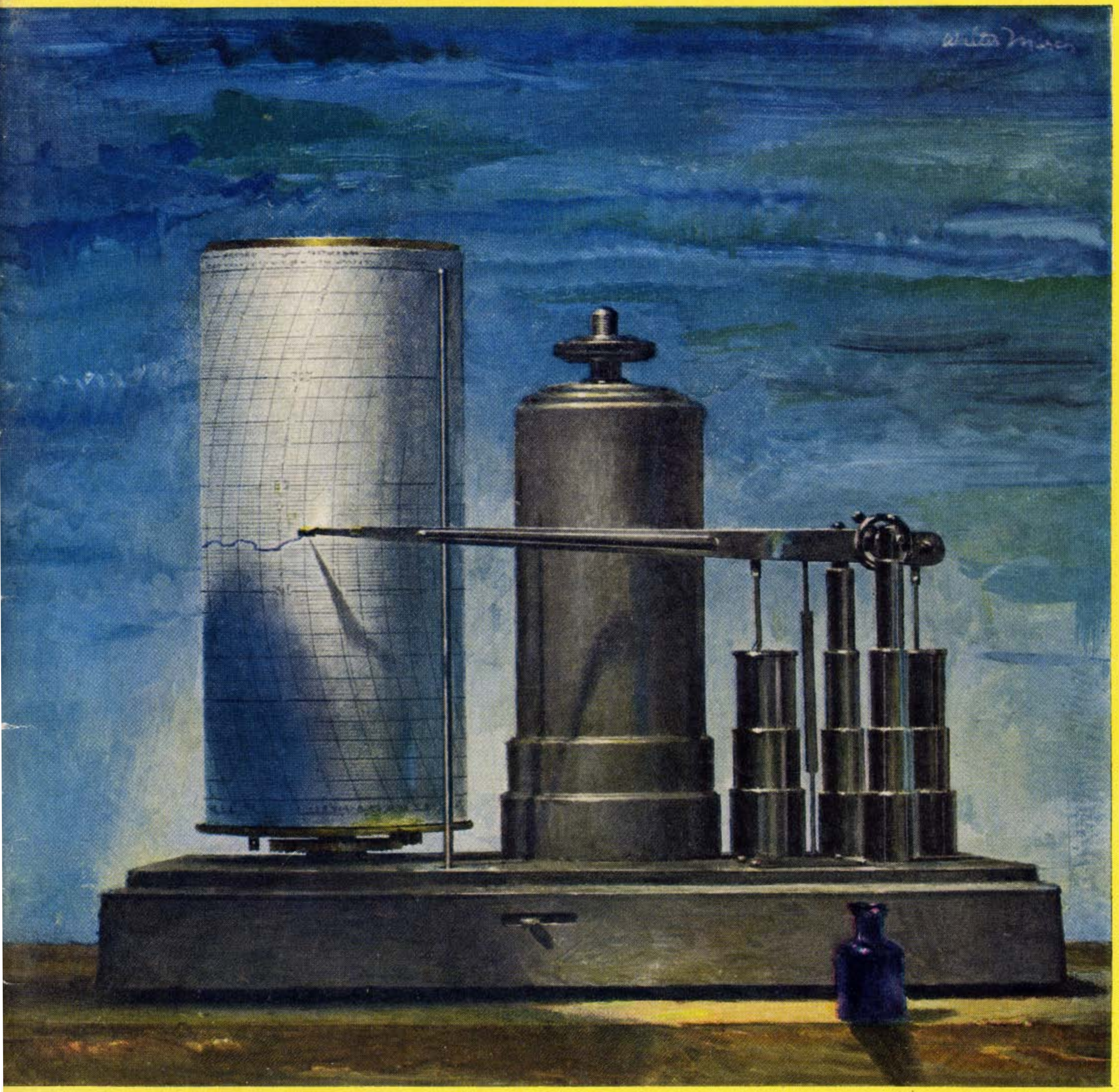
SCIENTIFIC AMERICAN



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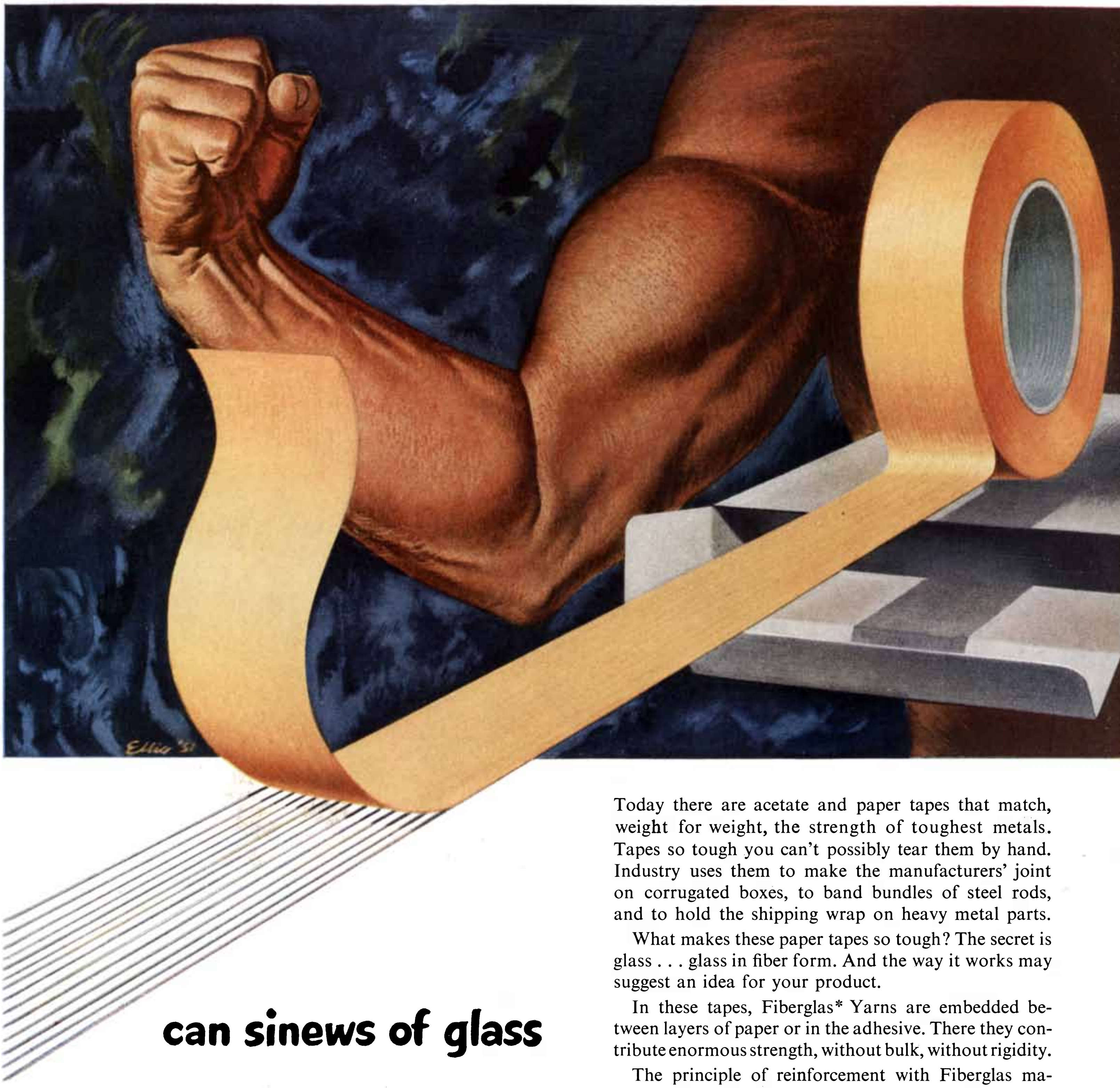
December 1951



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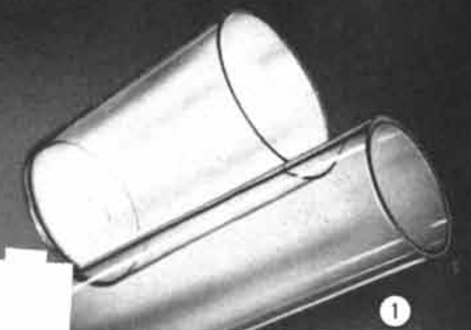

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1851 *Corning means research in Glass* **1951**

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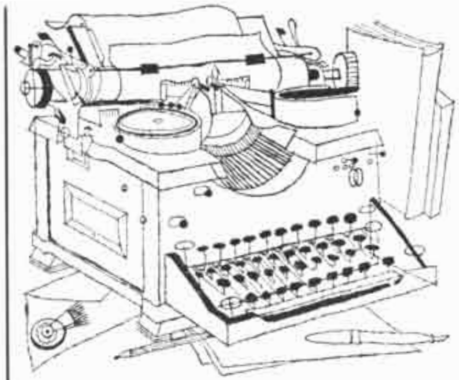

LETTERS

Sirs:

In connection with his review [Scientific American, October] of *Methods of Operations Research* by Philip M. Morse and George E. Kimball, J. Bronowski goes at some length into the nature of operations research and gives a rather dark picture of its probable future in war and peace. I would like to comment briefly on this part of his review.

Bronowski believes that what is new in operations research "for academic science" is its extensive use of the theory of probability, which he associates with the biological and social sciences as distinguished from the "exact" sciences. He further excludes the theory of probability from what he calls the classical mathematics of exact quantities, and explains that since the latter is unsuited to the requirements of the social sciences, "workers in Great Britain, the U. S. and the U.S.S.R. have built the beautiful mathematics of probability." This is a remarkable statement. As everyone knows, probability theory was laid down by Pascal and Fermat in the 17th century, long before there was any social science, and was extensively developed on the European continent by such mathematicians as the Bernoullis, Laplace and Gauss. Furthermore, modern applications of probability theory are not confined to the biological and social sciences. With the rise of quantum theory over the past 50 years, as "exact" a science as physics has been permeated by probability considerations. In spite of these facts Bronowski tells us that the probability approach to nature as an experiment "is still a stranger in most university departments." The novelty of operations research does not lie solely, nor even mainly, in its use of the theory of probability.

Since operations research is the organized application of scientific method to operating problems, it uses whatever techniques are most suitable for the solution of such problems, and among the foremost are the theories of probability and statistics. It is no more committed to them, however, than is chemical analysis to the use of glass containers. The true novelty of operations research lies in other directions.

At the close of his review Bronowski reaches the conclusion that "the heroic age is over," the major contributions of operations research in the past. "Nor is the art of war," he says, "likely to offer again such a creamy surface to skim. The easy successes have been scored; the simple mistakes which they put right are understood and should not be made again." It is possible that Bronowski here underestimates the capacity of human beings to repeat their errors, especially under changing conditions.

With the risks attendant on all such statements, I would like to put forward the alternative view that operations research is at the diaper stage, that its great successes are in the future. First, as to its military applications: Operations research is applied at three levels, the use of weapons or gadgets, tactics and strategy. For simplicity consider only the first of these. The notion that we have learned the optimal use of present weapons, or those in the development stage, will not bear scrutiny. In a recent article in *The New York Times* Hanson Baldwin says: "We are passing through a period of technological revolution in warfare, which has by no means ended. The influence of [new developments] has been more profound than at any time since the invention of gunpowder, but the greatest effects still lie in the future." Second, as to the nonmilitary applications: I cannot do more here than point out that there have been a few industrial applications in this country under conditions conducive to success. These conditions include not only the scientific ability and practical sense of the workers, but the intelligence and understanding of the top-level administrators from whom they must receive the closest sort of cooperation. Under

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New York 20, N. Y.

RCA RADIO CORPORATION of AMERICA

such conditions operations research is far more than "a painstaking combination of cost accounting, job analysis, time and motion study and the general integration of plant flow."

HORACE C. LEVINSON

Kennebunk, Me.

Sirs:

The item *ACS v. AMA* in your department "Science and the Citizen" for October gives the erroneous impression that chemists introduced the original version of the bill H. 1205 in the Pennsylvania Legislature in order to permit them to become directors of clinical laboratories. Actually, of course, chemists are and always have been directors of many clinical laboratories in the State of Pennsylvania. The original version of the bill was sponsored by the M.D.'s in an effort to prevent chemists from serving as directors of clinical laboratories in the future. The revised bill H. 1205, recently signed by Governor Fine of Pennsylvania, obviously is a compromise measure. It does, however, stop the attempt of the medical profession to exclude all but M.D.'s from serving as directors of clinical laboratories. Briefly stated, the American Chemical Society has always maintained that the criterion that should be followed is the competence of the individual to supervise and direct the work of a clinical laboratory rather than a particular degree–M.D.

WALTER J. MURPHY

Editor
Chemical and Engineering News
Washington, D. C.

Sirs:

In his contribution to the admirable survey "The Human Resources of the U. S." in your September issue, Dr. Karl T. Compton paints a gloomy picture of the acute shortage of engineers. He tries to explain it by past warnings and rumors about overcrowding of the profession and by the "unforeseeable" Korean War. In order to alleviate it he would forcibly allocate engineers to priority jobs and prevent their desertion by military draft. At the same time he hopes to attract new students by propaganda about wonderful prospects.

All this sounds paternalistic and nearly totalitarian to this writer. Are we so busy fighting communist dictatorship that we forget our own economic theories such as free competition and the law of supply and demand?

If students stayed away from Compton's M.I.T. and other technical institutes, and engineers deserted their profession, it was not due to propaganda.

Half a cupful...
can sink a boat

Power boat skippers don't frighten easily.

Yet they're scared stiff of gasoline seepage. "It's dynamite," they tell you, "—half a cupful can blow your boat to 'Kingdom Come'."

So they put boat builders right on the spot when it comes to gas tanks.

They want tanks made of metal that sea air, bilge, or gasoline won't corrode ... metal that's easy to fabricate, to weld gas-tight ... metal that doesn't form sludge that "gums up" fuel lines and leaves you going nowheres, slow.

Now that's a mighty tall order.

But boat builders filled it. Filled it with a metal that satisfies *their* demands ... and the strict requirements of the Yacht Safety Bureau. Filled it with a metal that qualifies in every respect for gas tanks, among stock boat builders.

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Then the answer can be ready at your hand when these critical times are over and Inco Nickel Alloys are available in any quantity for any use again.

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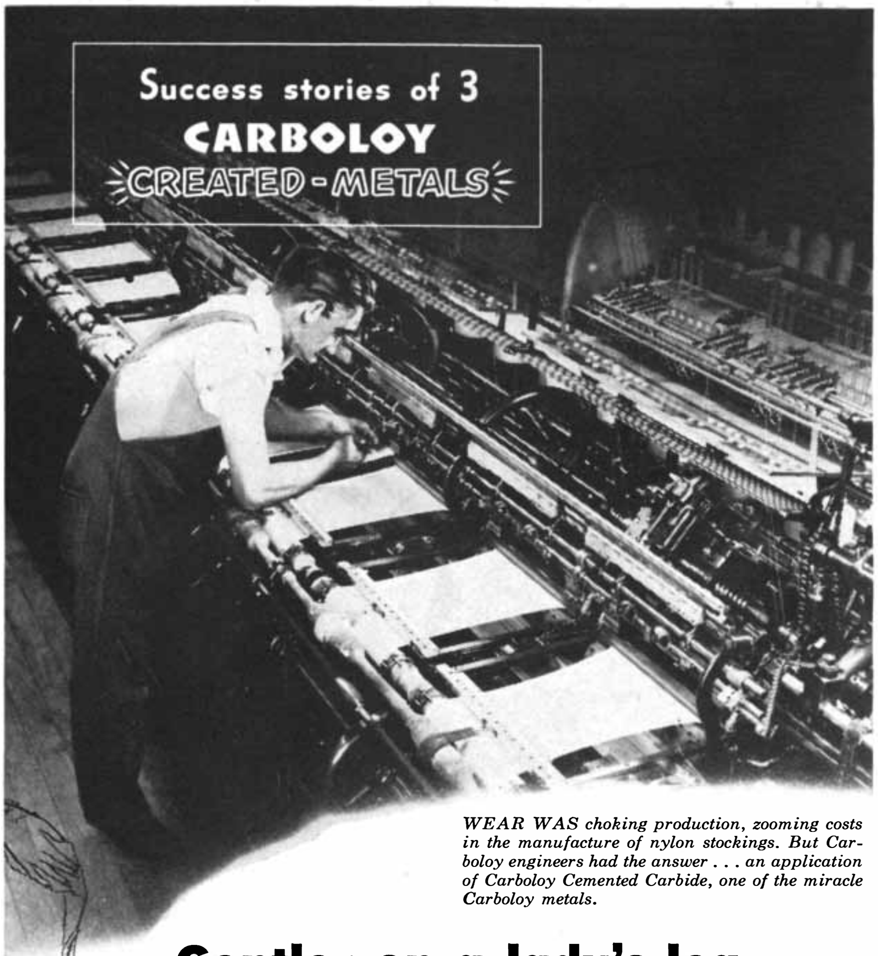


They simply found out that it was better to work at manual labor or in commercial fields rather than invest long years of study and productive talent for poor pay and high-handed treatment.

They are now returning because employers bid each other up in a frantic scramble for the brain power which they made light of too long. Soon we may have a new period of relative oversupply and economic squeeze between the grindstones of management and labor unions.

What can alleviate these recurrent crises and stabilize the balance between supply and demand? Only an organization of engineers and industrial scientists which is strong and vigilant enough to maintain the dignity and economic security of the profession. Intelligent management will learn to appreciate such an organization just as they are finding out that relations with labor are smoothed by cooperation with well-known unions.

If engineers are decently paid and given a voice in the plant management, it will not be necessary to freeze them to their jobs. They will stay voluntarily and double their productivity by working with minds free from worries and grudges.

WALTER J. ALBERSHEIM, DR. ENG.

Asbury Park, N. J.

Sirs:

Karl T. Compton's article entitled "Engineers" in your September issue was an excellent summary of the manpower situation in the engineering field. In his suggestions for alleviating the present and future shortage of trained persons, Mr. Compton did not, however, recognize the potential of women in engineering.

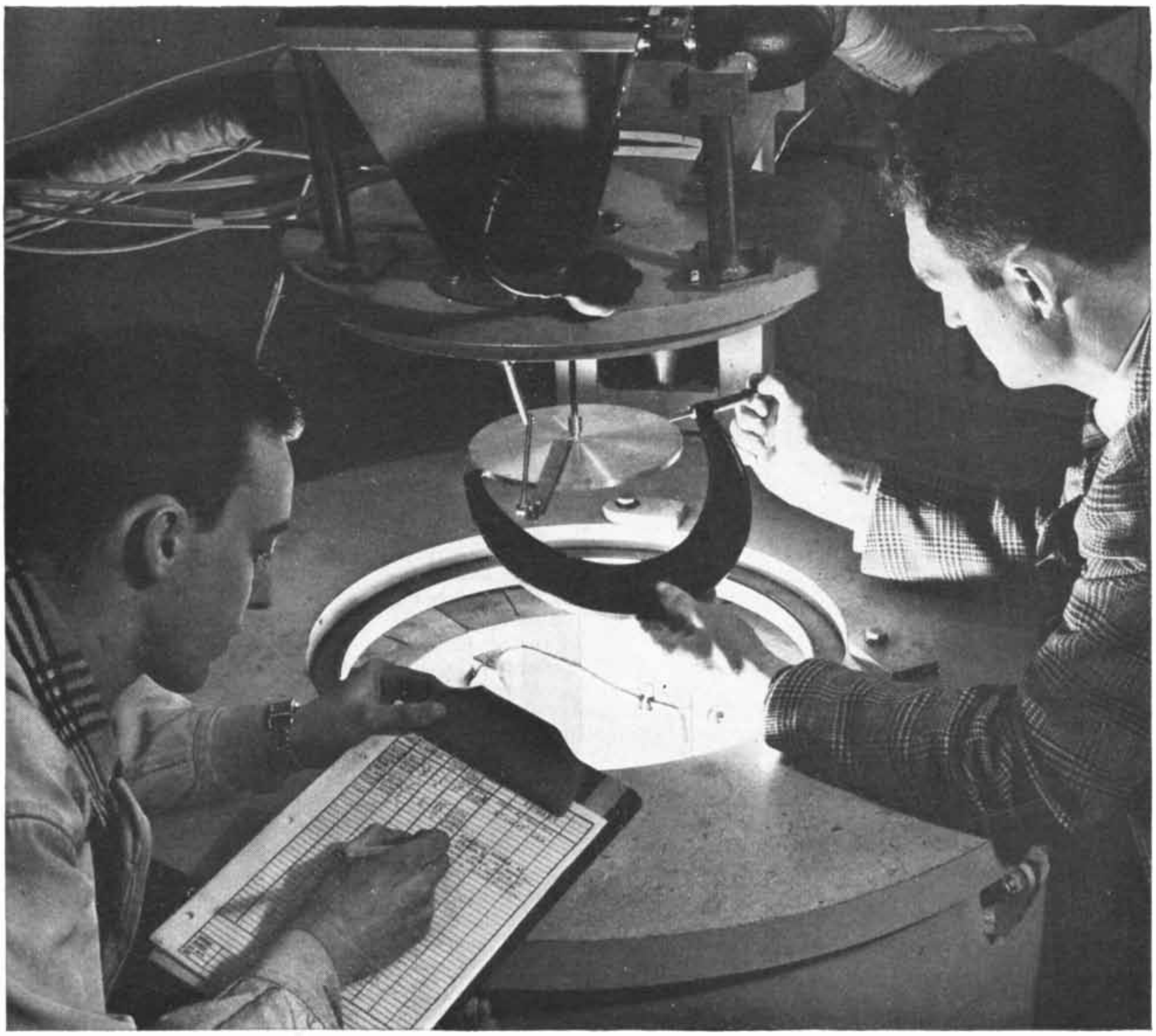
Women who are trained to work at the professional level should be given the opportunity to work at this level. And, more important, girls who are now choosing their careers must be encouraged to enter engineering if they have capabilities in that direction. These advances would increase the resources of the country in both science and engineering.

The Society of Women Engineers, an organization of graduate engineers and women with comparable experience, helps its members to use their training and aptitudes fully. We also reach young women with information on the opportunities in engineering and the preparation required for such careers.

We feel that the progress made by women in engineering has been very encouraging.

EVELYN JETTER

Society of Women Engineers
Queens, N. Y.



50 AND 100 YEARS AGO

DECEMBER 1901. "In a paper lately read before the French Academie des Sciences, Messrs. Capitan and Breuil give a description of two caves or grottoes which they have discovered, whose walls are covered with a remarkable series of drawings of animals which date from the Paleolithic epoch. Many of them are striking in their execution. All the figures are of a correct design and present details which are easily recognizable."

"The photographs of the new star in Perseus made by Prof. G. W. Ritchey of the Yerkes Observatory revealed the presence of a very faint nebula surrounding the star. Later photographs show that enormous changes have taken place in the nebula, confirming a theory long ago advanced by Sir William Herschel, according to which changes take place in the nebulae in the course of time. This theory has not been generally accepted, but now it may be said to be proved by these photographs, showing actual changes which have taken place in the nebula surrounding Nova Persei during the brief period of seven weeks. This would seem to indicate that the gaseous matter forming nebulae is ever undergoing a process of change and formation, and that from this material—the star-dust scattered throughout the depths of space—new worlds and star-systems are being evolved."

"The time is rapidly approaching when the nation, through its representatives, will be called upon to decide where the great Isthmian Canal shall be built. The President's commission has done its work, which consisted not merely in a thorough survey of the Nicaragua route, but an examination on the spot of the Panama scheme."

"A site has been secured in Washington, D.C., for the building of the Bureau of Standardization. Two buildings, to be erected at a cost of $250,000, have been authorized, and will be begun at once."

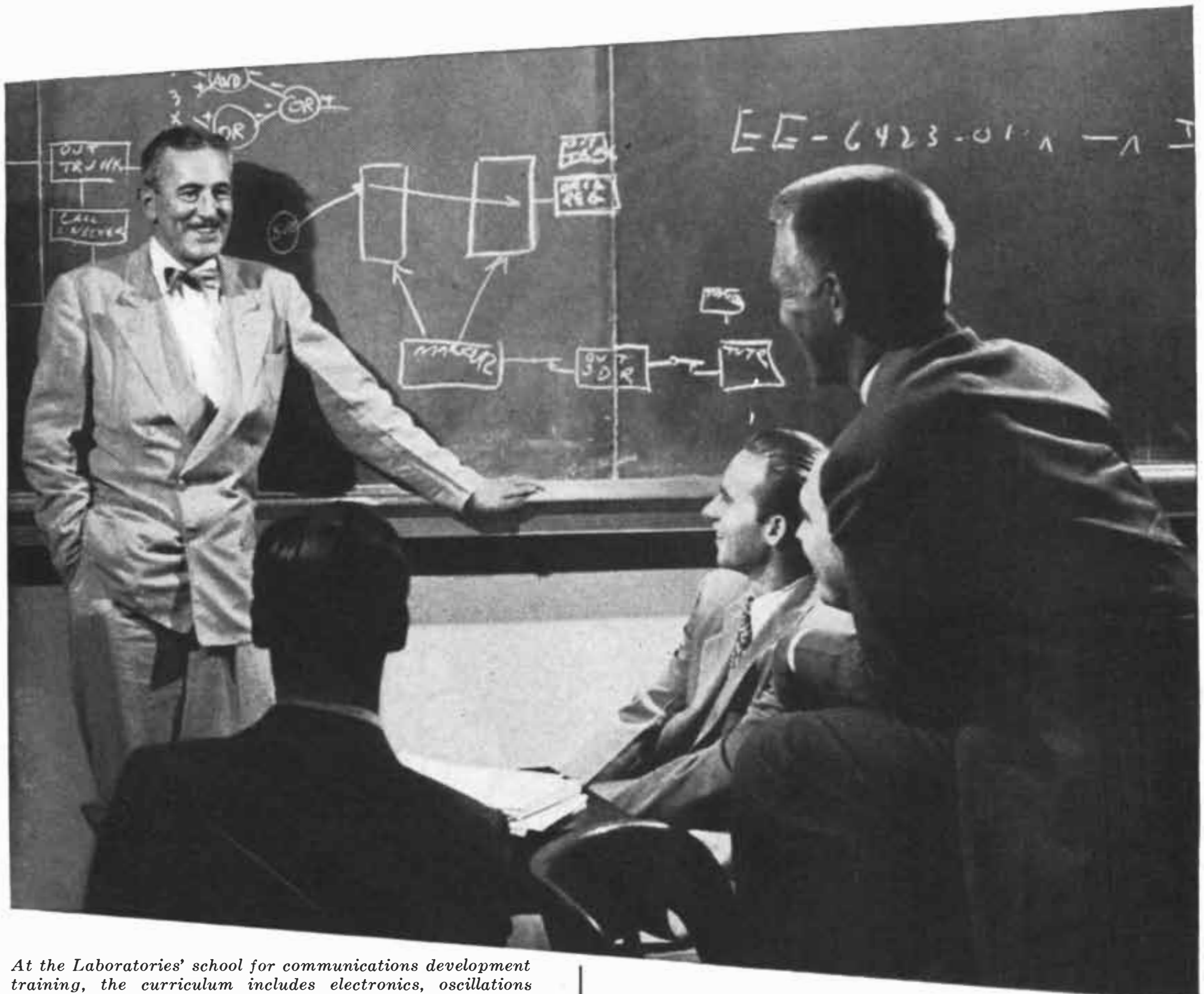
"The award of the Nobel Prizes has just been announced as follows: physics, Prof. Roentgen, of Munich; chemistry, Prof. van't Hoff, of Berlin; medicine, Dr. Behring, of Marburg."

"Liquid hydrogen is an agent of research which will enable us to examine into the properties of matter at the lowest-maintained temperature ever reached by man. The effect of a temperature of 21 deg. absolute on the electric resistance of the pure metals is a problem of great interest. In passing from the melting point of ice to the boiling point of hydrogen, pure platinum loses resistance till only one-fortieth remains, and in the case of electrolytic copper the remaining resistance is only one fifty-seventh of what it was at starting. Such results suggest the approach to the condition of what may be called relatively perfect electric conductivity as the zero of absolute temperature is approached. Now we can maintain a temperature within less than 16 deg. of this zero, and the investigator who will make the further attempt to reduce this distance by an equivalent amount, thereby reaching a steady temperature of 4 deg. or 5 deg. absolute, will indeed face a problem of almost insuperable difficulty."

"It appears to be pretty generally accepted that Marconi has succeeded in sending across the Atlantic audible signals from his wireless telegraphic station in Cornwall, England, to Signal Hill, Newfoundland — a distance of 1,800 miles. To be sure, the Newfoundland experiments have not been accepted by all scientists as conclusive. Prof. Dewar, if he has been correctly quoted, does not believe that the possibility of transmitting signals across the Atlantic has as yet been adequately demonstrated. On the other hand, Mr. Edison accepts the report as authentic, and Prof. Bell has cabled his congratulations and has offered his place on the coast of Nova Scotia as a place for future experiment."

"The rays of radium act energetically on the skin. The effect produced is similar to that resulting from the action of the Roentgen rays. The first observation of this action was by Messrs. Walkoff and Giesel. Mr. Giesel kept on his hands, for two hours, radiferous barium bromide enveloped in a sheath of celluloid. The rays, acting through the celluloid, caused a slight redness on the skin. Two or three weeks later the redness increased and inflammation set in. The skin finally sloughed off. Mme. Curie, by carrying in a small sealed tube a few centigrammes of the same very active matter, has had similar burns, although the small tube was inclosed in a thin metallic box. In particular, an exposure

They're headed for new frontiers



At the Laboratories' school for communications development training, the curriculum includes electronics, oscillations and waves, switching and transmission. Each subject is directly keyed to the latest fields of telephone research.

EACH year the Bell System selects hundreds of engineering graduates from technical schools, to find the answers to communications problems through the application of science and technology. A specifically qualified group joins Bell Laboratories to develop *tomorrow's* telephone system — also, in the present emergency, more powerful electronic devices for the armed services.

They come — thanks to the competence of our nation's educators—with an excellent grounding in fundamentals. To equip them still further, the Laboratories operate a school at graduate level for advanced communications.

The new men receive an intensive course in the latest theory and techniques. At the same time they take their places as members of the Technical Staff doing responsible work which, with their classroom instruction, reveals where they can make the most of their aptitudes.

More than ever America's future must depend on men and women who are trained to think far ahead in technology whether for tomorrow's telephones or national defense. By helping them, Bell Telephone Laboratories help make America's telephone system the world's best, help the armed forces keep our country strong.

BELL TELEPHONE LABORATORIES

Exploring and inventing, devising and perfecting, for continued improvements and economies in telephone service.

AMERICAN TELEPHONE & TELEGRAPH CO. BELL SYSTEM AND ASSOCIATED COMPANIES of less than half an hour produced at the end of fifteen days a red spot, resulting in a blister that was similar to a superficial scald."

DECEMBER 1851. "Among the most remarkable phenomena within the range of physical chemistry are those of Catalysis, or, as it has also been called, the 'Action of Presence.' There are a certain number of bodies known to possess the power of resolving compounds into new forms without undergoing any change themselves. Kirchoff discovered that the presence of an acid, at a certain temperature, converted starch into sugar and gum, no combination with the acid taking place. Edmund Davy found that powdered platinum, moistened with alcohol, became red-hot, fired the spirit, and converted it into vinegar, without undergoing, itself, any chemical change. This power, whatever it may be, is common in both organic and inorganic nature, and on its important purposes Berzelius has the following remarks: 'This power gives rise to numerous applications in organic nature and it may hereafter be discovered that it is by an action analogous to that of catalytic power that the secretion of such different bodies is produced, all of which are supplied by the same matter, as the sap in plants, and the blood in animals.' "

"When vaccination was introduced fifty years ago, it was heralded as the best boon of medical discovery to man, as it was supposed that it effected an entire change in the system, and perfect immunity from variolous affections. Experience has dissipated those brilliant anticipations. In the majority of cases vaccination only produces a partial change in the system, and leaves it open to both varieties of the small pox. No microscopic observation nor chemical analysis has yet disclosed the elementary principles of the virus, or the molecular condition of the system for which it has an affinity."

"At the meeting of the Institution of Civil Engineers in London on November 25, Sir William Cubitt in the chair, a paper from Col. Samuel Colt, of the United States, on his revolving fire-arms, was read and highly applauded, as it was the first communication received from America. The manufacturing of fire-arms, Colt's pistols as well as other fire-arms, is done in quite a different manner in America from what it is in England. In England the greatest number of all the parts of a gun are made by hand; in America they are made by machinery. The advantages of the latter mode are great, for the lock of one pistol, or any one part of a pistol, will fit the same part of another like pistol equally well."

THE COVER

The painting on the cover shows a microbarograph, one of the many instruments that the modern meteorologist uses to predict the weather (*see page 64*). By means of a sensitive element in the cylinder in the center of the painting, this instrument continuously records the variations in the pressure of the atmosphere. The instrument was furnished by the Friez Instrument Division of the Bendix Aviation Corporation.

THE ILLUSTRATIONS

Cover by Walter Murch

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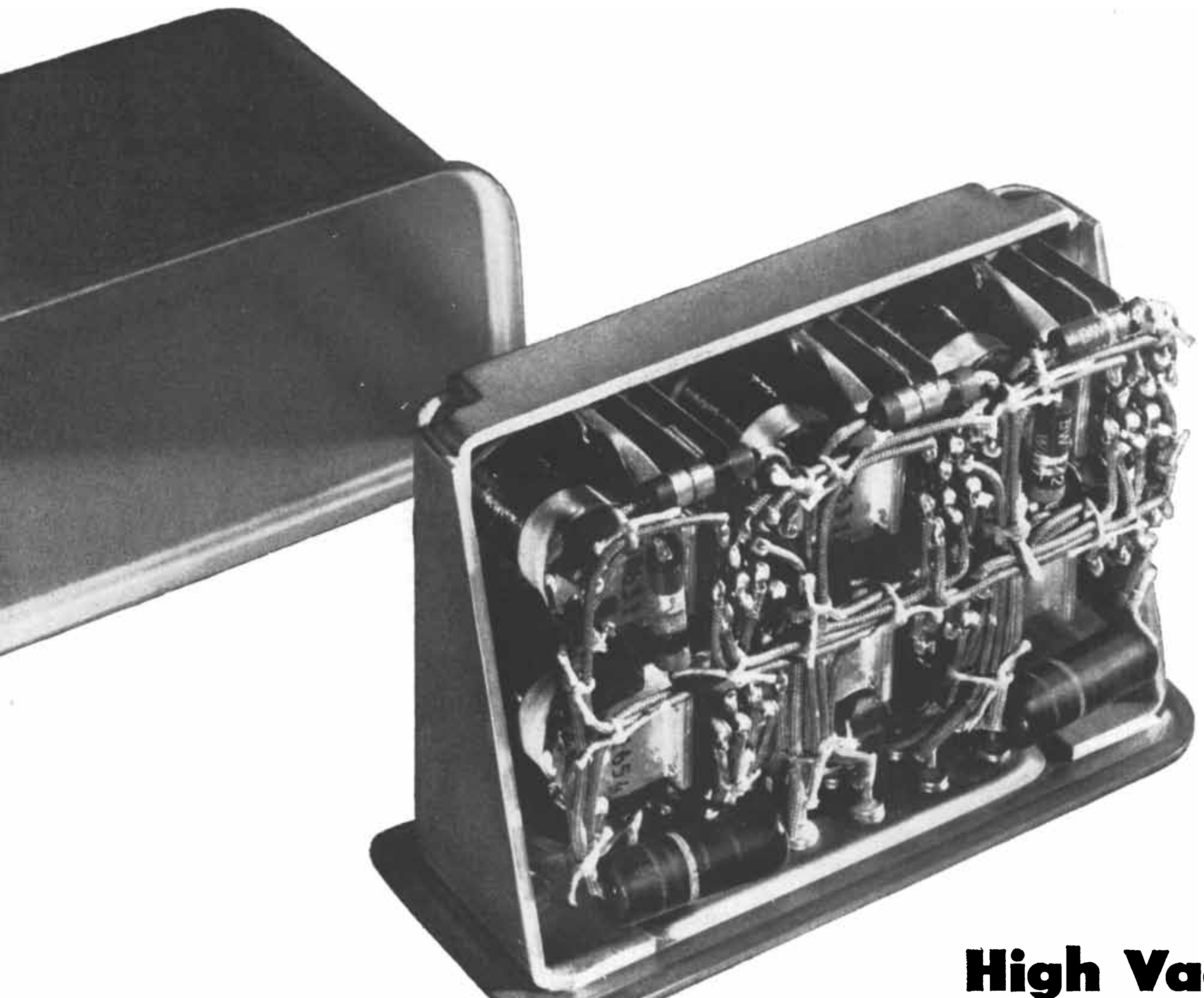

High Vacuum
helps this mechanical brain think clearly

high vacuum research and engineering

THIS little nest of relays is a "brain" which evaluates incoming impulses and issues orders to a mechanism that may be vital in a paper mill, a food processing plant, or an intercontinental bomber.

It took a great many human brain-hours to work out its intricate, compact mechanism. But a few fungus spores drifting in from a warm, humid atmosphere, a little dust, acid fumes, even rapid air pressure variations—any of these might undo the ingenuity that conceived it.

For security against these intruders, the relay manufacturer, C. P. Clare and Company, turned to the service offered by the Electro-Seal Corporation, Des Plaines, Illinois. Within a few minutes after Electro-Seal puts a DPi diffusion pump to work, all traces of moisture and 99.999 per cent of the air have been removed from the sealed assembly. Then a Consolidated Leak Detector is connected to the system and a jet of helium is played over the unit to check for leaks. (This instrument, which embodies another DPi high vacuum diffusion pump, can sound an alarm for a leak so small that a thimbleful of air would take 30 years to get through.)

Finally, Electro-Seal backfills with purified inert gas and sends the relay off to a long, useful life and duties for which an unsealed relay might be totally unfitted—demonstrating again how effectively DPi puts high vacuum at industry's service in a relatively new field, as we've been doing for years in the electron tube industry.

Perhaps we can help you, too. To find out, write to *Distillation Products Industries,* Vacuum Equipment Department, 751 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

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SCIENTIFIC AMERICAN

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CONTENTS FOR DECEMBER 1951 VOL. 185, NO. 6

ARTICLES

DEPARTMENTS

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Managing Editor: Leon Svirsky
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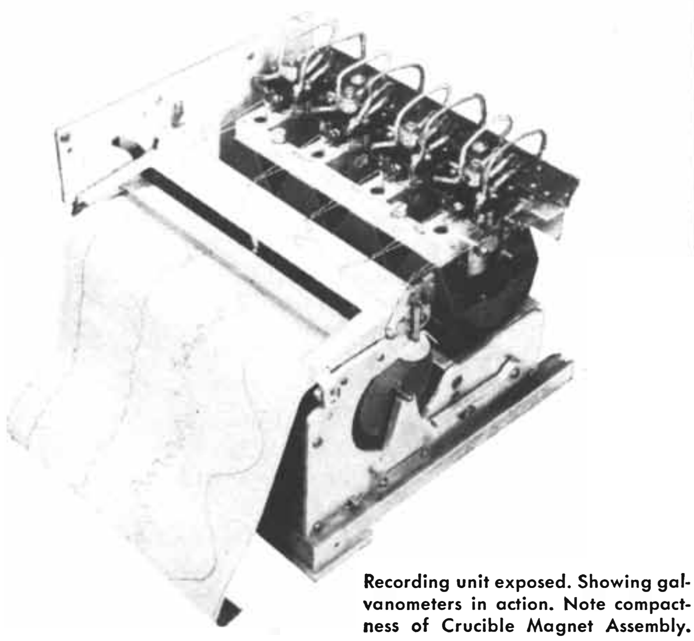
What's New at CRUCIBLE

about permanent alnico magnets



Recording unit exposed. Showing galvanometers in action. Note compactness of Crucible Magnet Assembly.

When Sanborn Company of Cambridge, Massachusetts, big name in recording equipment, first started working on the design and construction of their new "Poly-Viso" Recorder, they ran into a magnet problem.

This recorder makes available permanent simultaneous tracings on one piece of paper of four different kinds of information which, for the first time, are directly written, in rectangular coordinates. That meant that Sanborn needed four separate but compact galvanometers. Crucible was called in, and here's the way Crucible magnet specialists solved the problem.

After careful study of the limits of the equipment, a master magnet was designed that consisted of four pairs of magnetic poles cast on a single base. This eliminated the need for bolting four magnets together, and reduced the amount of space required by the galvanometer assembly. An added feature of this special magnet assembly is a unique and exclusive Crucible method of strengthening the pole pieces of the individual magnets so as to retain maximum field strength. This also adds to the sensitivity of the galvanometer assembly.

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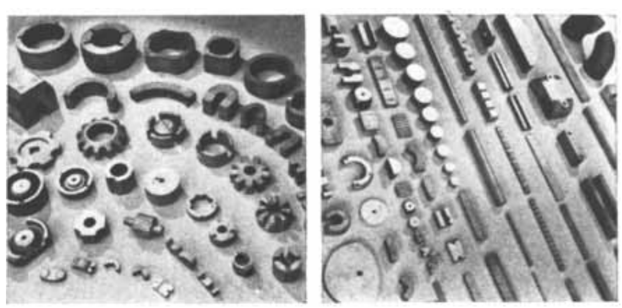

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SCIENTIFIC AMERICAN

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SOLAR FLARES

Generally associated with the sunspots, these occasional eruptions in the atmosphere of the sun emit mighty blasts of energy which on earth cause auroras and disrupt radio and wire communication

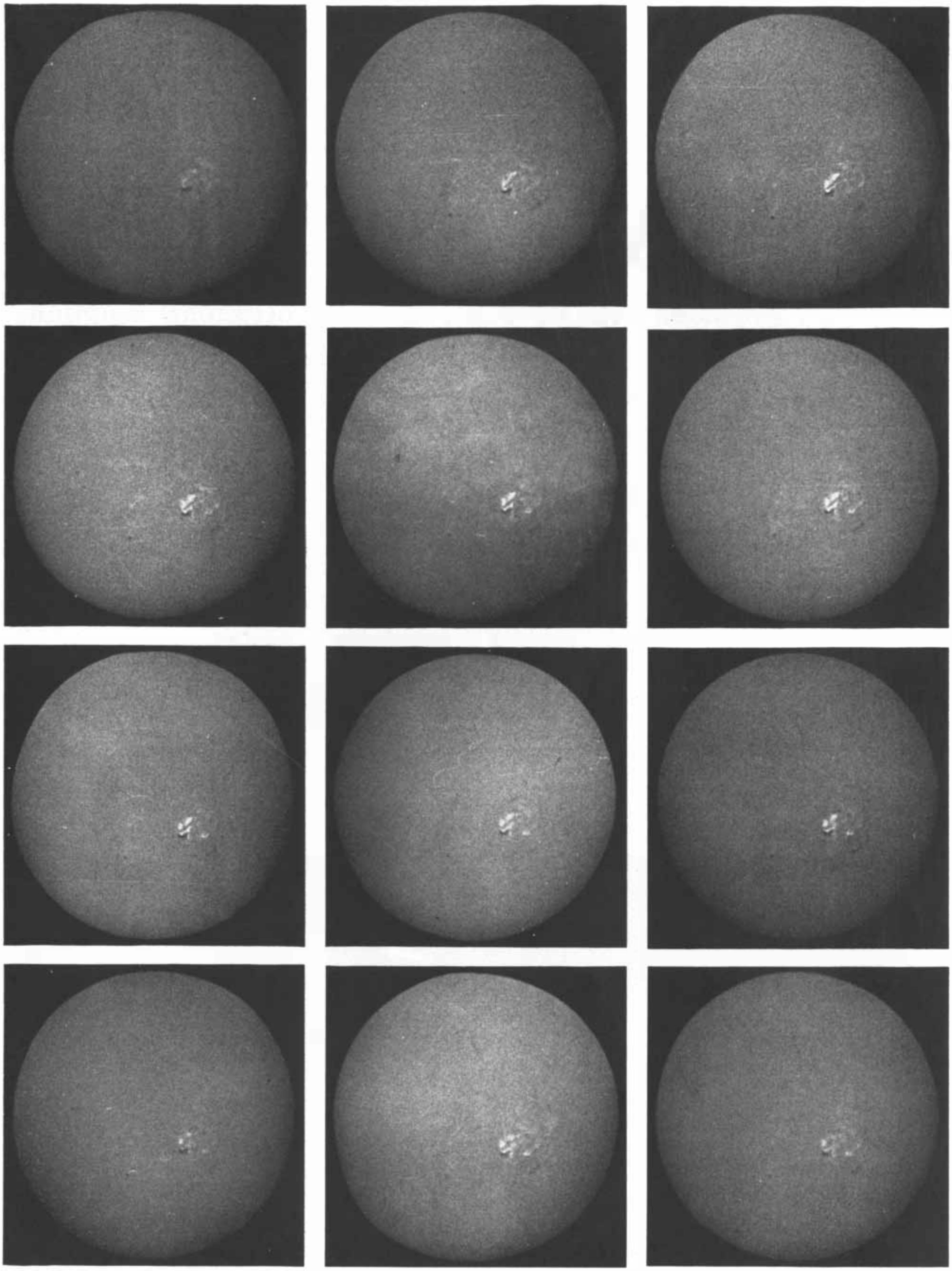
by John W. Evans

THE sun is not ordinarily news, but once in a long while it crashes the headlines like an earthquake. Radio transmission fades out; Northern lights are seen from Mexico City; Western Union teletypes clatter out meaningless gibberish. All because the great eye of a sunspot is looking straight at the earth. It is actually a kind of twinkle in the eye that does the damage—a solar flare, which is quite the most potent form of solar disturbance known.

Flares appear without warning on the atmospheric rim of the sun, usually in or near large sunspot groups. Against the overpowering glare from the underlying photosphere—the visible surface of the sun—the flares are not detectable through the unassisted telescope. We can see them only by filtering out all light except that which originates in the flares themselves and in the surrounding solar atmosphere, known as the chromosphere. This trick is possible because of fundamental differences between the light spectrum of the photosphere and that of the chromosphere and flares. The bright photosphere spectrum is continuous, with all wavelengths represented. The chromosphere and flares, on the other hand, have a spectrum of discrete lines at the particular wavelengths of light emitted or absorbed by the elements that compose the chromosphere. When the chromosphere is viewed against the bright background of the photosphere, these lines appear as dark absorption bands. But by attaching a filter to our telescope which lets through only the light of one of the strong chromospheric lines and rejects all other wavelengths, we can reduce the apparent brightness of the photosphere by perhaps 3,000 times while leaving the brightness of the chromosphere practically unaffected. The brighter flares then stand out like Kipling's sunflower in the coal cellar.

In selecting a single line of the spectrum we are automatically selecting for observation only those atoms that radiate that particular line. Flares and other features of the chromosphere present their most striking appearance in the strong

BRIGHT FLARE of May 18, 1949 was photographed at the McMath-Hulbert Observatory of the University of Michigan. The flare is made visible against the sun by photographing it in the alpha spectral line of hydrogen.



DEVELOPMENT OF A FLARE on April 18 of this year was photographed at a station of the Air Force on Sacramento Peak in New Mexico. These photographs show the entire disk of the sun at intervals of five minutes for a period of an hour. The flare is somewhat larger than the average, but its history is typical.

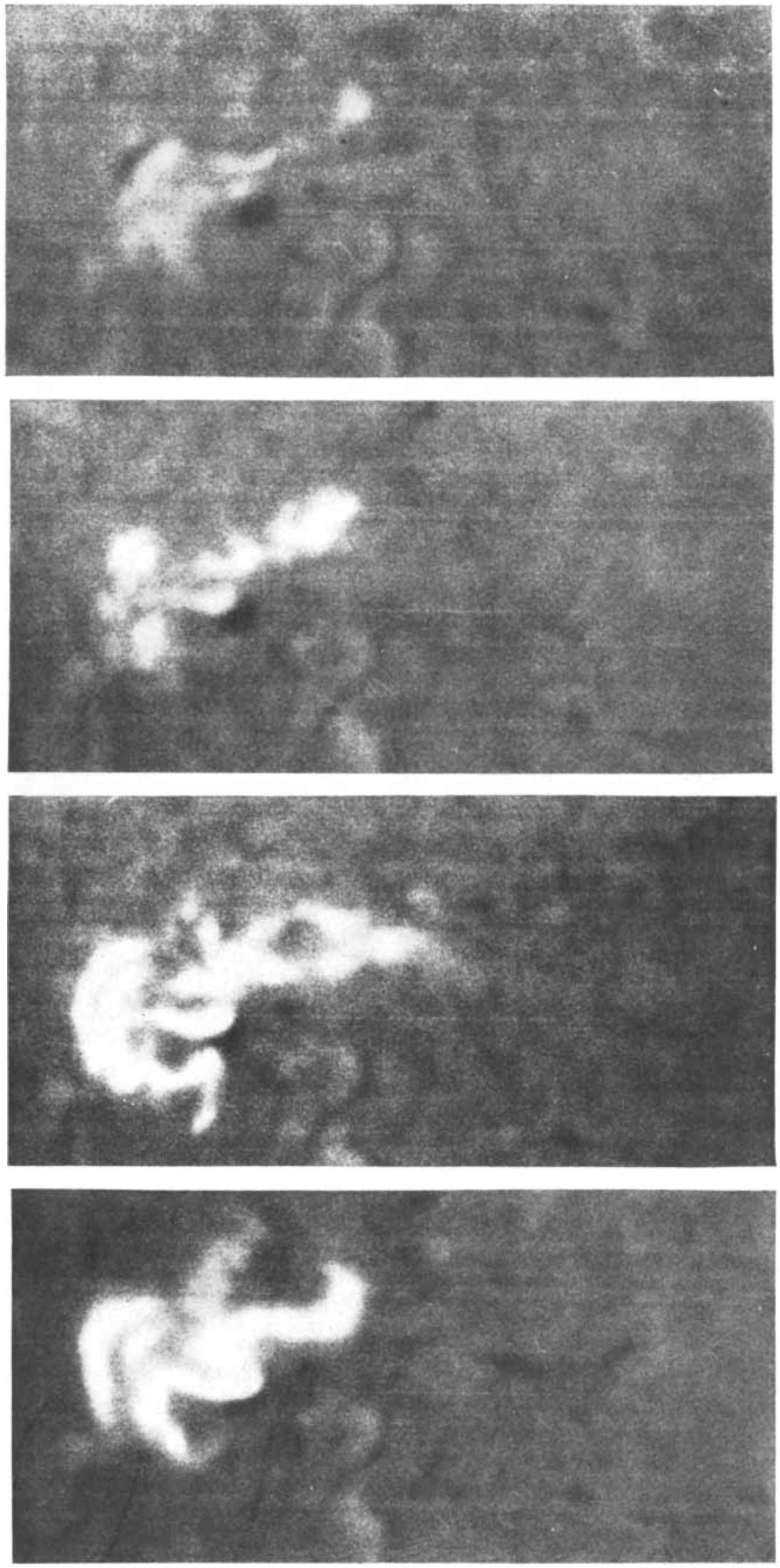
lines of hydrogen and ionized calcium. We can think of the chromosphere as being composed essentially of hydrogen with some slight impurities, and the hydrogen lines are very intense. The fundamental lines of calcium are even stronger, however, because while calcium is not abundant in the chromosphere, the environment of temperature and pressure is just right to keep most of the calcium atoms in the appropriate condition to emit or absorb light.

THE first sign of a flare is a brilliant fleck of light in the neighborhood of a sunspot. It grows before our eyes like a great pool of white-hot molten metal being poured out on a dirty irregular floor. Within a few minutes, sometimes only a few seconds, the pool spreads out to an area of millions or even billions of square miles. No spectacle in nature gives a more vivid impression of inexorable and irresistible power. A large flare starts as nothing and expands with explosive rapidity into a glaring red sea, so vast that it could gobble up the earth like a pill. Here and there a bright point of light flashes out briefly and dies, like a secondary flare within the flare. It looks like the play of light on the clouds of a distant thunderstorm reduced to slow motion.

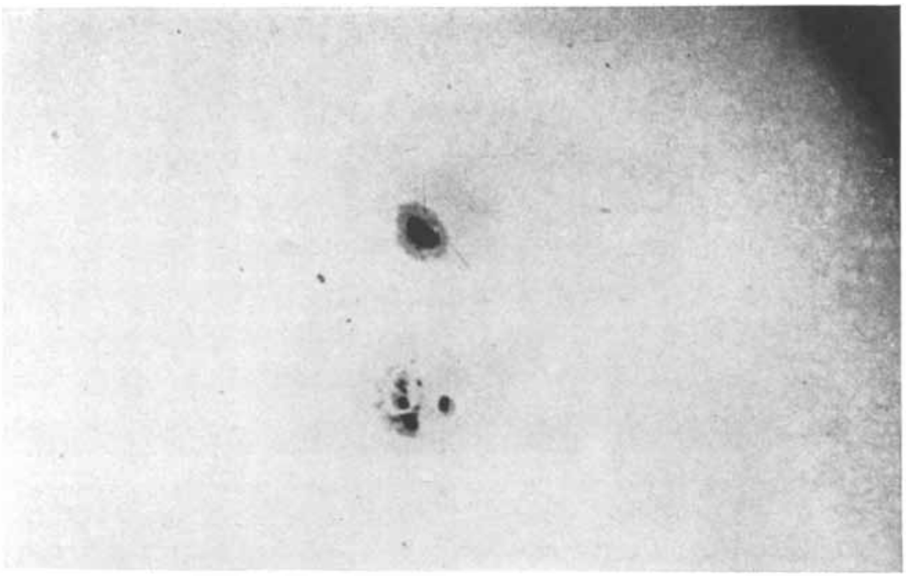
After reaching its quick climax the flare fades away; in half an hour or so it has disappeared. The lifetime of a flare depends on its size. Large flares tend to be much longer-lived, brighter and more prone to disturb the terrestrial ionosphere than small ones. The largest ones are apt to black out radio transmission completely. Fortunately most of the flares are small.

On the relatively rare occasions when a flare appears at the edge of the sun's disk, we can observe its height directly. The few flares that we have been fortunate enough to see in profile usually swell into a solid-looking dome of material extending well above the chromosphere; occasionally they throw off a flat appendage which rises perhaps 20,000 miles, with only a slender umbilical filament connecting it to the flare below. Several extremely bright dome-shaped prominences, which probably were flares, have been photographed in motion pictures with the coronagraph of the High Altitude Observatory of Harvard University and the University of Colorado at Climax, Col. The pictures reveal violent internal motions within the flare. This state of internal turbulence reminds one of the motions in a terrestrial thunderhead; it may be due to a very similar type of convection.

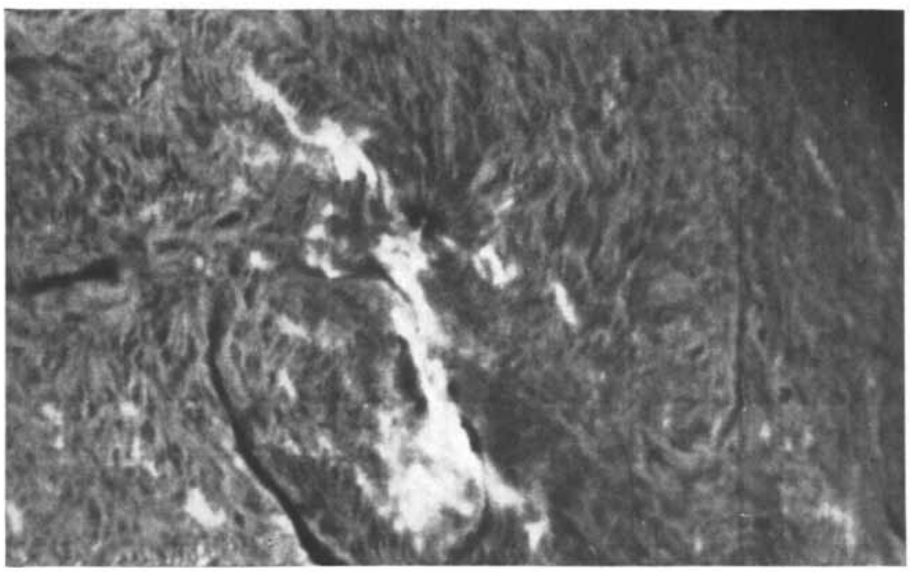
Flares are much more frequent than one might suppose from the rarity with which they break into the headlines. For the past year and a half a flare patrol, which monitors the sun photographically at five-minute intervals, has been main-



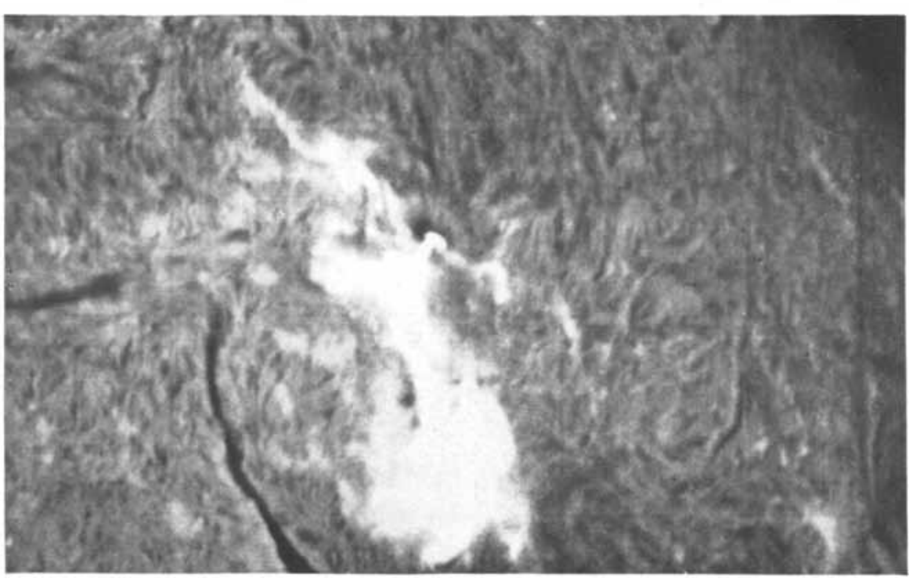
CLOSEUP OF A FLARE on May 10, 1949 was made at the McMath-Hulbert Observatory. This flare appeared to have been the cause of the year's most severe geomagnetic storm, which commenced some 34 hours afterward.



GROUP OF SUNSPOTS on August 8, 1937 was photographed at Mount Wilson Observatory. This photograph was made by many wavelengths of light.



BEGINNING OF FLARE in the same region was photographed 11 minutes later. This photograph was recorded only by the red light of hydrogen.



HEIGHT OF FLARE in the same region was photographed after another interval of 11 minutes. This photograph was also made by light of hydrogen.

tained at a laboratory of the High Altitude Observatory in Boulder, Col., and a station of the Air Force on Sacramento Peak in New Mexico. In 16 months of operation we detected 424 flares on the sun—roughly one every eight hours. There is no doubt whatever that the flares are connected with sunspot activity. All but three of the 424 flares were seen to stem from visible spots on the sun. When a group of spots is growing rapidly, it produces many small flares; the big flares come when the spots have reached their prime. Then as the spots shrink, the flares diminish in size and frequency. The spots and flares are now in a waning phase of the 11-year cycle; by about 1956 they should increase in activity.

ASTRONOMERS have been studying flares for many years; the High Altitude Observatory is a mere baby of less than two years in the field. Information about them has been collected painfully bit by bit by great observatories and devoted individuals throughout the world. The detailed studies of large flares have come mainly from the Mount Wilson Observatory in California, the McMath-Hulbert Observatory in Michigan, the Observatoire de Meudon in France and the Kodaikanal Observatory in India. Foremost among the patient, persevering observers who have collected data on the small flares are M. A. Ellison and H. W. Newton, of the Royal Observatories at Edinburgh and Greenwich, and R. G. Giovanelli, of the National Standards Laboratory in Australia.

If the directly observable features of flares were all we had to worry about, we could probably have devised a satisfactory theory to account for them by now. But it is not so simple. Apparently what we see directly is only a minor aspect of a major disturbance. Large flares cause a variety of disruptions on our planet—radio fadeouts, magnetic storms, auroras, earth currents that upset wire communications and long-distance power transmission. Here is a region of the solar atmosphere which for no known reason suddenly becomes excited, gives off a little bit of light (so feeble that we must use special instruments to see it at all) and yet produces a tremendous outpouring of invisible forms of energy which are felt almost immediately on the earth, 93 million miles away. The chief problem that interests us at the moment is how those distant flares can set off the chain of happenings we witness here on earth.

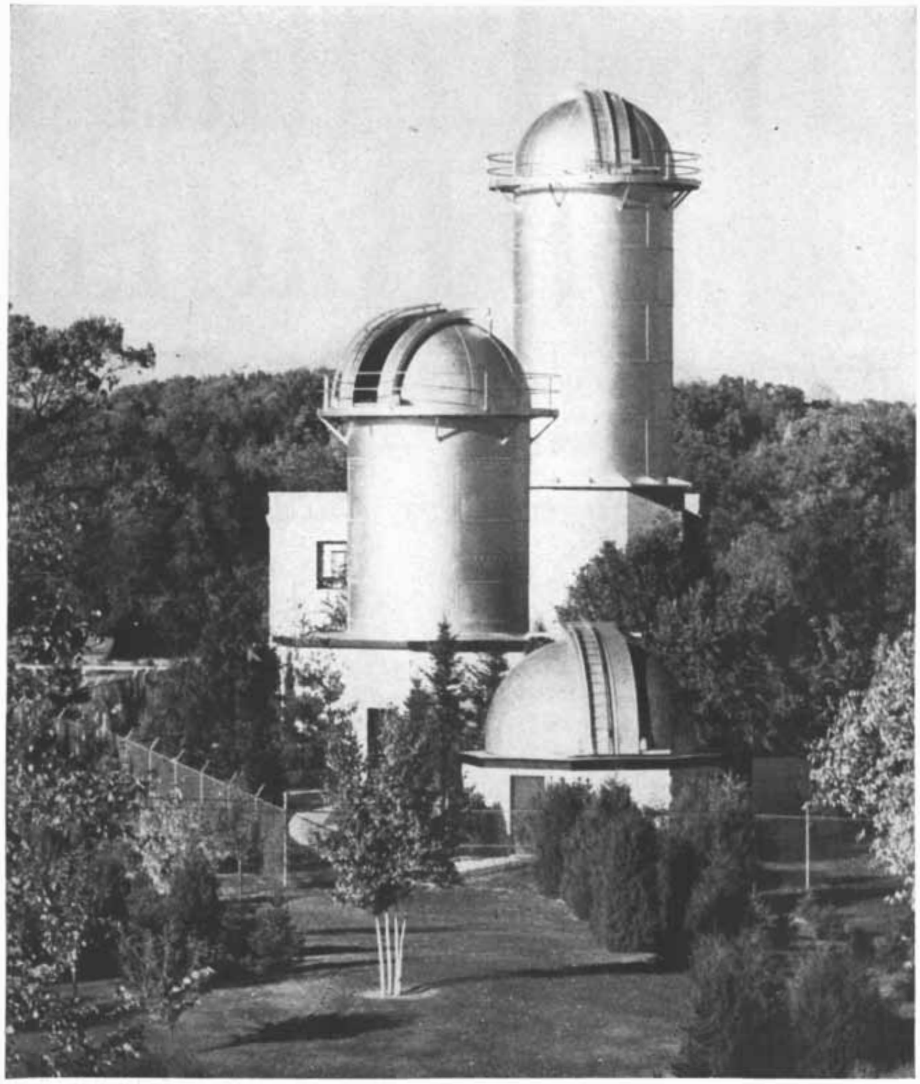
Quite obviously the flares on the sun depict the travel of radiation rather than matter. A flare moves so rapidly that it is improbable we are actually seeing a transport of material. If that were the case, the particles of matter would have to move with velocities of thousands of miles per second, and while an astronomer is accustomed to take such speeds in his stride, where the movement of material is involved he expects to find corresponding Doppler shifts in the spectra of the moving atoms. No such shifts are observed. We conclude that the apparent motion we see is the spreading of a wave of excitation in the chromosphere, analogous to the motion of a searchlight spot over a cloud.

Of the energy that leaps from the flare into space, the first form to reach us is ultraviolet radiation. Its effect is concentrated in the ionosphere, the region in the upper atmosphere from 20 to 200 miles up where free electrons and their mating positive ions roam in the thin air. The ionosphere is the roof that reflects radio waves around the curved earth. When a sudden extra dose of ultraviolet radiation from a flare hits the ionosphere, it forms an abnormally dense layer of ionization at the lower limit of the region. The layer absorbs the energy of the radio waves and converts it into heat. Reception by radio sets fades or fails altogether.

Hours after the ultraviolet burst, showers of charged particles arrive. The magnetic field of the earth separates the positive and negative charges and produces an electric current in the ionosphere. This induces sympathetic currents in telegraph wires and causes magnetic storms. The incoming particles also collide with air molecules and excite them to luminescence, and we are treated to gorgeous auroral displays in abnormally low latitudes.

All these effects require quantities of power. Since the earth can intercept only about one billionth of the total energy output of a flare (if it radiates uniformly in all directions into space), we can only conclude that the amount of ultraviolet and corpuscular energy a flare gives off must be perfectly stupendous.

Besides these forms of energy, flares apparently also emit high-frequency radio noise and cosmic rays. The radio noise, in particular, is very energetic; in some frequencies the noise emitted during flares is 10,000 times as intense as the noise normally radiated by the whole sun. The studies of the cosmic-ray and radio-noise effects are just beginning. They promise to yield a whole new field of knowledge about flare activity.



TOWER TELESCOPES of the McMath-Hulbert Observatory are the instruments that were used to make the photographs on pages 17 and 19.

OUR present information on flares, though still incomplete, gives us a fair starting point for devising a theory of their underlying causes and the processes by which they operate. The primary theoretical problem is to find a process capable of pouring out such tremendous quantities of invisible energy with so little emission of light. Obviously the explanation that a flare is a hot spot on the sun (as, in fact, it is) does not go far enough, for if heat alone were responsible for the radiated energy, the flare should be blindingly bright to the eye—perhaps more intense than all the rest of the sun.

During the past few years astrophysicists have sought to explain the flares, as well as other features of the sun, in terms of the motions of electrons and protons in the sun's magnetic fields. A magnetic field serves as a guide for charged particles and must play an important role in any activity involving the material of the chromosphere, where the great majority of particles are electrons and protons.

Donald H. Menzel of the Harvard College Observatory thinks that flares may consist of radiations from a tiny region on the sun where there occurs a violent compression of chromospheric material caught in an unstable magnetic pocket which tries to shrink itself out of existence. This is only an initial suggestion and reams of theoretical work will be necessary to explore it. Giovanelli has approached the problem from an entirely different viewpoint. His ingenious theory is that the energy of flares may be produced through the acceleration of electrons by rapidly changing magnetic fields, on much the same principle as the operation of a cyclotron. Sunspot groups are known to create such changes in fields. Giovanelli calculates that under certain conditions of density and changes in the directions of the magnetic fields, electrons could be accelerated by the associated electric fields to a velocity where they could excite at least the visible appearance of a flare. Thus far the theory has not reached the point of considering the invisible radiations, and it remains to be seen whether the energy supply is great enough. The British cosmologist Fred Hoyle has suggested a modification of Giovanelli's theory. If electrons and protons are accelerated in a very small volume of space near a sunspot, he says, they may reach an extremely high acceleration, producing a local hot spot. Hoyle believes that the flare is a secondary phenomenon, excited by radiations from this region.

John W. Evans is a member of the staff of the High Altitude Observatory of Harvard University and the University of Colorado.

The Lethal Effects of Radiation

What is the mechanism by which high-energy waves and particles damage living things? A number of investigations have begun to outline it as a complex chain of physical and chemical events

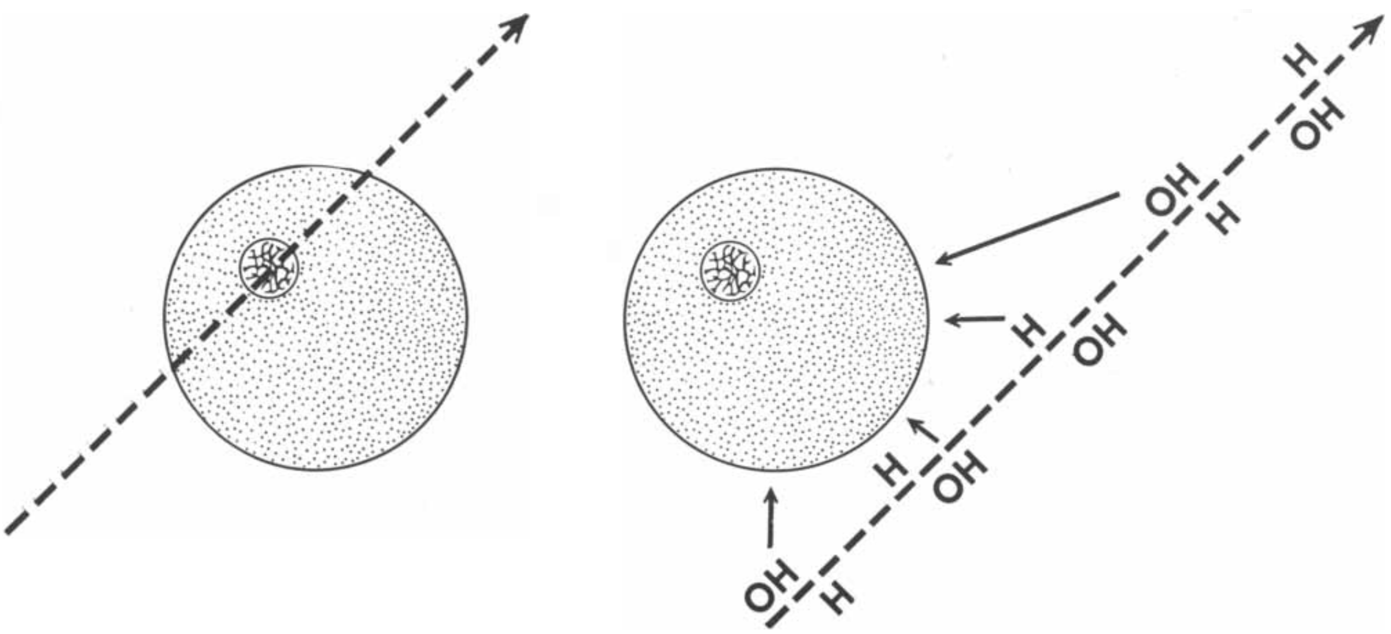
by Edward Spoerl

WHY and how does radiation kill? Since 1945 U. S. biologists have focused an immense amount of study on this important question, but we are still far from any clear answer to it. Here is an invisible lethal force which attacks from the blue without being felt or sensed in any way, and over a period that may vary from days to years produces a slow death of the organism. It is clear that the breakdown and death occur at the most fundamental level of life—in the body's cells. But the process by which this happens remains a mystery. We can only speculate about possible mechanisms.

We know that some tissues of the body are much more sensitive to radiation than others. In general, cells that are dividing and reproducing rapidly are more affected than the less active ones. It is in the sites where blood cells are manufactured that radiation does its readiest damage. Most vulnerable are the lymphoid tissues—the lymph nodes, spleen, tonsils and so on—which produce and store white blood cells. Radiation destroys these factories of the white cells and breaks down the cells themselves. Since the white cells are one of the most important defenses against bacteria, this damage greatly lowers the body's resistance to infection. The bone marrow, which manufactures the red blood cells, is similarly sensitive to radiation. Also vulnerable are the sex glands, the skin (which loses its hair when exposed to heavy radiation), the linings of the gastrointestinal tract and the walls of the blood capillaries (which may be so weakened that the victim has hemorrhages throughout his body).

The first troublesome question is: By what means does radiation produce these effects on the body? Is the damage to the tissues due to direct action by the radiation (*i.e.*, to a breakup or destruction of the cells) or to some indirect effect, such as the conversion of body substances into poisons or the release of poisons from the injured cells? There are differing schools of thought on these issues, but however the problem is approached, all roads lead eventually to investigation of what is happening in the cell. For obvious reasons most of the fundamental studies of radiation effects have been done on the simpler plants and microorganisms.

Such studies show that radiation



EFFECTS ON THE CELL can be direct or indirect. The radiation (*dotted line*) can damage the cell by passing through it (*left*) or by manufacturing reactive groups of atoms that pass through the cell wall (*right*).

affects cells in various ways. It may kill the cells outright; it may interfere with their growth; it may change their genes and heredity. For instance, Cornell University investigators who studied corn seeds irradiated in the atomic bomb test at Bikini found that the seeds produced stunted plants with mottled leaves; the mottled areas consisted of dead cells and cells that were alive but colorless instead of the usual green. Under the microscope it could be seen that the heredity-carrying chromosomes in many of the cells were disrupted. The same general effects have been demonstrated in numerous experiments on bacteria and fungi: irradiation kills many of the cells, causes genetic mutations, inhibits respiration and, by stopping cell division, sometimes produces abnormally large cells.

SINCE the life and death of a cell ultimately depends on its metabolism, or chemistry, it is here that we must look for the basic effects of radiation. Fundamentally these effects are due to the radiation's ionizing action on the atoms and molecules of which the cell is composed. Any radiation, whether in the form of X-rays or gamma rays or particles such as neutrons or beta particles, ionizes the atoms among which it passes; that is to say, it removes an electron from a neutral atom, creating a positive ion, and the released electron then joins another atom to form a negative ion. This is not a selective process: the radiation will ionize impartially any atom or molecule in its path, whether it is water, a protein, an enzyme, a hormone or any other substance. And the ionization may change the molecule in an important way, making it a great deal more active chemically.

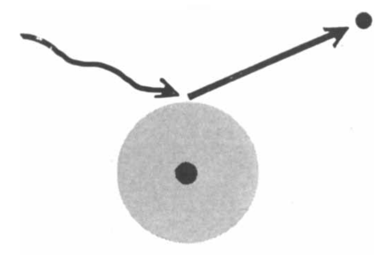
Now the main constituent (about 70 per cent) of most cells is water. Consequently when radiation passes through a cell, the water molecules are most likely to be ionized, simply because of their predominance in numbers. This suggests that the ionization of water may be one of the chief means, perhaps the major one, by which radiation produces its effects on cells. Such a theory is strongly supported by the known facts about the chemical behavior of water molecules when they are irradiated. It appears that radiation removes an electron from the water molecule and forms a positive H_2O ion. The H_2O^+ ion then breaks down to H^+ and OH. The free electron may become attached to another water molecule and form a negative H_2O ion, which in turn breaks into H and OH^-. These fractions may react with one another to form not only water molecules but also H_2O_2 (hydrogen peroxide) and HO_2. Furthermore, the free hydrogen can combine with oxygen in the living cell and through a series of reactions produce more HO_2 and H_2O_2. The important fact is that the ionization of water and the resulting reactions yield four powerful oxidizing agents: H_2O_2, O and the free radicals OH and HO_2. These agents can oxidize substances in a cell and thus interfere with its normal chemical reactions.

WHAT kind of damage could they do? E. S. G. Barron of the University of Chicago, who has given this matter a good deal of study, suggests that the oxidizing agents may inactivate enzymes, thereby disturbing the cell's metabolism. Enzymes are the organic catalysts that assist or make possible the chemical reactions in cells. They are proteins. Now the enzyme protein molecule contains sulfur and hydrogen linked together in sulfhydryl groups (SH), and it is known that many enzymes cannot function if these groups are oxidized or otherwise changed. Barron believes that the oxidizing agents formed in an irradiated cell oxidize the sulfhydryl groups and thus put the enzymes out of action.

He and his co-workers have found strong experimental evidence to support this theory. For instance, they have shown that when solutions of certain simple compounds containing a sulfhydryl group are exposed to X-rays, the radiation oxidizes these compounds. In other experiments they irradiated dilute solutions of the actual enzymes, that is, enzymes requiring sulfhydryl groups for their action. They found that the various kinds of radiation they used—X-rays, alpha, beta and gamma rays—inactivated these enzymes.

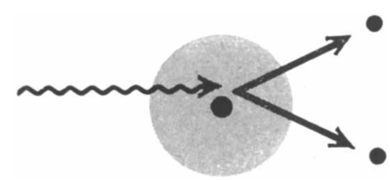
Carrying the experiments a step further, they proved that the oxidation of sulfhydryl groups is reversible; *i.e.*, the enzymes can be reactivated. For example, by adding to the solution a compound such as glutathione, which supplies sulfhydryl groups, they made inactivated enzymes function again. But this is possible only when the enzymes have received moderate doses of radiation. After a large dose the enzymes can be reactivated only partly or not at all. This indicates that the heavy dose produces some additional damage besides oxidation of the sulfhydryl groups; that it changes, or "denatures," the enzyme protein in some way. What this change may be is not yet known.

These experiments seem to support the idea that radiation damages or kills cells mainly by an indirect process. The radiation ionizes water to form oxidizing agents; the oxidizers inactivate enzymes; this in turn starves the cell. But we have no evidence that this process is the major means by which radiation attacks the living cell. Radiation may work its damage in many other ways. Perhaps it disrupts the protein directly by breaking the molecule's chemical bonds. Perhaps it kills cells by injuring or changing their nuclear material.

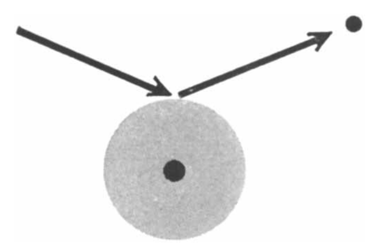


PHOTOELECTRIC EFFECT is due to a wave (*upper left*) striking an atom (*gray circle*) and ejecting one of its electrons (*upper right*).

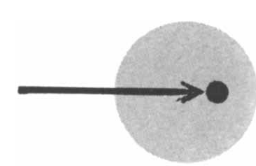
COMPTON EFFECT occurs when a high-energy wave (*left*) encounters a slow-moving electron (*right*) and accelerates it to high speed (*arrow*).



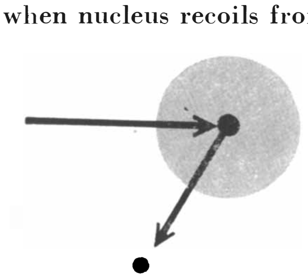
PAIR PRODUCTION is the result of a wave interacting with the field of the nucleus (*center*) to produce a positive and a negative electron.



ELECTRON IS REMOVED from its orbit, as in the photoelectric effect (*top of page*), when a particle rather than a wave collides with an atom.



NUCLEUS IS ACCELERATED when a particle strikes it. Cloud of electrons about the nucleus lags behind when nucleus recoils from collision.



RADIOACTIVE NUCLEUS is the result of the absorption of a particle by the nucleus. Another particle is later expelled by the nucleus.

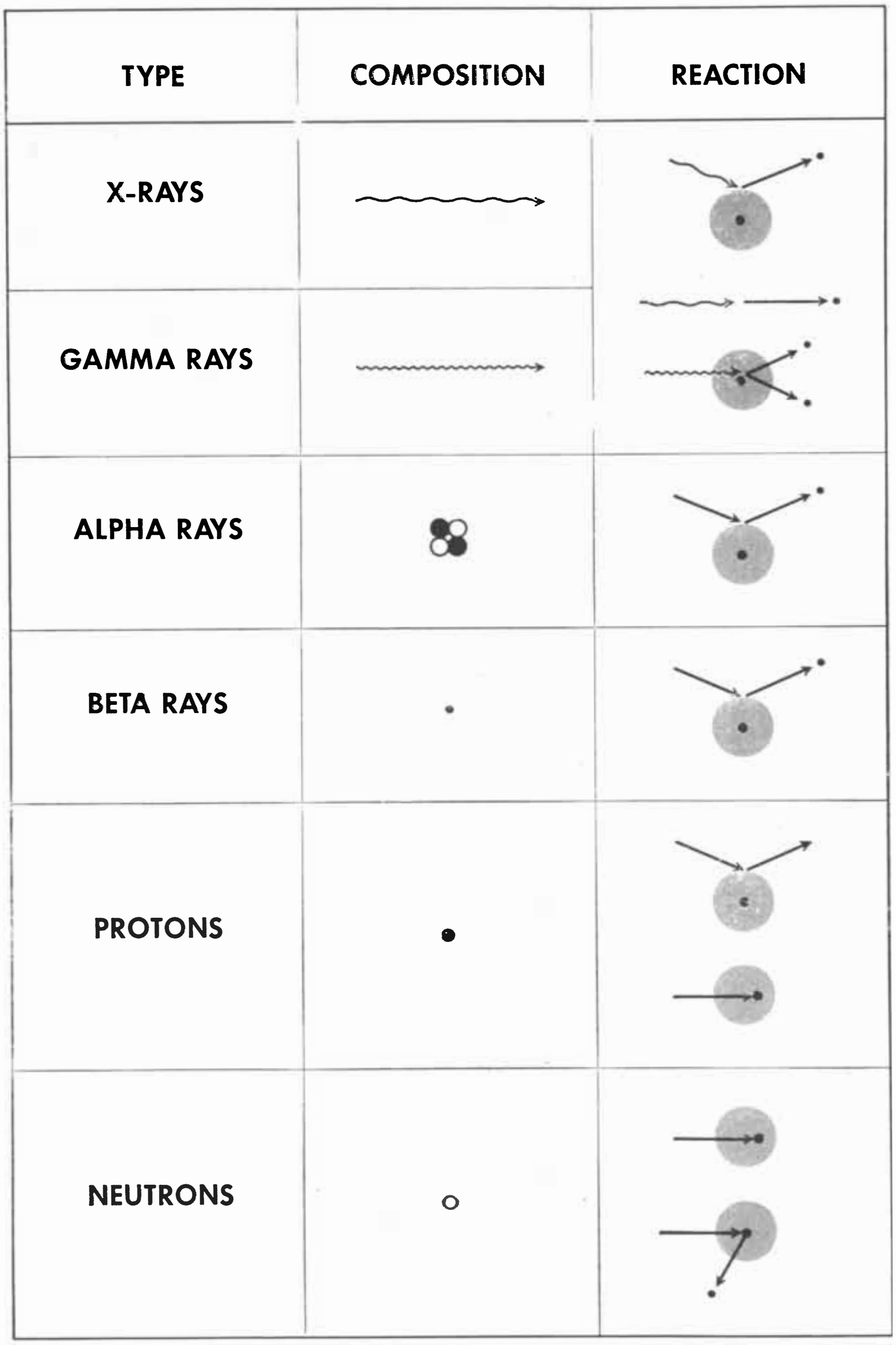
It is believed that radiation causes the mutation of genes in the cell nucleus by some kind of direct action, perhaps by a hit on the large gene molecule. Since many mutations are lethal, this may be an important means by which cells are killed.

It is definitely known that oxygen plays an important role in the killing of cells by radiation. A recent experiment at the University of Southern California showed that rats can survive much larger doses of radiation if their oxygen supply is reduced below normal. In the biological laboratories of the Atomic Energy Commission at Oak Ridge, which is one of the principal centers of research on radiation effects, similar findings have been made: plants and fruit flies that are X-rayed in an atmosphere lacking oxygen have a much smaller percentage of chromosome aberrations and mutations than those irradiated in air. To be sure, it has not yet been proved that the effect of the oxygen is connected with the formation of oxidizing agents by the ionization of water, but the experiments at least indicate that the radiation works indirectly.

The results of such experiments suggest that mutation may be produced by an indirect chemical route rather than by the radiation's direct attack on the genes. This idea is further supported by some recent experiments at the University of Texas. Hydrogen peroxide, which as we have seen is one of the products of the ionization of water, was added to media in which bacteria were growing. Although the culture was not irradiated, mutant strains of bacteria appeared in it after a short time. The mutants were like those produced by radiation. In other words, hydrogen peroxide, a known product of radiation, is itself capable of causing mutation. Apparently it does not do so directly, because it caused cells to mutate only in a growth medium; it did not work in water. Perhaps the hydrogen peroxide reacts with organic material in the growth medium to produce organic peroxides, which, as has been proved in other experiments, are effective mutagenic agents.

There is evidence also that in its effects on the division of cells radiation operates indirectly through a chemical mechanism. It has long been known that cell division is sensitive to radiation. One striking illustration is its effect on cells of colon bacteria. These rod-shaped bacteria ordinarily are only a few microns long; they divide into daughter cells before they grow much longer than that. But a small dose of radiation, which prevents them from dividing, can cause them to grow into spaghetti-like filaments more than a hundred microns long. Now it has been observed that cells which are actively growing and dividing contain more sulfhydryl groups than do resting cells. Moreover, the addition of sulfhydryl-containing substances to the growth medium can speed up the cells' rate of division. Apparently they need these groups to assist the division process. It looks, therefore, as if radiation could stop the division of cells by oxidizing the sulfhydryl groups.

Radiation may also act on another chemical cycle involved in cell division. There is a certain acid in the nucleus of the cell—desoxypentosenucleic acid—which seems to play an important part in the division of the cell. Radiation apparently inhibits the formation of this acid, perhaps by inactivating the enzyme system that catalyzes it. The Nobel-prize chemist George Hevesy, who has studied this effect with the aid of radioactive phosphorus, has suggested that the inhibition of formation of the nucleic acid in question accounts for the selective effect of radiation on tumor cells. As is well known, radiation affects tumor cells more than it does normal cells—which is the basis for the use of X-rays and radium for cancer treatment. A distinguishing characteristic of tumor cells, of course, is that they divide rapidly. They therefore need the desoxy



PHYSICAL EFFECTS of various radiations on the atoms of living things are outlined in this chart. The symbols at the right are defined on the preceding page. The electromagnetic radiations are indicated by wavy lines. The alpha particle is made up of two protons and two neutrons.

nucleic acid, and Hevesy points out that radiation may retard the growth of a tumor by cutting off the supply of this acid. But this is only speculation; we know too little about the functions of the nucleic acids to be able to accept or reject such a theory at this stage.

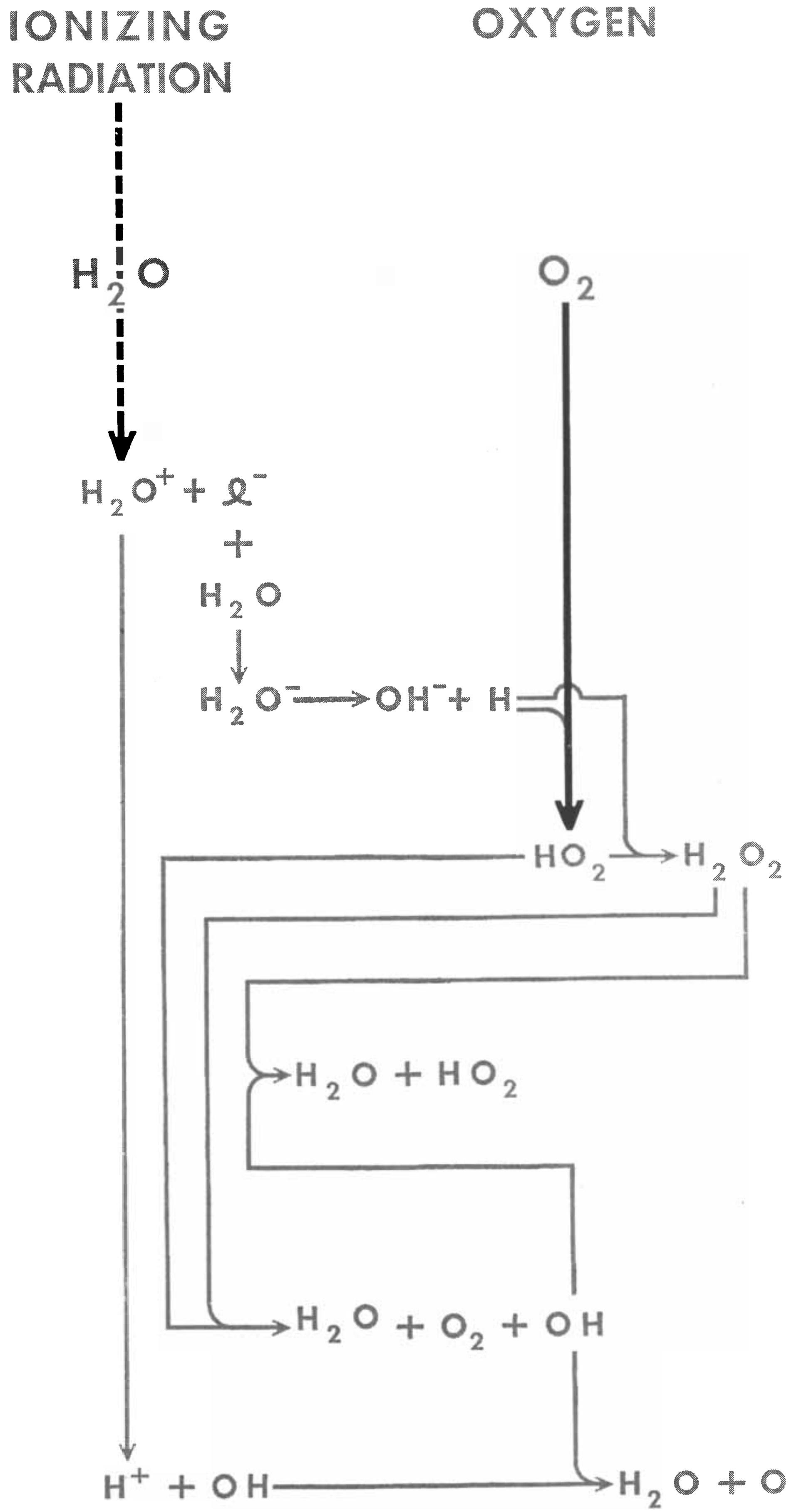
FROM the work that has been done on radiation effects a few points seem to be reasonably clear. Oxidations evidently play an important part in radiation damage. The decomposition of water and the resultant formation of oxidizing agents may be one of the chief means by which radiation injures and kills cells. An indirect chemical mechanism could account for the various radiation effects: mutation, interference with cell division, inhibition of growth, the death of the cell. But the happenings in a cell are so complex that they are exceedingly difficult to investigate, and progress in the field of radiation effects has been slow.

One of the main reasons for devoting so much study to radiation effects, of course, is to discover ways of combatting them—a matter of some urgency in our radioactive age. So far the treatment of radiation sickness has had to be directed toward the symptoms and end results rather than toward the basic mechanism. Blood and plasma transfusions, plus the feeding of iron, vitamins and possibly amino acids, can restore the supply of blood cells and replace broken-down tissues. Antibiotics such as aureomycin can protect the weakened victim against infections. Certain substances, such as protamine and toluidine blue, have had some effect in stopping hemorrhage. Some cases of radiation injury have responded to the drug desoxycorticosterone acetate, presumably because this substance counteracts histamine-like poisons that may be released by radiation damage.

AT a more basic level, the studies of the oxidation effects in cells suggest that a sulfhydryl-supplying substance such as glutathione may be helpful. In experiments on animals this material so far has not been effective as a treatment; it protects the animals only if it is given before they receive the dose of radiation.

Obviously the key to the whole problem lies in a better understanding of how a cell lives and functions. When that mystery has been unraveled, we may be able to cope with radiation, cancer and many of our other ills.

Edward Spoerl is leader of the biochemistry research group at the Mound Laboratory, operated for the Atomic Energy Commission by the Monsanto Chemical Company.



CHEMICAL EFFECTS of ionizing radiation on water, which comprises about 70 per cent of living matter, are outlined in this chart. The water molecule breaks down and its atoms recombine, some of them with oxygen, in other groupings, notably the reactive hydrogen peroxide (H_2O_2).

How to Teach Animals

Some simple techniques of the psychological laboratory can also be used in the home. They can train a dog to dance, a pigeon to play a toy piano and will illuminate the learning process in man

by B. F. Skinner

TEACHING, it is often said, is an art, but we have increasing reason to hope that it may eventually become a science. We have already discovered enough about the nature of learning to devise training techniques which are much more effective and give more reliable results than the rule-of-thumb methods of the past. Tested on animals, the new techniques have proved superior to traditional methods of professional animal trainers; they yield more remarkable results with much less effort.

It takes rather subtle laboratory conditions to test an animal's full learning capacity, but the reader will be surprised at how much he can accomplish even under informal circumstances at home. Since nearly everyone at some time or other has tried, or wished he knew how, to train a dog, a cat or some other animal, perhaps the most useful way to explain the learning process is to describe some simple experiments which the reader can perform himself.

"Catch your rabbit" is the first item in a well-known recipe for rabbit stew. Your first move, of course, is to choose an experimental subject. Any available animal—a cat, a dog, a pigeon, a mouse, a parrot, a chicken, a pig—will do. (Children or other members of your family may also be available, but it is suggested that you save them until you have had practice with less valuable material.) Suppose you choose a dog.

The second thing you will need is something your subject wants, say food. This serves as a reward or—to use a term which is less likely to be misunderstood—a "reinforcement" for the desired behavior. Many things besides food are reinforcing—for example, simply letting the dog out for a run—but food is usually the easiest to administer in the kind of experiment to be described here. If you use food, you must of course perform the experiment when the dog is hungry, perhaps just before his dinnertime.

The reinforcement gives you a means of control over the behavior of the animal. It rests on the simple principle that whenever something reinforces a particular activity of an organism, it increases the chances that the organism will repeat that behavior. This makes it possible to shape an animal's behavior almost as a sculptor shapes a lump of clay. There is, of course, nothing new in this principle. What is new is a better understanding of the conditions under which reinforcement works best.

To be effective a reinforcement must be given almost simultaneously with the desired behavior; a delay of even one second destroys much of the effect. This means that the offer of food in the usual way is likely to be ineffective; it is not fast enough. The best way to reinforce the behavior with the necessary speed is to use a "conditioned" reinforcer. This is a signal which the animal is conditioned to associate with food. The animal is always given food immediately after the signal, and the signal itself then becomes the reinforcer. The better the association between the two events, the better the result.

For the conditioned reinforcer you need a clear signal which can be given instantly and to which the subject is sure to respond. It may be a noise or a flash of light. A whistle is not effective because of the time it takes to draw a breath before blowing it. A visual signal like a wave of the arm may not always be seen by the animal. A convenient signal is a rap on a table with a small hard object or the noise of a high-pitched device such as a "cricket."

YOU are now ready to start the experiment with your dog. Work in a convenient place as free as possible from distraction. Let us say that you have chosen a "cricket" as your conditioned reinforcer. To build up the effect of the reinforcer begin by tossing a few scraps of food, one at a time and not oftener than once or twice a minute, where the dog may eat them. Use scraps of food so small that 30 or 40 will not greatly reduce the animal's hunger. As soon as the dog eats each scrap readily and without delay, begin to pair the cricket with the food. Sound the cricket and then toss a piece of food. Wait half a minute or so and repeat. Sound the cricket suddenly, without any preparatory movements such as reaching for food.

At this stage your subject will probably show well-marked begging behavior. It may watch you intently, perhaps jump on you, and so on. You must break up this behavior, because it will interfere with other parts of the experiment. Never sound the cricket or give food when the dog is close to you or facing you. Wait until it turns away, then reinforce. Your conditioned reinforcer is working properly when your subject turns immediately and approaches the spot where it receives food. Test this several times. Wait until the dog is in a fairly unusual position, then sound the signal. Time spent in making sure the dog immediately approaches the food will later be saved manyfold.

Now, having established the noise as the reinforcer, you may begin teaching the dog. To get the feel of the technique start with some simple task, such as getting the dog to approach the handle on a low cupboard door and touch it with its nose. At first you reinforce any activity which would be part of the final completed act of approaching and touching the handle of the cupboard. The only permissible contact between you and the dog is *via* the cricket and the food. Do not touch the dog, talk to it, coax it, "draw its attention" or interfere in any other way with the experiment. If your subject just sits, you may have to begin by reinforcing any movement, however slight. As soon as the dog moves, sound the cricket and give food. Remember that your reaction time is important. Try to reinforce as nearly simultaneously with the movement as possible.

After your subject is moving freely about, reinforce any turn toward the cupboard. Almost immediately you will notice a change in its behavior. It will begin to face toward the cupboard most of the time. Then begin to reinforce only when the dog moves nearer the cupboard. (If you withhold reinforcement too long at this stage, you may lose the facing response. If so, go back and pick it up.) In a very short time—perhaps a minute or two—you should have the dog standing close to the cupboard. Now begin to pay attention to its head. Reinforce any movement that brings the nose close to the handle. You will have to make special efforts now to reduce the time between the movement and the reinforcement to the very minimum. Presently the dog will touch the handle with its nose, and after reinforcement it will repeat this behavior so long as it remains hungry.

Usually it takes no more than five minutes, even for a beginner, to teach a dog this behavior. Moreover, the dog does not have to be particularly smart to learn it; contrary to the usual view, all normal dogs will learn with about equal facility by this conditioning technique.

Before going on with other experiments test the effect of your conditioned reinforcer again two or three times. If the dog responds quickly and eats without delay you may safely continue. You should "extinguish" the response the dog has already learned, however, before teaching it another. Stop reinforcing the act of touching the cupboard handle until the dog abandons this activity.

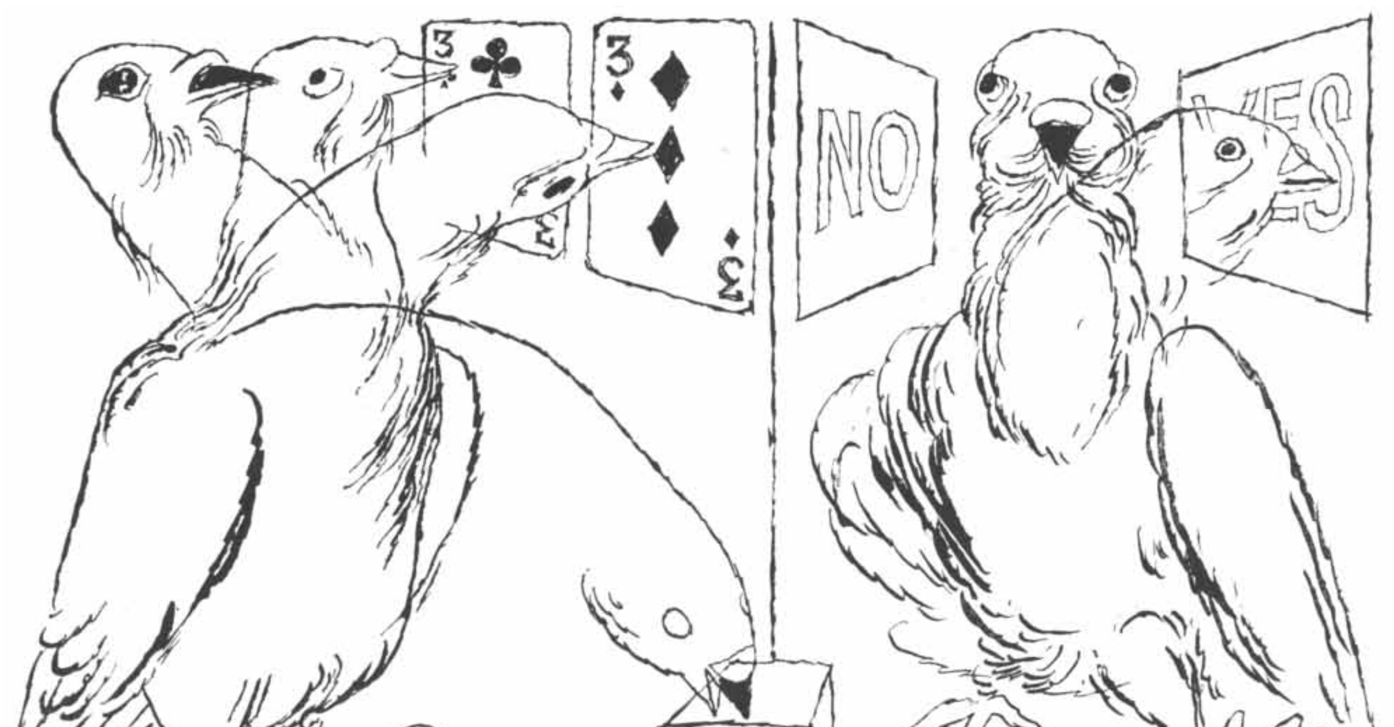
As a second test, let us say, you want to teach the dog to lift its head in the air and turn around to the right. The general procedure is the same, but you may need some help in sharpening your observation of the behavior to be reinforced. As a guide to the height to which the dog's head is to be raised, sight some horizontal line on the wall across the room. Whenever the dog, in its random movements, lifts its head above this line, reinforce immediately. You will soon see the head rising above the line more and more frequently. Now raise your sights slightly and reinforce only when the dog's head rises above the new level. By a series of gradual steps you can get the dog to hold its head much higher than usual. After this you can begin to emphasize any turning movement in a clockwise direction while the head is high. Eventually the dog should execute a kind of dance step. If you use available food carefully, a single session should suffice for setting up this behavior.

HAVING tested your ability to produce these simple responses, you may feel confident enough to approach a more complex assignment. This time suppose you try working with a pigeon. Pigeons do not tame easily. You will probably want a cage to help control the bird, and for this you can rig up a large cardboard carton with a screen or lattice top and windows cut in the side for observing the bird. It is much less disturbing to the bird if you watch it from below its line of vision than if you peer at it from above. In general keep yourself out of the experimental situation as much as possible. You may still use a cricket as a conditioned reinforcer, and feed the bird by dropping a few grains of pigeon feed into a small dish through a hole in the wall. It may take several daily feedings to get the bird to eat readily and to respond quickly to the cricket.

Your assignment is to teach the pigeon to identify the visual patterns on playing cards. To begin with, hang a single card on a nail on the wall of the cage a few inches above the floor so that the pigeon can easily peck it. After you have trained the bird to peck the card by reinforcing the movements that lead to that end, change the card and again reinforce the peck. If you shuffle the cards and present them at random, the pigeon will learn to peck any card offered.

Now begin to teach it to discriminate among the cards. Let us say you are using diamonds and clubs (excluding face cards and aces) and want the bird to select diamonds. Reinforce only when the card presented is a diamond, never when it is a club. Almost immediately the bird will begin to show a preference for diamonds. You can speed up its progress toward complete rejection of clubs by discontinuing the experiment for a moment (a mild form of punishment) whenever it pecks a club. A good conditioned punishment is simply to turn off the light or cover or remove the card. After half a minute replace the card or turn on the light and continue the experiment. Under these conditions the response which is positively reinforced with food remains part of the repertoire of the bird, while the response that leads to a blackout quickly disappears.

There is an amusing variation of this



PIGEON can be taught to choose one card rather than another and even apparently to read. This is done by "reinforcing" the animal when it pecks the right card and turning out the light when it pecks the wrong one.

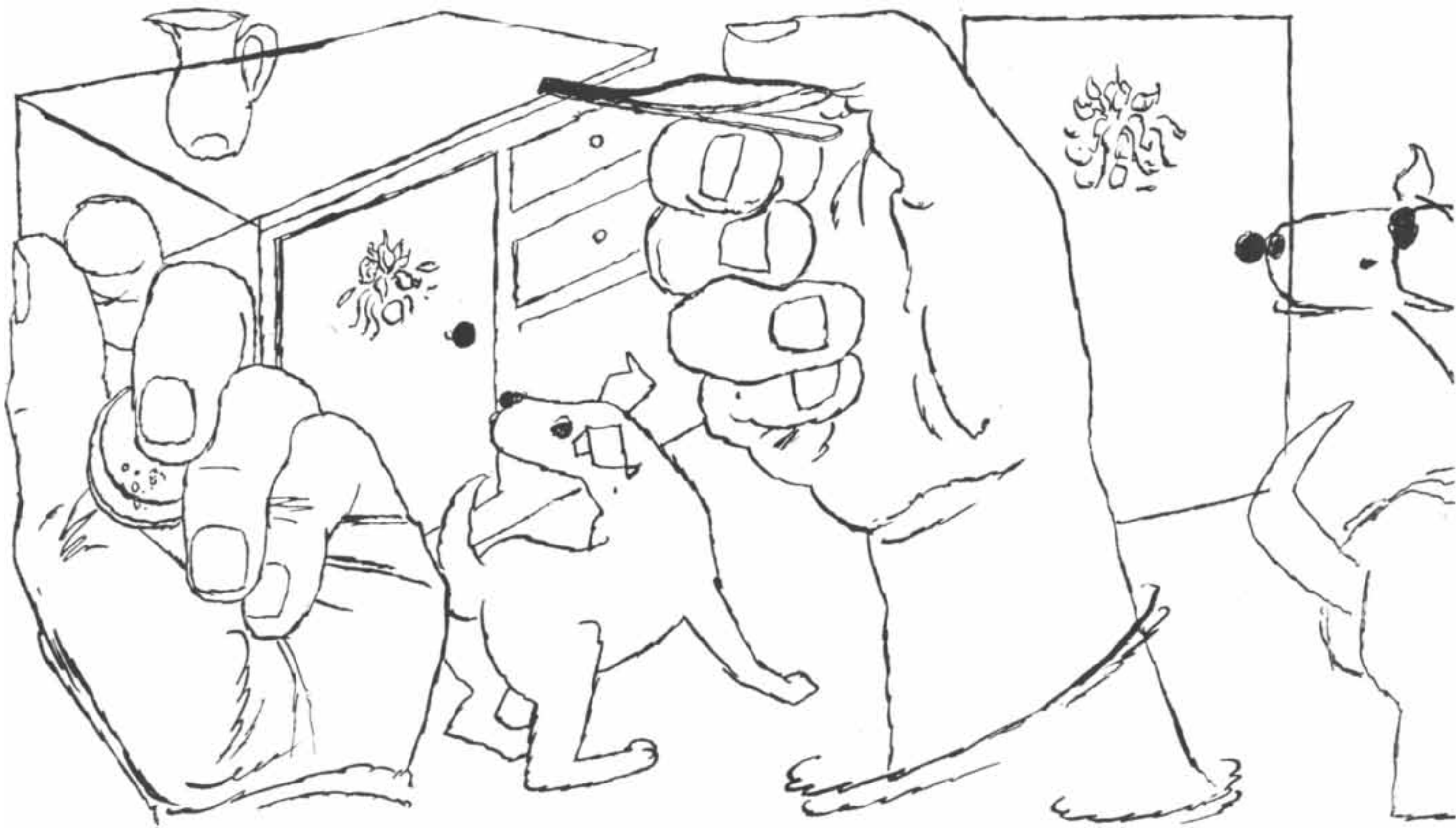
experiment by which you can make it appear that a pigeon can be taught to read. You simply use two printed cards bearing the words PECK and DON'T PECK, respectively. By reinforcing responses to PECK and blacking out when the bird pecks DON'T PECK, it is quite easy to train the bird to obey the commands on the cards.

The pigeon can also be taught the somewhat more "intellectual" performance of matching a sample object. Let us say the sample to be matched is a certain card. Fasten three cards to a board, with one above and the two others side by side just below it. The board is placed so that the bird can reach all the cards through windows cut in the side of the cage. After training the bird to peck a card of any kind impartially in all three positions, present the three chosen cards. The sample to be matched, say the three of diamonds, is at the top, and below it put a three of diamonds and a three of clubs. If the bird pecks the sample three of diamonds at the top, do nothing. If it pecks the matching three of diamonds below, reinforce it; if it pecks the three of clubs, black out. After each correct response and reinforcement, switch the positions of the two lower cards. The pigeon should soon match the sample each time. Conversely, it can also be taught to select the card that does not match the sample. It is important to reinforce correct choices immediately. Your own behavior must be letter-perfect if you are to expect perfection from your subject. The task can be made easier if the pigeon is conditioned to peck the sample card before you begin to train it to match the sample.

IN A MORE elaborate variation of this experiment we have found it possible to make a pigeon choose among four words so that it appears to "name the suit" of the sample card. You prepare four cards about the size of small calling cards, each bearing in block letters the name of a suit: SPADES, HEARTS, DIAMONDS and CLUBS. Fasten these side by side in a row and teach the pigeon to peck them by reinforcing in the usual way. Now arrange a sample playing card just above them. Cover the name cards and reinforce the pigeon a few times for pecking the sample. Now present, say, the three of diamonds as the sample. When the pigeon pecks it, immediately uncover the name cards. If the pigeon pecks DIAMONDS, reinforce instantly. If it pecks a wrong name instead, black out for half a minute and then resume the experiment with the three of diamonds still in place and the name cards covered. After a correct choice, change the sample card to a different suit while the pigeon is eating. Always keep the names covered until the sample card has been pecked. Within a short time you should have the bird following the full sequence of pecking the sample and then the appropriate name card. As time passes the correct name will be pecked more and more frequently and, if you do not too often reinforce wrong responses or neglect to reinforce right ones, the pigeon should soon become letter-perfect.

A toy piano offers interesting possibilities for performances of a more artistic nature. Reinforce any movement of the pigeon that leads toward its pressing a key. Then, by using reinforcements and blackouts appropriately, narrow the response to a given key. Then build up a two-note sequence by reinforcing only when the sequence has been completed and by blacking out when any other combination of keys is struck. The two-note sequence will quickly emerge. Other notes may then be added. Pigeons, chickens, small dogs and cats have been taught in this way to play tunes of four or five notes. The situation soon becomes too complicated, however, for the casual experimenter. You will find it difficult to control the tempo, and the reinforcing contingencies become very complex. The limit of such an experiment is determined as much by the experimenter's skill as by that of the animal. In the laboratory we have been able to provide assistance to the experimenter by setting up complicated devices which always reinforce consistently and avoid exhaustion of the experimenter's patience.

The increased precision of the laboratory also makes it possible to guarantee performance up to the point of almost complete certainty. When relevant conditions have been controlled, the behavior of the organism is fully determined. Behavior may be sustained in full



DOG can easily be trained to touch its nose to the handle of a cupboard with the aid of a mechanical "cricket." The experimenter holds the cricket in one hand and a bit of food in the other. When the dog makes any move-

strength for many hours by utilizing different schedules of reinforcement. Some of these correspond to the contingencies established in industry in daily wages or in piece-work pay; others resemble the subtle but powerful contingencies of gambling devices, which are notorious for their ability to command sustained behavior.

THE human baby is an excellent subject in experiments of the kind described here. You will not need to interfere with feeding schedules or create any other state of deprivation, because the human infant can be reinforced by very trivial environmental events; it does not need such a reward as food. Almost any "feed-back" from the environment is reinforcing if it is not too intense. A crumpled newspaper, a pan and a spoon, or any convenient noisemaker quickly generates appropriate behavior, often amusing in its violence. The baby's rattle is based upon this principle.

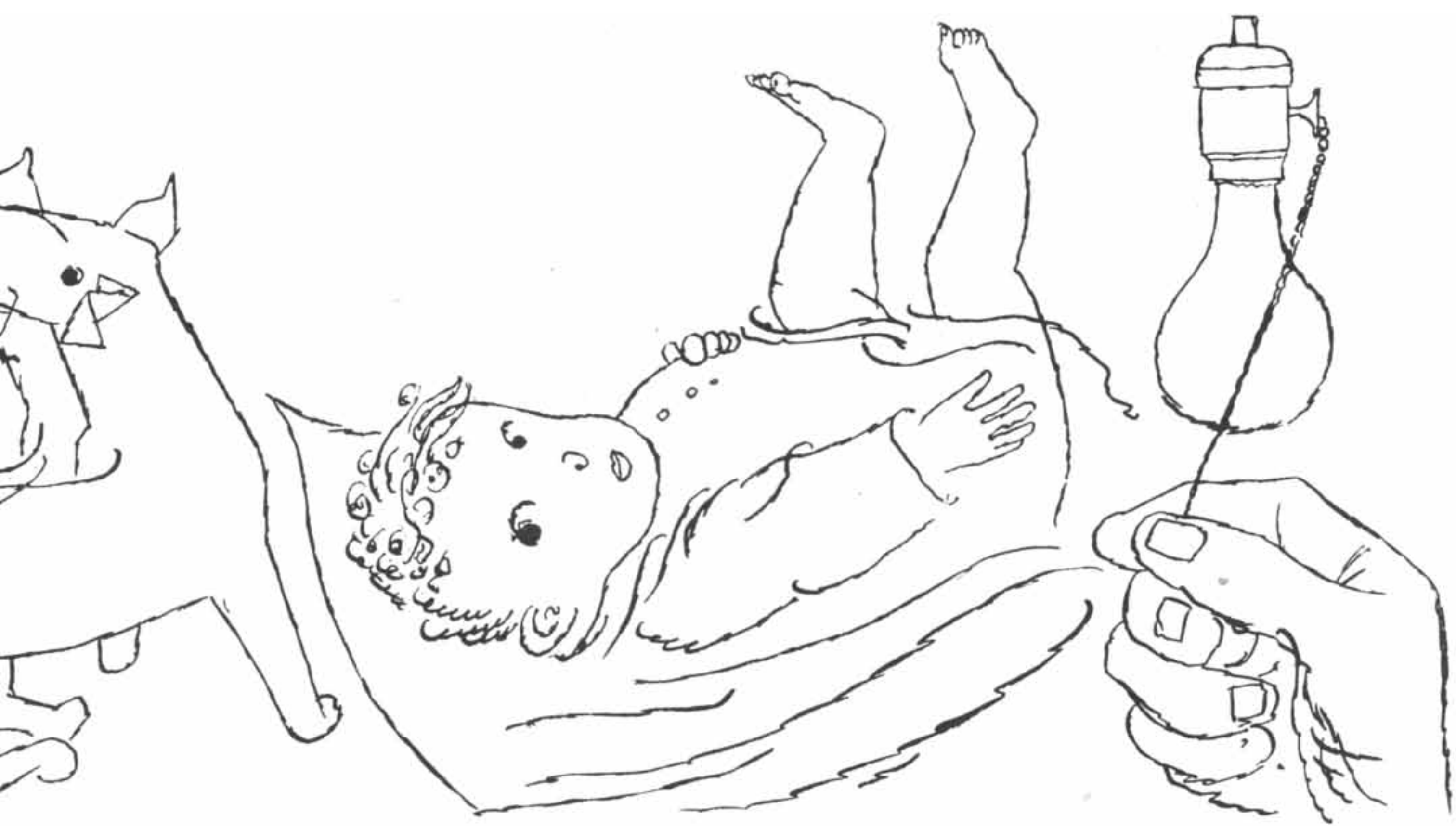
One reinforcer to which babies often respond is the flashing on and off of a table lamp. Select some arbitrary response—for example, lifting the hand. Whenever the baby lifts its hand, flash the light. In a short time a well-defined response will be generated. (Human babies are just as "smart" as dogs or pigeons in this respect.) Incidentally, the baby will enjoy the experiment.

The same principle is at work in the behavior of older children and adults. Important among human reinforcements are those aspects of the behavior of others, often very subtle, that we call "attention," "approval" and "affection." Behavior which is successful in achieving these reinforcements may come to dominate the repertoire of the individual.

All this may be easily used—and just as easily misused—in our relations with other people. To the reader who is anxious to advance to the human subject a word of caution is in order. Reinforcement is only one of the procedures through which we alter behavior. To use it, we must build up some degree of deprivation or at least permit a deprivation to prevail which it is within our power to reduce. We must embark upon a program in which we sometimes apply relevant reinforcement and sometimes withhold it. In doing this, we are quite likely to generate emotional effects. Unfortunately the science of behavior is not yet as successful in controlling emotion as it is in shaping practical behavior.

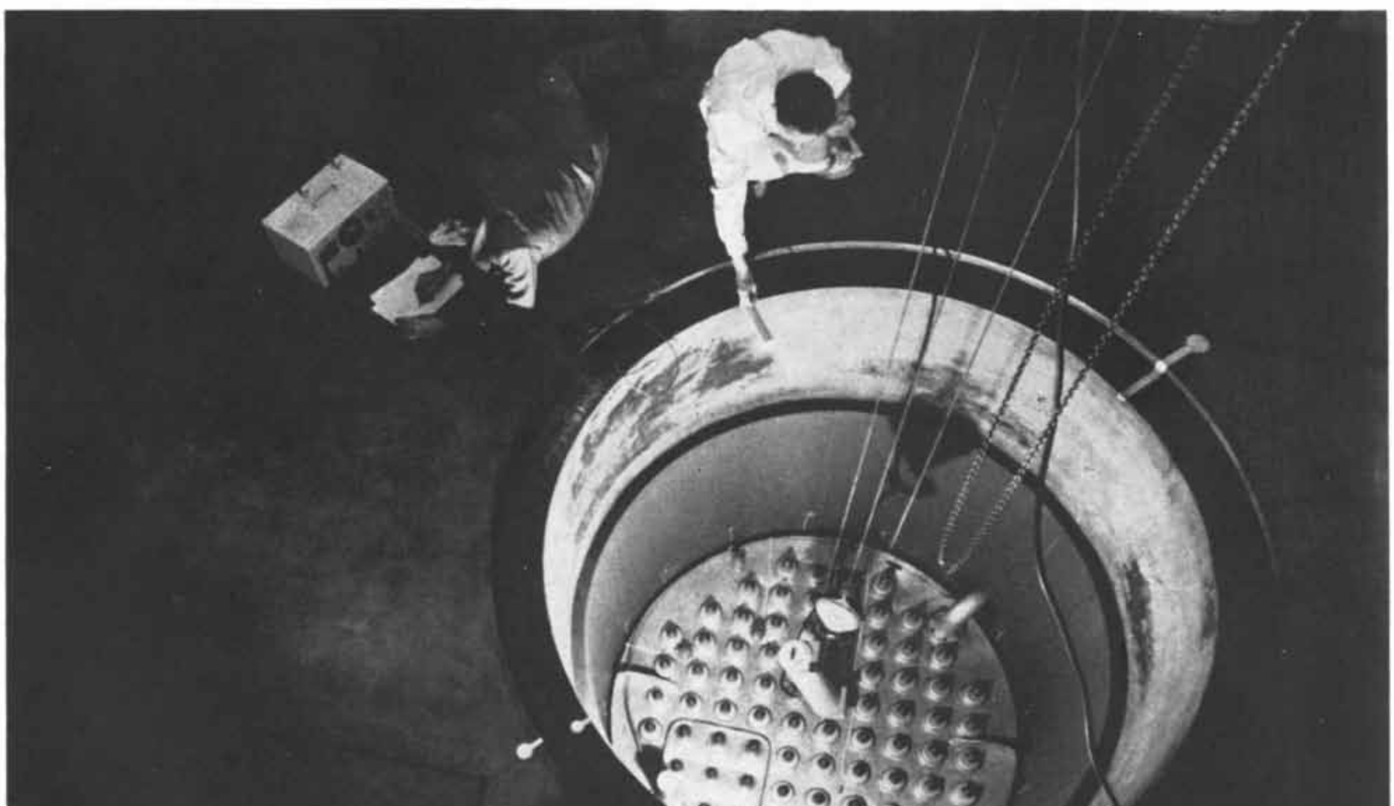
A scientific analysis can, however, bring about a better understanding of personal relations. We are almost always reinforcing the behavior of others, whether we mean to or not. A familiar problem is that of the child who seems to take an almost pathological delight in annoying its parents. In many cases this is the result of conditioning which is very similar to the animal training we have discussed. The attention, approval and affection that a mother gives a child are all extremely powerful reinforcements. Any behavior of the child that produces these consequences is likely to be strengthened. The mother may unwittingly promote the very behavior she does not want. For example, when she is busy she is likely not to respond to a call or request made in a quiet tone of voice. She may answer the child only when it raises its voice. The average intensity of the child's vocal behavior therefore moves up to another level—precisely as the head of the dog in our experiment was raised to a new height. Eventually the mother gets used to this level and again reinforces only louder instances. This vicious circle brings about louder and louder behavior. The child's voice may also vary in intonation, and any change in the direction of unpleasantness is more likely to get the attention of the mother and is therefore strengthened. One might even say that "annoying" behavior is just that behavior which is especially effective in arousing another person to action. The mother behaves, in fact, as if she had been given the assignment to teach the child to be annoying! The remedy in such a case is simply for the mother to make sure that she responds with attention and affection to most if not all the responses of the child which are of acceptable intensity and tone of voice and that she never reinforces the annoying forms of behavior.

B. F. Skinner is professor of psychology at Harvard University.



ment toward the handle, the experimenter sounds the cricket and tosses the food. Babies are just as smart as dogs in learning such tricks. At right a baby is taught to lift its arm when a lamp is turned off and on.

ALUMINUM TANK is seen during the construction of the reactor through an opening in its concrete shielding. A technician works on one of the movable cadmium sheets that are used to control the activity of the reactor.



URANIUM RODS are seen in the top of the tank as technicians measure the neutron intensity of the reactor during its first run on July 30. At higher power levels the opening above the reactor is closed by tanks of water.

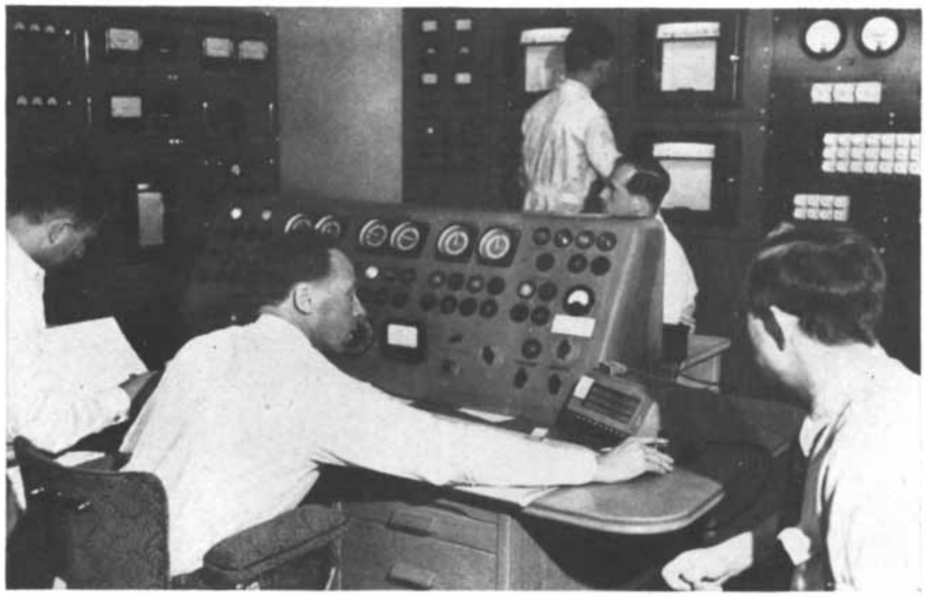
NORWAY REACTOR

Norwegians and Dutch join to build one of the heavy-water type

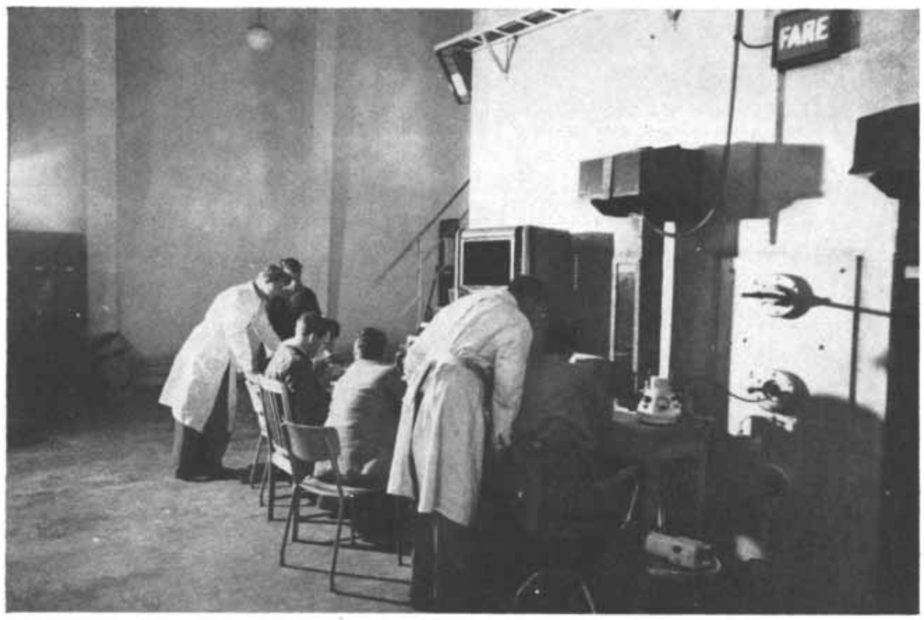
LAST SUMMER Norway and the Netherlands jointly followed the U. S., Britain, Canada, France and presumably the U.S.S.R. in completing a reactor for the controlled release of atomic energy. Located at Kjeller, a suburb of Oslo, the new reactor uses Dutch uranium as fuel and Norwegian heavy water as moderator. The two governments were joined in the project by the big Norwegian hydroelectric firm Norsk Hydro, which thus becomes the first private enterprise to own part of a reactor. (The U. S. companies that have built or operated reactors have done so on a contract basis.)

The photographs on these three pages, made by the Norwegian magazine *Aktuell*, show that the Kjeller reactor is almost identical with the U. S. heavy-water reactor at Argonne National Laboratory. This is remarkable because the builders of the new machine had completed their design before the detailed construction of the Argonne reactor was made public a year ago. Moreover, they had had no access to classified information. Like the Argonne reactor, the Kjeller machine consists primarily of some three tons of uranium rods suspended in a six-foot aluminum tank containing six and a half tons of heavy water. Surrounding the tank is about two feet of neutron-reflecting graphite, which in turn is surrounded by sheets of cadmium and six feet of concrete. The cost of the reactor was about $500,000, which makes it the cheapest ever built.

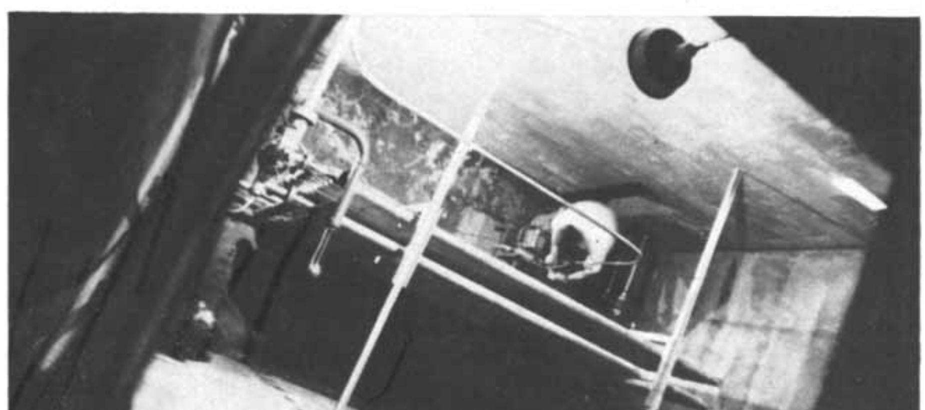
The Kjeller reactor is designed for research and the small-scale production of artificial isotopes rather than the manufacture of plutonium. The reactor tank is pierced by six tubes through which materials can be placed in its interior. To allow slow neutrons to diffuse out of the pile for experiments there is a column of graphite that goes through the concrete shield to the graphite around the tank. There are also two smaller openings that go through to the wall of the tank for experiments with fast neutrons. In full operation the reactor develops something more than 100 kilowatts of heat, which is dissipated by a system of pipes.



CONTROL ROOM of the reactor contains its sensory and motor instruments. In the center is Gunnar Randers, managing director of the project.



CONCRETE SHIELDING of the reactor is seen from the outside. The sign which appears at the upper right indicates that the reactor is in operation.



COOLING SYSTEM is a double bank of pipes. When the reactor operates at the 100-kilowatt level, heavy water will leave the tank at 100 degrees F.

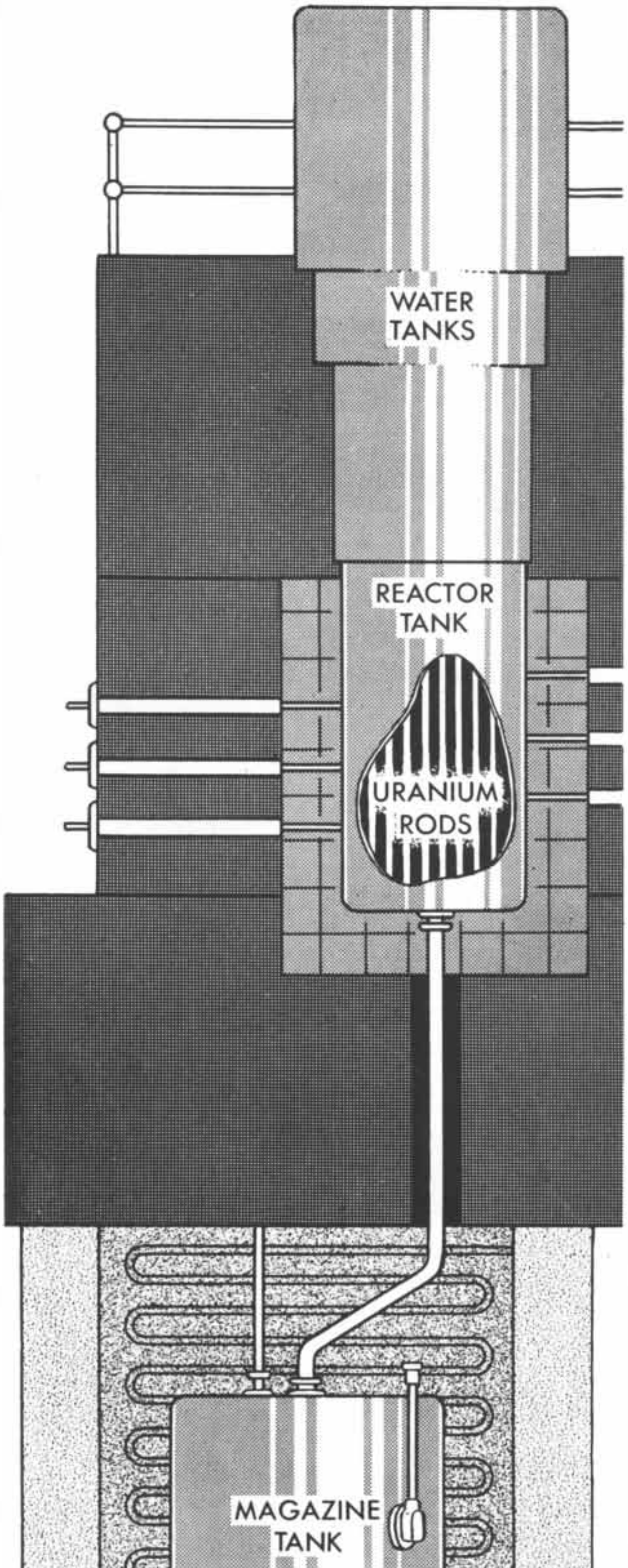
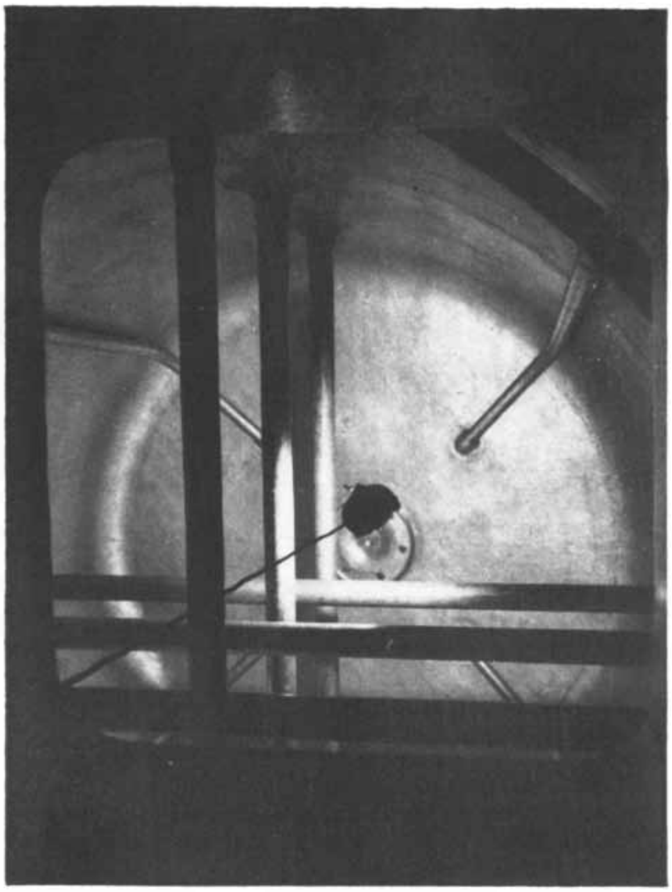


DIAGRAM of reactor shows relationship of its parts. Bottom tank permits quick evacuation of heavy water.



INSIDE of reactor tank when uranium is not in place shows tubes in which test materials are inserted.

AFTERMATH of the reactor's christening with a bottle of champagne. The bottle was dashed against shielding.

The case of the occasional flasher

There's a nearby but faint, cool, small star, catalogued L-726-8, that seemed no different from the other unvarying stars in the heavens until its image on a Kodak Spectroscopic Plate showed an oddity. At unpredictable intervals, L-726-8 flares up by almost two magnitudes and then in a few minutes sinks back to the 13th magnitude.

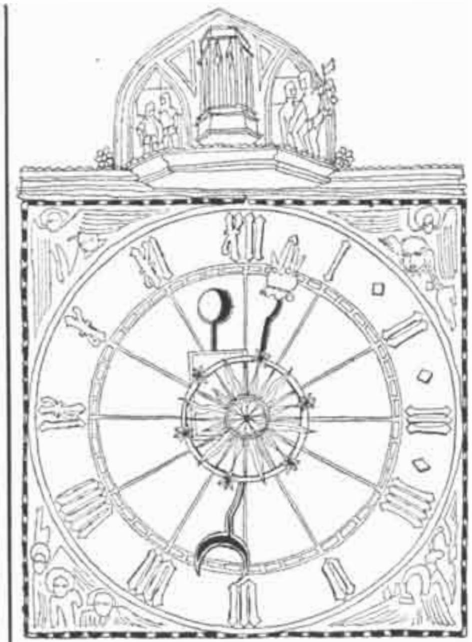
Photography has since caught several others in the same act. Now the world's astronomers are searching with excitement for the reason why.

If you would like to learn about the photography of the night sky, you can get the 112-page Kodak book "Photography in Astronomy" ($2.75 at your Kodak dealer's). If your photographic interest extends to other technologies, a copy of the new edition of "Kodak Sensitized Materials for the Scientific and Industrial Laboratory" is yours without cost. Just write to Eastman Kodak Company, Rochester 4, N. Y.

Multiple exposure by E. F. Carpenter with the 36-inch telescope of the University of Arizona on a Kodak Spectroscopic Plate, Type 103a-O. Five images of L-726-8 are marked. The very bright one is No. 2. Twenty minutes elapsed between the first and last; each exposure was two minutes.

Kodak
TRADE-MARK

SCIENCE AND



$3.5 Million for NSF

THE National Science Foundation has an appropriation of $3.5 million, which will enable it to begin the operations for which it was established in the coming year. This compromise amount was voted by Congress in the closing hours of its last session, after the House had cut the Foundation's $14 million request to $300,000.

The Foundation announced that it will spend about $1.5 million of its allowance in grants for basic research in biology, medicine, mathematics, physical sciences and engineering, and $1.35 million for fellowships. The remaining $650,000 will be devoted to developing a national policy on basic research and scientific education, to disseminating scientific information and to such services as the National Scientific Register, now administered by the U. S. Office of Education.

The Foundation's graduate fellowships will be awarded by the National Research Council. Applications for research grants will be reviewed by the heads of the Foundation's three research divisions and committees of outstanding scientists. The Division of Physical, Mathematical and Engineering Sciences is under Paul E. Klopsteg, physicist of Northwestern University. John Field, Stanford physiologist, heads the Division of Biological Sciences and is also temporarily in charge of the Division of Medical Research.

Nobel Award in Medicine

THE 1951 Nobel prize in physiology and medicine was awarded to Max Theiler of the Rockefeller Foundation for his research on yellow fever. Theiler developed a vaccine against the disease which has been injected into 50 million people in the last 20 years. He created the vaccine by infecting mice with yellow-fever virus and passing it from one mouse to another to weaken its virulence. After 200 passages through mice and 100 transfers in unhatched chicken eggs it was weakened enough to be used. Theiler had been proposed for a Nobel prize three times before he won the award this year.

Moratorium on Color

COLOR TELEVISION is back in the laboratory, its commercial exploitation halted by request of the Federal government. Charles E. Wilson, Director of Defense Mobilization, asked the Columbia Broadcasting System to stop producing color receivers in order to conserve scarce materials, but told the television industry that there was no objection to continued research. CBS, whose color system is the only one at present authorized by the Federal Communications Commission, immediately announced that it would comply with the request; it also canceled all color broadcasts, explaining that there were too few sets in use to justify continuing them.

The entire television industry, including CBS, appeared relieved by the order. The CBS sets, retailing at $700 apiece, were not finding many purchasers. CBS, the Radio Corporation of America and other potential producers will now have an opportunity to improve their systems and equipment without the complications of production competition.

Exercise Desert Rock

FIVE atomic test bombs were exploded by the Atomic Energy Commission last month at its Nevada proving ground. The experiments were designed to provide information on possible tactical uses of atomic weapons. The first explosion apparently was much smaller than any previous nuclear detonation; to newspaper reporters watching from mountainsides at a distance it looked smaller than the blast of a few tons of TNT which was set off for purposes of comparison just before. The four subsequent tests, all much more powerful, included studies of the effects of the new bombs on guns, tanks and dug-in positions at various distances from the explosion.

Army troops took part in some of the tests, called "Exercise Desert Rock." In one exercise 1,200 paratroopers set up battle positions on the test range, withdrew for the explosion and then returned for lessons in decontaminating the equipment they had left at the site.

A photographic paper factory of E. I. du Pont de Nemours & Company in Rochester, N. Y., 2,000 miles from the test site, closed down because the paper was being ruined by exposure to radioactive dust particles blown all the way from Nevada and caught in the plant's air-conditioning system.

The Atomic Energy Commission has resumed the exchange of research information, on a limited scale, with other countries. By an amendment to the Atomic Energy Act Congress has relaxed the almost total ban that was imposed in 1946; it gives the AEC permission to exchange atomic data, excluding weapon construction, with countries that do not "threaten the security" of the U. S. and that adopt approved secrecy precautions. The information the U. S. is willing to give, according to Congressional spokesmen, has to do with the refining of ores and the purification of fissionable material. In return the AEC expects to get data on reactor research from Great Britain and Canada.

Dept. of Higher Mathematics

CAN the present arms race end without a war? An approach to this question by means of simultaneous differential equations has been contributed to the British journal *Nature* by L. F. Richardson, a physicist turned psychologist. With the aid of three variables and eight constants, he finds that the answer is yes.

He writes: "There have been only three great arms races. The first two of them ended in wars in 1914 and 1939; the third is still going on. From so few events we cannot hope to draw any reliable conclusions by statistics." Instead of statistics, therefore, he sets up two differential equations expressing the rate of change of a nation's war preparations as a function of its rival's war preparations and of both countries' defensiveness, submissiveness, objection to armament costs and "feelings about the treaty situation." The coefficients for submissiveness were introduced "to represent the well-known fact that great Powers have sometimes suppressed very much smaller Powers without any fighting."

But what are the chances of avoiding fighting when both Powers are great? Noting that "the present world tension is between two groups sufficiently nearly equal to be alarmed about each other," Richardson assumes "for the sake of mathematical simplicity" that their defensiveness, submissiveness and objection to the cost of armament are the same, and he throws out the factor for attitude toward treaties. With these simplified equations, he finds that a day will come when the sum of the war preparations of both nations will begin to decrease. In other words, if a war has not already taken place by that date, the arms race will come to an end peacefully.

Richardson is unable to fix the date, because this would require knowing the coefficients of defensiveness, submissiveness, and so on, of the Powers concerned. But he claims that his equations are "instructive . . . provided that we remember that such a treatment is a caricature."

The Dangerous Safety Belt

WHEN an airplane crashes, the safety belt that passengers are required to fasten around their waists may become a deadly hazard. A British physician named Donald Teare examined 28 victims of a crash at the London Airport and found that 16 of them were killed by chest and abdomen injuries resulting from "acute flexion of the body over the safety belt." Eight of the victims had suffered a rupture of the aorta—an extremely rare injury, almost never found except in plane accidents.

One of the two survivors of the crash was the stewardess, who was in the tail of the plane, apparently the safest spot. Teare urged, as many others have proposed, that the passenger seats in planes be arranged to face the rear of the plane. The specific injuries that killed most of the victims of the London crash, he said, might have been avoided if the passengers "had been seated with their backs to the engine and supported by cushioned upholstery."

Heavier Cosmic Rays

THE cosmic rays that bombard the earth from outer space, once thought to be just protons (the nuclei of hydrogen atoms), are now known to include considerably heavier elements as well. Until recently no nucleus heavier than about atomic number 40 (zirconium) had been found in these rays ("Heavy Elements from Space," by Edward P. Ney; SCIENTIFIC AMERICAN, May). The nuclei are generally detected by their tracks in photographic plates sent up in balloons. Recently a group of physicists decided to see if they could catch bigger nuclei by using a bigger trap, *i.e.*, a thicker photographic emulsion. Plates with an emulsion an eighth of an inch thick—100 times thicker than those used in ordinary photography—were sent up in plastic balloons to an altitude of 110,000 feet. As hoped, they did catch some bigger game. Nuclei up to about atomic number 49 were identified in the emulsion. (Element 49 is indium.)

Herman Yagoda of the National In-

stitutes of Health, who analyzed the tracks, said he had determined the size of the nuclei both by the amount of ionization they produced in the emulsion and by the sum of the charges of the fragments into which the nuclei had broken down.

Algae Factory

ALGAE, plants that grow in water, have attracted a great deal of attention in recent years as a possible food and raw material. They contain a high proportion of protein and fat, and they could be processed into industrial oils and greases, animal fodder and perhaps human food. The question has been: Can algae be grown cheaply enough to make these uses practicable? To answer that question, the first algae factory has just gone into production in Cambridge, Mass.

Under a grant from the Carnegie Institution of Washington, the research firm of Arthur D. Little, Inc., has built a pilot plant where it is cultivating the one-celled fresh-water alga called Chlorella. The plant has two units with a total growing area of 1,200 square feet. The two units use two different "assembly-line" devices: in one the suspension of Chlorella in fresh water is pumped continuously through a large tube of transparent plastic; in the other it is pumped through a trough with a transparent plastic cover. The plant, exposed to sunlight, grows continuously, and it is harvested daily.

Studies are now under way to find out the best environment for growing algae, and to learn whether another species might be more suitable than Chlorella. One big problem in algae production is to get a good yield of product for a given volume of water. In nature a pond produces only one pound of algae for 100,000 gallons of water. J. E. Myers of the University of Texas has shown that in a tube, with extra rations of carbon dioxide, production can be raised to half a pound per gallon. Another important recent finding is that the composition of the algae can be greatly affected by changes in the environment. This makes it possible to produce various kinds of algae to order. Grown in a nitrogen-rich medium, Chlorella contains more than 50 per cent protein, which makes it valuable as food. If the nitrogen concentration in the growing medium is reduced, the fat content of the alga can be raised to over 85 per cent, in which form it is a good raw material for industrial oils and greases.

Joe's Stuff

THE huge and promising new class of chemicals known as the fluorocarbons has moved from the laboratory to the factory. They are now being produced by the ton in a plant of the Minnesota

To our Colleagues in American Business . . .

Specifications of raw or semi-manufactured materials often present problems. These arise frequently when engineers and designers feel that their ideas can only be carried out in a highly special way. Sometimes this is the case, of course. But Revere very often finds that many "specials" are not really necessary, and that proper selection will make standard items not only perfectly suitable in every respect, but will avoid delivery delays and price premiums and reduce stockroom complications.

A recent case involved a company making aluminum building products, such as louvred window shutters, attic ventilators, mail boxes, roof ventilators, and so on. The company is modern, aggressive, and capably staffed in engineering, design, purchasing and production departments, as well as sales. Revere as a producer of aluminum coiled sheet was given the opportunity to make a thorough study of factory methods and end uses, and their relationship to specifications. This collaboration developed the fact that it should be unnecessary to specify more than one aluminum alloy, which seemed to have everything the manufacturer needed in strength, workability and beauty. As a result of Revere's well-documented recomendations, a trial order of this alloy was entered.

When the material was put through the factory on a production basis, it surpassed expectations. The chief engineer and the purchasing department thereupon changed all their specifications to conform with those set up by Revere. As a result, Revere has been receiving a good part of the company's business.

This case is cited not merely because it illustrates a fine way to get orders. What is really important about it is the evidence it provides of the value of team work. In Revere, the team works this way: a capable salesman calls on a prospect, and asks for the opportunity to do more than solicit an order. The Technical Advisory staff, if permitted, applies its knowledge, skill and ingenuity in overcoming problems and setting up specifications in collaboration with the prospect. Once an order is received, the capable mill employees, including methods and production departments, set up proper mill and shipping procedures, and carry through the order with careful efficiency. Team work of this kind has contributed mightily to create Revere's outstanding position. However, it should not be overlooked that in this description of the team, the customer is included. He very definitely belongs. You might say he is the catcher, plus an infielder or two and a couple of outfielders, while the rest of the home team, including the pitcher, is Revere. The guy at bat is the problem and is struck out.

Many customers tell us we play that kind of ball exceedingly well, and we are proud of that. However, there are other companies, in every league, who do likewise. So Revere suggests that no matter what it is you buy, nor from whom, whether it be glass or plastics, steel or fabrics, you join your suppliers' teams. The improvement in the score may surprise you considerably.

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Fluorocarbons, which are semi-organic compounds in which some or all of the hydrogen of the organic molecule has been replaced by fluorine, were first made some 15 years ago by Joseph H. Simons and other workers at Pennsylvania State College ("Fluorocarbons," by J. H. Simons; SCIENTIFIC AMERICAN, November, 1949). During the war they found an important use in the U-235 gaseous diffusion plant at Oak Ridge. The Manhattan Project code-named Simons' compounds "Joe's Stuff." The original method of producing fluorocarbons by a catalytic process was costly, but in 1948 Simons discovered a much cheaper and better electrochemical process. An electric current is passed through a mixture of a hydrocarbon and dry hydrogen fluoride, and the hydrogen and fluorine switch places, yielding hydrogen gas and a fluorocarbon. It is this process that is now in production in Minnesota.

While a fluorocarbon is usually similar to its corresponding hydrocarbon in some properties, others will be direct opposites. The outstanding quality of most fluorocarbons is their tremendous stability; they resist heat, acids, alkalies, insects, fungi and weathering. A highly inflammable hydrocarbon, when converted into the corresponding fluorocarbon, becomes fire-resistant enough to serve as a fire extinguisher. The stability of the fluorocarbons promises fireproof, corrosion-resistant plastics, lubricants, dyes and paints. Fluorocarbons will also make more powerful detergents.

Minnesota Mining is now producing only relatively small amounts at comparatively high prices—around $5 a pound. Its first objective is to enable industry to get acquainted with fluorocarbons and learn how to use them.

Doctor, Lawyer, Beggar, Thief

WILLIAM H. Sheldon's famous classification of human physiques into ectomorphs, mesomorphs and endomorphs has been put to all sorts of psychological and medical uses. Now the Harvard University anthropologists Earnest A. Hooton and Frederick Stagg find that physique has a significant correlation with a person's occupation.

They studied photographs of 2,631 former Harvard students, taken between 1876 and 1912 in connection with physical education at the university. Then they traced the subjects of the photographs to learn what had become of them after leaving Harvard. They found that graduates who went into government service tended to be of the lean, ectomorphic type; scientists also were thin, but with leanings toward a mesomorphic (muscular) build; the lawyers were on the endormorphic (fat) side. In engineering and business the

German crowd, part of the 1,250,000 from East and West Berlin, sees a typical RCA television program.

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You've read the story of last summer's TV demonstrations in Berlin. It attracted a million and a quarter Germans—including thousands who slipped through the Iron Curtain to see Western progress at work.

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Programs witnessed by Berliners included live talent shows, sports events, news commentaries, and dramatizations of the Marshall Plan. Observers pronounced reception fully up to American standards—another impressive demonstration of democracy's technical ingenuity and leadership.

* * *

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

Part of the 401 cases of RCA equipment shipped to Berlin for television demonstrations.

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muscular, stocky types were more often successful, while fleshy and lightly built men tended to give up and try something else. Among the Harvard graduates who became manual laborers, the more muscular, surprisingly, tended to abandon this field for other careers, while the weaker types remained laborers.

Domesticated Adrenals

CIVILIZED man may have lost some of the ability to withstand shock and stress that wild animals possess, it is suggested by some studies performed by Curt P. Richter of the Johns Hopkins Hospital.

Richter made a detailed investigation of the biological effects of domestication on the Norway rat. He compared wild rats with tame rats bred in the laboratory. Of the many differences between them, one was particularly striking: the tame rats had much smaller and less active adrenal glands. As a result of the atrophy of these organs the rats were less resistant to stress and fatigue (see "The Alarm Reaction," by P. C. Constantinides and Niall Carey; SCIENTIFIC AMERICAN, March, 1949).

Richter believes the decline of their adrenal glands may be largely due to natural selection in a controlled environment. What is true of the rat might be true of domesticated man. Said Richter: "Man may have undergone parallel changes during his transition from a wild to a controlled, protected environment. As he has become more civilized, his adrenals may have become less efficient, thus accounting for the present-day high incidence of diseases that respond so remarkably to treatment with cortisone and ACTH."

Balls of Fire

THE Southwest has a new mystery almost as baffling as the flying saucers of a few seasons back. In a period of 11 days seven brilliant green fireballs flashed across New Mexico and California. They appeared to be meteors, but meteors of this size normally are seen only once every three or four months. Furthermore, they fell to earth silently, instead of exploding with a loud bang as they should.

Lincoln La Paz, head of the Institute of Meteoritics at the University of New Mexico, said his staff has been unable to recover any meteoritic pieces from the green fireballs, "although we've been chasing them since December, 1948." On November 8 just before noon two green fireballs simultaneously streaked across New Mexico. La Paz, declaring the phenomenon "without parallel in the whole of recorded history," said: "I'm almost inclined to ask those fellows out in Nevada what they are doing."

Behind the EYES OF RESEARCH

PUBLISHED IN THE INTEREST OF FURTHERING ANALYSIS AND RESEARCH THROUGH MODERN OPTICAL INSTRUMENTATION

MAPPING METEORS

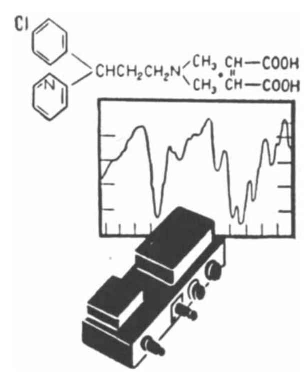
How far does a burning meteor travel in the atmosphere? How long does its trail last? What happens 70 miles up? Answers to questions like these can give scientists important clues to the behavior of guided missiles, high-speed projectiles, or rockets. Like meteors, all of them hurtle at terrific speeds through the rarefied air of the upper atmosphere.

The Baker-Schmidt camera, designed and built by Perkin-Elmer, is the first instrument specifically developed to photograph meteors. It can photograph 40 times more meteors than any other existing camera. The behavior of a meteor in flight, as recorded on the camera's curved film, tells researchers how a rocket ship or guided missile would behave under similar altitude conditions. The camera's optics are fast and accurate enough to catch the trail of a buckshot-sized meteor on a black, cloudless night.

PURER DRUGS—AT LOWER COST

Infrared spectrometry—the new scientific method of product control—is an important factor in today's mass production of wonder drugs. Take the case of penicillin. There are many kinds of penicillin, and a penicillin broth contains most of them—but the "G" variety is the best germ killer. The manufacturer must know, quickly and accurately, the small amount of penicillin G that is present in fermentation vats holding as much as 15,000 gallons of the broth.

To do so, Merck & Company has developed a simple procedure using a Perkin-Elmer Infrared Spectrometer. Accurate penicillin G assays are obtained in about two hours for $3.50 per assay. Penicillin production at Merck plants proceeds smoothly and economically—and prices are kept low—thanks to the growing use of infrared in Product Control.



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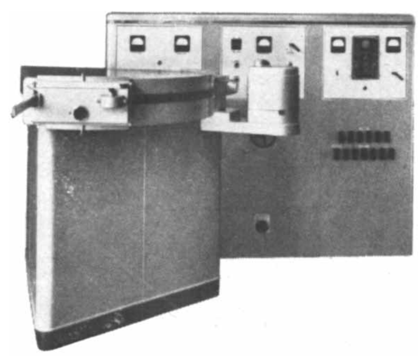

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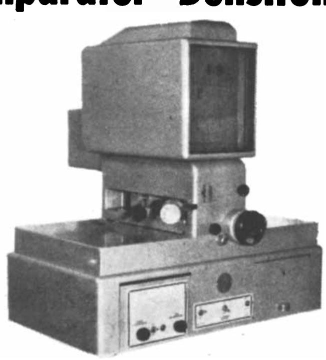

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ELECTROPHORESIS

It is the migration of charged particles in a fluid between two electrical poles. In recent years the phenomenon has been used with signal success to study and to separate protein molecules

by George W. Gray

NATURE is restless—motion is one of its most fundamental attributes. "All things flow," declared Heraclitus 2,500 years ago, and modern science is continually turning up new evidence in support of his generalization. On the grand scale we have the testimony of the stars and nebulae; at the microscopic level we can see the eternal Brownian movement of tiny particles. Robert Brown, the 19th-century botanist who discovered the cell nucleus, first observed this perpetual motion in the dancing of pollen grains in a drop of water. In our century the Brownian movement has been studied by many eminent experimenters and theorists, including Albert Einstein, and we know that the random motion is characteristic of all particles in gaseous and liquid suspensions, from the largest colloids to the smallest molecules.

Brownian movement is responsible for the diffusion of molecules and for the chance contacts among them that result in chemical reactions. Important and helpful as this random motion is to the formation of new compounds, it is obstructive when the chemist desires to isolate one of the compounds from a mixture. Faced with this problem of separating out molecules of a particular composition or species, he has resorted to various schemes. Crystallization is one stratagem for getting a fraction pure; sedimentation, assisted by the centrifuge, is another. A third technique is based on the electrical properties of particles. This remarkable method of analysis is known as electrophoresis. The term, derived from the Greek, means "borne by electricity."

Electrical Migration

The principle of electrophoresis has been known for nearly a century and a half. In 1807 a Russian physicist named Alexander Reuss observed that when electricity was passed through glass tubing containing water and clay, colloidal clay particles moved toward the positive electrode. Michael Faraday in England and E. H. Du Bois-Reymond in Germany confirmed his discovery and extended it, showing that any negatively-charged particles in solution or suspension moved toward the positive electrode and positively-charged particles in the opposite direction. What was more, particles moved at differing speeds depending on the number of excess charges they carried; the greater the number of charges, the faster the migration. The way was thus opened to use electrophoresis as a means of separating particles out of a mixture according to their electrical properties. Physicists and chemists in half a dozen countries contributed to the further exploration of the phenomenon. Bit by bit over the decades the theory of electrophoresis was built into a logical structure and methods were developed for applying it to laboratory problems.

Today there are three different techniques. We shall take them in the order in which they were developed. The oldest is known as microscopic electrophoresis.

Under the Microscope

The first essential for an electrophoretic experiment is an electrically active particle. This means a particle with more positive than negative charges on its surface—in other words, an ionized particle. Many particles, *e.g.*, those of certain gums, sugars, and the huge composite molecules known as polysaccharides, carry no excess charges on their surfaces. They therefore remain essentially stationary in the electric field, and it is useless to attempt to study them by electrophoresis. But practically all proteins carry unbalanced distributions of surface charges, and electrophoresis is ideally adapted to the analysis, separation and identification of these biologically important substances.

The second requisite is a solution that conducts electricity. Distilled water is a poor conductor, but the addition of a pinch of salt, acid, alkali or other ionizing compound (known as an electrolyte) will quickly render it conducting.

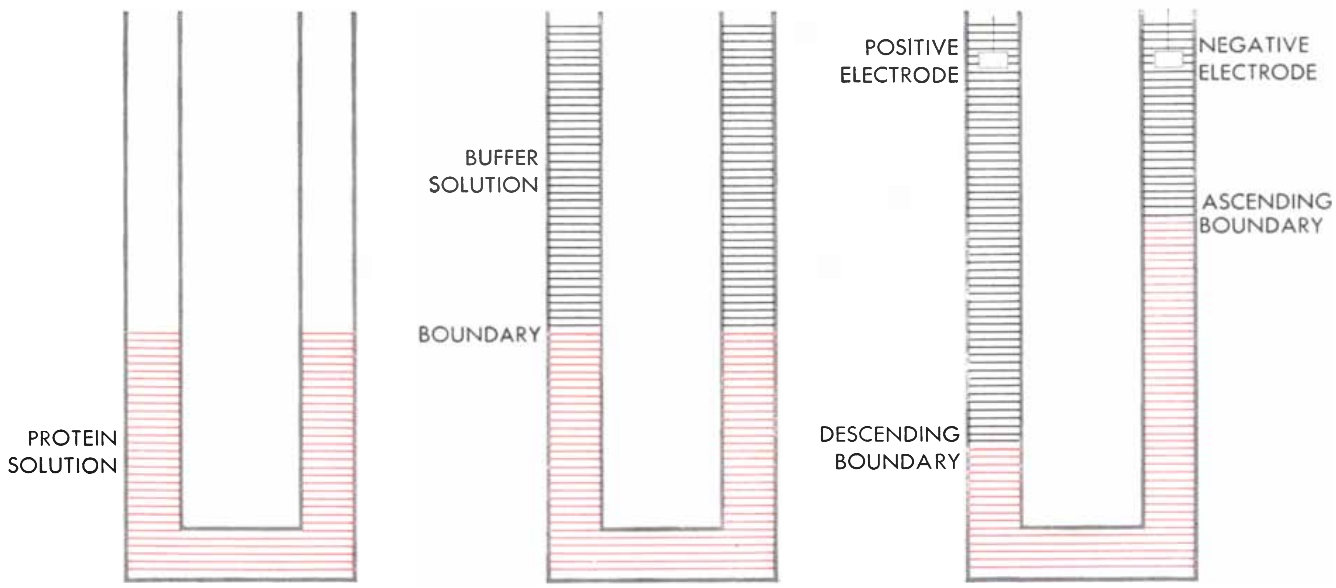
In the microscopic method of electrophoresis the experimenter watches and measures the migration of particles in a solution or suspension contained in a glass tube placed horizontally on the stage of a microscope. Only relatively large objects that can be seen under the microscope, such as blood cells, protozoa, bacteria and colloidal particles, lend themselves to investigation by this method. This would seem to rule out molecules, inasmuch as even the largest are invisible, but chemists have found it possible to study protein molecules indirectly by introducing tiny quartz spheres into the solution. The molecules attach themselves to the spheres in an adhering layer one molecule thick, and thereafter the protein-surfaced quartz responds to the electric current in terms of the charges on the protein.

The microscopic method has been used to study surface phenomena and immune bodies in liquids. John H. Northrop and Moses Kunitz found it useful in their investigation of enzymes at the Rockefeller Institute for Medical Research. Harold A. Abramson employed it at Columbia University in studies of red blood cells and soluble proteins. Recently G. L. Ada and Joyce D. Stone, at the Walter and Eliza Hall Institute in Australia, turned to the microscopic method to study the effect of certain agglutinizing viruses on human red cells.

But the microscopic technique is not often used today. It has been largely supplanted by a newer method which is better suited to the separation of particles, is applicable to large quantities of material and does not require visibility, so that it can be applied to the smallest molecules and even the molecular fragments known as ions. This method is called moving-boundary electrophoresis.

The Moving Boundary

Instead of observing individual particles, the experimenter measures the movement of the boundary of a mass of particles. The material to be studied is poured into the bottom of a U-tube. On top of this, in the two arms of the U, is placed an electrolytic ("buffer") solu-



MIGRATION OF A PROTEIN by electrophoresis is shown in these three diagrams. At the left a protein solution (*red*) is placed in a U-shaped tube. In the center a buffer solution is carefully laid atop the protein solution. At the right a current is passed through the solutions and the protein migrates toward one of the electrodes.

tion. It is laid on carefully so that there is a sharp boundary between the two solutions (*see drawings at the top of this page*). An electric current is then passed through the solutions by means of a positive electrode inserted in the top of one arm of the tube and a negative electrode in the other. The object is to see how fast the boundary moves under the urge of electricity—and in what direction.

If the material under study is a protein, carrying an excess of positive charges on its molecular surface, the boundary moves toward the negative electrode. Each charge serves as a little tugboat to tow the huge molecule in the direction of motion of the positively-charged stream, and the more tugs there are, the faster, of course, the molecule moves.

It is possible by changing the acidity of the solution to slow down this movement. As the *p*H (concentration of hydrogen ions) is progressively raised, the boundary moves slower and slower, until finally a point is reached at which it becomes stationary. If the *p*H is further increased to make the solution alkaline, the negative charges on the protein will begin to assert themselves, operating as tugs pulling in the opposite direction, and then the boundary will move toward the positive electrode. The composition of the electrolytic solution is therefore a matter of the greatest importance in electrophoresis. Its degree of acidity or alkalinity must be regulated with high precision. The balance between acid and base is so delicate that the slightest interference—such as absorption of carbon dioxide from the air or of a trace of alkali from the glass tube—can render the electrophoretic calculations inaccurate. To protect the precision of the concentration the chemist adds certain salts which act to maintain the *p*H at a constant level, the salts themselves absorbing any tendency to variation. These substances, cushioning the chemical blows to which a solution is subject, are called buffers. Some of the recent advances in moving-boundary technique must be credited to the development of more satisfactory buffer systems.

The stage of buffered concentration at which a substance reaches electrical equilibrium and ceases to move toward either electrode is a measure of its isoelectric point. Every electrically responsive compound has its own isoelectric point, and this characteristic is important because it tells something about the substance's structure and chemical properties. The moving-boundary method has established the isoelectric points of hundreds of proteins and other biologically active molecules. The method has scored its greatest triumphs in identifying hidden substances, whose presence in some instances was not even suspected, in complex materials such as blood or milk.

The moving-boundary method has brought in a new era of biochemical research in the past 15 years. It owes its coming-of-age principally to a group of experimenters in Sweden, and most of all to the famous chemist Arne Wilhelm Kaurin Tiselius. Indeed, Tiselius is so closely associated with the development that the modern type of moving-boundary equipment is commonly called "the Tiselius apparatus."

Exciting Invention

Tiselius was born in Stockholm in 1902, fell in love with chemistry in high school and selected Uppsala as his university because there he could study under The Svedberg. Svedberg, then engaged in developing the ultracentrifuge, called the attention of his student to electrophoresis as another means for studying proteins. After graduation Tiselius joined Svedberg in a research project which introduced him to the moving-boundary method. Certain anomalies in the experiments led Tiselius to investigate possible sources of error in the existing apparatus and the prevailing technique, and he spent the next five years testing the possibilities and limitations. When he presented himself for the doctor of science degree in 1930, he submitted a comprehensive review of electrophoresis as his thesis. And with this account Tiselius apparently bade electrophoresis adieu.

He turned to the investigation of adsorption and diffusion. The new interest took him on an exploratory trip to the Faroe Islands in search of zeolite crystals for diffusion experiments and in 1934 to Princeton University on a year's Rockefeller Foundation fellowship. In Princeton he met John H. Northrop and M. L. Anson of the Rockefeller Institute staff. Close association with these biochemists rekindled his interest in electrophoresis. Nobody needed to point out its possibilities to Tiselius; he was keenly aware from his previous studies that it could be enormously helpful, provided only that the technique were made exact and discriminating. When he got back to Uppsala, he resumed experiments with the moving-boundary method.

The first fruit of this study came in the summer of 1937. Tiselius announced in the *Transactions* of the Faraday Society of London the development of a new apparatus for electrophoretic analysis. His paper not only described the design and operation of this equipment but reported a discovery which gave evidence of its value as an analytical tool. Employing it to analyze the serum of blood, he had found that the blood fraction known as globulin was in reality a mixture of three substances. He named them alpha globulin, beta globulin and gamma globulin.

The publication of this paper fired the imagination of biochemists all over the world. Its arrival in a laboratory was like the touching of a spark to tinder, for immediately researchers began to inquire how they might buy, borrow or build one of these powerful machines.

Chain Reaction

When Tiselius' paper arrived at the Rockefeller Foundation's International Health Division, which was then studying the viruses of yellow fever and influenza, its staff decided that the new tool might be useful in the virus program. They sent Frank L. Horsfall to Uppsala in January, 1938, and he brought back a Tiselius apparatus—one of the first to reach the U. S. Meanwhile, the Tiselius report had also attracted the attention of Duncan A. MacInnes and Lewis G. Longsworth at the Rockefeller Institute. Longsworth began to build an apparatus according to the Tiselius design. The homemade instrument he constructed launched him on a career which was to make his laboratory one of the world's leading centers of electrophoretic research.

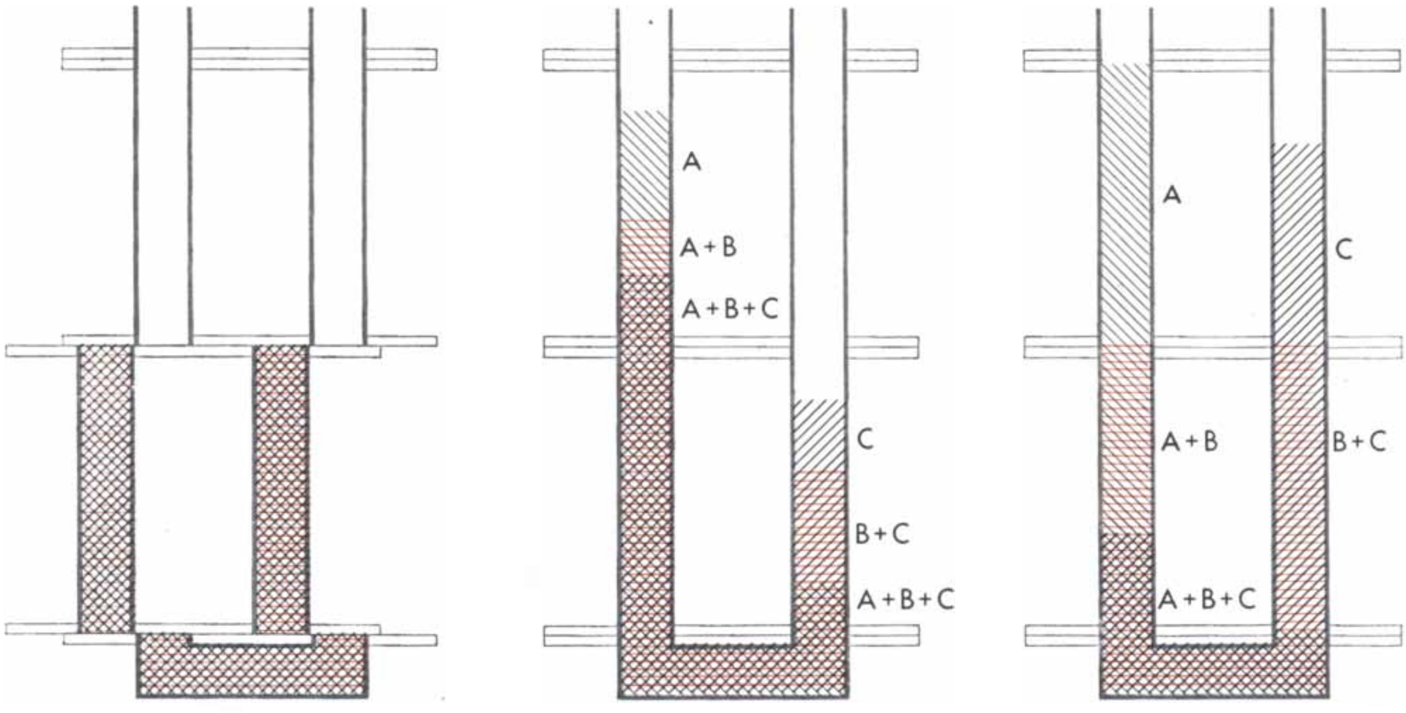
Longsworth showed his new apparatus to Karl Landsteiner, who was working at the Institute with several substances so similar to one another chemically that they could be distinguished only by their differing effects on experimental animals. Landsteiner offered Longsworth a mixture of two substances—the egg albumins of the guinea hen and the duck—and asked: "Can your electrophoresis demonstrate any physical difference between these materials?" Longsworth put a solution of the mixture through the apparatus and found at once that the two albumins separated, forming boundaries that moved at different speeds. This made a profound impression on Landsteiner. From being skeptical and lukewarm he now became an ardent proponent of electrophoresis, and wanted everything that came his way submitted to its analysis. He was constantly on the lookout for new test material. A man driving a donkey along a New York street was stopped and asked for permission to sample a little of the animal's blood for testing. "No," retorted the driver, "this donkey is going on the stage of the Metropolitan Opera and can't afford to lose any blood!"

The anatomical laboratory of Columbia's College of Physicians and Surgeons and the department of physiological chemistry at the Yale Medical School also adopted the Tiselius apparatus. The Yale group, consisting of Reginald A. Shipley, Kurt G. Stern and Abraham White, decided in 1937 to use electrophoresis to study the hormones of the anterior lobe of the pituitary gland. They started to build an apparatus based on Tiselius' 1930 doctoral thesis, not knowing about the new instrument he had just developed. At this opportune moment Svedberg arrived in the U. S. for a visit. Newspaper reporters who met his ship in New York asked Svedberg what was new in science. "The most exciting thing in Sweden is an apparatus developed by my colleague Tiselius for separating proteins electrically," he answered. The reporters clamored for details, but the professor protested that they were too technical for a newspaper story. "Full specifications are being published in the *Transactions* of the Faraday Society," he added. When the Yale group read this interview in *The New York Times,* they made a beeline for the *Transactions.* From the description and references given there Stern built the Yale Medical School's first Tiselius apparatus.

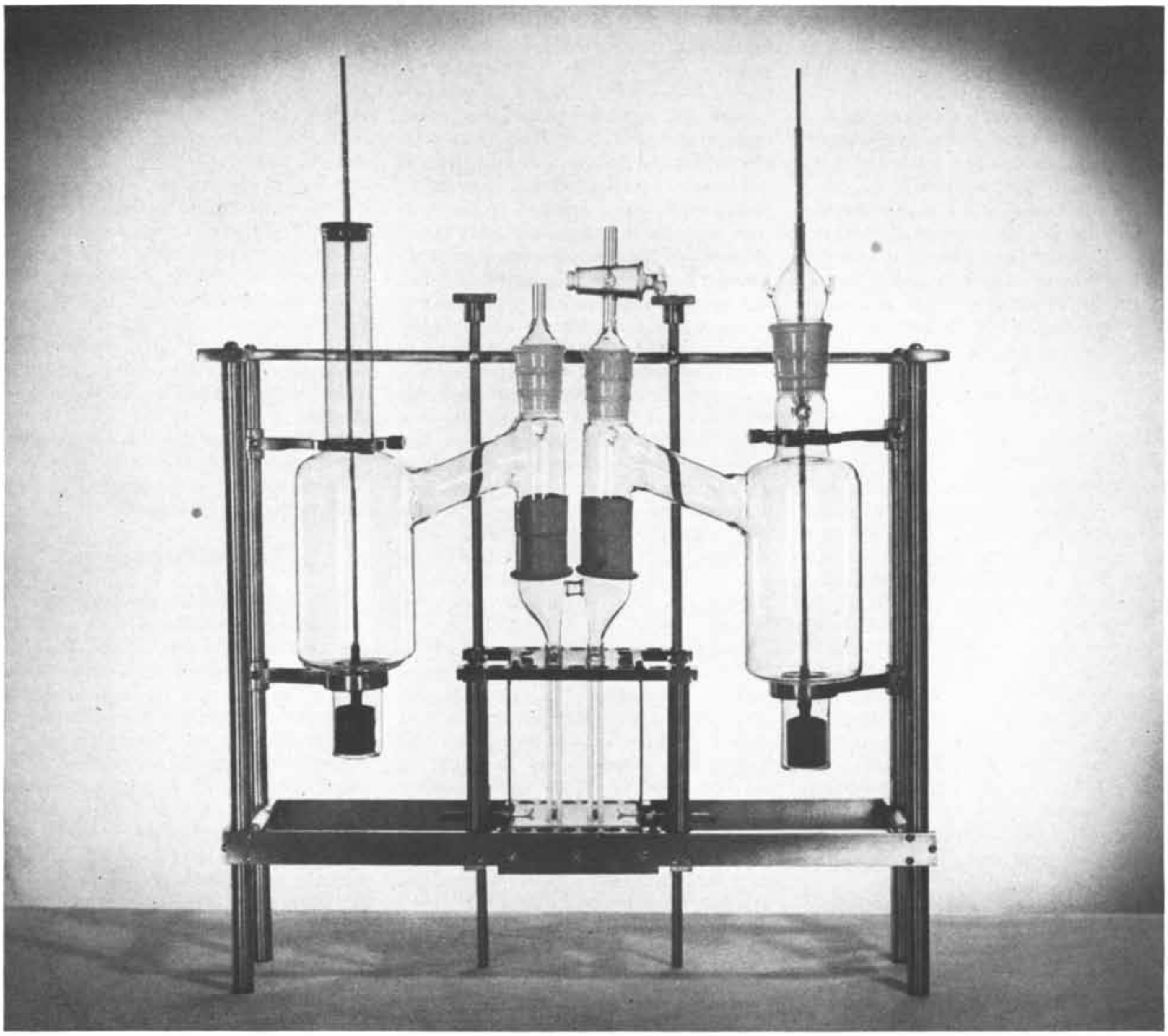
In like manner the Faraday Society paper started a chain reaction of electrophoretic interest in laboratories in England and on the Continent.

Tiselius' Stratagems

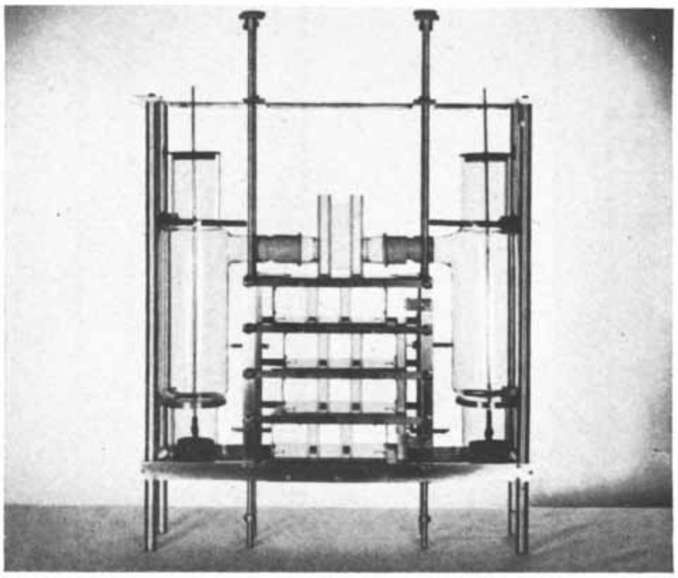
Before Tiselius, all moving-boundary systems used in electrophoresis had been deficient in "resolving power." No matter how well defined the boundary was at the beginning of an experiment, as soon as the substances in a mixture began to migrate, the boundary became fuzzy. It was difficult to determine where one component left off and another began. Everyone familiar with electrophoresis knew the cause of the difficulty. The passage of electricity through any medium generates heat, and in the case of a solution this heating sets up convection currents within the liquid. It was these random currents that disturbed



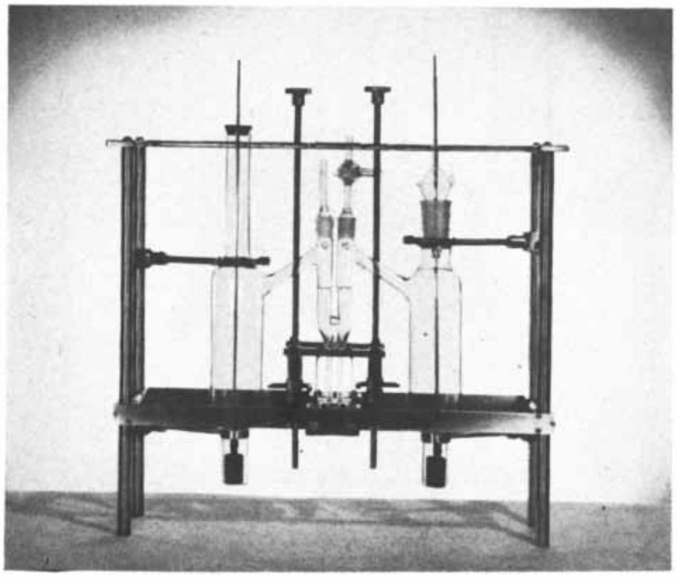
SEPARATION OF A PROTEIN is shown in a U-tube made up of sections. At the left a mixture of three proteins has been placed in the bottom of the tube and a buffer solution in the top. In the center and at the left, when the protein mixture and the buffer solution are in contact, each protein moves in a characteristic way.



ELECTROPHORESIS CELL has a U-tube at bottom center. The electrodes are in the glass columns at left and right. The U-tube is made narrow so that its contents can be cooled to prevent convection currents.



MACRO CELL is used for relatively large-scale separations of proteins. It has four movable sections.



MICRO CELL is used when only small amounts of material are available for the electrophoretic analysis.

and distorted the boundaries. The basic problem was to find some means of dissipating the heat.

Tiselius met this problem with two inventions. First, he used straight-sided tubing, instead of the conventional round kind, for his U-tube. The tubing has a narrow rectangular cross section, like the slot of a mail chute. Such a shape exposes more wall surface for a given volume, and so provides better cooling to the solution within. His second stratagem was to immerse the U-tube in a cooling bath of water held at a certain temperature just above the freezing point. This temperature, about 39 degrees Fahrenheit, is the temperature of maximal density of the solution, meaning the point at which a change in temperature produces the least change in density and therefore a minimum of convection. Hence it is the most favorable temperature for electrophoresis.

The cold-water bath increased the resolving power of the apparatus. But this sharpening of the boundaries would be of little value unless they could be observed and measured precisely. To care for that need, Tiselius equipped his apparatus with an optical system which rendered the boundaries visible. They showed up as shadows or schlieren, from which the system is known as the "schlieren method." Originally developed in France by J. B. L. Foucault about 100 years ago for testing lenses and mirrors, the method is based on the fact that at a boundary between two transparent materials of different density the light rays are bent or refracted, thus casting shadows which mark the place of refraction. The German physicist A. Toepler later adapted Foucault's method to the study of optical inhomogeneities in front of the lens or mirror, and Tiselius' application stems from both Foucault and Toepler.

Tiselius introduced another important innovation in the U-tube which greatly facilitated the trapping of specific fractions after separation of a mixture into its components. Hugo Theorell of the Nobel Institute in Stockholm had had the idea of doing this by means of rubber disks which could be slipped between the different solutions in the tube at the boundaries in such a way as to isolate them in separate compartments. With this device Theorell had obtained relatively pure separations of several proteins. Tiselius improved on it by making the U-tube itself in a series of sections, each of which can be shifted to one side and thus separated from the rest of the tube. This makes it possible to separate a fraction for examination with the minimum disturbance of the contents. The sections slide on glass flanges that are sealed with a chemically inert lubricant. This is the way the apparatus operates in a simple form of the experiment: At the beginning of the experiment the solution of mixed proteins fills the lower sections of the U-tube in both arms, and a buffer solution fills the upper sections. When the electric current is turned on, the proteins travel up the cathode arm. The current is turned off when the upper boundary in this arm reaches the top of a section. The section is then slid on its flanges to the right. Trapped in the cathode arm of the section, especially in its upper part, is a pure fraction of the fastest-moving protein, for this protein is present in purest form at the leading boundary. Similarly a pure sample of the slowest-moving fraction can just as easily be trapped at the trailing boundary in the other limb. An ideal form of the experiment, in which the fastest protein is trapped in the cathode arm and the slowest in the anode, is illustrated on page 47.

The longer the path through which the molecules migrate, the more complete will be the separation of components out of a mixture. This means that the arms of the U-tube have to be extended as high as possible. But Tiselius hit upon a more convenient way to accomplish the same result. He introduced a pistonlike plunger which is slowly lowered by clockwork into the arm up which the migration is ascending. This counterpressure against the moving buffer solution displaces the whole sequence of separated components in the direction opposite to their migration—the effect is similar to the motion of a line of people climbing a descending escalator. The same effect may also be accomplished by flowing fresh buffer solution into the area above the ascending column. The rate of flow is adjusted so that the fastest component will just succeed in climbing up the tube while the slower components will gradually be washed back. In this manner the resolving power of the apparatus is greatly increased.

Peaks and Valleys

Electrophoresis is the most effective technique known for locating and recovering physiologically active substances in a relatively pure state. The Tiselius machine is a more discriminating separator, for example, than the ultracentrifuge. And yet, even with the most refined apparatus, some mixture remains in the fractions. No matter how strong the electric current flowing through the solution, the Brownian movement is still at work, and the path of an individual molecule moving with the current is at best a series of forward-going zigzags, never a straight line. Thus there is always some diffusion from one fraction to the next. Moreover, even in a single compound the molecules are not all exactly alike in the number and distribution of surface charges. This means that some move more slowly than others. Therefore the moving boundary of any given fraction is actually a blurred line rather than a sharp boundary.

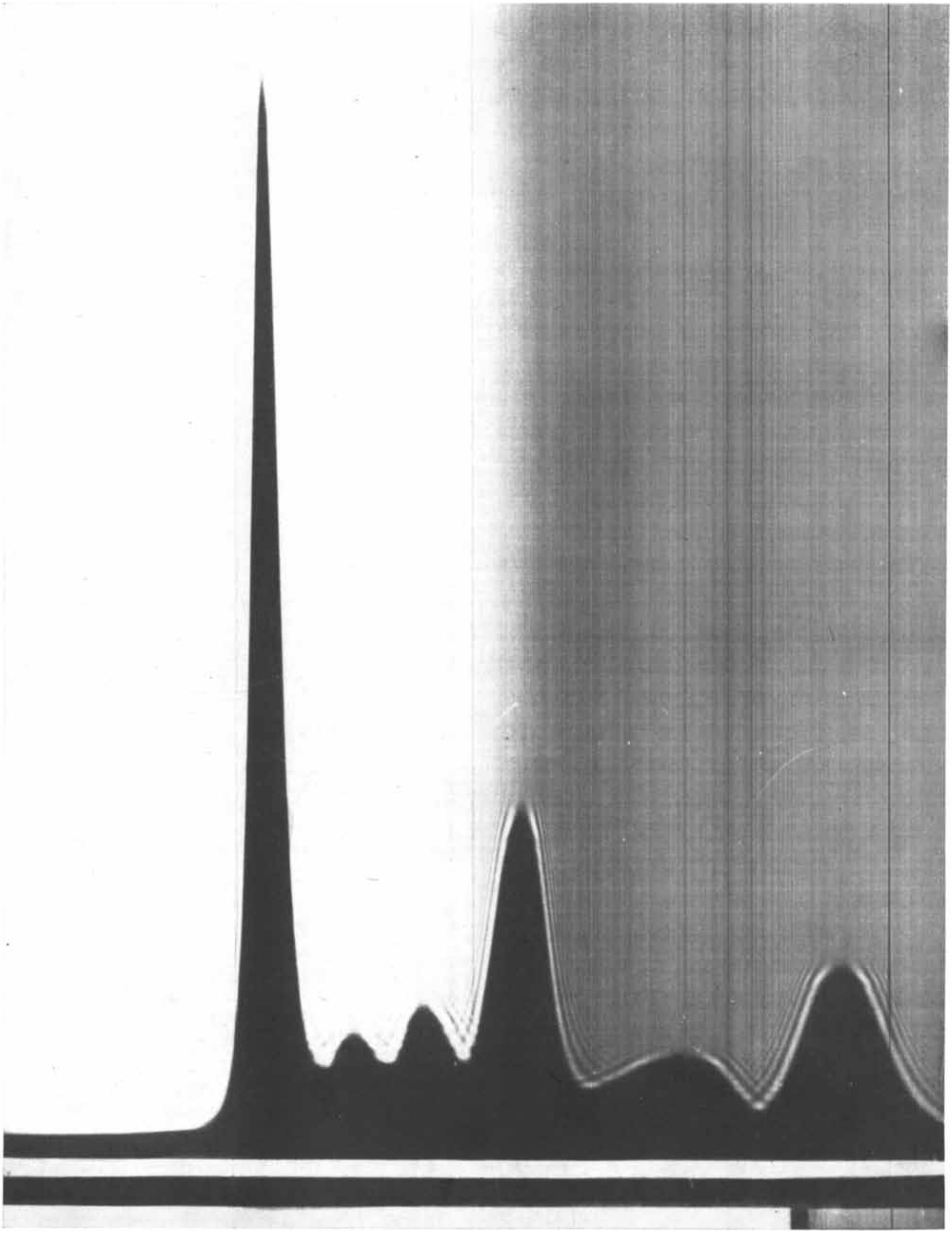
J. W. Williams, whose laboratory at the University of Wisconsin has three powerful electrophoresis installations in almost continuous operation, recently said: "I am almost sure that no one has ever obtained in a laboratory, either by electrophoresis, ultracentrifugation or any other means, a pure fraction of a protein—that is, one in which all the molecules are alike."

Despite the lingering impurities, however, electrophoresis remains one of the most discriminating analytical tools of the biochemist. Since its introduction in 1937 numerous improvements have been made in the equipment. The most striking has been in the method of recording the boundaries. The original apparatus, using the schlieren optical system, recorded images which showed the position of each boundary as a dark band. Longsworth introduced a mechanical "schlieren-scanning" device in 1939 which gave a more complete picture in the form of a succession of peaks and valleys. Each peak represents the position of a boundary in the moving column, and the area under the peak indicates the concentration of the chemical fraction responsible for the boundary.

Also in 1939 there came into use another scheme for recording the boundaries—a system known as the "cylindrical-lens" method. It was applied to the Tiselius apparatus by Harry Svensson of Uppsala, utilizing ideas developed earlier by J. Thovert of Paris and J. St. L. Philpot of Oxford. The cylindrical-lens method projects the diagram on a ground glass screen for visual observation as well as on the sensitized film for photography, and the image (*see page 53*) shows as a curve outlined by a jagged line of peaks and depressions—in contrast with the blacked-out solid image projected by the schlieren-scanning method. The schlieren image is illustrated by an electrophoretic analysis of human blood plasma on page 50. The towering peak is the shadow of the albumin boundary. Albumin (molecular weight 70,000) is the plasma protein with the greatest number of surface charges; hence it travels fastest in the electric stream. It is also the most abundant of the plasma constituents. In the normal blood of all animals the albumin peak looms tallest and covers more territory than that of any other fraction. The peaks that follow it are those of the globulins.

The globulins are all of approximately the same molecular weight—around 180,000. The ultracentrifuge therefore is powerless to separate them. But fortunately they differ in the magnitude of electric charges on their molecular surfaces, and these differences enabled Tiselius to identify them. He named the fastest-moving globulin alpha, the next in speed beta and the slowest gamma.

Soon after Longsworth devised his



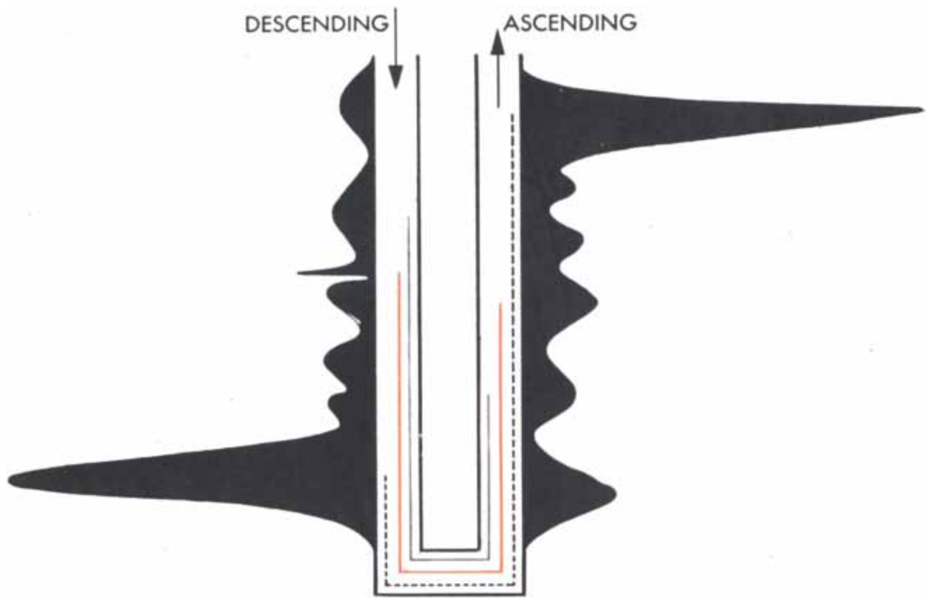
ELECTROPHORETIC DIAGRAM of human blood serum was made with the schlieren-scanning method at the Rockefeller Institute for Medical Research. Each peak on the diagram represents the boundary of a blood protein. The first peak shows the concentration of albumin; the second, of alpha-one globulin; the third, of alpha-two globulin; the fourth, of beta globulin; and the fifth, of gamma globulin. The pattern was made with serum taken from a pregnant woman, which has a relatively high concentration of globulins.

schlieren-scanning method and installed it in the apparatus at the Rockefeller Institute, he began to experiment with buffer solutions of varying electrolytic concentrations. He found that with a certain combination, using Veronal (the well-known barbiturate) as the buffer, a hitherto unknown globulin appeared in the plasma pattern. Its peak lifted out of the valley between albumin and alpha globulin. Fractions were tested and found to be unquestionably globulin. The new-found material was labeled alpha-one globulin, while the fraction Tiselius had named alpha was now designated as alpha-two. Alpha-one moves electrophoretically at a speed close to that of albumin, and in previous experiments it had been carried along with the albumin and had masqueraded as part of that large fraction.

Longsworth's discovery strikingly demonstrated the strategic importance of the buffer. It was only by employing a buffer composed of univalent ions that he forced the masked globulin to reveal itself. This barbiturate, which has the highest resolving power of any buffer so far known, is in practically universal use today.

In addition to the schlieren-scanning method and the cylindrical-lens method, an optical technique using the phenomenon of interference fringes as the indicator was recently introduced in Switzerland and Germany. But the fringe method is still in an early stage of development.

A further advance in observational methods has just been reported from Uppsala. Harry Svensson, one of Tiselius' chief collaborators, has devised a system which gives a sort of combined interference and schlieren diagram. This has the advantage of showing on the same photograph both absolute concentrations and concentration gradients. Because of its higher sensitivity, the combination optical system permits the study of solutions more dilute than those that could be analyzed by the older methods.



GEOMETRIC RELATIONSHIP of the schlieren-scanning diagram to boundaries in a U-tube is shown by this drawing. The pattern is that of human blood serum. For simplicity the boundaries of only three proteins are shown in the U-tube: albumin, beta globulin and gamma globulin. The pattern of the descending proteins differs somewhat from that of the ascending.

Zone Electrophoresis

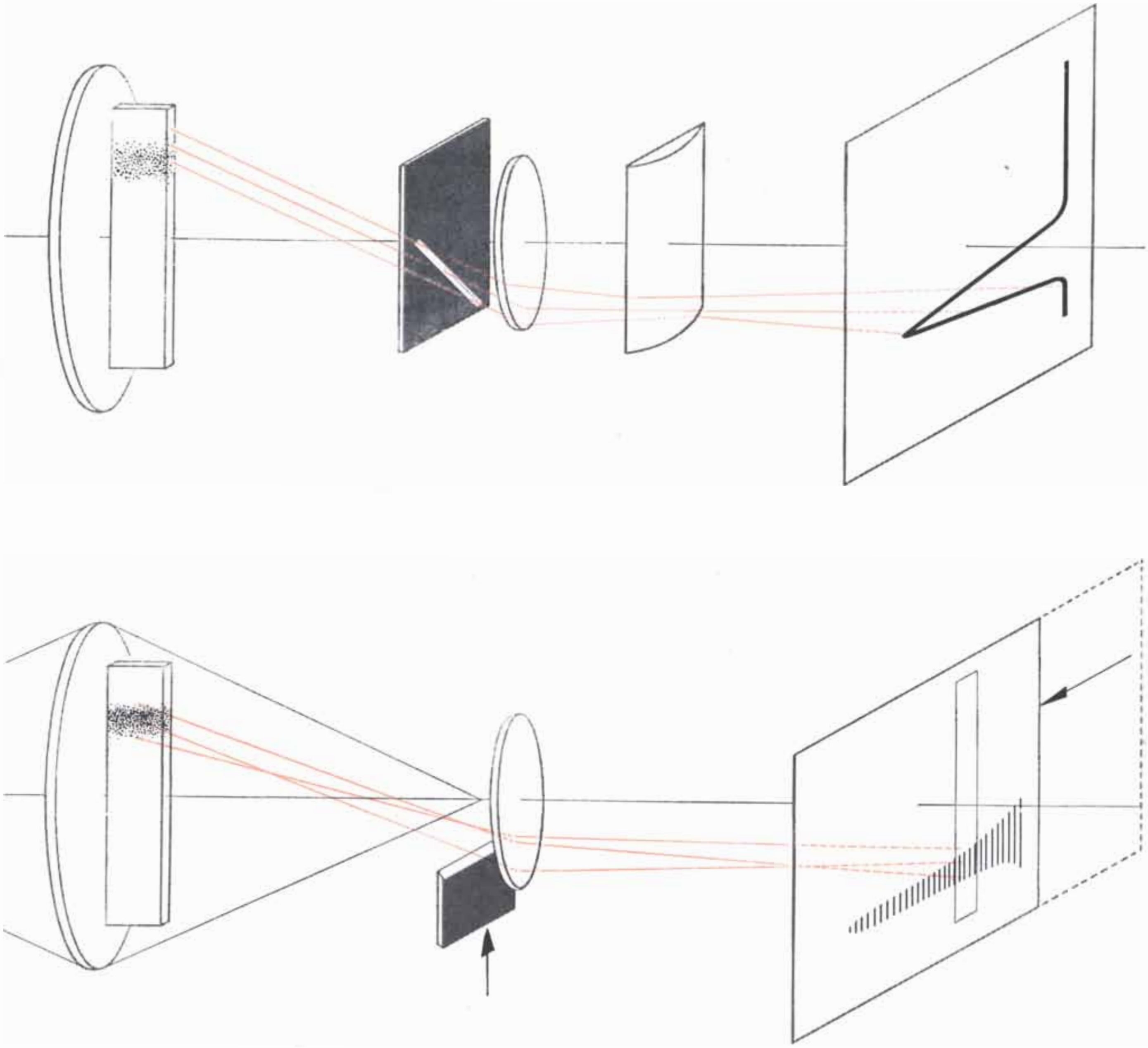
Within the last three years a third technique of electrophoresis has developed. In the two described so far—microscopic and moving-boundary electrophoresis—the particles flow in a liquid medium. The newer method flows them through a solid medium. The separated particles do not manifest themselves as moving boundaries but bunch together into zones in the solid; hence the method is known as zone electrophoresis. It was developed independently in Germany, Sweden and the U. S. Among the pioneering investigators are Emmett L. Durrum at the Fort Knox Field Research Laboratory of the U. S. Army; Tiselius, Svensson and Ingra Brattsten at Uppsala, and Theodore Wieland and Fritz Turba in Germany.

The solid most frequently employed in zone electrophoresis is filter paper. A rectangular strip of paper lies horizontally with its two ends dipping into two vessels. These contain a buffer solution and are equipped with opposite electrodes. When a specimen of the mixture to be analyzed is dropped on the surface of the filter paper, it forms a spreading spot. If now a current is passed through the paper between the two electrodes, the components of the mixture will move with the current at speeds determined by their individual surface charges. The effect will be to separate the components and transport them through the paper over varying distances. The final result is a series of spots or zones, each of which is an isolated fraction of one of the components. The distance of each separated spot from the area where the mixture was originally placed is a measure of the mobility of the particles making up that particular spot, and the density and area of the spot provide an index to the quantity of that material in the mixture.

Many of the substances separated in this way have characteristic colors that identify them. Even when they are colorless, it is easy to bring out the spots by dipping the strip of paper in certain dyeing reagents. With the zones thus enhanced, it is possible to plot a line representing the zoning of a mixture into its fractions and obtain a curve which closely approximates the pattern of peaks and valleys obtained by moving-boundary electrophoresis. In a sense zone electrophoresis is like the separation method known as paper chromatography [SCIENTIFIC AMERICAN, April], except that the separation factor is electricity instead of solubility.

The most obvious advantage of zone electrophoresis is the simplicity and inexpensiveness of the equipment. Besides filter paper, glass powder or silica gel can be used as the solid medium. Tiselius and others claim that zone electrophoresis has several superiorities over the moving-boundary method, to wit: it separates and isolates the individual components of a mixture, instead of merely forming concentration gradients; it makes it possible to study smaller amounts of material at lower concentrations, and it permits development of "techniques of two-dimensional electrophoresis and devices for continuous flow preparative work."

All these advantages have to be bought, however, at the cost of a less well-defined medium, since the filter paper, glass powder or other solid has adsorption and osmotic effects which tend to interfere with the electrophoretic flow. In a recent paper listing the advantages Tiselius and Henry G. Kunkel admitted to a doubt whether it will be possible for zone electrophoresis to achieve "the accuracy obtained with the sensitive optical methods employed in free electrophoresis for locating and quantitating components." In other words, for exactitude in appraising the quantities of protein fractions contained in blood plasma and other body fluids, the moving-boundary method is still the most dependable tool of the biochemist. But zone electrophoresis is in its very young infancy. With dozens of experimenters now taking it up, we may confidently expect radical advances and



OPTICS of the cylindrical-lens (*top*) and schlieren-scanning (*bottom*) diagrams are compared. One side of a U-tube with a schematic boundary is shown at the left. The nature of the diagrams is illustrated at the right.

productive extensions of the technique in the future.

Electrophoresis is enormously interesting as a demonstration of human imagination and inventiveness, but its prime importance lies in its value as a research tool. Tiselius was spurred to design his ingenious apparatus because of a curiosity about the nature of the invisible particles in blood, just as his teacher Svedberg had invented the ultracentrifuge because he was troubled by ignorance of the molecular weights of proteins. Svedberg's ultracentrifuge and Tiselius' electrophoresis made it possible to isolate the constituents of blood without chemical reactions, and thus to prove that these fractions were individual proteins—not merely fragments split off from a master molecule. The brilliant analysis of the serum proteins that Tiselius accomplished by means of his invention won him a professorship of biochemistry in 1937 and the Nobel prize in 1948. Uppsala made his department into an Institute of Biochemistry and set up funds to construct a suitable building, and the Rockefeller Foundation provided equipment for it.

In Medicine

Electrophoresis has been taken up by the medical chemist and clinician and is now an important part of the equipment of many hospitals. It provides the most convenient and dependable means of analyzing the protein content of the body's fluids and tissues. In the case of a few specific conditions, such as nephrosis, certain liver diseases and the malignant process of the bone marrow known as multiple myeloma, electrophoresis is of direct value as a diagnostic tool.

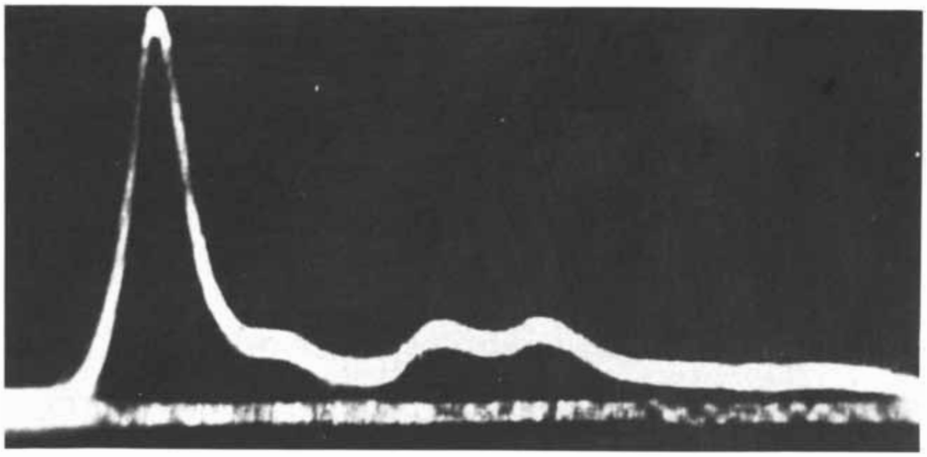
In multiple myeloma, for example, the electrophoretic pattern of the blood often shows a sharp peak in the region of the gamma globulin. The substance responsible for this peak is a special kind of protein which is found only in multiple-myeloma patients. Electrophoretic analysis of the blood plasma of more than a hundred cases of this disease treated at the Mount Sinai and Montefiore Hospitals in New York showed that half the patients carried the substance in their circulation. The other half did not, but their electrophoretic pattern revealed other abnormalities.

The electrophoretic diagram of a patient's blood plasma or serum is not to be taken as specific for a particular disease but rather as an index to the physiological condition of the patient. For example, if the diagram shows an excess of gamma globulin, the inference is that the body is suffering from an infection, for most of the antibodies evoked by the presence of infectious microbes are gamma-globulinlike proteins. An increase in the alpha globulin, a result of the breakdown of tissue proteins, is likely to herald a fever-producing disease, such as pneumonia, tuberculosis or Hodgkin's. When the blood shows a decrease in albumin and an increase in gamma globulin, the clinician looks to the liver as a possible seat of the disease, because it is the main factory for albumin production. When the liver fails, other tissues try to make up for the lower albumin level, it is believed, by pouring out an excess of globulins.

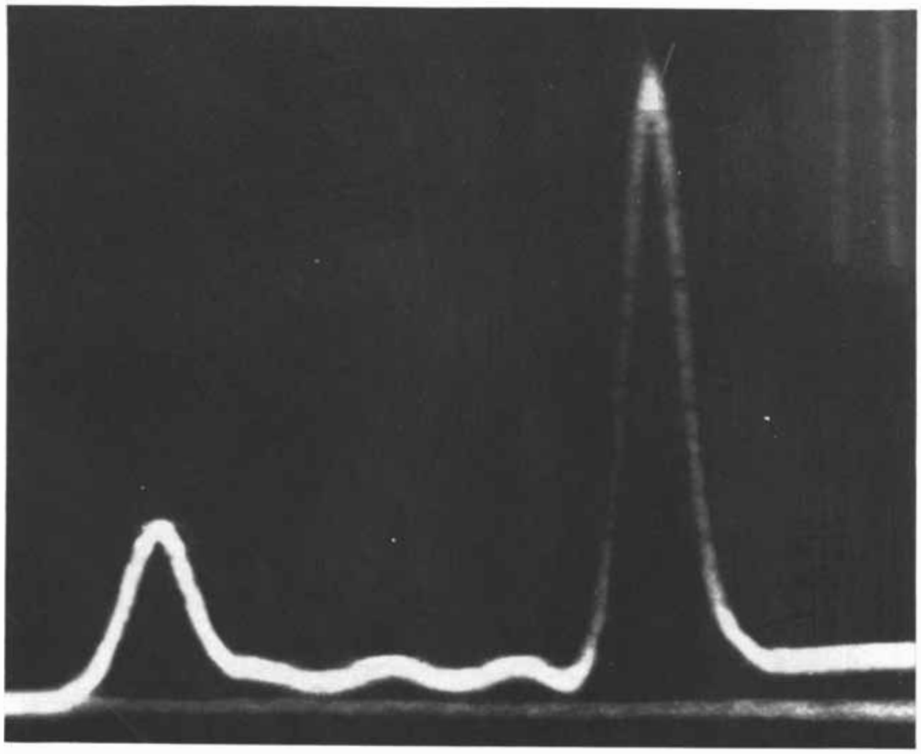
Since the blood bathes all cells and picks up the products of every kind of tissue, its contents naturally reflect the over-all condition of the body. Electrophoresis thus gives the doctor a picture of what is circulating in the blood, and how much of each component. Its report of what is in excess and what in deficient amount, as well as what is new and unknown, enables him to narrow his search for the trouble to specific organs or tissues. Even though electrophoresis cannot be regarded as a primary prognostic or diagnostic device at the present time, its service as the biological chemist's most reliable analytical stratagem gives it a practical value to clinical medicine.

Its application to clinical medicine has been aided by the development in recent years of compact, self-contained installations of the moving-boundary type of apparatus. Kurt G. Stern, whose part in building the first Tiselius apparatus at Yale was mentioned earlier, and who is now at Brooklyn Polytechnic Institute, has recently been active in the movement to provide moving-boundary equipment in lightweight units that occupy small space and require a minimum of expert operational supervision. Other designers also have contributed to commercial advances in this field. As a result, several types of "packaged" instruments are to be found among the more than 400 electrophoresis machines now in use in the U. S. in hospitals, clinics, medical schools and research institutions. Paper electrophoresis and other forms of zone electrophoresis are also being tested for hospital service, and favorable results are reported. It seems safe to predict that in the course of a few years electrophoresis will be as indispensable to medical practice as X-rays are today.

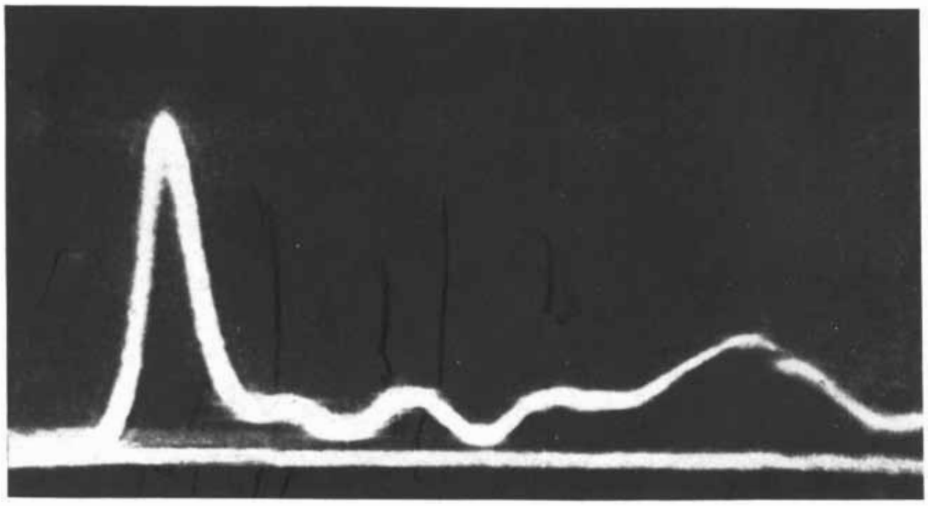
George W. Gray, author of The Ultracentrifuge *and other articles that have appeared in this magazine, is a member of the staff of the Rockefeller Foundation.*



NORMAL subject has this serum pattern. The diagram was made with the cylindrical-lens method for the Lenox Hill Hospital in New York.



MULTIPLE MYELOMA patient has pattern with a big peak in gamma globulin region. The diagram was made for Montefiore Hospital in New York.



PERIARTERITIS patient has pattern with peak characteristic of infectious diseases. The diagram was made at Mount Sinai Hospital in New York.

The Scars of Human Evolution

Although man stands on two legs, his skeleton was originally designed for four. The result is some ingenious adaptations, not all of them successful

by Wilton M. Krogman

IT has been said that man is "fearfully and wonderfully made." I am inclined to agree with that statement—especially the "fearfully" part of it. As a piece of machinery we humans are such a hodgepodge and makeshift that the real wonder resides in the fact that we get along as well as we do. Part for part our bodies, particularly our skeletons, show many scars of Nature's operations as she tried to perfect us.

I am not referring to our so-called vestiges—those tag-ends of structures which once were functional, such as the remnant of a tail at the base of the spine, the appendix, the pineal or "third" eye, the misplaced heart openings of "blue babies," or the like. Nor do I mean the freak variations that crop up in individuals. I am discussing the imperfect adaptations the human race has made in getting up from all fours.

We have inherited our "basic patents," as W. K. Gregory of the American Museum of Natural History calls them, from a long line of vertebrate (backboned) ancestors: from fish to amphibian to reptile to mammal and finally from monkey to ape to anthropoid to *Homo sapiens*. In all this evolution the most profound skeletal changes occurred when we went from a four-legged to a two-legged mode of locomotion.

Gregory has very aptly called a four-legged animal "the bridge that walks." Its skeleton is built like a cantilever bridge: the backbone is the arched cantilever; the vertebrae of the forward part of the backbone are slanted backward and those of the rear forward, so that the "thrust" is all to the apex of the arch; the four limbs are the piers or supports; the trunk and abdomen are the load suspended from the weight-balanced arch; in front the main bridge has a drawbridge or jointed crane (the neck) and with it a grappling device (the jaws).

When all this was up-ended on the hind limbs in man, the result was a terrific mechanical imbalance. Most of the advantages of the cantilever system were lost, and the backbone had to accommodate itself somehow to the new vertical weight-bearing stresses. It did so by breaking up the single-curved arch into an S-curve. We are born, interestingly enough, with a backbone in the form of the simple ancestral arch, but during infancy it bends into the human shape. When we begin to hold our head erect, at about the age of four months, we get a forward curve in the backbone's neck region; when we stand up, at about a year, we get a forward curve in the lower trunk; in the upper trunk and pelvic regions the backbone keeps its old backward curve.

BUT we achieve this at a price. To permit all this twisting and bending, Nature changed the shape of the vertebrae to that of a wedge, with the thicker edge in front and the thinner in back. This allows the vertebrae to pivot on their front ends as on hinges, like the segments of a toy snake. On the other hand, it also weakens the backbone, particularly in the lower back region, where the wedge shape is most pronounced. Heavy lifting or any other sudden stress may cause the lowermost lumbar vertebra to slip backward along the slope of the next vertebra. The phrase "Oh, my aching back" has an evolutionary significance!

There are other ways in which the backbone may literally let us down. The human backbone usually has 32 to 34 vertebrae, each separated from its neighbor by a disk of cartilage which acts as a cushion. Of these vertebrae 7 are cervical (in the neck), 12 thoracic (upper trunk), 5 lumbar (lower trunk), 5 sacral (at the pelvis) and 3 to 5 caudal (the tail). Every once in a while the seventh cervical vertebra may have an unusually long lateral process; if long enough, this protruding piece of bone may so interfere with the big nerves going down to the arm that it has to be sawed off by a surgeon. Most people have 12 pairs of ribs, borne by the 12 thoracic vertebrae, but occasionally the transverse processes of the next lower segment, the first lumbar vertebra, are so exaggerated that they form a 13th pair of ribs. In some people the lowest (fifth) lumbar vertebra is fused with the sacral vertebrae. The latter are usually united into one bone, called the sacrum, but sometimes the first sacral vertebra fails to join with its mates. All these idiosyncrasies can cause trouble.

The "Achilles' heel" of our backbone is the unstable lower end of the vertebral column. This is where we reap most of the evil consequences of standing up on our hind legs. It is a crucial zone of the body—the pathway for reproduction and the junction point where the backbone, the hind end of the trunk and the legs come together. The skeletal Grand Central Station where all this happens is a rather complicated structure consisting of the sacrum and the pelvis. The pelvis is not only a part of the general skeletal framework of the body but also a channel for the digestive and urogenital systems and the coupling to which the muscles of the hind legs are attached. When we stood up on our hind legs, we burdened the pelvis with still another function, namely, bearing the weight of the upper part of the body. How have we changed our pelvis to adapt it to its new position and burdens?

The pelvic structure is made up of three sets of paired bones, the ilium, the ischium and the pubis. The three bones meet at each side in the hip socket, where the head of the thighbone articulates. In standing erect man tilted the whole structure upward, so that the pelvis is at an angle to the backbone instead of parallel to it. The relative position of the three pelvic bones changed, with the pubis now in front instead of below.

The bones also were altered in shape. The iliac bones, formerly elongate and bladelike (in the anthropoids), are now shortened and broadened. They form the crests of our hips, and they help support the sagging viscera, especially the large intestine. The pubic bones help to form the subpubic arch—that "arch of triumph" beneath which we must all emerge to life and to the world. The ischial bones retreat to the rear; they are the bones that bear the brunt of sitting through a double feature or before a television screen.

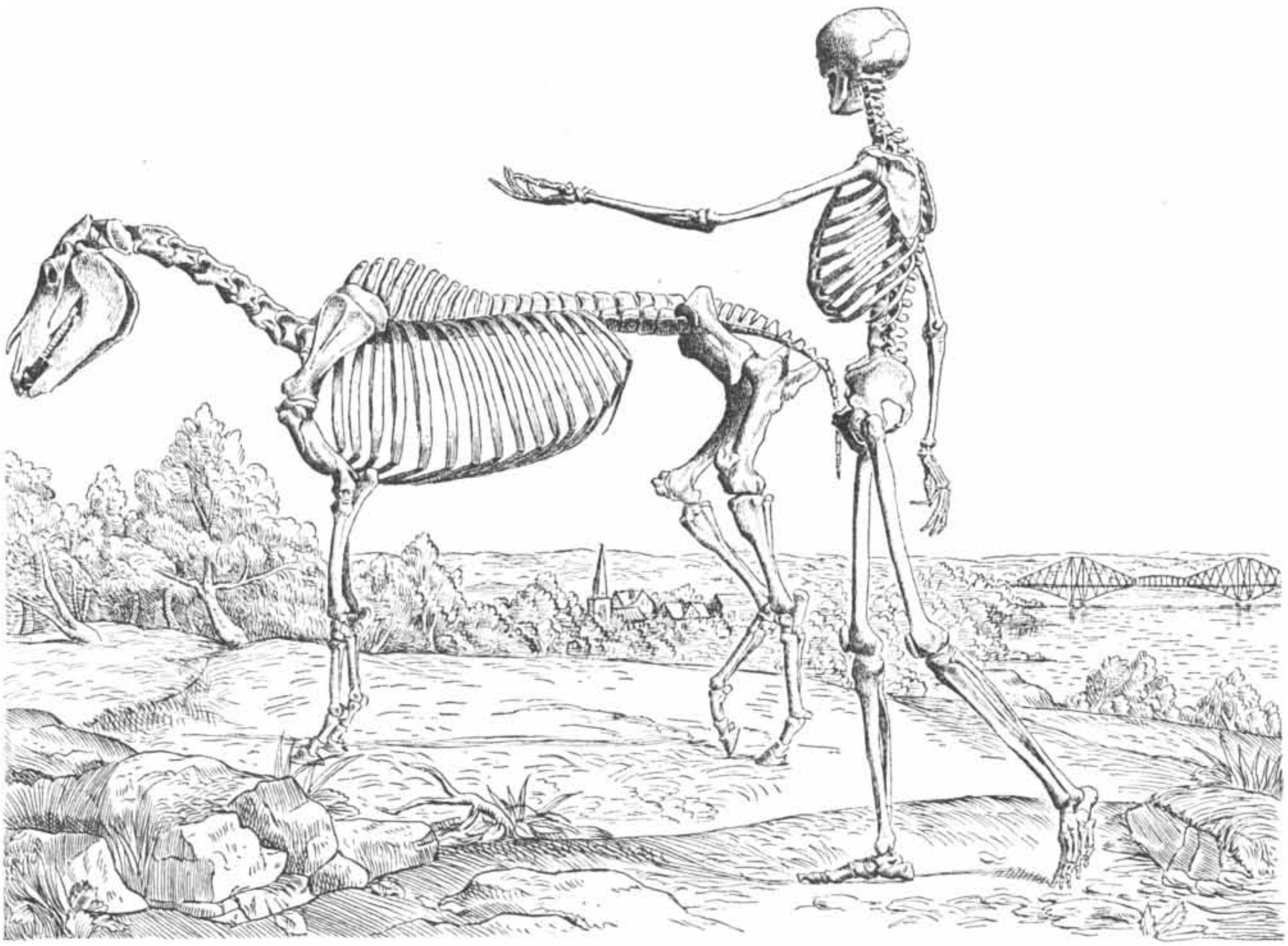
THE greatest change is in the zone of contact between the iliac bones and the wedgelike sacrum—the so-called sacroiliac articulation. Here are focused the weight-bearing stresses set up by the erect posture. Two things have happened to adapt the pelvic structure for "thrusting" the weight of the trunk to the legs. The area of contact between the sacrum and the iliac bones has increased, strengthening the articulation. In the process the sacrum has been pushed down, so that its lower end is now well below the hip socket and also below the upper level of the pubic articulation. This has brought trouble, for the sacrum now encroaches upon the pelvic cavity and narrows the birth canal that must pass the fetus along to life. Furthermore, the changes have created an area of instability which far too often results in obscure "low back pain" and in "slipped sacroiliacs."

The shortening of the iliac bones has increased the distance between the 12th (lowest) rib and the top or crest of the ilium. This has given us our waist, but it has also materially weakened the abdominal wall, which now, for about a palm's breadth, has only muscle to support it. The greatest weakness of the upright posture is the lower abdominal wall. In four-legged animals the gut is suspended by a broad ligament from the mechanically efficient convex vertebral arch. The burden of carrying the weight of the viscera is distributed evenly along the backbone. Up-end all this and what happens? First of all, the gut no longer hangs straight down from the backbone but sags parallel to it. Secondly, the supporting ligament has a smaller and less secure hold on the backbone. One result of the shift in the weight-bearing thrust of the abdominal viscera is that we are prone to hernia.

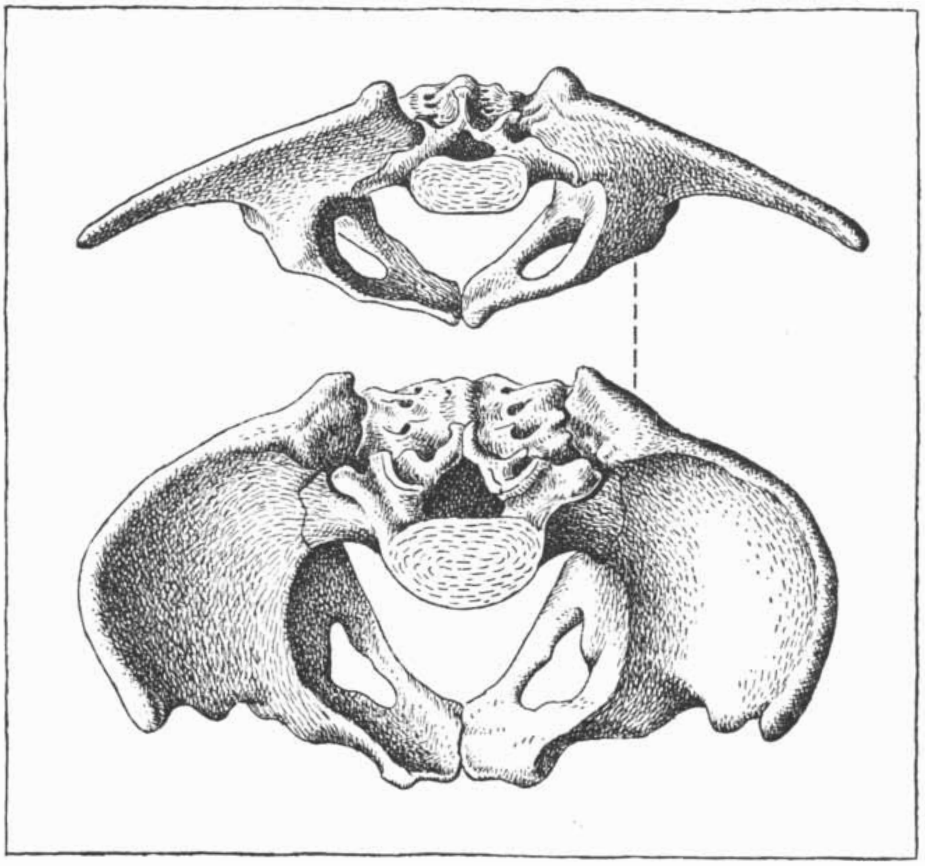
Nature has made a valiant effort to protect our lower belly wall. She invented the first "plywood," and made it of muscle. Three sheets of muscle make up the wall, and their fibers crisscross at right and oblique angles. This is all right as far as it goes, but it has not gone far enough: there is a triangular area in the wall which was left virtually without muscular support—a major scar of our imperfect evolution.

The upright posture required a major shift in the body's center of gravity, but here Nature seems to have done a pretty good job. The hip sockets have turned to face slightly forward instead of straight to the sides; the sockets and the heads of the thighbones have increased in size, and the neck of the thighbone is angled a bit upward. As a result of this complex of adjustments the bodily center of gravity is just about on a level with a transverse line through the middle of the hip sockets, and the weight of the trunk upon the pelvis is efficiently distributed on the two legs.

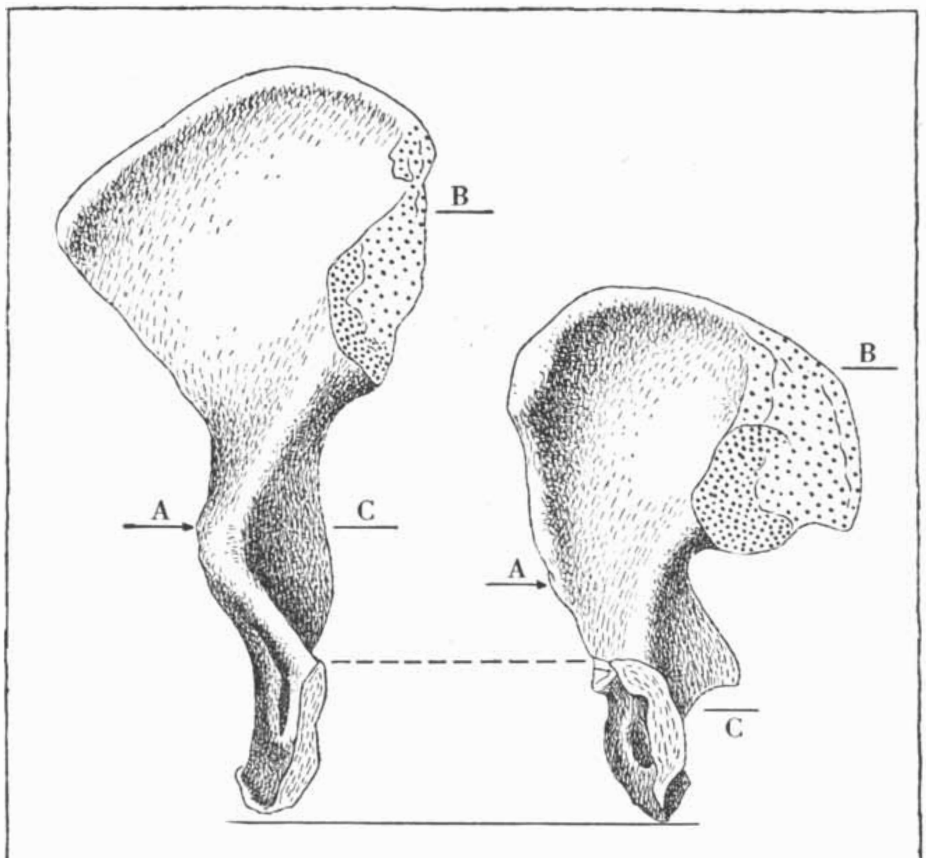
Though it does not directly involve the skeleton, I might mention here that the blood circulation is another factor that is not helped by our upright position. Since the heart is now about four feet above the ground, the blood re-



BACKBONES of the horse and man illustrate the principal problem of adapting the quadruped skeleton to biped purposes. The horizontal backbone of the horse is gently arched between two supports, rather like the cantilever bridge in the right background. The vertical backbone of man, in contrast, is curved like an S.



TOP VIEW OF THE PELVIS of the gorilla (*top*) and man (*bottom*) show how the latter has developed to support the weight of the abdominal organs. The dotted line indicates the width of the sacrum in man.



INSIDE VIEW OF THE HIP BONE of the gorilla (*left*) and man (*right*) show how the latter has become shorter. The dotted line and the letters A, B and C indicate similar anatomical features in both structures.

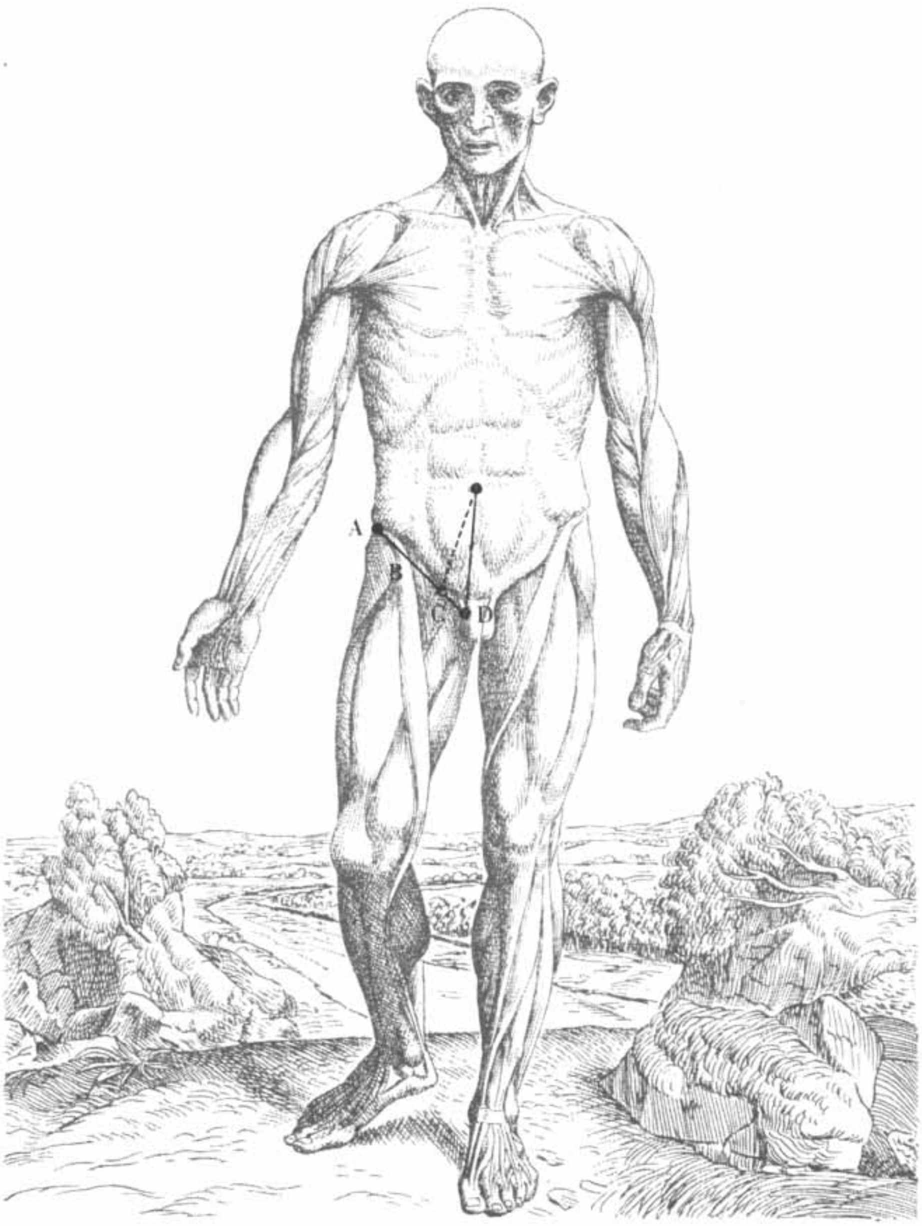
turned to the heart from the veins of the legs must overcome about four feet of gravitational pull. Often our pumping system and veins find the job too much, and the result is varicose veins. The lower end of the large intestine also is affected, for its veins, when up-ended in a vertical position, become congested more easily, so we get hemorrhoids.

Even more serious is the danger to the circulation along the vertebral column. Two great vessels, an artery and a vein, run down this column. At the level where these vessels divide into two branches, one for each leg, the right-sided artery crosses over the left-sided vein. In a quadruped this presents no problems, but in the erect position the two vessels must cross a sharp promontory of bone at the junction of two vertebrae, and the viscera piled up in the pelvis press down on them. During pregnancy the pressure may increase so much that the vein is nearly pressed shut, making for very poor venous drainage of the left leg. This is the so-called "milk leg" of pregnancy.

GOING back to the skeleton, it is clear that the two-legged posture places a much bigger burden on our feet. They have adapted themselves to this by becoming less of a grasping tool (as in the monkeys) and more of a load-distributing mechanism. We have lost the opposability of the big toe, shortened the other toes and increased the length of the rest of the foot. The main tarsal bones, which form the heel, ankle joint and most of the instep, now account for half the total length of the foot, instead of only a fifth as in the chimpanzee. We have also achieved a more solid footing by developing two crosswise axes, one through the tarsals and the other through the main bones of the toes. The little-toe side of our foot is relatively neglected—the toe is little because it is not so useful. Our fallen-arch troubles, our bunions, our calluses and our foot miseries generally hark back to the fact that our feet are not yet healed by adaptation and evolutionary selection into really efficient units.

Now let us go to the other extreme—to the head. A lot has gone on there, too. We have expanded our brain case tremendously, and there can be no doubt that many of the obstetrical problems of Mrs. H. Sapiens are due to the combination of a narrower pelvis and a bigger head in the species. How long it will take to balance that ratio we have no idea. It seems reasonable to assume that the human head will not materially shrink in size, so the adjustment will have to be in the pelvis; *i.e.*, evolution should favor women with a broad, roomy pelvis.

If the head has increased in size, the reverse is true of the facial skeleton. Bone for bone the face has decreased in size as we proceed from anthropoid



TRIANGLE OF WEAKNESS in the abdominal wall lies between the epigastric artery (C) and the central abdominal muscles. A is the hip; D, the pubic bone. B on the line between A and D is the inguinal ligament.

to man. To put it succinctly, we have a face instead of a snout.

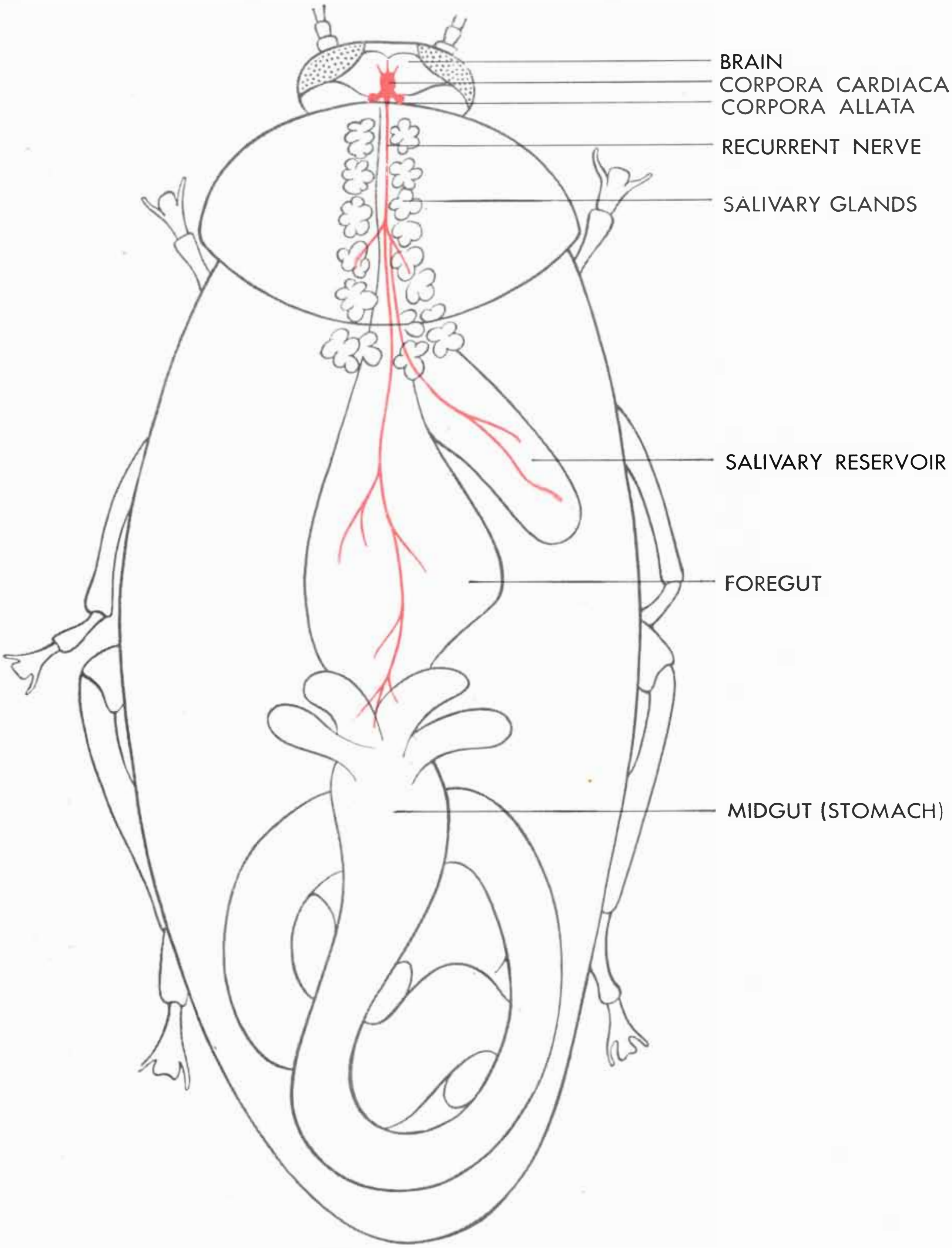
What about the teeth in that face of ours? All mammals have four kinds of teeth: incisors in front, canines at the corner, premolars and molars along the sides. With but few exceptions the mammals have both a milk set and a permanent set of teeth. About 100 million years ago, or maybe a bit more, the first mammals had 66 permanent teeth, of which 44 were molars or premolars. Most mammals today have 44 teeth, including 28 molars and premolars. But man, and the anthropoid, has only 32 teeth—8 incisors (upper and lower), 4 canines, 8 premolars and 12 molars. The loss has been greatest in molars, next in incisors, then in premolars, with the canine a veritable Rock of Gibraltar.

While the face bones have decreased in size, our teeth have remained relatively large. Many orthodontists believe that this uneven evolutionary development may be partly responsible for the malocclusion of teeth in children. Certain it is that some human teeth are apparently on the way out: the third molars ("wisdom teeth") are likely to be impacted or come in at a bad angle, and many people never have them at all. Perhaps in another million years or so we shall be reduced to no more than 20 teeth.

It is mayhap a form of human conceit—the egotism born of a highly evolved brain—to worry about our bodily imperfections or inadequacies. As the philosopher said:

The world is old and thou art young;
The world is large and thou art small;
Cease, atom of a moment's span
To hold thyself an All-in-All!

Wilton M. Krogman is professor of physical anthropology at the University of Pennsylvania.



ORGANS of the woodroach are shown in this schematic drawing. Near the top is the glandular structure, composed of the corpora cardiaca and the corpora allata, that controls the growth and development of the insect.

THE WOODROACH

This two-inch variety of the cockroach can be a convenient and useful laboratory animal. The effects of experimental operations on it may be significant with respect to mammals

by Berta Scharrer

THE laboratory investigator who keeps up a battle to rid his rat colony of cockroaches may well consider giving up the rats and working with the cockroaches instead. From many points of view the roach is practically made to order as a laboratory subject. Here is an animal of frugal habits, tenacious of life, eager to live in the laboratory and very modest in its space requirements. The roach, to be sure, is an awkwardly small animal to work on, but there are varieties of roaches large enough for experiments. A particularly useful subject is a species named *Leucophaea maderae,* to which the common name woodroach may be given from its natural habitat. This giant among roaches, nearly two inches long, is a native of Africa and is also found in South America. Our stock colony is derived from specimens which originally arrived in the U. S. from South America as stowaways in a shipment of laboratory monkeys. The woodroach was such a stranger here that entomologists at first had difficulty identifying it. The insect quickly made itself at home in the laboratory, however, and we soon saw its possibilities as an experimental animal.

The woodroach thrives on an inexpensive diet of apples, carrots and dog-chow, and it needs no water other than that in its food. It breeds readily in the laboratory, producing a hatch of 30 to 35 young every three months, and it is unusually long-lived as insects go, with a life expectancy of up to two and a half years. The woodroach is ovoviviparous: that is, the young hatch from the egg at the moment they leave the mother. Like all insects, the young woodroaches (nymphs) grow in spurts; they have an average of eight molting periods, with a noticeable increase in size after each molt. Since roaches belong to the relatively primitive class of insects that do not pass through a complete metamorphosis into an adult form (as butterflies and moths do), they have no pupal stage; they merely acquire a pair of wings after the last molt which they do not use for flying.

The tough little creature survives all manner of experimental treatments. It is an ideal subject for surgery, for it needs no anesthetic (it keeps perfectly quiet if fastened between sheets of soft tissue paper) and it is resistant to infection, so the operating instruments need not be sterilized.

Experimental studies of roaches can tell us a great deal more about higher animals than one might suppose. On close inspection the organs of an insect reveal themselves to be basically much like those of higher animals. This should not be too surprising, since all animals have certain basic functions in common, such as the digestion of food and responses to stimuli. The digestive organs of the woodroach, like those of higher animals, are divided into segments, each of which performs a special task. Food is stored in the foregut and digested in the midgut, the insect's stomach. The roach has salivary glands which secrete a clear fluid. It has a nervous system that controls the proper functioning of these organs. Behind the roach's brain is a small but complex glandular structure consisting of two parts, called the corpora cardiaca and the corpora allata. These tiny organs, less than a tenth of an inch long, are very important to the insect, as we shall see.

HERE, then, is an animal in which we can conveniently investigate the factors that control some basic bodily functions common to all animals, such as digestion of food, growth and development. We can have an almost unlimited number of subjects to experiment on and can perform an almost limitless variety of experiments. So far most of the work on the woodroach has been concerned with its hormonal and nervous systems.

Insects, like man and other vertebrates, have hormones which correlate the activities of the various organs of the body. An insect's development to maturity is controlled by the interaction of two substances—the growth and differentiation hormone and the juvenile hormone. The first is responsible for the insect's molts, its growth in size and the changes that produce its wings and other adult characteristics. The second acts as a checkrein on the first; it holds back any metamorphosis of the insect until the animal has reached the proper size.

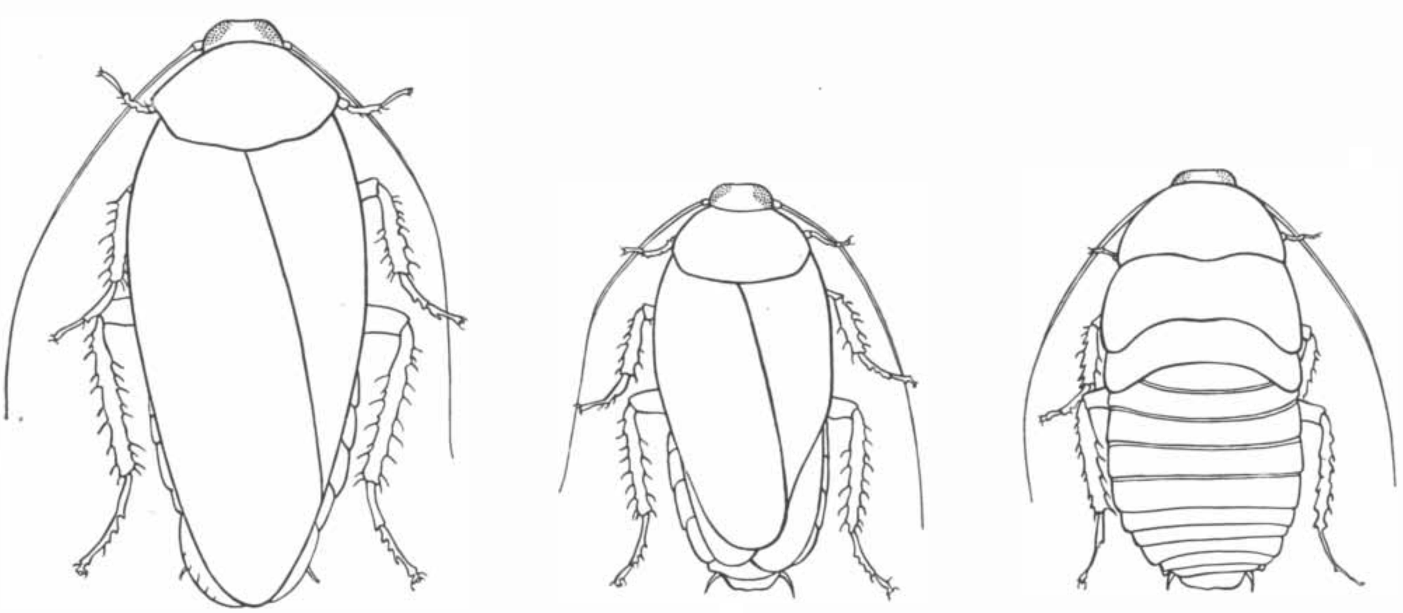
There is a simple way to find out the role of each hormone: just remove the gland that produces it. In the woodroach, though the glands are very small, we can do this without too much difficulty with the aid of a powerful dissecting microscope. Let us see what happens when we remove the corpora allata, one of the hormone-secreting glands in the insect's head. We dissect out the corpora allata from some woodroach nymphs and watch their development. The immature insects molt, sprout wings and become adults. But they are stunted adults; they look in every respect as if they did not quite make the grade. They are smaller than normal; their wings do not cover the entire body as they should; they are precocious creatures which give every sign of having become adults prematurely. And so they have, for the removal of the corpora allata deprived them of the restraining influence of the juvenile hormone, so that the metamorphosis came before they had reached their full growth.

The corpora allata also play a role in adult woodroaches, though it is quite different from the function they perform in nymphs. This role has to do with the production of young. The mother woodroach, we have noted, has a gestation period of three months. Removal of the corpora allata from a mother during the first week of this period prevents her eggs from developing. The yolk destined to nourish the embryo fails to appear, and certain accessory glands that are supposed to furnish a substance needed by the embryo do not function properly. But the corpora allata are important only during the first week or 10 days; once the embryos are well started, the gland can be removed without harm to them.

LET us now consider the organ which is closely associated with the corpora allata—the corpora cardiaca. Like the corpora allata, the corpora cardiaca have

OPERATING THEATER for the woodroach is beneath a dissecting microscope. The insect is taped down and surgery performed on it with the instruments beside the microscope stage. The vessel at center is a light filter.

long been suspected to produce hormones. When we remove this organ from insects, however, we get a disappointing and mystifying result: the insects seem to get along all right without it. What could be the function of the corpora cardiaca? An examination of the head glands of the woodroach under the microscope offered a clue. The corpora cardiaca are intimately associated with certain peculiar cells that occur in the brain. These cells, called neurosecretory, are both nerve cells and gland cells; they are known to secrete hormones. The corpora cardiaca of the woodroach contain



REMOVAL OF GLAND affects the development of the woodroach. At left is a normal adult woodroach. In center is a premature adult resulting from the removal of the corpora allata. At right is a nymph at the same stage.

glandular material of the same kind as the neurosecretory cells of the brain. Apparently this material "migrates" along a nervous pathway from the neurosecretory part of the brain to the adjacent corpora cardiaca, where it seems to be stored in considerable quantity. It looks, therefore, as if the corpora cardiaca serve as a storehouse for the brain-cell hormones.

This interpretation clears up several otherwise puzzling questions. For one thing, it explains why removal of the corpora cardiaca produces no drastic changes; the insects can get along without the reservoir of hormones because they continue to receive a supply of the same hormones from the source in the brain. So far as can be determined, the corpora cardiaca hormones perform exactly the same tasks as the brain hormones; *i.e.*, they control an insect's development, its color adaptation and the maturation of its eggs. What makes the reservoir hypothesis particularly attractive is that it matches a very similar situation in higher vertebrates. For many years it was thought that the posterior lobe of the pituitary gland in man and other mammals secreted its own hormones. But investigators have been puzzled by the fact that these hormones are indistinguishable from hormones secreted by the brain. There is now good evidence that the hormones in the pituitary's posterior lobe are only stored there and actually come from the neurosecretory portion of the brain, by a nervous route such as that taken by the brain hormones in insects. This new turn in our knowledge of the origin and transport of hormones opens up many promising avenues for further research. We are quite aware that the theory still requires more proof, but it serves to show how fruitful the investigation of insects can be, as far removed from mammals as they are.

THE woodroach has made another very significant contribution to our knowledge, this one having to do with cancer. As so often in research work, it all started as an accidental observation. We found that when both the corpora allata and the corpora cardiaca were removed, the roaches often developed tumors in distant parts of the body. The part attacked most frequently was the stomach, but tumors also arose in the forward part of the gut and in the salivary glands. Many of the tumors gave all the signs of malignant cancer: they grew with great speed, invaded healthy tissues and as a rule led to the death of the animal.

We assumed at first that the cause of these pathological growths was a hormonal imbalance, resulting from the removal of the secreting glands. It is well known that interference with the balance of hormones in mammals can produce tumors. But we soon discovered that hormone deficiency was not responsible for the roaches' tumors; they developed such growths even when they were supplied with hormones by grafts of tissue to replace the removed corpora allata. Apparently it was the surgery itself—some accidental injury connected with the removal of the gland—that caused the insects to develop tumors.

On investigation the injury responsible for the tumors turned out, quite unexpectedly, to be the cutting of a nerve. The nerve in question, called the recurrent nerve, is so intimately connected with the head glands of the woodroach that it is impossible to remove them without cutting it. That the insects' tumors were due to the severing of this nerve was proved beyond question; when the recurrent nerve is cut with fine scissors without injury to the head glands, about 75 per cent of the roaches so operated on develop tumorous growths. Moreover, the tumors grow only in organs controlled by the recurrent nerve.

The reason this finding was so unexpected is that it was the first time tumors had been induced in an animal by an injury to the nervous system. Radiations, hormones, chemicals of various kinds—all these have been proved to produce cancers in experimental animals, but never before have the nerves been clearly and directly implicated, although nervous disturbances have been suspected to contribute to tumors in connection with other factors. The woodroach experiments now invite further inquiry into possible nervous factors in cancers of higher animals.

A follow-up study of the tumors in roaches has already yielded some interesting results. For example, female roaches are more vulnerable to tumors (*i.e.*, die sooner) than males. But when the sex organs of males and females are removed, the difference in survival rates disappears. This suggests that the woodroach has sex hormones. Whether or not such hormones are present in any insect has long been a debated question; the woodroach offers a start toward settling it.

THERE may well be other fields in which the woodroach could prove valuable as a tool for experimentation. It may join the fruit fly, the silkworm, the flour beetle and other laboratory favorites from the insect world as a subject for studies in genetics, endocrinology and biochemistry. Dogs, guinea pigs and rats, valuable as they are, do not tell the whole story of animal biology, and the insects can contribute in their own ways to filling gaps in the story.

Berta Scharrer is assistant professor of research in the Department of Anatomy of the University of Colorado.

What GENERAL ELECTRIC People Are Saying

E. E. CHARLTON

Research Laboratory

STERILIZING FOODS AND DRUGS WITH ELECTRONS: Probably the most promising and imminent application of high energy cathode rays is in the field of sterilization. Studies to determine the lethal effect of cathode rays on various types of bacteria and mold cultures indicate that the spore formers of the bacteria are more resistant than the non-spore formers, and that the bacteria are more resistant than the mold cultures. Likewise, some preliminary data with viruses indicate that they are still more resistant than the bacteria. A dose of a million roentgens was found to be lethal to bacteria concentration of approximately 10^8 per cc, while approximately 0.3 million roentgen was the lethal dose for molds.

The lethal effect produced by the irradiation in the case of bacteria has been attributed to the result of a single ionization in a sensitive volume within the cell.

Sterilization without appreciable temperature rise is what makes the application of cathode rays to sterilization an attractive one and in particular, for use in those cases of temperature sensitive materials. It appears that many types of heat sensitive pharmaceuticals such as antibiotics and hormones can be electron sterilized in their final glass or plastic containers without reduction in potency of the material or other adverse effects.

4th District Branch
Medical Society of the State of New York
September 20, 1951

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R. P. HAVILAND

Large Apparatus Division

"BUMPER," TWO-STAGE ROCKET PROGRAM: In an effort to more nearly realize the full advantages of a multi-stage design, in 1946 the Army Ordnance Department decided to embark upon a program of design and development of a two-stage test vehicle of better performance than any vehicle then available.

A co-operative program, called "Bumper," was established. Basic responsibility for the program was assigned to General Electric's Project Hermes.

The vehicles selected were the American WAC Corporal for the second stage, and the German A-4 (V-2) for the first stage.

So far, the Bumper Program has: (1) demonstrated the techniques of launching large two-stage vehicles and of securing separation at high velocities and altitudes: (2) established a new velocity record of 7550 feet per second, or 5150 miles per hour; (3) established a new altitude record of 250 miles above the earth; and (4) demonstrated two-way communication with an object 250 miles above the earth—this being above the D, E, and F layers of the ionosphere.

Electrical Club of Montreal, Canada
October 24, 1951

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H. M. ROZENDAAL, M.D.

Research Laboratory

NEW INDUSTRIAL HAZARDS: A review of the literature on health aspects of the Atomic Energy industry indicates the enormous scope of the problems involved. The experience of the last 10 years makes it clear that a new industry has been developed which is already larger than most other industries in the United States and the operation and products have many significant effects upon workers and general public.

In the Atomic Energy installations there have been developed Health Physics branches which together with the medical and safety groups have been responsible for the exceptionally fine record of safe operations in the new industry.

Since 1946 there have been 5 radiation injuries. Considering the number of people employed in the new industry and the types of hazards encountered, this is a remarkable record of accident prevention. The execution of this program of radiation protection has cost the A.E.C. between \$3 and \$4 of every \$100 spent for operations. There is reason to believe that experience and new knowledge may decrease this cost and possibly produce greater operation efficiency.

13th Ohio State Safety Conference
Cleveland, Ohio
September 18, 1951

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M. M. BORING

Technical Personnel

TOMORROW'S ENGINEERS: I consider you who work in our offices and laboratories the most important group I can possibly reach . . . I am asking you to make your voices heard by those who are coming up through our schools so that they will not deny themselves the advantages of an engineering career because of the ridiculous belief that engineers are a dime a dozen.

But how? Many of you are members of engineering societies and can take action in your communities by presenting facts to school guidance counselors and teachers and speaking before assemblies and classes. Many of you as parents and members of PTAs can tell your story effectively. Don't sell the parent short in your thinking, for the records prove that many careers are the fulfillment of parents' wishes that their children become happy and successful.

Use your facilities. You have the facts. Surround those facts with the romance of the profession—the challenging problems and the brilliant solutions—and drive for action.

General Electric MONOGRAM
November–December 1951

You can put your confidence in—

GENERAL ELECTRIC

Weather Instruments

The variable temperature, pressure, moisture and movement of the atmosphere are sensed by devices that have evolved from the rain gauge and the wind vane to rockets and radar

by David I. Blumenstock

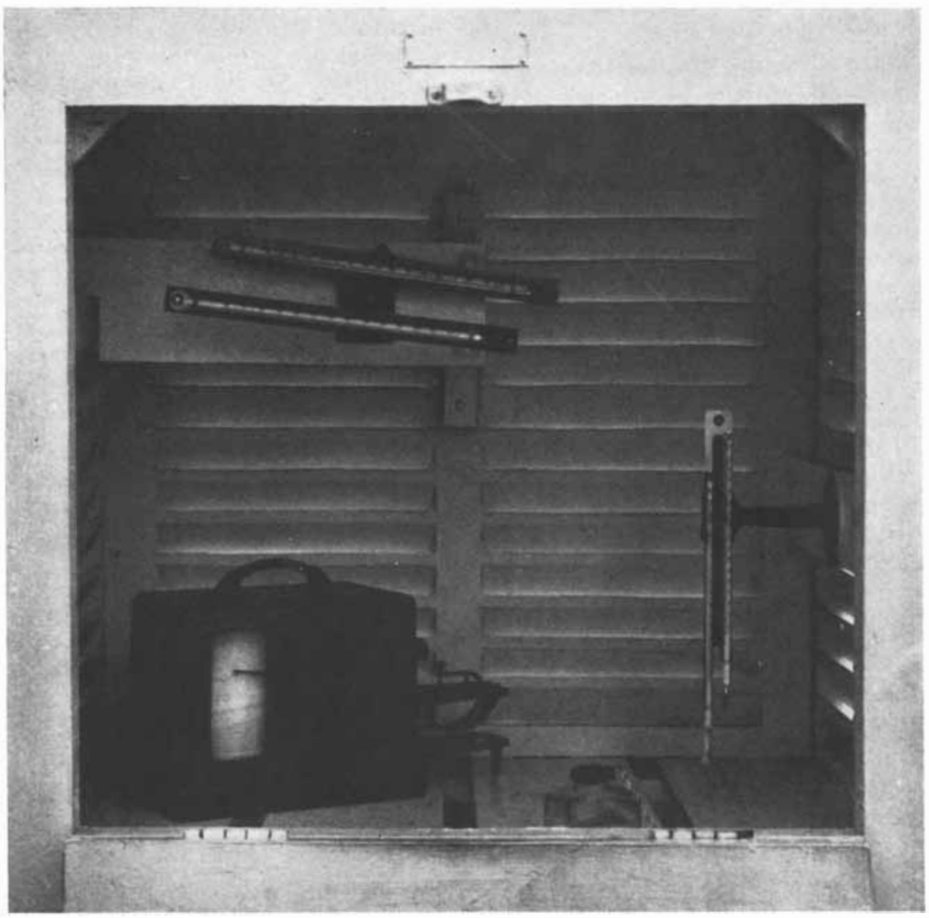
MAN was a fairly expert weather observer long before he ever heard of thermometers or barometers. The jut-jawed men who roamed the forests of Europe 25,000 years ago probably were able to read the skies with a knowing weather eye, and civilized man has been recording shrewd observations on the weather ever since he began to write. From Hesiod of the eighth century B.C., the earliest Greek recorder of weather lore, we get such maxims as this: "Take heed what time thou hearest the voice of the crane from the high clouds uttering her yearly cry, which bringeth the sign for plowing and showeth forth the season of rainy weather, and biteth the heart of him that hath no oxen." In the logs from old sailing ships are excellent accounts of the winds and weathers of the seven seas: hurricanes off the Bahamas, winds ripping through the Straits of Magellan, arctic cold that froze the briny spray in the scuppers. The most skilled weather observers, of course, were the sailors and farmers, and they have given us a vast folklore of useful weather proverbs, such as the one that goes: "Red sky at night, sailors' delight; Red sky at morning, sailors take warning."

As far as visual observations go, the modern weatherman is no more skilled than the ancient farmers and sailors. Visual observations are still important in sizing up the weather, for they provide an indispensable total picture—the general plot of the ever-changing weather story. But to follow that story in detail, to read the paragraphs and sentences and words, one must look to the information provided by weather instruments. The giant forward strides in our understanding of weather during the past three centuries are largely attributable to the development of weather instruments that are used in conjunction with visual observations.

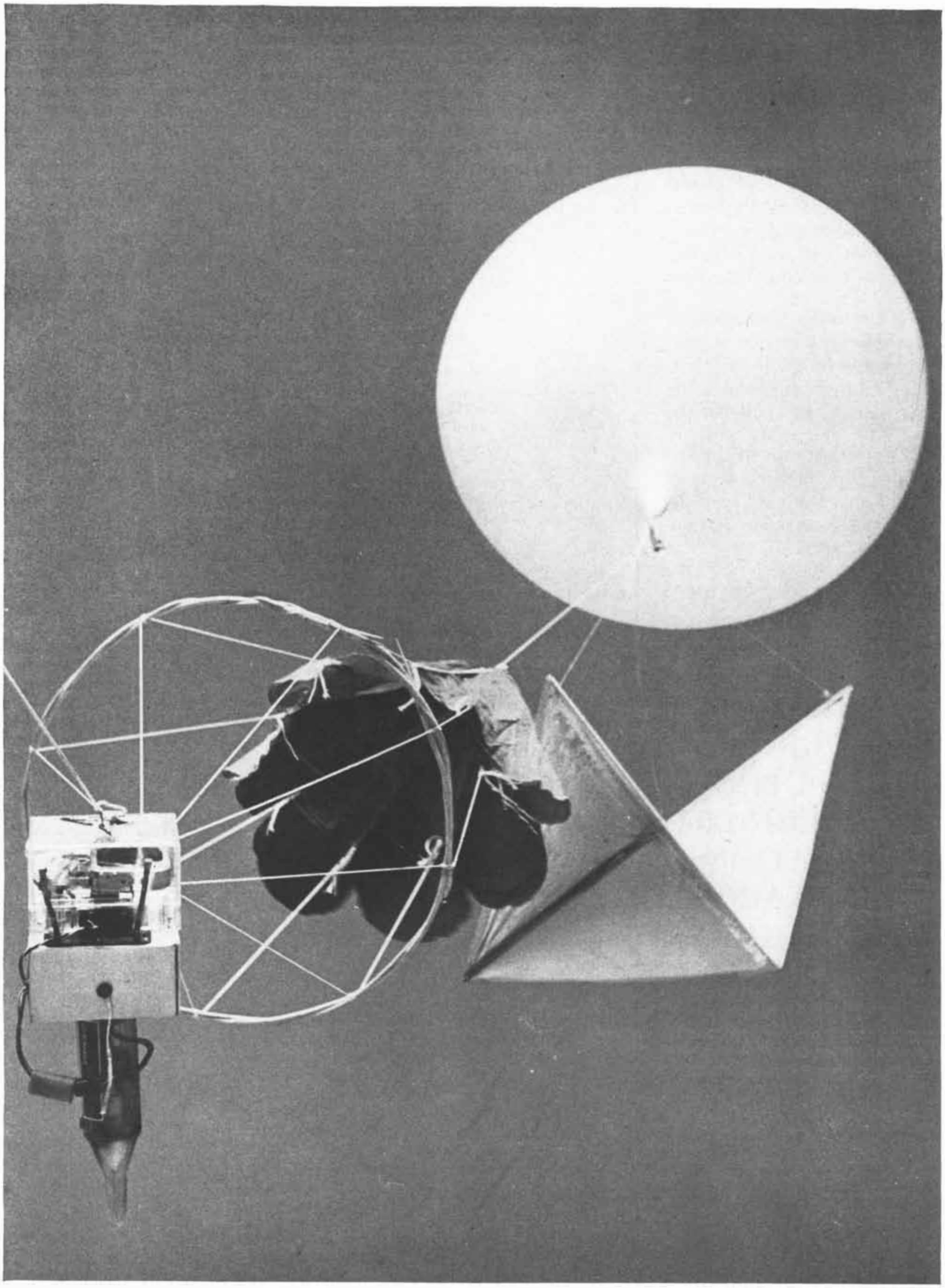
The oldest of all weather instruments is the rain gauge. No one knows where or when man first used one, but it must have existed in simple form in earliest historical times. A rain gauge is merely a receptacle for catching and measuring rainfall. Any closed container such as a jar or can will do. One can imagine that early man may have referred to rainfall amounts in terms of "a large jarful," "a small jarful" or "half a jar."

The simplest modern rain gauge catches the rain in a wide-mouthed funnel leading to a cylindrical tube beneath. Usually the mouth of the funnel is exactly 10 times as large in cross section as the cylinder, so that a fall of one-tenth of an inch of rain will fill the cylinder to a depth of one inch. This 10-fold amplification of the rain depth makes it easier to measure the fall accurately. Refined versions of the gauge have shields to prevent evaporation or scattering of the collected raindrops and devices for precise, automatic measurement of the collection. Some weigh the water; others drop it into a tiny, carefully balanced bucket which dumps its collected catch as soon as one-hundredth of an inch of fall has accumulated. Rain gauges are used to measure snowfall as well as rainfall. The collected snow is melted and the melt is then weighed to determine its rain equivalent. Snow varies greatly in moisture yield: a light, fluffy snow may yield only one inch of melt for 15 inches of fall, whereas a dense, well-packed fall may produce an inch of melt from six inches of snow.

Another simple instrument, probably at least as old as the rain gauge, is the wind vane. Since wind direction has an important bearing on the weather, the



INSTRUMENT SHELTER of an Air Weather Service installation houses a maximum-minimum thermometer, a barograph and a wet-bulb thermometer.



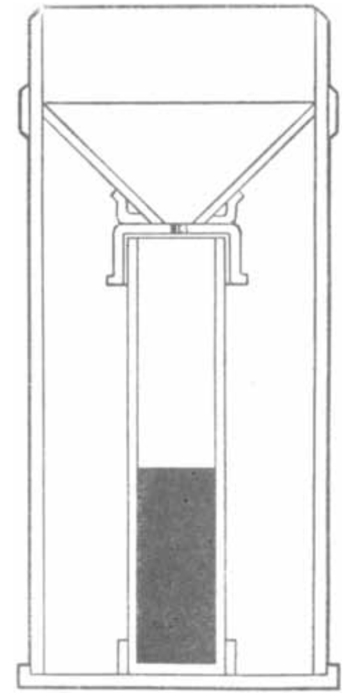
RADIOSONDE (*left*) is borne aloft by a balloon at an Air Weather Service installation. Between the radiosonde and the balloon are a parachute and a reflector to aid in the tracking of the balloon by means of radar.

earliest peoples must have used some kind of vane, even if only a free-pivoting reed attached to the top of a pole. The wind vane of course is still standard equipment on practically every farmer's barn.

THE more sophisticated weather instruments, notably the thermometer and the barometer, were not invented until the beginning of the age of modern science in the 17th century. The inventor of the thermometer was the great astronomer and physical scientist Galileo Galilei. Galileo's thermometer consisted of a U-tube sealed at the top of one arm and partly filled with water. The water, poured in the open end, trapped some air at the top of the sealed arm. When the temperature rose, the trapped air expanded and pushed the water down; when the temperature fell, the air contracted and the water rose. The volume occupied by the trapped air, as indicated by the water level, was a measure of the temperature.

Galileo's was a so-called gas thermometer; nowadays our thermometers usually measure the contraction and expansion of a liquid, such as mercury or alcohol, rather than air. We also have instruments based on the expansion and contraction of solids, like the bimetallic strips in recording thermometers. For really precise measurement, however, we have available a new type of thermometer which is based not on the expansion-contraction principle but on electrical resistance. When the temperature of a substance changes, its resistance to an electric current also changes. If a high-voltage current is passed continuously through a ceramic bead, the variations in current voltage serve as a measure of the variations in the temperature of the bead. Such resistance elements are used in recording thermometers for scientific experiments.

The barometer was invented soon after the thermometer; its inventor, indeed, was Galileo's secretary, Evangelista Torricelli. It involved a far more sophisticated concept than the idea of the thermometer. Galileo and his contemporaries realized that the atmosphere had weight; they had also been struck by the fact that a suction pump could not siphon water any higher than about 34 feet above ground level. But they had failed to see the connection between these two facts. Torricelli was the first to suspect that they were related; *i.e.*, that a column of water 34 feet high balanced the weight of the atmosphere. He set out to test this deduction. To reduce the balance to reasonable proportions, he used a column of mercury instead of water, mercury being 13 and a half times as heavy as water. His apparatus was a mercury-filled U-tube with one arm sealed at the top and the other open. The column of mercury in the sealed arm was one pan of his balance



Rain gauge

and the column of atmosphere pressing down on the surface of the mercury in the open arm was the other. He found that the atmosphere supported a column of mercury some 29 inches high.

Torricelli at first explained the mercury's behavior on the basis of Aristotle's theory that "nature abhors a vacuum." But then he noted that the height of the mercury varied from day to day. Reasoning that "nature would not, as a flirtatious girl, have a different *horror vacui* on different days," he discarded Aristotle's notion and concluded that the variations in the mercury's height must be due to changes in atmospheric pressure.

THIS discovery was the beginning of modern meteorology. Within a very few years observers came to realize that high air pressure was generally associated with fair weather and low air pressure with unsettled weather. Torricelli's barometer became known as a "weather glass." About 1670 the English scientist Robert Hooke invented the wheel barometer, consisting of a U-tube mercury barometer to which was attached a dial face with a pointer that turned as the barometer rose or fell. Then the term "weather glass" assumed even more explicit meaning, for the readings on the dial were translated into expressions such as "Very Dry," "Fair," "Rain" and "Stormy." For the first time an instrument directly related to weather forecasting had come into use.

Actually the relationship between weather and barometric pressure is not nearly so strict as the first users of the weather glass believed. Only at the extremes does the pressure predict the weather with a good degree of reliability. In low latitudes a falling glass with the pressure descending below 28 inches nearly always means that a hurricane is approaching. At all latitudes a rising glass with the pressure ascending above 30.5 inches nearly always means dry weather. But between these two extremes there is considerable variability.

The mercury barometer in common use today has a straight glass tube resting in a well of mercury. Like the thermometer, the barometer has developed into various species. One is the aneroid barometer. It consists of a metal cup partly exhausted of air and covered with a flexible metal plate. As the outside air pressure increases, it pushes inward on the plate. This change of position is communicated to a dial pointer through a series of gears and springs.

By 1650 the weather observer had available four major instruments: the rain gauge, wind vane, thermometer and barometer. In 1668 Hooke added the anemometer for determining wind speed. Hooke's anemometer consisted of a plate attached to an arm that was free to pivot upward against a spring. When the plate was held into the wind, the force of the moving air pushed the plate upward. The amount of the upward swing was a measure of the wind speed. Today the cup anemometer and the pressure-tube anemometer have replaced the Hooke type. The cup anemometer is simply a wheel with spokes but no rim; cups attached to the ends of the spokes catch the wind and spin the wheel around at a rate proportional to the wind speed. The pressure-tube anemometer has an open-ended tube mounted on a wind vane. The tube pivots to face constantly into the wind, and a pressure gauge inside measures the wind's force, or speed.

Wind speeds are conventionally reckoned on a scale that was worked out in 1806 by Admiral Sir Francis Beaufort of the British Navy. He based the units on the effects of the wind's force on a typical British man-of-war. Thus a wind of such force as to drive a "well-conditioned man-of-war, under all sail and clean full," at the rate of one to two knots in smooth water was called a "light breeze" and assigned the number 1 on the Beaufort scale. The scale runs from 0, corresponding to "calm," to 12, for a "hurricane"—a wind to which the British man-of-war "could show no canvas." Today the scale is used on the weather maps of the U. S. and many other countries. The wind-force values on land have been related to the behavior of smoke, trees, dust, loose paper and other familiar objects. A wind that raises dust and bits of paper or small dead leaves and stirs the smaller branches of a tree is "gentle," Force 4, and is blowing at 8 to 12 miles per hour. If the wind bends small trees, sways the largest branches of big trees and makes telegraph wires sing, it is a "moderate gale," blowing at Force 7 and 25 to 31 m.p.h. A "strong gale," rated Force 9, is a wind that blows at 47 to 54 m.p.h. At sea the various wind velocities are reckoned from the state of the water surface.

After Hooke's invention of the anemometer, there remained just one more major instrument to be added to the surface weather observatory. What was required was an instrument for measuring the water content of the atmosphere. About the middle of the 18th century it appeared in the shape of the wet-bulb thermometer. Its inventor is believed to have been James Hutton, the famous Scottish geologist. The wet-bulb thermometer is based on the simple and ingenious idea of calculating the moisture content of the air from the rate of evaporation of a moist cloth exposed to it. The moist cloth is wrapped around a thermometer bulb. Evaporation, which takes heat, cools the cloth and the bulb. Consequently the temperature recorded on the thermometer is a measure of the amount of evaporation that is taking place and hence of the degree of saturation of the atmosphere. The cloth around the bulb is kept moist by having an end constantly dipped in a well of water. To prevent the instrument from becoming blanketed by a layer of air full of moisture from the evaporating cloth, the thermometer is either whirled around or equipped with a fan so that it is always exposed to fresh air. An ordinary thermometer mounted beside the wet-bulb thermometer gives comparative readings that permit ready calculation of the relative humidity of the air.

Another instrument for measuring humidity is the hair hygrometer; it has the advantage that it can make a continuous record of humidity changes. A hair lengthens when the humidity increases and shortens when the humidity decreases. Human hair, particularly blond hair, is the most reliable. The hair is attached by a series of levers to a recording arm with a pen point which traces a line on paper on a rotating drum; the arm moves up and down as the hair lengthens and shortens.

The meteorologist's equipment today includes other instruments for recording the speed and direction of clouds, the intensity of sunlight, the height of the cloud ceiling, the spectrum of sunlight, the faint light given off by the night sky, the intensity of the atmosphere's electrical field and a host of other special details.

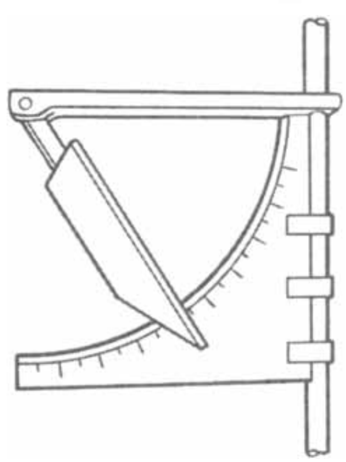
Very early after the scientific study of weather began, it became obvious that observations at ground level told only a small part of the weather story. Above and beyond the surface air lies a vast atmospheric ocean where major trends in our weather are often determined. The exploration of that ocean began one day in 1749.

About the middle of July in that year, on a morning unusually bright and clear for that place and season, two scholarly looking gentlemen laden with some special homemade paraphernalia appeared in an open field in the Camlachie district of Glasgow, Scotland. They were attended by a crowd of curious townfolk, who had heard that an unprecedented experiment was to take place. The two men, Professor Alexander Wilson of the University of Glasgow and a helper named Thomas Melvill, unfurled a chain of six paper kites from four to seven feet long. From the leading kites in the string hung thermometers, each with a paper tassel attached. Before launching the chain of kites the professor and his helper ignited the waxy cords by which the thermometers were suspended. By the time the kite chain had risen to its maximum height at the end of the kite rope, the cords burned through and the thermometers fell to earth, their fall being broken by the paper tassels acting as parachutes. While Melvill held the kite rope, Professor Wilson raced across the field and picked up the thermometers as quickly as possible to note their readings before they changed to the ground-level temperature. In this manner Wilson made temperature soundings of the atmosphere to a height of several hundred feet.

Wilson continued his kite experiments throughout the summer. They attracted great interest. Many scientists had taken temperature and pressure readings at high altitudes on mountains, but Wilson was the first to obtain observations from the free upper air—unaffected by close contact with the ground.

For over 30 years the kite remained the only equipment for sounding the free atmosphere. Then on October 15, 1783, Jean François Pilâtre de Rozier of Metz made the first ascent in a balloon (filled with warmed air), and a few months later J. A. C. Charles rose much higher in an improved balloon, filled with hydrogen. Soon balloons were a common sight in the skies over London, Paris, St. Petersburg and many other cities.

Scientists were quick to take advantage of this means for making observations in the upper atmosphere. The year after Charles' ascent from Paris, the British physician John Jeffries and the French aeronaut François Blanchard (inventor of the parachute) made balloon observations of pressure and temperature and brought down samples of air for chemical analysis. By 1804 J. L. Gay-Lussac and J. B. Biot of France had got up to 23,000 feet and found the temperature there to be only 14.9 degrees Fahrenheit. In the following decades many other meteorological ascents were made, but the enthusiasm of the scientist-balloonists was suddenly checked when, on a spring day in 1875, two men of a crew of three died of lack of oxygen in an ascent to 27,950 feet.



Pressure-plate anemometer

This disaster prompted the Frenchmen Gustave Hermite and Georges Besançon to design an unmanned balloon for meteorological soundings. After years of work they successfully tested the first "balloon sonde" in November, 1892. Filled with hydrogen, it rose several hundred feet in the air and then burst, as it was designed to do, and floated down by parachute to deposit its weather instruments undamaged on the ground.

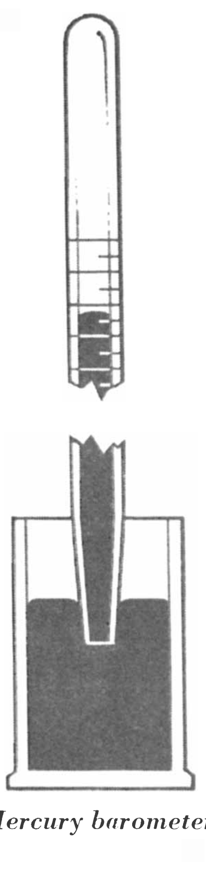
THE sounding balloon quickly became a standard weather equipment and remains so to this day. Balloons now probe the atmosphere to heights of 100,000 feet or more. Tracked by radar or by the telescopic theodolite, they measure the speed of the winds at high altitudes. For measurements of pressure, temperature and humidity the favorite instrument is the radiosonde, a balloon-borne apparatus containing a radio transmitter which sends back signals giving the temperature, humidity and pressure values at regular intervals. The instruments that feed this information to the transmitter are tiny elements of ingenious design—a bimetallic strip for measuring temperature, a metal aneroid barometer and a coated metal measuring device whose electrical resistance varies with the humidity.

A new variation of the radiosonde is the dropsonde; this one goes down instead of up. It is dropped from a plane in flight and sends back radio signals to report on weather conditions between the plane and the earth's surface, thousands of feet below. This device is standard equipment on weather planes of the U. S. Air Force, which also carry a complete battery of other weather instruments; they are actually fully equipped flying weather stations.

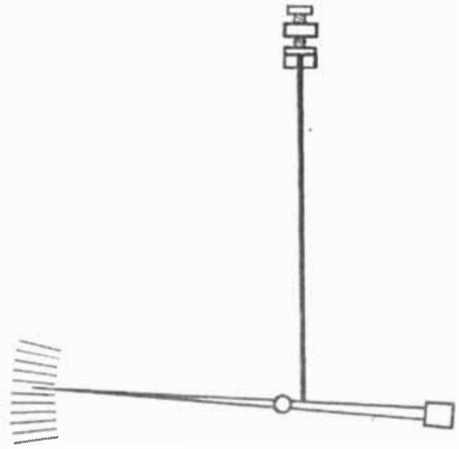
Another innovation of recent years is the automatic weather station. One was installed on a reef in the Coral Sea during the war. Powered by a gasoline engine, it automatically broadcast twice a day the air pressure, wind direction and speed and temperature at that location. Some day automatic weather stations such as this may broadcast weather observations from remote, inaccessible regions of the world, such as the Upper Amazon Basin, the Arctic and Antarctic, the Tibetan Highlands and mountain peaks far removed from civilization.

Probably the most spectacular and uncanny of the new weather instruments is the "rain scope." During their early studies of radar in the late 1930s the British noticed that images sometimes showed up on the radar screen when there was no plane in the sky nor any other obvious target to account for the echoes. They eventually determined that the mysterious echoes were produced by raindrops or large flakes of snow. During the war special studies of the effects of the atmosphere on radar beams were made both in Britain and at the M.I.T. Radiation Laboratory in the U. S. It was discovered that radar, particularly at certain frequencies, could pick up not only raindrops and snow but also layers of air of contrasting temperature or moisture content—in other words, cold fronts and clouds.

Nothing much was done to apply these findings to weather work until Colonel J. T. Wilson of Canada decided in 1944 to use radar as a rain-detection instrument. Wilson's tests were phenomenally successful. On the circular, maplike face of the radar scope one could actually "see" a cold front moving in from the northwest 160 miles away. First there appeared at the edge of the scope a mass of echoes as from raindrops. In the next few hours the boundary of the storm moved slowly inward toward the center of the scope, which marked the location of the observing station. Almost to the minute, when the line touched the scope center the patter of



Mercury barometer



Hair hygrometer

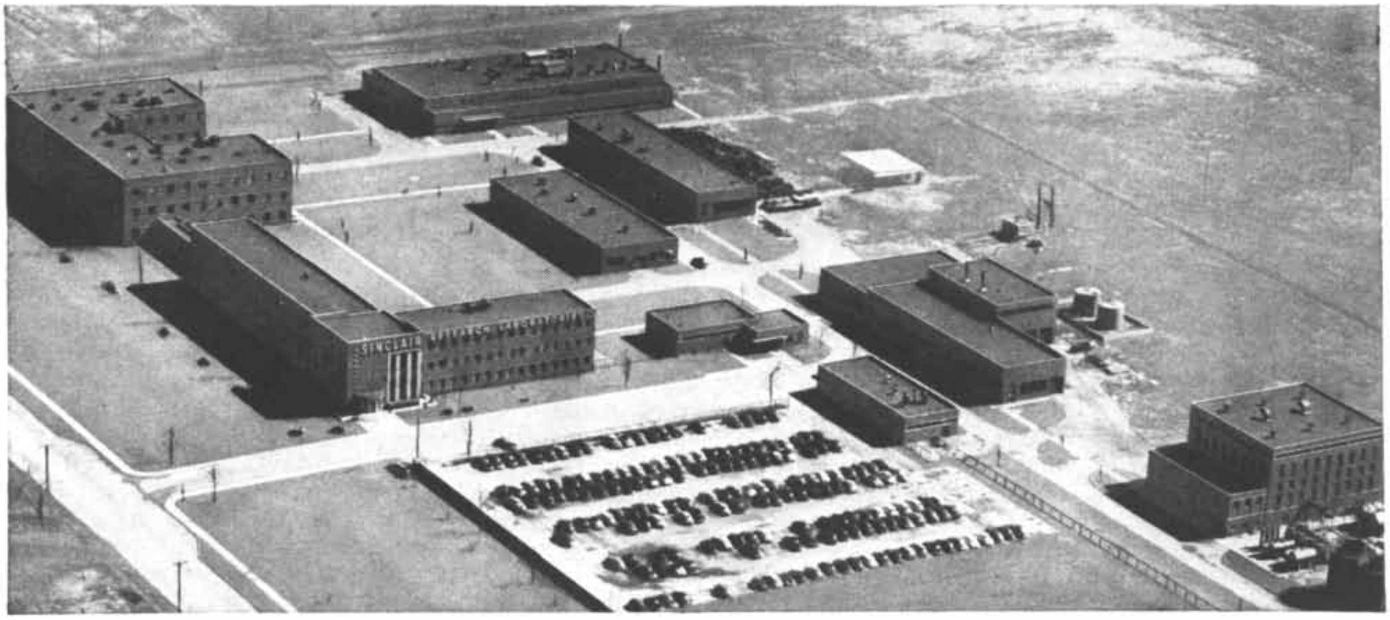
rain could be heard on the roof of the radar shack overhead. Here was a weather instrument that gave a panoramic view of the rainfall over a wide area. It permitted the tracking of large storms with previously unthought-of precision.

Radar storm-detection has already come into use at a few major weather stations in the U. S. The Army Signal Corps radar at Orlando, Fla., detects hurricanes while they are still far out at sea. At other stations radar tracks approaching fronts and thunderstorms. Heavy rainstorms can be predicted to the hour, sometimes to the minute. Unfortunately a radar storm-detection unit is expensive to build, difficult to maintain and requires skilled operators—so such units are not yet in common use.

THE question of how our weather is influenced by events in the atmosphere above 20 miles is still to be explored. We do know that winds in the upper atmosphere sometimes steer our major storms. For example, during the hurricane that swept up the Atlantic 200 miles off Cape Hatteras on October 17 this year, weather forecasters observed that a long, narrow zone of ultra-speedy winds was blowing from southwest to northeast high above the storm and on either side of it. They predicted that the hurricane would move northeast, and it did, in fact, take the course they had predicted.

Rockets carrying special recording instruments are now probing the atmosphere to heights of a hundred miles and more over the U. S. Because this is still a military project, little is known about the results of the experiments. It is certain, however, that as we learn more about what is going on in the upper atmosphere hundreds of miles above the earth's surface, we shall come to understand our weather a great deal better.

David I. Blumenstock, meteorologist, was the author of The Upper Atmosphere, *which appeared in the January, 1949, issue of this magazine.*



SINCLAIR RESEARCH LABORATORIES—nine buildings containing the most modern testing equipment known—have contributed many of today's most important developments in petroleum products, production and refining. Under the Sinclair Plan, the available capacity of these great laboratories is being turned over to work on the promising ideas of independent inventors everywhere.

An Offer of Research Facilities to Inventive Americans Who Need Them

The Sinclair Plan is opening up the Company's great laboratories to every American who has an idea for a better petroleum product

INVENTIVE Americans are often at a loss today. Not because of any lack of ideas, but because of a need for expensive facilities to find out if and how their ideas work.

This was no obstacle in our earlier days. The Wright Brothers designed their first airplane with the help of a foot-square homemade "wind box"—and the plane flew.

In contrast, the man with a new idea in airplane design today often needs a supersonic wind tunnel costing millions.

In short, science and invention have become so complex that a man with an idea for a better product often needs the assistance of an army of specialists and millions worth of equipment to prove his idea has value.

Within the petroleum field, the Sinclair Plan now offers to provide that assistance.

Under this Plan, Sinclair is opening up its great research laboratories at Harvey, Illinois, to independent inventors who have sufficiently good ideas for better petroleum products or for new applications of petroleum products.

If you have an idea of this kind, you are invited to submit it to the Sinclair Research Laboratories, with the provision that each idea must first be protected, in your own interest, by a patent application, or a patent.

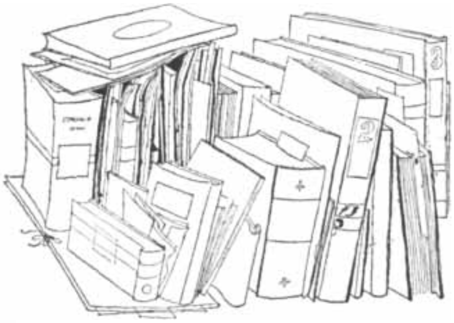
The inventor's idea remains his own property

If the directors of the laboratories select your idea for development, they will make, in most cases, a very simple arrangement with you: In return for the laboratories' investment of time, facilities, money and personnel, Sinclair will receive the privilege of using the idea for its own companies, free from royalties. This in no way hinders the inventor from selling his idea to any of the hundreds of other oil companies for whatever he can get. Under the Plan, Sinclair has *no control* over the inventor's sale of his idea to others, and has *no participation* in any of the inventor's profits through such dealings. Moreover, it is a competitive characteristic of the oil business that the new products adopted by one company are almost invariably adopted by the whole industry. This means that the very fact of his agreement with Sinclair should open up to the inventor commercial opportunities which might otherwise be hard to find.

How to proceed: Instructions on how to submit ideas under the Sinclair Plan are contained in an Inventor's Booklet available on request. Write to: W. M. Flowers, Executive Vice-President, Sinclair Research Laboratories, Inc., 600 Fifth Avenue, New York 20, N. Y. for your copy.

IMPORTANT: *Please do not send in any ideas until you have sent for and received the instructions.*

SINCLAIR—A Great Name in Oil



CHILDREN'S BOOKS

Concerning the popularization of science for younger readers: a Christmas survey

by James R. Newman

TWO Christmas seasons ago this department reviewed an extensive list of children's books about science, attempting to give the reader some notion of the trends and the books available in this special literature. The present review brings the list up to date, dealing with the children's science books that have appeared since 1949.

The quality of popularizations of science for children continues to be only fairly satisfactory. Few, if any, of the recent books are outstanding. The books available for 6- to 12-year-olds are better than those for adolescents. Generally the pictures exhibit more ingenuity and imagination than the text. Prices naturally have risen; now and then you will find a bargain, but the book with meager text and nondescript illustration that costs about $2.00 is all too common. The discriminating adult reader has had few occasions to celebrate the literary output offered him during the past two years; the children's list is much the same. Nonetheless the parent with a youngster interested in science is sure to find a number of instructive and agreeable books in this assortment.

Physical Sciences

ATOMS AT WORK, by George P. Bischof. Harcourt, Brace and Company ($2.25). Where others have failed, Mr. Bischof, a teacher at the Brooklyn Technical High School, has succeeded admirably in telling the story of atoms and molecules for children of 10 to 14. He has the knack of effective analogy, writes unpretentiously, avoids the flesh-creeping and gee-whiz techniques, emphasizes the constructive uses of atomic energy. His discussion of electricity and the nuclear basis of chemistry is exceptionally good. A modest book and to my knowledge the best of its kind.

WORLDS IN THE SKY, by Carroll Lane Fenton and Mildred Adams Fenton. The John Day Company ($2.50). A readable book for 9 to 13s about stars, planets, comets, meteors and galaxies. The illustrations are disappointing, but they are clear and serve to help the story along.

OBSERVING THE HEAVENS, by Peter Hood. Oxford University Press ($1.75). The first volume in the new Oxford Visual Series. A handsome colored frontispiece reproduces a chart of the Northern heavens engraved in the time of Queen Elizabeth, and there is information on telescope making and the features of the heavens, directed mainly to the amateur observer. An adolescent possessed of considerable skill might be able to build his own telescope by following Hood's directions and then make use of the book as an observing guide. On the whole, however, the book struck this reviewer as unimpressive. Its page layout and typography are likely to repel all but those rare children with a passion for self-improvement.

PICTURE BOOK OF CHEMISTRY, by Jerome S. Meyer. Lothrop, Lee & Shepard Co., Inc. ($2.00). The fifth in a series of science picture-books written by Mr. Meyer and illustrated by Richard Floethe. Earlier volumes dealt with the weather, astronomy, atoms and molecules and the earth. They are plainly written, accurate and mildly entertaining. Children in the 9-to-13 group should find them digestible.

FIRST CHEMISTRY BOOK FOR BOYS AND GIRLS, by Alfred Morgan. Charles Scribner's Sons ($2.75). Simple experiments that teen-agers can perform with ordinary household objects, thus learning chemistry without incinerating themselves and impoverishing their parents. The exercises include producing crystals, dissociating water, testing for starch, acids and bases, removing iodine stains, softening hard water, secret writing, precipitation, electrolyzing salt, making soap. Illustrations.

A FIRST ELECTRICAL BOOK FOR BOYS, by Alfred Morgan. Charles Scribner's Sons ($3.00). The revised edition (including a new chapter on electronics, radar and television) of a book for adolescents containing historical, theoretical and practical information on everything from accumulators to X-rays. Mr. Morgan is an experienced popularizer, and the many excellent diagrams enhance the value of this introduction, especially for a youngster with experimental inclinations.

PATTERNS IN THE SKY, by W. Maxwell Reed. William Morrow & Company ($2.50). The story of the constellations, written, the author says, in response to the repeated requests of "friends of all ages." In the opinion of this reviewer he should have referred them to other books. This one is a rehash and dull.

EVERYDAY WEATHER AND HOW IT WORKS, by Herman Schneider. Whittlesey House ($2.75). Step by step Mr. Schneider builds up a thoroughly comprehensible picture of what makes the weather and explains how to use maps and to make a home weather-forecasting station. Directly written, offering a considerable number of simple, admirably instructive experiments, and strongly supported by several hundred of Jeanne Bendick's illustrations, this is the best of the primers on the subject. For children of 10 (with a little help) and up—and by no means to be spurned by adults.

YOU AMONG THE STARS, by Herman and Nina Schneider. William R. Scott, Inc. ($2.25). A book that says well what it has to say but should say more. Its analogies explaining compound motions and other elusive matters are ingenious, but the concept of gravity, which is one of the central themes of the account, is left as a large indigestible lump for the young reader to assimilate as best he can. To explain why people on the other side of the earth do not fall off, surely more must be said than merely to ascribe their good fortune to "the pull of gravity." The lithographs by Symeon Shimin are colorful.

Biological Sciences

CATS, by Wilfrid S. Bronson. Harcourt, Brace and Company ($2.00). The happy cat, says Mr. Bronson, is the one kept as a pet in the suburbs or country. These conditions afford him a full life—sybaritic by day, adventuresome and predatory by night. Bronson recounts the typical 24-hour routine of a cat thus blessed, and throws in facts about cats' eyes, facial muscles and diet. He also goes into why they purr, cannot descend a telegraph pole backward, keep clean, are slaves to habit, and so on. Animal psychologists may not always agree with the author's interpretations of cat motives, responses and intentions, but the vast tribe of cat-lovers of all ages will enjoy and believe every word. Illustrations by the author.

THE FIRST BOOK OF TREES, by M. B.

Cormack. Franklin Watts, Inc. ($1.75). A fully illustrated introduction for children of about 8 or 9. Helene Carter's green-tinted drawings of trees, seeds, leaves, fruits and flowers are better than average. An acceptable if not particularly inspired little primer.

A Child's Book of Horses, by E. Joseph Dreany. Maxton Publishers, Inc. ($.50). Brief essays for 6- to 8-year-olds about the Morgan, Palomino, Arabian, Cayuse, Percheron, Clydesdale, Shetland, Appaloosa; likewise polo ponies, steeplechasers, hackneys, fire and circus horses. Unpretentious and colorful. Illustrations.

State Birds and Flowers, by Olive L. Earle. William Morrow & Company ($2.00). It appears that each of the 48 states has a bird and a flower as its popular emblems. (The mockingbird represents no less than six states, and the wood thrush for some obscure reason represents the District of Columbia.) The author writes a descriptive note and draws a picture for each selection. Unfortunately black-and-white illustrations, even when executed as skillfully as these, do not really fit the needs of a nature book, especially for children. For an audience from 10 to 16.

Hop, Skip and Fly, by Irmengarde Eberle. Holiday House ($2.00). A reissue of a wholly delightful book about the habits and adventures of small creatures such as bats, snails, lizards and frogs. For this revision the author has added one story, omitted those of the wasp and the ant and made other minor changes. With its felicitous sketches, its humor and graceful blend of entertainment and instruction, this is among the brightest of the books for 7 to 10s.

Outdoor Adventures, by Hal H. Harrison. The Vanguard Press, Inc. ($2.75). Fifty-one brief encounters with fawns, possums, snakes, praying mantises, slugs, water lilies, bats, moths, chipmunks and other forms of life. A minor mystery: the adventurers are identified as Mr. Harrison's children "Billy" and "Jane," although his offspring are actually named George and Gretchen. A fair book with good photographs. For 8 to 12s.

Sea and Shore, by Clarence J. Hylander. The Macmillan Company ($3.00). Strange Sea Life, by Gladys Vondy Robertson and Vera Graham. Henry Holt and Company ($2.50). The Hylander book is a quiet, straightforward description of the plant and animal life to be found along the seashore: seaweed, clams, sponges, sea urchins, jellyfish, oysters, periwinkles, snails, anemones, crayfish, crabs, whelks, corals, kelps, mussels, barnacles. It is illustrated by photographs and drawings and may be recommended for 10- to 14-year-olds who enjoy exploring tidal pools, rocky shores and beaches. Intended for a younger group, the Robertson and Graham book is a less successful effort primarily because it emphasizes the weird and fearsome aspects of ocean life. This is an approach to be discouraged for educational even more than for literary reasons. Natural wonders need no make-up; man has an inclination toward terror which requires no nourishment.

Let Them Live, by Dorothy P. Lathrop. The Macmillan Company ($2.00). Man, disagreeable, fearsome, greedy and foolish fellow that he is, has exterminated a number of the animals that inhabited the earth when he first appeared, and has all but eliminated many other species. Some of them, this book points out, are extremely important to his welfare. Miss Lathrop pleads colorfully and reasonably, if occasionally oversentimentally, on behalf of beavers, owls, chipmunks, milk snakes, moles, worms, bats, foxes, coyotes, trumpeter swans, pronghorn antelopes, wood ducks, fur seals, egrets, pelicans, gulls, crows, woodchucks, black bears, pumas, praying mantises and various other insects. Attractive drawings by the author. Recommended as a conservation primer for children of 9 and older.

Monsters of Old Los Angeles, by Charles M. Martin. The Viking Press ($2.50). Life Through the Ages, written and illustrated by Charles R. Knight. Alfred A. Knopf, Inc. ($2.50). Martin's book is a fictionalized account of life among the prehistoric animals of the La Brea Tar Pits in California. Ricky, a raccoon, is the hero. Your child may take this or leave it—it doesn't matter. The Knight book is a reissue of one published in 1946; the drawings of various antediluvian creatures by the best-known artist in the field are superb in their gruesome way.

Animal Tools, by George F. Mason. William Morrow & Company ($2.00). The author, a naturalist-artist on the staff of the American Museum of Natural History, has written a number of volumes on animals' tracks, sounds, weapons and homes. This volume on the tools animals use to build their nests, keep stable in flight, sting, lay eggs, clean themselves, gather food, is unquestionably one of Mr. Mason's best and will appeal to people of all ages. Among the more intriguing items are the ants that use their young as sewing machines and

the sea otter which, floating on its back, uses a stone balanced on its chest for an anvil to break the shells of clams for a cocktail.

STRIPE: THE STORY OF A CHIPMUNK, by Robert M. McClung. William Morrow & Company ($2.00). THUNDER WINGS: THE STORY OF A RUFFED GROUSE, by Olive L. Earle. William Morrow & Company ($2.00). Attractive little nature books for 6- to 10-year-olds. They have large type and are simply written and unsentimental. One does not, however, get much for the money.

THE NATURE DICTIONARY, by John Hayes Melady; illustrated by Samuel Nisenson. The World Publishing Company ($2.00). A large-format, 110-page picture guide for pupils, parents and teachers. It deals with animals and plants from aardvark to zinnia. The descriptions of these organisms are unobjectionable, but the 500 color illustrations of them are weakly executed and even more feebly reproduced.

A FIELD GUIDE TO THE SHELLS, by Percy A. Morris. Houghton Mifflin Company ($3.75). A revised and enlarged edition of a guide to the shells found on the Atlantic and Gulf Coasts, from *Abra aequalis* (small, white, rather plump bivalve) to *Zirfaea crispata* (small, oblong, cold-water burrowing clam). It includes the Flamingo Tongue, Hairy Triton, Humphrey's Wentletrap, Key-Hole Limpet, Little Dog Whelk, Rocking Chair Limpet, Little Staircase Shell, Baby Bonnet, Bleeding Tooth, Prickly Jingle and Zebra Periwinkle. Full, simple descriptions of each specimen, including their habits; 1,000 photographs, many in color. A compact, strongly made, well-printed, pocket-sized book. The perfect shore companion for children and adults.

A FIRST BOOK OF TREE IDENTIFICATION, by Matilda Rogers. Random House ($2.50). Miss Rogers describes about 75 of the familiar trees of the U. S. and Canada. There are photographs of typical branches and leaves, but unfortunately not of the whole trees. The reproductions are only passable.

PLANTS IN THE CITY, by Herman and Nina Schneider. The John Day Company ($2.50). This first volume in a new series, "Nature in the City," describes the form and habits of the plant life of built-up areas: how trees manage to thrive in crowded quarters and find nourishment in tiny bits of soil; how grasses, lichens and vines, adapting themselves to urban conditions, find lodgment and nourishment on roofs, in the cracks of walls or sidewalks, in alleyways and on telephone poles. Directions for making plant aquariums, window boxes and the like. A passable but somewhat lifeless book, as if written to order.

HOW TO KNOW THE WILD FLOWERS, by Alfred Stefferud. Henry Holt and Company ($2.00). A straightforward catalogue with a good deal of authoritative information about several hundred specimens of wildflowers, by the editor of the U. S. Department of Agriculture's famous yearbooks. The text, though obviously dependable, is clogged with descriptive details and the black and white line drawings add little of value. Children are apt to find this dull.

THE GREAT WHALES, by Herbert S. Zim. William Morrow & Company ($2.00). The many science books by Herbert Zim set a standard in their class. This volume, ably illustrated by James Gordon Irving, keeps to the mark. In a flowing narrative, unburdened by jargon or unessentials, Zim describes the physical and social habits of whales, explains their diving apparatus, their feeding and mating, where they live, how fast they can swim, why they spout, who their enemies are. None of the questions children are apt to ask about these remarkable mammals remains unanswered. For 8- to 12-year-olds.

FLOWERS: A GUIDE TO FAMILIAR AMERICAN WILDFLOWERS, by Herbert S. Zim and Alexander C. Martin. Simon and Schuster ($1.00). INSECTS: A GUIDE TO FAMILIAR AMERICAN INSECTS, by Herbert S. Zim and Clarence A. Cottam. Simon and Schuster ($1.00). Each of these little books in Simon and Schuster's Golden Nature Guides is a most satisfying pocket companion. The authors know the subject and how to write about it and have selected their examples skillfully; the illustrations, all in color, are attractively reproduced; the binding is stout and durable; the format could scarcely be improved; the price is comfortable. A thoroughly happy publishing venture.

GOLDEN HAMSTERS, by Herbert S. Zim. William Morrow & Company ($2.00). Hamsters are small, golden-brown rodents with large black eyes, short legs and even shorter tails. They live in rock piles and fence rows, steal immense quantities of grain, and breed prodigiously—a single female may give birth to from 50 to 100 young in a year. Because they are clean and easily tamed, they have within the last few years become very popular in the U. S. as pets. This book tells something of their history and habits and provides instructions on caring for them at home—if your children have cultivated this curious taste. Hamsters are easy to keep; the important thing apparently is not to let them escape, for if loosed on the country they would be a serious menace to the farmer. Zim's unencumbered text is accompanied by Herschel Wartik's illustrations. For 8 to 12s.

OWLS, by Herbert S. Zim. William Morrow & Company ($2.00). Owls live in the Arctic and in the Tropics and nest in every one of the 48 states; the tiny elf owl is smaller than a robin, and the great gray owl may have a wingspread of five feet; owls have transparent third eyelids, can turn their heads through a 270-degree angle (180 degrees is our limit), fly almost silently, have enormous appetites (one pair of barn owls fed their brood over 1,500 mice and rats in three months), eat only animals, are occasionally cannibals, swallow everything they catch and vomit what they cannot digest, are fearless and predatory but never fight back when attacked by other birds and are valuable to man as destroyers of the animals who would otherwise destroy his crops. These and many other facts appear in Mr. Zim's book, vividly adorned by James Gordon Irving's drawings. For children 8 to 12.

Social Sciences

THE MIND AT WORK AND PLAY, by Sir Frederic Bartlett. The Beacon Press ($2.50). The 119th series of Christmas Lectures for children given at the Royal Institution in England, dealing with such fundamentals of psychology as the workings of the mind in measuring size and judging distance, learning habits, memory, optical illusions, idiosyncrasies of observation, effects of fatigue. The emphasis is on simple experiments illustrating these various attributes of mind. While the lectures themselves were undoubtedly effective in awakening the listeners' interest—especially because the audience participated in the experiments—the book tends to get mired in long descriptive passages which are neither stimulating nor easy to follow. A disappointing book but perhaps suitable for elementary classroom use. Illustrations.

TOWN MEETING MEANS ME, by Mina Turner. Houghton Mifflin Company ($1.50). The municipal machinery of a typical small American community run by the town meeting system: how the officials are elected, what their duties are, where the money comes from, who spends it and for what. An introduction, suitable for second- or third-graders, to what used to be called "civics" but has now been transformed, as in this volume, to something less deadly and more useful. Illustrations by Lloyd Coe.

Medicine

MILESTONES OF MEDICINE, by Ruth Fox. Random House ($2.75). Short stories of various discoveries contributing to medical knowledge; for example, X-rays, radium, insulin, vitamins. The author casts her tales in conventional dramatic form, but she writes capably. Her book is certain to give entertainment as well as sound information to teen-agers.

THE STORY OF MEDICINE, by Joseph Garland, M.D. Houghton Mifflin Company ($3.00). A literate, instructive history of medicine from the earliest times, enlivened by anecdotes and apt quotations from original sources. The illustrations are nondescript, but Dr. Garland's attractive style sustains attention and stamps this as one of the better recent science books for children. For age 12 and up.

Technology

DIESEL-ELECTRIC 4030, by Henry Billings. The Viking Press ($2.50). Mr. Billings takes the reader (8 to 100) on a ride in the cab of a Diesel-electric locomotive pulling one of the New York Central trains from Harmon to Albany, en route to Chicago. He recounts every detail of the engineman's duties and of the railroading features along the way; the last chapter explains how the Diesel works. The narrative purrs along as nicely as the engine itself; the intricacies of the machinery are neatly disentangled; the illustrations, also by Billings, serve their purpose to perfection. No train-lover's library can dispense with this one.

CONSTRUCTION AHEAD, by Henry Billings. The Viking Press ($3.00). The growth of a modern highway from a deer path and Indian trail, worn through the woods by hoofs and moccasins, to a four-lane concrete road built with bulldozers, motor-graders, giant pan scrapers and steam shovels. Selecting as his example the road now known as New York Route 199, Mr. Billings traces its 300-year history and gives a detailed, aptly illustrated account of how roads were built in the past and how they are built today. A fresh theme well handled, and an excellent story that will give pleasure to adolescents and adults.

TELEVISION STORY, by John J. Floherty. J. B. Lippincott Company ($2.75). The technical, program-making and commercial aspects of television reported by a professional writer of books for the young. Anecdotal and awe-stricken.

AVIATION FROM THE GROUND UP, by John J. Floherty. J. B. Lippincott Company ($2.75). Concerning the various aspects of modern aviation: jets, helicopters, military planes, commercial airlines, high-altitude flying, crop spraying, photography, the Berlin airlift, and so on. As smooth and of about the same general quality as an advertising brochure. For children 12 and over.

O.K. FOR DRIVE-AWAY, by Henry B. Lent. The Macmillan Company ($2.50).

Mr. Lent tells a few tales about the early history of the automobile and then takes the reader on a tour of the assembly line and proving grounds of a large Detroit factory. He manages to make a dull and unnecessarily complex story out of good material but does not forget to mention repeatedly the brand of car made at the plant visited. Intended for about 12-year-olds.

Biography

CHAIM WEIZMANN: BUILDER OF A NATION, by Rachel Baker. Julian Messner, Inc. ($2.75). The story of the noted Russian-born chemist who, more than any other single person, was responsible for the founding of the new state of Israel and became its first president. A breathless book but a readable one. For ages 10 and over.

TRAILBLAZER TO TELEVISION, by Terry and Elizabeth P. Korn. Charles Scribner's Sons ($2.50). Dr. Arthur Korn, who died in the U. S. in 1945, was a German physicist who invented phototelegraphy, known in this country as facsimile, which is the transmission of pictures, originally by wire but now without the aid of wires. This is a biography (for those 12 and over) by his widow and daughter-in-law. Korn was undoubtedly an able scientist, and some of his work is explained; one may also assume that he had definite traits of character besides being a Good Man, but there is little proof of it in these pages, most of which offer merely a bewildering catalogue of his many travels and studies.

HENRY FORD, ENGINEER, by Louise Neyhart. Houghton Mifflin Company ($2.75). A portrait exhibiting its subject as a composite of Archimedes, King Solomon, St. Francis, Abraham Lincoln and David Harum. The illustrations for the book are striking, but the text makes it sound unlikely that Henry Ford ever existed. Intended for readers of high-school age.

THE GREAT HOUDINI, by Beryl Williams and Samuel Epstein. Julian Messner, Inc. ($2.75). Miss Williams and Mr. Epstein present a sympathetic but not idolatrous biography of the greatest of modern magicians. Their description of Houdini's amazing skills, tricks, swindles, props and other hocus-pocus is absorbing; the chapter explaining the blend of genius and fakery of which Houdini's secrets were compounded will be a revelation for those who have not read earlier books on the subject. A first-rate book for teen-agers, not only because of its readability but also because while emphasizing, as Houdini himself always did, the explicable, physical, unmagical basis of his remarkable feats, it vividly conveys a sense of the wonder and the art of his legerdemain.

Home Experimentation

MORE EXPERIMENTS IN SCIENCE, by Nelson F. Beeler and Franklyn M. Branley. Thomas Y. Crowell Company ($2.50). The authors are experienced in contriving home experiments, this being the third of their books on the subject. They furnish for 10- to 14-year-olds thoroughly understandable directions for researches on such matters as heating by refrigeration, telegraphy, static electricity, erosion, osmosis, papermaking, water pressure. A nicely balanced manual, instructive and considerate alike of health and property.

PLAY WITH PLANTS, PLAY WITH TREES and PLAY WITH VINES, by Millicent E. Selsam. William Morrow & Company ($2.00 each). For children of 8 to 12, in fact for anyone who likes to grow things, these little books, skillfully illustrated by James Macdonald and Fred F. Scherer, are first-class. Miss Selsam tells how to raise plants from roots, stems, leaves and seeds; how to make a home tree-aquarium, how to grow vines and help them climb; how to tell time by observing the regular circling of their stem tips; how to prove the importance of light, water and starch in organic life; how to make prints of leaves and how to mount them in an album. She conveys this and a great deal of other information with clarity and a distinctive charm.

WEATHERCRAFT, by Athelstan F. Spilhaus. The Viking Press ($2.00). With a few ordinary tools and such commonplace objects as a wire hanger, an egg-beater, a set of measuring spoons, a tin can, a broomstick and a light bulb, a boy of high-school age can build himself a pretty good weather station. Dr. Spilhaus, who is dean of the Institute of Technology at the University of Minnesota, tells how to make and use a rain gauge, an anemometer, a wet-bulb and dew-point thermometer, a hair hygrometer, a simple barometer and similar instruments; also how to keep records and predict rain or shine. An original and engaging introduction to meteorology.

Miscellaneous

ALL AROUND YOU, by Jeanne Bendick. Whittlesey House ($2.00). A brief primer of science for 6- to 8-year-olds which touches lightly on such topics as weather, plant growth, animal habits, the sun, moon and stars. Miss Bendick's illustrations are charming, but the text is painfully self-conscious in its attempt to be artless, and what was perhaps a good idea does not quite come off.

THE FIRST BOOK OF STONES, by M. B. Cormack. Franklin Watts, Inc. ($1.75). The director of the Roger Williams Park Museum in Providence, R.I., tenders reliable information about different kinds of stones, explains how they came to be what and where they are and lays out a syllabus for junior collectors. The blurb says the book is for 6 to 10s, but unless your child is a budding Lyell, you had better read this as 8 to 12.

TIME OUT FOR YOUTH, by Arthur S. Gregor. The Macmillan Company ($2.50). How to survive adolescence without becoming more of a misfit than necessary. Mr. Gregor writes intelligently and with good will, offering a number of sensible maxims for parents, who also have good will but are apt to mess things up. His advice to adolescents, however, is pretty stilted and the adolescent mature enough to take it will not need it.

MIRACLE AT KITTY HAWK: THE LETTERS OF WILBUR AND ORVILLE WRIGHT, edited by Fred C. Kelly. Farrar, Straus and Young, Inc. ($6.00). This book has been noted earlier in SCIENTIFIC AMERICAN, but because of the universality of its interest should be mentioned again. The story of Kitty Hawk has never been so well told. Here are all the wonderful details of the preparations for the first power-driven flight, a survey of the early development of aviation and its pioneers, revealing self-portraits of the Wrights, a history of their travels, trials, failures and triumphs. A fascinating book.

YOU AND SPACE TRAVEL, by John Lewellen. Childrens Press, Inc. ($1.50). Mainly about Newton's Third Law of Motion, jets, rockets and space ships. Mr. Lewellen handles his material unevenly; some of it will go down well with 10- or 11-year-olds, some will stump adolescents; the working of jet engines is made unusually clear, but the explanation of gravitation will leave you puzzled as to why the moon does not fall on the earth.

THE BOOK OF AMAZING FACTS, by Jerome S. Meyer. The World Publishing Company ($2.00). In what, after all, is a thoroughly vulgar enterprise, Mr. Meyer does surprisingly well. Much better than the egregious Ripley, he recounts facts about the "dumbest" and the most intelligent machines; the windiest, coldest, driest, hottest spots on earth; the smallest, most dangerous, largest, swiftest, laziest, most poisonous, longest-lived animals; the most calamitous disasters; the longest poem, most prolific novelist, largest painting, biggest word, best boxer. If you like this sort of thing, this is the sort of thing you will like.

GUIDED MISSILES: ROCKETS AND TORPEDOES, by Frank Ross, Jr. Lothrop, Lee & Shepard Co., Inc. ($2.75). A history of the development of these ominous devices from their first recorded military use in 13th-century China. Mr. Ross does not succeed in explaining simply the principles of missile operation, but he keeps his narrative moving briskly and most boys over 12 will follow it eagerly. In any event a book of this kind is to be preferred to science fiction. Photographs.

OXFORD JUNIOR ENCYCLOPAEDIA. VOL. IV: COMMUNICATIONS, edited by Laura E. Salt and Robert Sinclair. Oxford University Press ($8.50). Another handsome installment of an excellent reference work. This volume is about man's efforts "to communicate with his fellows by signs or sounds, and by travel on land, on sea and in the air." The plan whereby each volume comprises a separate subject has undeniable advantages, yet occasionally produces curious results; thus, for example, the entry "motion pictures" does not appear in this book but rather in the volume on recreations.

MILK FOR YOU, by G. Warren Schloat, Jr. Charles Scribner's Sons ($2.00). How cows make milk, the details of the milking process, operations in a milk plant. For 5- to 9-year-olds.

EVERYDAY MACHINES AND HOW THEY WORK, by Herman Schneider. Whittlesey House ($2.50). How to repair (or put out of order) such mysterious common objects as oilcans, pressure cookers, bobbing birds, ball-point pens, vacuum cleaners, electric motors, lawn mowers, pianos, furnaces, toasters, refrigerators, locks, thermostats, music boxes, valves, coaster brakes, eggbeaters, ball bearings, piggy banks, clocks, mousetraps, violins, bells, washing machines, carpet sweepers, gas ranges. All this is explained so that even adults can understand. Excellent drawings by Jeanne Bendick. For children 9 and over. A superior book.

LET'S LOOK UNDER THE CITY, by Herman and Nina Schneider. William R. Scott, Inc. ($1.50). Another good book by the Schneiders. This small paperbound volume tells children of 6 to 8 about the underground installations that supply a city dwelling with gas, water, electricity, telephone and sewage facilities. For this age group there is no better science book than one which presents a fresh story about everyday things.

THE BOY'S BOOK OF MODEL RAILROADING, by Raymond F. Yates. Harper and Brothers ($2.50). Instructions on the repair of model trains, the making of stations, switches, signals, scenery, bridges, viaducts, remote-control gadgets; how, in other words, to pursue the small-train hobby while pretending to be doing it for your children. Mr. Yates has also taken pains to lay out simple jobs the children can do so as not to disturb you.

Conducted by Albert G. Ingalls

MANY would-be amateur telescope makers forego the sport of mirror making because they have no place to set up the conventional mirror-grinding pedestal. This, however, need not be an obstacle; mirrors have been ground on tables, in bathrooms, in jail, and even in a morgue on a marble slab between two corpses.

David P. Barcroft of Madera, Calif., has improvised from dime-store pans adequate equipment for grinding and polishing a mirror on a bench or almost anywhere. The drawings at the left in the illustration on the opposite page contain an exploded view of the parts above the assembled dingbat. Barcroft attached the square baking pan to the bench with four blobs of pitch. He pitched the tool to a block of wood, centered this block in a common pie pan, poured plaster of Paris around it to half the depth of the pan and allowed it to set.

During grinding and polishing the upper pan may be rotated now and then. This is the equivalent of the conventional walking around the pedestal. When a tool is evenly supported, as with soft pitch on a highly rigid backing such as thick metal, there is little need to walk around the pedestal often. But when the backing is relatively flexible, as in the device described here, astigmatism due to uneven support of the tool may be ground into the mirror unless the tool is rotated a little at least once or twice a minute. Somewhat to Barcroft's surprise, continued use has not bent the light tinware of his assembly, nor does the pie pan with its cargo take off on the anticipated flight across the room.

To forestall rust Barcroft waxed the pans with paraffin. The addition of Dif, Oakite, Soilax, borax or cream of tartar to the water used should accomplish the same result. As a reservoir for the gunk he sometimes inserts a second and shallower square pan between the two already described.

Fifteen years ago E. B. McCartney of Minneapolis, Minn., sent to this department the kitchen or bathroom mirror-grinding dingbat shown at the right in the illustration on this page. This was briefly described in these columns in February, 1936. Ten years later it was dusted off and used in grinding half a dozen six-inch mirrors, whereon its true worth became apparent. It is enthusiastically recommended even to mirror makers who have pedestals but who do not enjoy standing up to work.

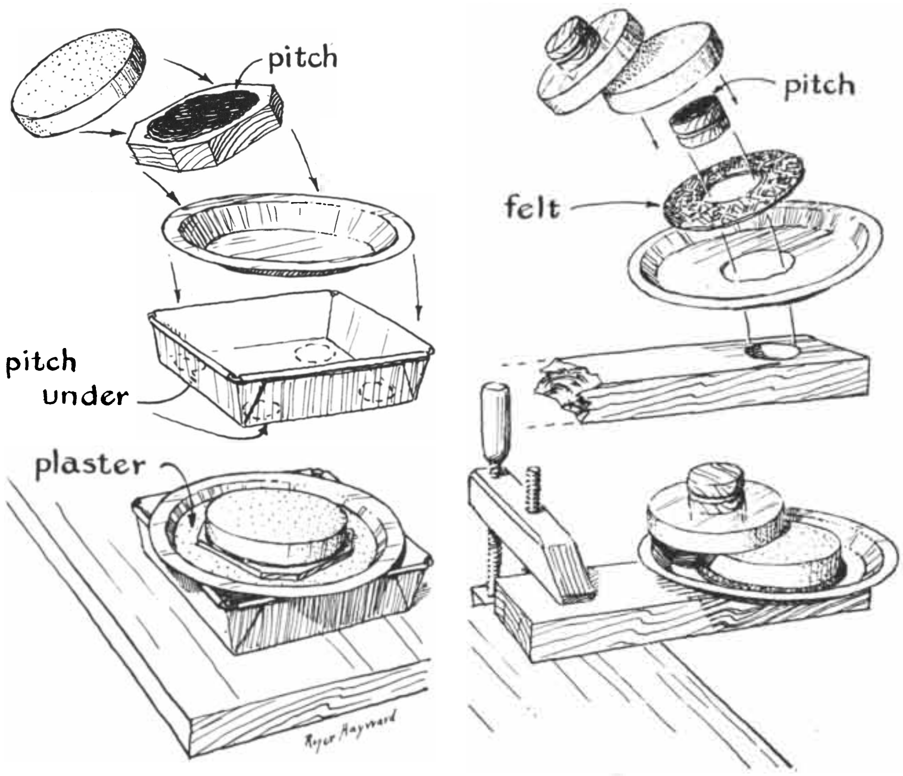
The 14-inch length of two-by-six plank that forms its base may be clamped or screwed, overhanging, to a bench, table or other support. The pan is a special shallow layer-cake pan only five eighths of an inch deep, permitting the mirror to overhang it at the ends of the strokes. The central hole cut in it by McCartney is 2⅝ inches in diameter and need not be perfectly round. The drawing describes the rest of the details. In the original the gasket is smaller than the mirror and is 1/32-inch thick.

During use the anticipated leakage from the felt-to-glass contact joint did not materialize; the device is well housebroken. An added point in its favor is the fact that the mirror and tool may be quickly exchanged, inverted or returned to normal position without fussing or preparation except for rinsing. Thus it is good equipment for the method of grinding and polishing in which, forgetting the gradual-approach and guessing-game method described in the treatises, the curve is excavated at the start to full ultimate depth of sagitta and maintained thereafter by working inverted half the time.

Commenting on the wooden handles, Roger Hayward, the illustrator of this department, urges the desirability of keeping the pitch-covered areas small. "When I made my first mirror many years ago I used a 3½-inch-diameter wooden handle pitched to the back. After the mirror was figured and the handle knocked off, a bulge appeared in the figure where it had been. The pitch was also probably too hard." Similar instances have often been reported to this department. For pitching glass to handles your editor has always kept a special can of very soft pitch. With this even the 4¼-inch handle disk shown in *Amateur Telescope Making*, page 288, has never produced the often-described effect. The soft pitch may also be a little less likely to let go and leave the handle in the hand and the mirror fragments on the floor. However, a large handle blinds the lap during work. Many advanced amateurs and practically all professionals omit the handle altogether.

ROGER HAYWARD was invited to contribute and illustrate his theory of the tiny pinhole in the Foucault test and to describe his favorite design for the testing equipment. He writes:

"When the Foucault test is used merely for detecting errors of figure in spherical mirrors there seems to be no lower limit to the size of the pinhole that may



Simple equipment for the kitchen telescope maker

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be used, provided there is enough light. When, however, the test is used for observing and measuring the figure of a paraboloid at its mean center of curvature, the story is quite different. W. F. A. Ellison describes in *Amateur Telescope Making*, page 84, an amateur who almost discarded a perfectly good mirror because he tested with too small a pinhole. A diagram of the light rays as they intersect in the vicinity of the focus of a paraboloid shows what the trouble is.

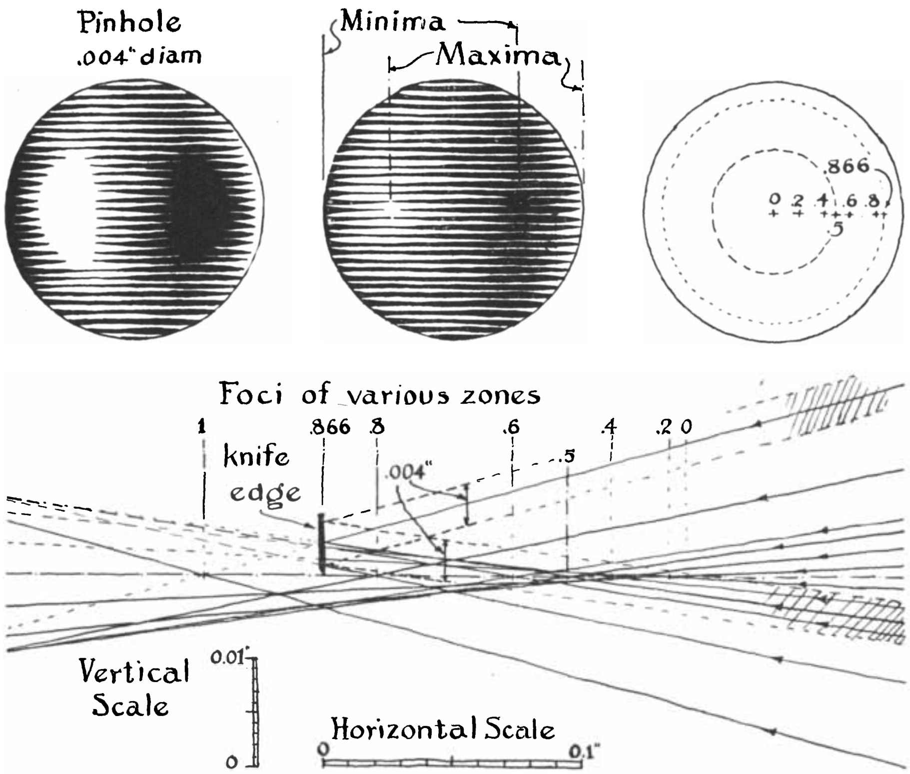
"The lower part of the drawing at the top of the opposite page shows the focus of a 6-inch paraboloid of 24-inch focal length when tested at its mean radius of curvature of 48 inches. The foci of the various zones are indicated. (The vertical and horizontal scales are different, but this does not affect the argument.) We must imagine that around each of the rays in the drawing there is a pencil of light the same size as the pinhole. The knife-edge is shown at the focus of the .866 zone, which the figure shows to be the point of sharpest focus. This corresponds to the circle of least confusion in astigmatic optics. If the pinhole used in the test is .006-inch in diameter, which is the size of this circle of least confusion, it will be clear that from one side of the mirror the pinhole will be completely obscured and from the other completely clear. The exact converse will be true at the .5 zone. The central figure above the diagram shows how this test should look, the maxima being the unobstructed pinhole and the minima being no light at all.

"At the upper left-hand part of the illustration a sketch shows the result of the use of a .004-inch pinhole. Two large patches appear, one completely black and the other of maximum brilliance. In neither of these patches will there be any apparent detail such as zones due to the polishing tools and other causes.

"These diagrams, which are constructed from the geometrical theory of optics, show the knife-edge at the .866 zone instead of the more usual .707 zone. This placing of the cutoff has the remarkable properties that the darkest and lightest parts of the focogram are at the margin and the half-radius points. The mirror therefore appears to be slightly concave instead of having the effect of flatness as when the cutoff is .707. (It may be of interest that .866 is the square root of 3 divided by 2, and that the square root of ½ is .707.)

"If the mirror being tested were the usual 6-inch with 48-inch focal length, the smallest pinhole which should be used would be .0015-inch. A focogram with a .001-inch pinhole would have the same appearance as the .004-inch pinhole in the illustration.

"There is no good reason for striving for a tiny pinhole, since the cutoff is really formed between the knife-edge and the image of *only one side* of the pinhole. In fact the pinhole may be dis-

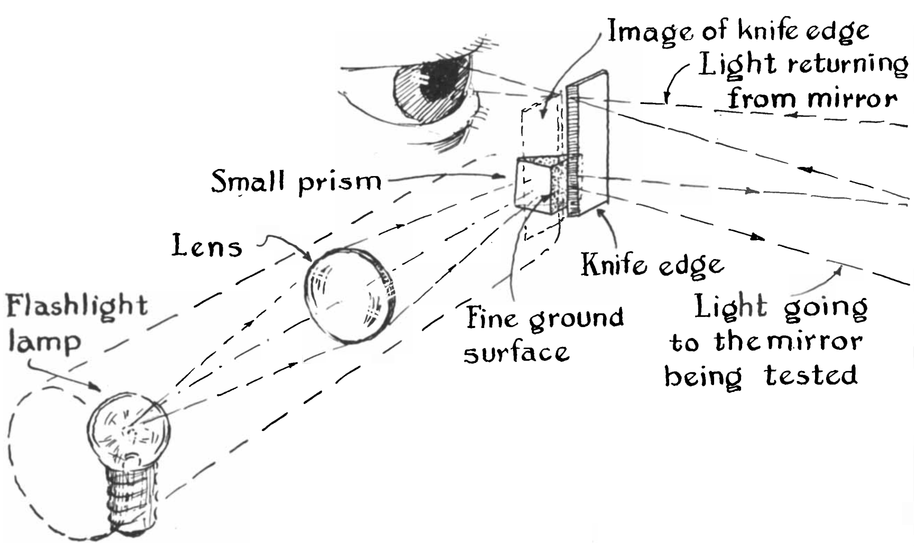


A study of the theory of testing pinhole size

pensed with altogether and a single knife-edge used for both the defining edge of the light source and the cutoff. At one point it forms a boundary of the light source and at another it intercepts its own reflected image. This arrangement is also much easier to clean than a pinhole."

Since the lamp and knife-edge move toward or away from the mirror as a unit, $r^2/2R$ is used in place of r^2/R.

TWO silent motion-picture films, *How to Make a Mirror and Telescope* (8 mm., 100 feet, 8 minutes) and *Making a Telescope* (16 mm., 400 feet, 15 minutes) are available at a $5 rental fee from the Amateur Astronomers of the Franklin Institute, Philadelphia, Pa. They serve chiefly to show the uninitiate what telescope making is like, and as entertainment and a source of argument in club groups. A group of advanced amateurs who recently discussed the idea of demonstrating fine close mirror-making techniques by means of motion pictures concluded that the more difficult skills are too elusive for this medium. One amateur who has worked as a professional stated that he spent weeks watching a noted old-time professional in the flesh without being able even then to capture his touch and technique, especially his pressure trick. Perhaps this statement may act as a challenge to some amateur motion-picture producer. A film aimed entirely at the advanced amateur, with no concessions to the tyro, would please the tyro most. He would drink it in and work to reach its level.



Testing between the knife-edge and its reversed image

AN INDEX OF ARTICLES AND AUTHORS

The following index lists all the articles and authors that appeared in Scientific American *during 1951 with the exception of those published in the September issue entitled* Human Resources of the U. S. *The index also lists the principal book review in each issue. Shorter book notes are not indexed.*

BIBLIOGRAPHY

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

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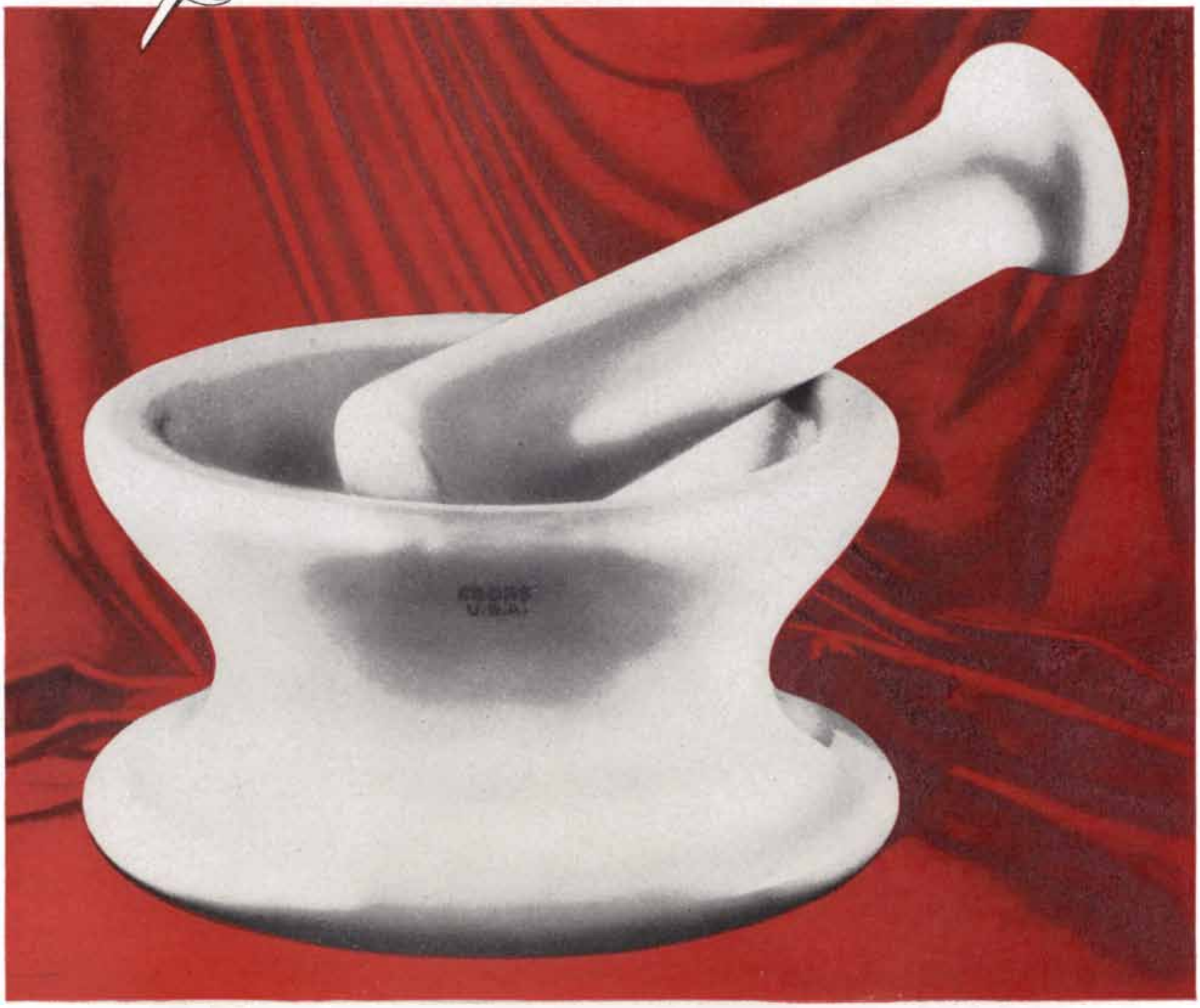
Rx: ALCOA ALUMINA FOR FINE GRINDINGS



Long the symbol of prescription druggists, the mortar and pestle represents fine grinding—and fine grinding calls for ALCOA Alumina.

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Photo by Mechling

"The hopes and fears of all the years..."

Who can fail to respond to the wonder and magic of Christmas . . . to its messages of kindness and friendship . . . to its promise of hopes fulfilled and fears dispelled?

The Christmas spirit and the work of science can go hand in hand to help in many ways to fulfill long-held hopes and dispel age-old fears.

Almost every day we read of advances in the treatment of disease and the relief of suffering. New ways are being found to grow more food and make other good things available to more people throughout the world. Through scientific means the earth's heaven-given abundance is being released in numerous ways for the benefit of mankind.

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