEMS OF SCIENCE TEACHING IN THE SECONDARY SCHOOLS. Harvard University Printing Office, 1953.

A POLICY FOR SCIENTIFIC AND PROFESSIONAL MANPOWER. Columbia University Press, 1953.

SCIENCE IN SECONDARY SCHOOL TODAY. *Bulletin of the National Association of Secondary School Principals*; January, 1953.

THE TEACHING OF SCIENCE IN PUBLIC HIGH SCHOOLS. Philip Johnson. U. S. Office of Education Bulletin No. 9, 1950.

CURIOSITY IN MONKEYS

DISCRIMINATION LEARNING BY RHESUS MONKEYS TO VISUAL-EXPLORATION MOTIVATION. Robert A. Butler in *Journal of Comparative and Physiological Psychology*, Vol. 46, No. 2; April, 1953.

THE GREAT APES. Robert M. Yerkes and Ada W. Yerkes. Yale University Press, 1929.

MICE, MONKEYS, MEN AND MOTIVES. Harry F. Harlow in *Psychological Review*, Vol. 60, No. 1; January, 1953.

A FAMILY OF SOLAR ECLIPSES

ECLIPSES OF THE SUN. S. A. Mitchell. Columbia University Press, 1924.

ECLIPSES OF THE SUN AND MOON. Sir Frank Dyson and R. v. d. R. Woolley. Clarendon Press, 1937.

SUPPLEMENT TO AMERICAN EPHEMERIS, 1954: TOTAL ECLIPSE OF JUNE 30, 1954. Government Printing Office, 1953.

TOTAL ECLIPSES OF THE SUN. Mabel Loomis Todd. Houghton, Mifflin Co., 1894.

BLOOD

BLOOD CELLS AND PLASMA PROTEINS. Edited by James L. Tullis. Academic Press Inc., 1953.

BLOOD TRANSFUSION IN CLINICAL MEDICINE. P. L. Mollison. Blackwell Scientific Publications, 1951.

THE RABBIT PLAGUE

CHANGES IN THE MORTALITY RATE DUE TO MYXOMATOSIS IN THE AUSTRALIAN WILD RABBIT. Frank Fenner in *Nature*, Vol. 172, No. 4371, pages 228-230; August 8, 1953.

CLASSIFICATION OF MYXOMA AND FIBROMA VIRUSES. Frank Fenner in *Nature*, Vol. 171, No. 4352, pages 562-563; March 28, 1953.

MYXOMATOSIS IN AUSTRALIA—A STEP TOWARDS THE BIOLOGICAL CONTROL OF THE RABBIT. F. N. Ratcliffe, K. Myers, B. V. Fennessy and J. H. Calaby in *Nature*, Vol. 170, No. 4314, pages 7-11; July 5, 1952.

THE SHAPE OF RAINDROPS

THEORETICAL CLOUD PHYSICS STUDIES. Final Report on Contract Nonr757, Project No. NRO82093. Office of Naval Research, January 31, 1953.

ULTRAMICROCHEMISTRY

INTRODUCTION TO THE MICROTECHNIQUE OF INORGANIC ANALYSIS. A. A. Benedetti-Pichler. John Wiley & Sons Inc., 1942.

MICROCHEMICAL METHODS USED IN NUCLEAR RESEARCH. B. B. Cunningham in *Nucleonics*, Vol. 5, pages 62-85; 1949.

QUANTITATIVE ULTRAMICROANALYSIS. P. L. Kirk. John Wiley & Sons Inc., 1950.

THE END OF THE MOAS

THE MOA-HUNTER PERIOD OF MAORI CULTURE. Roger Duff. Bulletin No. 1 of the Canterbury Museum. New Zealand Department of Internal Affairs, 1950.

THE AMATEUR SCIENTIST

ELECTRONICS: EXPERIMENTAL TECHNIQUES. William C. Elmore and Matthew Sands. McGraw-Hill Book Company, Inc., 1949.

AMATEUR TELESCOPE MAKING. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.

AMATEUR TELESCOPE MAKING—ADVANCED. Edited by Albert G. Ingalls. Scientific American, Inc., 1952.

AMATEUR TELESCOPE MAKING—BOOK THREE. Edited by Albert G. Ingalls. Scientific American, Inc., 1953.

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